

# Detecting and Analysis of Polar Orbiting Satellite Signal Using Low Cost Hardware Configuration With Software Defined Radio.

By

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## FINAL YEAR DESIGN PROJECT REPORT

This Report Presented in Partial Fulfillment of the Requirements for  
the Degree of Bachelor of Science in Computer Science and  
Engineering

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DAFFODIL INTERNATIONAL UNIVERSITY  
Dhaka, Bangladesh

January 13, 2025

# APPROVAL

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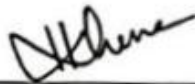
This Project titled "Detecting and Analysis of Polar Orbiting Satellite Signal Using Low Cost Hardware Configuration With Software Defined Radio," submitted by [Md. Shayed Hasan Shakib] and to the Department of Computer Science and Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on 13-01-2025.

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# DECLARATION

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I hereby declare that this project has been done by me under the supervision of **Md. Sazzadur Ahamed, Assistant Professor**, Department of Computer Science and Engineering, Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for the award of any degree or diploma.

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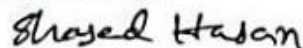
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# ABSTRACT

This project-based research focuses on detecting and analyzing signals from polar-orbiting weather satellites using software-defined radio (SDR) technology. Polar-orbiting weather satellites, such as transmit weather-related data via VHF radio frequencies ( 137 MHz) as they traverse north-to-south or south-to-north orbits. These signals can be captured using an SDR receiver, a circular polarized antenna, and a computer system to process the received signal. The captured signals are processed with software to record the incoming data. Thats why it called Software Defined Radio. This recorded audio is then decoded using another software based on which types of data captured and later producing satellite weather images. These images provide valuable insights into cloud cover, temperature distribution, and other meteorological phenomena, offering significant potential for further research in weather analysis, climate monitoring, and environmental studies. This project also analyze two types of circular polarized antenna. The two different setup on antenna system can show which is better for this particular geo-location. This project-based research demonstrates how affordable, accessible tools can be employed to decode real-time satellite data into actionable imagery. The approach also highlights the feasibility of independent satellite signal research, contributing to educational and scientific endeavors. The findings and methodologies outlined in this project-based research pave the way for broader applications in atmospheric science, disaster management, and sustainable development.

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# Chapter 1

## Introduction

In this chapter I introduce the system of capturing weather images data, why i started this project, main objecting of this project, how am i going to do that and what will be the outcome throughout this project.

### 1.1 Introduction

We are surrounded by countless radio waves, many carrying meaningful data, while others are just static noise. These waves travel through the air and pass through our bodies unnoticed. Since the invention of the radio, humans have been able to hear analog signals transmitted as voices or sounds. Over time, radio technology has evolved into digital and hybrid systems, enabling more advanced communication. Software-Defined Radio (SDR) has revolutionized this field by allowing users not only to hear but also to visualize and analyze these invisible signals, transforming how we interact with the radio spectrum. This project-based research explores the use of SDR technology to detect and analyze signals from polar-orbiting weather satellites, such as NOAA 15, 18, and 19, which transmit weather data at 137 MHz in the VHF range. Using an MSI2500 SDR receiver, a homemade QFH antenna positioned 15 feet above ground, a V-Dipole antenna, and a 75-foot RG6 coaxial cable, the satellite signals are captured and processed with various SDR software to compare the signal processing performance. The recorded audio is then decoded using WxToImg software, producing weather images. In this Chapter I mainly brief why I take this project for my FYDP, what are the objective, how I've done this work, what are the outcomes and brief about each chapter following.

### 1.2 Motivation

The main motivation to implement this project comes from my interest at radio signal. Before my teenage time, I accrued a broadcast radio receiver from my father, that's when got interest in Radio. By the time passed, I explored various bands of radio waves, but signals from the sky or satellite interests me most. I am also deeply encouraged by the climate and weather related matters. And as a computer science student I also heavily touched by the Software Defined Radio architecture. So while everything aligns at the Polar Orbiting Satellite Band, I wanted this project done in this geo-location based

weather satellite imagery ground station.

### 1.3 Objectives

My main objective of this project is that create a SDR base ground station that will received NOAA, METEOR satellite signals which are free of cost. Every day there will be some images received from satellite, and by the end of a year, there will be lots of images which can be use for further meteorological researches.

- **Develop a Localized Satellite Ground Station:** To design and implement a geo-location-specific ground station using affordable tools such as an SDR (MSI2500), homemade antennas, and decoding software, enabling independent access to real-time satellite data.
- **Explore Satellite Radio Signal Reception:** To study and understand the reception of radio signals, focusing on polar-orbiting satellites that transmit weather and climate data in the VHF band (137 MHz).
- **Compare Antenna Performance:** To design, test, and compare the performance of two antenna types—Quadrifilar Helix (QFH) and V-Dipole—under local geographic and environmental conditions to determine which is more effective for satellite signal reception.
- **Leverage Software-Defined Radio Technology:** To utilize Software-Defined Radio (SDR) architecture for capturing and processing signals, demonstrating the practical applications of SDR in modern communication and data analysis.
- **Contribute to Weather Monitoring and Research:** To generate and analyze satellite imagery for local weather monitoring, fostering deeper insights into climate and atmospheric conditions, and contributing to environmental studies.

### 1.4 Methodology

The project involves designing a localized ground station to capture and analyze VHF signals (137 MHz) transmitted by polar-orbiting satellites like NOAA 15, 18, and 19. An MSI2500 SDR receiver is used alongside two antennas,

A homemade Quadrifilar Helix (QFH)

A V-Dipole mounted Antenna.

The antennas are evaluated based on their ability to capture satellite signals under local environmental conditions. And before that, the antenna was measured by the Vector Network Analyzer called VNA. Signals are recorded using various SDR software and processed with WxToImg to decode them into satellite weather images. These images are analyzed to extract meteorological insights such as cloud cover and temperature distribution.

After getting the decode images, they will be placed under a image gallery on a website.

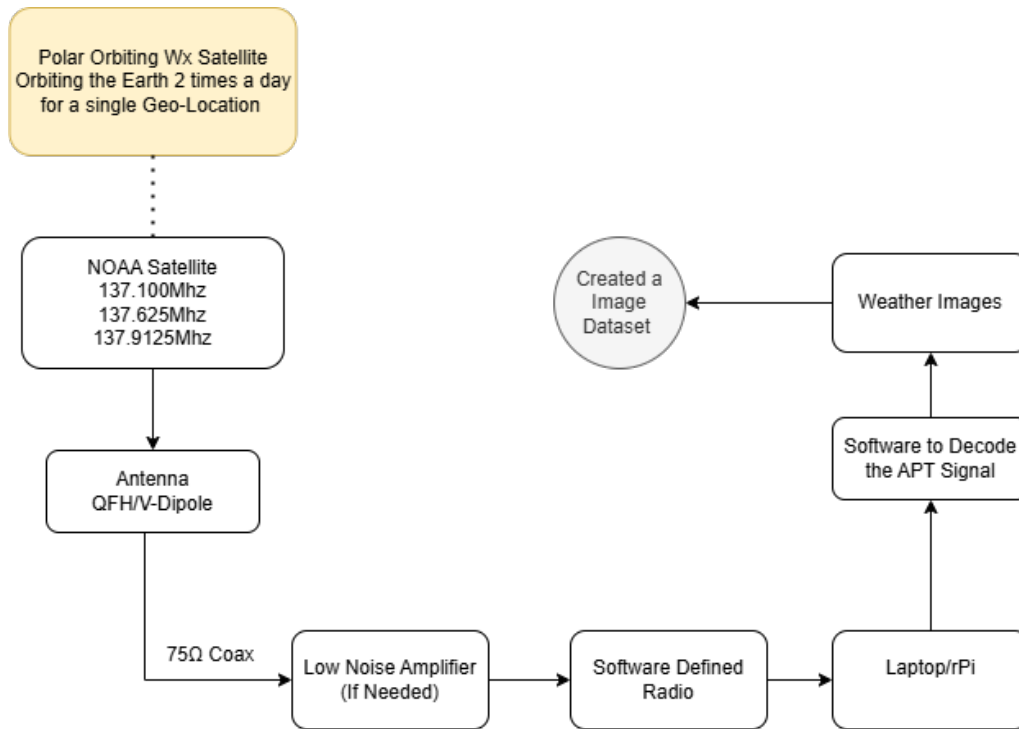


Figure 1.1: Methodology Diagram

## 1.5 Project Outcome

The project will aim to establish a localized ground station that will be capable of receiving and decoding signals from polar-orbiting weather satellites. Using Software-Defined Radio (SDR) technology along with QFH and V-Dipole antennas, the system will capture VHF signals from satellites such as NOAA 15, 18, and 19. These signals will be decoded into weather images. The performance of the two antenna types will be compared to determine which configuration works best for satellite signal reception in the specific geographic location. Ultimately, this project will demonstrate the power of SDR in weather monitoring and satellite signal analysis, offering an accessible and cost-effective method for gathering real-time meteorological data and facilitating further research in environmental and atmospheric studies.

## 1.6 Organization of the Report

The chapter-wise structure of this report follows:

- **Chapter 1:** This is introduction chapter, discuss about what this project about, motivation behind this, my main objective, a summery of proposed methodology, what could be the outcome and how I organize this report.
- **Chapter 2:** In this chapter I discuss about all the background knowledge of my about this project, related works, literature review and gap analysis.
- **Chapter 3:** In this chapter, I show how am I going to complete this project, what are

the requirements, details about proposed methodology, system diagram, functional and non-functional requirements, project plan, task allocation and etc.

- **Chapter 4:** This is where the real works begin, after all the proposed plan has been in mind and written paper, this is where I show how I did all the things in real life, meaning setup the environment, testing and evaluation, result and discussion about the result
- **Chapter 5:** In this chapter I discuss about the Software and Hardware Standards, Communication Standards, how this project going to impact on social and environment, impact on life, ethical aspects, financial analysis and project managements. In this chapter I also discuss about the complex engineering problems.
- **Chapter 6:** In the chapter 4 I already discuss about the result. Is the result matches my expected outcome? If not what was the limitation, if yes or not what could be done with this project in future for enhancement? this is what discussed in this Conclusion chapter.

# Chapter 2

## Background

In this chapter I discuss about all the background knowledge of my about this project, related works, literature review and gap analysis.

### 2.1 Introduction

The main focus of this project is Software Defined Radio (SDR), a technology that allows traditional radio hardware components to be replaced with software running on general-purpose hardware. This flexibility in signal processing has revolutionized the way radio systems are designed and deployed, enabling a wide variety of communication protocols and frequencies to be accessed and manipulated using software. SDR technologies have become a key part of various applications, including satellite communications, wireless networking, and broadcasting, providing a scalable and cost-effective alternative to traditional hardware-based systems. Several software platforms, such as SDRplay, SDR++, HSDR, SDR Sharp, and GNU Radio, are used in the project to process and interpret satellite signals. These software tools offer features like signal visualization, modulation, demodulation, and signal decoding, making them critical for managing the diverse signal types encountered in satellite communication.

The NOAA satellites are the second significant element in this project. These polar orbiting satellites are responsible for collecting weather and environmental data from around the globe. Their data transmission, especially Automatic Picture Transmission (APT), is widely used in various sectors, including weather forecasting, environmental monitoring, and disaster management. The NOAA satellites, including models like NOAA 15, 18, and 19, transmit weather-related data via VHF signals, which are captured using SDR receivers. The signals from these satellites provide essential information for understanding weather patterns, temperature changes, and climate variations, which can have significant impacts on agriculture, water management, and emergency services.

In addition to SDR and NOAA satellites, several other key components contribute to the functionality of the project. A Low Noise Amplifier (LNA) is used to boost the weak satellite signals received by the antenna, ensuring the signal is strong enough for processing and decoding. The antenna itself, such as a Quadrifilar Helix Antenna (QFH) or V-Dipole, plays a crucial role in capturing satellite signals efficiently, especially when considering factors such as the satellite's orbit, signal strength, and frequency range.

The various software platforms mentioned earlier, including WxToImg, APTDecoder, Gpredict, and Orbitron, are essential tools for decoding the satellite images and processing the data for further analysis. WxToImg is used to decode the APT signals from the NOAA satellites and convert them into weather images, which are then analyzed to determine various atmospheric and environmental parameters. Gpredict and Orbitron are satellite tracking software that help determine the precise timing of signal reception based on satellite orbits and locations. These tools, when combined with a suitable SDR receiver and antenna system, create a comprehensive system capable of capturing, decoding, and analyzing satellite signals.

Overall, operating the various components of this system requires a strong understanding of radio frequency signals, satellite communication protocols, and signal processing techniques. Over the years, I have gained this knowledge through a combination of hands-on experience and research in relevant fields, including the study of radio waves, antenna design, and software tools. The following subsections will delve into the background research that has contributed to my understanding of these systems and tools.

## 2.2 Literature Review

Software Defined Radio (SDR) was introduced in the late 1980s as a concept, primarily to provide more flexibility and reconfigurability in radio communication systems.[2] The idea was first proposed by Joseph Mitola III in his 1992 paper "Software-Defined Radio: A Modern Approach to Radio Frequency System Design," where he envisioned replacing traditional hardware components with software to perform signal processing tasks, making the system adaptable to various communication standards without requiring hardware changes.[3]

Key elements of SDR include:

- **Radio Frequency (RF) Front End:** This component converts analog signals into digital form.
- **Signal Processing:** Conducted through software, typically using tools like GNU Radio or MATLAB.
- **Software:** The algorithms that control tasks like modulation, demodulation, and other signal processing functions.

SDR is extensively used across diverse sectors, including military communications, satellite reception, and amateur radio, providing considerable advancements in both flexibility and efficiency.[4]

NOAA operates Polar-Orbiting Environmental Satellites (POES) that provide critical data for weather forecasting, climate monitoring, and environmental research. These satellites, launched since the 1960s,[1] orbit in low Earth orbit (LEO) and gather information on atmospheric conditions, temperature, humidity, and environmental changes. The current satellites, including NOAA-15, NOAA-18, and NOAA-19, are equipped with advanced

instruments like the Advanced Very High Resolution Radiometer (AVHRR) and the Microwave Humidity Sounder (MHS). These satellites help improve weather predictions, track natural disasters, and contribute to climate change studies.[1]

Table 2.1: NOAA Operational Status, Current Status, and APT Frequency.[1]

Satellite	Operational Status	Status	APT Frequency (MHz)
NOAA-11, -12, -14, -16, -17	Decommissioned	Non Operational	–
NOAA-15	AM Secondary	Operational	137.620
NOAA-18	PM Secondary	Operational	137.912
NOAA-19	PM Prime Services Mission	Operational	137.100

There are so many papers on Software Defined Radio Receiver. I try to read as much as possible. A brief of literature review is given below:

Weather Satellite Tracking with RTLSDR: NOAA 15 Image Reception and Signal Decoding.[5] This study highlights the importance of satellite tracking, focusing on NOAA-15 for weather monitoring and information transmission. It presents a low-cost solution using a Software Defined Radio (SDR) at 137.62 MHz and a V-dipole antenna to receive circularly polarized signals. The V-dipole’s directional characteristics enhance signal reception during specific satellite orbits, improving capture efficiency. The RTL-SDR USB dongle enables signal decoding for Automatic Picture Transmission (APT), producing high-quality weather images. The research underscores the affordability and simplicity of this hardware-software integration for receiving NOAA satellite signals, showcasing its role in global weather forecasting.

*Image Data Acquisition for NOAA 18 and NOAA 19 Weather Satellites Using QFH Antenna and RTL-SDR.*[6] This research successfully demonstrates the design and implementation of a Quadrifilar Helix antenna at 137.5 MHz, paired with RTL-SDR, to receive real-time weather data from NOAA 18 and NOAA 19 satellites. The system effectively captures, decodes, and processes Automatic Picture Transmission (APT) signals using WXtoImg software. The results show that the received satellite images are clear and descriptive, despite minor frequency offsets of 0.0685% for NOAA 18 and 0.0686% for NOAA 19, confirming the system’s reliability and performance.

*Image Data Acquisition for NOAA 18 and NOAA 19 Weather Satellites Using QFH Antenna and RTL-SDR.*[7] The paper explores a cost-effective solution for receiving data from NOAA satellites. It discusses the use of a custom polarized antenna and an RTL-SDR receiver, providing an affordable option for satellite data acquisition.

*Cost efficient design approach for receiving the NOAA weather satellites data.*[8] This research presents a cost-efficient satellite receiver setup for acquiring NOAA weather data in Lahore, Pakistan (Latitude: 31.54°, Longitude: 74.34°). The system uses a Real Tech Software Defined Radio (RTL-SDR), a custom-designed Quadrifilar Helicoidal Antenna

(QHA), and a Trifilar Balun, both constructed under precise conditions to enhance signal strength. The received signals, decoded using SDR Sharp and WXtoImg software, successfully produced weather images. This setup offers an affordable alternative to costly satellite ground stations, demonstrating its effectiveness for local weather monitoring and disaster management.

*Surfing the Radio Spectrum Using RTLSDR.*[9] This paper explores the use of a low-cost RTL-SDR as an educational tool to help undergraduate engineering students better understand signals in time and frequency domains. Traditional classroom teaching often focuses on mathematical concepts, making it difficult for students to grasp the practical nature of signals. The proposed approach enables in-class demonstrations and at-home activities, allowing students to independently explore the radio spectrum. This hands-on experience provides a cost-effective and enriching method to enhance their understanding of fundamental concepts in Signals and Systems or Communications courses.

*NOAA Image Data Acquisition to Determine Soil Moisture in Arequipa, Perú.* [10] This study presents a satellite data acquisition system using a RealTek RTL2832U software-defined radio (SDR) receiver, coupled with two specially designed antennas (a turnstile crossed dipole antenna and a quadrifilar helicoidal antenna). The system utilizes software like Orbitron, SDRSharp, WXToImg, and MATLAB for recording, decoding, and displaying Automatic Picture Transmission (APT) signals from NOAA satellites. The antennas' design parameters match well with simulation results. The satellite images received through this system are clear enough to be used for further analysis, aiding in the monitoring of irrigation effects on dry areas in Majes-Arequipa.

In conclusion, the six papers provide valuable insights into various methods of receiving and decoding NOAA satellite data using SDR technology, focusing primarily on cost-effective solutions for weather data acquisition. The studies commonly employ RTL-SDR receivers and WXtoImg software for processing APT signals, with differences in antenna designs such as QFH antennas and custom solutions. The papers highlight the successful use of these low-cost systems in diverse applications, including environmental monitoring, soil moisture analysis, and educational purposes. While some papers emphasize the design and implementation of antenna systems for better signal reception, others showcase the practical utility of these systems in real-world applications like disaster management and weather forecasting. Overall, these studies demonstrate that SDR-based systems, when coupled with well-designed antennas, offer a reliable, flexible, and affordable method for capturing and decoding satellite data.

### 2.2.1 Related Research

## 2.3 Gap Analysis

The gap analysis of my project compared to existing literature highlights several areas where my approach fills important gaps:

Table 2.2: Related Papers

Title	Paper Type	Date	Key Notes
Weather Satellite Tracking with RTLSDR: NOAA 15 Image Reception and Signal Decoding	Conference Paper	26-28 February 2024	Satellite: NOAA 15, Antenna: V-Dipole, Receiver: RTL-SDR V3, Software: WXtoImg
Image Data Acquisition for NOAA 18 and NOAA 19 Weather Satellites Using QFH Antenna and RTL-SDR	Web Conference Paper	26 October 2018	Satellite: NOAA 18, 19, Antenna: QFH, Receiver: RTL-SDR, Software: WXtoImg
A Low Cost Solution for NOAA Remote	Conference Paper	01 January 2018	Satellite: NOAA, Antenna: Polarized(Custom), Receiver: RTL-SDR
Cost efficient design approach for receiving the NOAA weather satellites data	Aerospace Conference	05-12 March 2016	Satellite: NOAA 18, Antenna: QFH, Receiver: RTL-SDR (generic), Software: WxToImg
Surfing the Radio Spectrum Using RTLSDR From Broadcast FM to NOAA Satellite, Exploring RTL-SDR	Journal Paper	14 Oct 2019	–
NOAA Image Data Acquisition to Determine Soil Moisture in Arequipa, Perú	IEEE Transactions on Nuclear Science	07 June 2021	Satellite: NOAA 15, Antenna: QFH & Turnstile, Receiver: RTL-SDR V3, Software: Wx-ToImg

- **Dual Antenna System:** Most existing studies, such as [6] and [10], use a single antenna type, typically the QFH antenna. In contrast, my project utilizes a **dual antenna system**, comparing both **QFH** and **V-Dipole antennas**. This comparison provides a more detailed analysis of antenna performance based on local conditions, signal strength, and image quality.
- **Use of MSI2500 SDR:** While most research, like [6], uses the RTL-SDR V3 receiver, my project employs the more advanced **MSI2500 SDR**, which offers improved sensitivity, signal quality, and bandwidth. This upgrade allows for better reception and clearer decoding of satellite signals, making it a significant improvement over the RTL-SDR.
- **Geolocation-Specific Ground Station:** Previous studies, such as [8] and [10], focus on general regions or test locations. My project, however, emphasizes a **geolocation-specific ground station**, optimized for a specific geographic area.

This ensures better adaptation to local environmental and atmospheric conditions that affect signal quality, resulting in more accurate satellite data reception.

- **Improved Signal Decoding Techniques:** Many studies, including [10] and [6], rely mainly on **WXtoImg** for decoding APT signals. My project enhances this by using multiple decoding tools, such as **SDRplay**, **SDR++**, and **HSDR**, offering better flexibility and reliability for real-time decoding and image processing.
- **Integration of Multiple Software:** While previous research, like [9], typically employs a single software tool with RTL-SDR, my project integrates several SDR software platforms. This multi-software approach allows for better signal reception, decoding, and adaptability to varying conditions, making the system more robust and flexible.

## 2.4 Summary

In summary, the background analysis, related works, and gap analysis highlight significant advancements in satellite signal reception and decoding, particularly with NOAA weather satellites. Existing research primarily focuses on cost-effective methods for receiving and processing satellite data using receivers like RTL-SDR V3 and single antenna systems, such as QFH or custom polarized antennas. Various software, including WXtoImg, SDRSharp, and Orbitron, are commonly used for signal decoding and image processing. However, these studies typically lack a comparative approach or are limited to specific geolocations, antenna systems, and software solutions. My project fills these gaps by employing a dual antenna system (QFH and V-Dipole) to compare performance based on the local environment, utilizing the more advanced MSI2500 SDR receiver for superior signal quality, and focusing on a geolocation-optimized ground station. Additionally, it integrates multiple SDR software platforms, offering greater adaptability and robustness for satellite image decoding. This approach aims to provide more accurate, reliable, and efficient satellite data reception, addressing some of the limitations present in prior studies, and contributes to the growing field of satellite ground stations for weather monitoring and environmental analysis.

# Chapter 3

## Research Methodology

In this chapter, I show how am I going to complete this project, what are the requirements, details about proposed methodology, system diagram, functional and non-functional requirements, project plan, task allocation and etc.

### 3.1 Methodology& Design Specification

#### 3.1.1 Overview

This chapter outlines the research methods and tools used to achieve the objectives of this study. The research focuses on the design, implementation, and evaluation of a low-cost satellite signal reception system using MSI2500 and custom antennas. The methodology involves both hardware and software components, including the construction of antennas, signal acquisition, decoding, and analysis. The chapter begins with a description of the research approach, followed by details of the experimental setup, data acquisition process, and software tools used. It also explains the geolocation parameters, system calibration, and data verification methods to ensure reliability. This structured approach provides a clear understanding of how the study was conducted to achieve its goals.

### 3.1.2 Proposed Methodology/ System Design

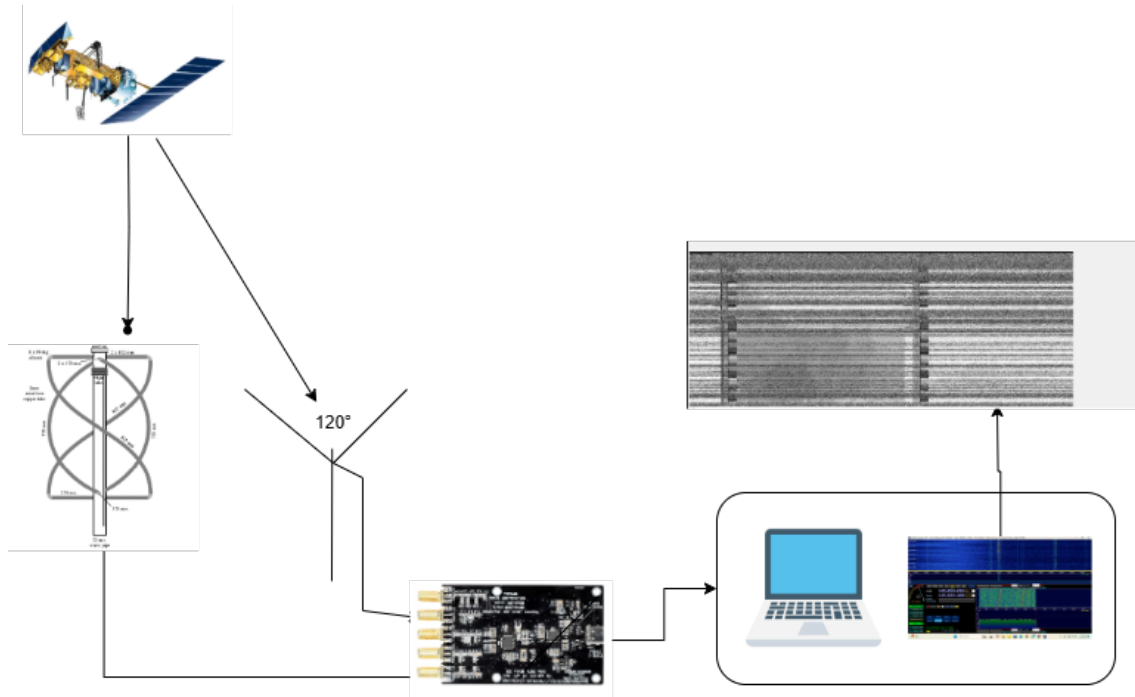


Figure 3.1: Methodology

- **Step 1: System Setup**

- Assemble the hardware components:
- Install the MSI2500 SDR receiver as the primary signal acquisition device.
- Set up two antennas (QFH and V-Dipole) for comparative signal reception.
- Connect the SDR and antennas using RG6 coaxial cable (75 ft) and install a Low Noise Amplifier (LNA) if required to improve signal strength.

- **Step 2: Satellite Identification and Tracking**

- Identify suitable NOAA satellites for data acquisition (e.g., NOAA 15, 18, 19).
- Use satellite tracking software like Gpredict or Orbitron to monitor satellite passes and determine signal availability.

- **Step 3: Signal Reception and Recording**

- Operate SDR software (e.g., SDRplay, SDR++, HDSDR) to tune to the NOAA APT transmission frequency range (137–138 MHz).
- Capture and record the radio frequency (RF) signals transmitted by the satellite.
- Save the raw audio files for further processing.

- **Step 4: Signal Decoding and Image Generation**

- Feed the recorded RF signal into decoding software like WxToImg or AptDecoder to decode Automatic Picture Transmission (APT) signals.
- Generate weather images from the decoded signal data.

- **Step 5: Comparative Antenna Analysis**

- Use both QFH and V-Dipole antennas in identical conditions to collect signal data.
- Compare the signal quality, image clarity, and reliability of each antenna type based on the received data and environmental factors.
- **Step 6: Data Validation and Analysis**
  - Validate the received images by comparing them with reference data or live weather maps from reliable sources.
  - Analyze the performance of the setup, focusing on the geolocation-specific reception quality and software efficiency.
- **Step 7: System Optimization and Documentation**
  - Refine system configurations (e.g., antenna alignment, gain adjustments in SDR software) for optimal signal reception.
  - Document findings, including antenna performance, software compatibility, and geolocation-specific observations, to support future work.

### 3.1.3 Functional and Nonfunctional Requirements

- **Satellite Signal Reception**
  - **Purpose:** The system must reliably receive signals from NOAA polar-orbiting satellites at the VHF frequency range (137–138 MHz).
  - **Method:** Use the MSI2500 SDR receiver to capture signals transmitted in Automatic Picture Transmission (APT) format from satellites like NOAA 15, 18, and 19.
- **Satellite Tracking**
  - **Purpose:** Satellite visibility and tracking are critical to determining optimal reception times and locations.
  - **Method:** Use tracking software like Orbitron or Gpredict to calculate satellite pass schedules and align the antenna setup accordingly.
- **Signal Decoding**
  - **Purpose:** Convert the raw RF signals into interpretable satellite images.
  - **Method:** Use decoding tools like WxToImg or AptDecoder to process the received APT signals into weather images. This involves demodulation and image rendering.
- **Antenna Comparison**
  - **Purpose:** Evaluate the performance of two different antenna designs (QFH and V-Dipole) for signal reception at the project’s geographic location.
  - **Method:** Record the signal strength, clarity, and image quality received from both antennas and compare the results.
- **Data Storage**
  - **Purpose:** Archive captured audio signals and processed images for analysis and documentation.

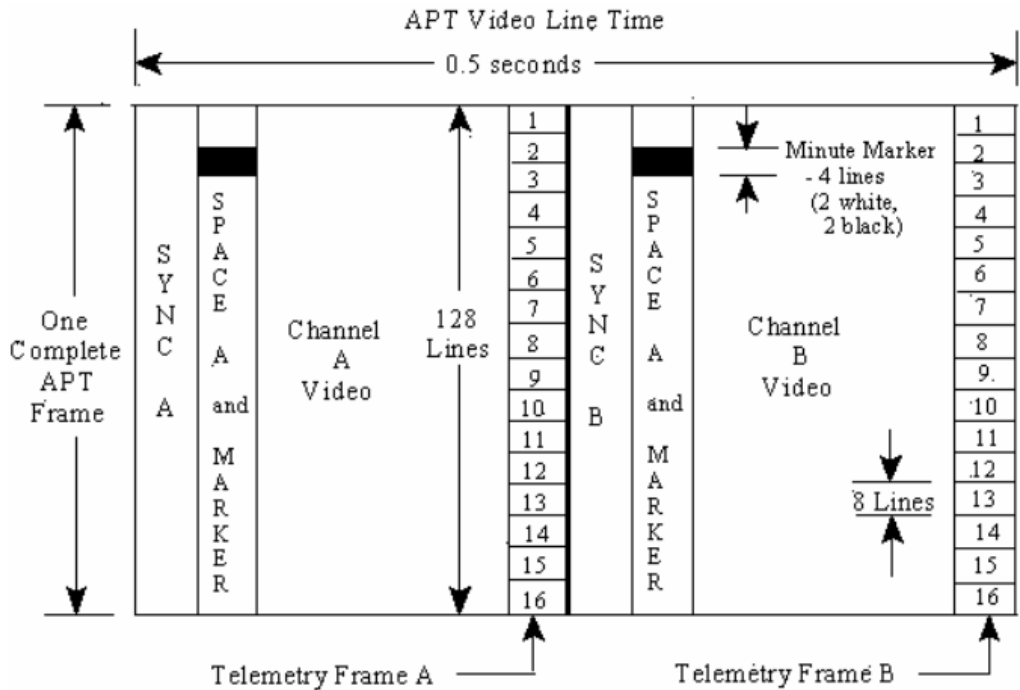
- **Method:** Use structured file storage to organize data by date, satellite, and processing outcomes.
- **Image Quality Validation**
  - **Purpose:** Ensure the accuracy and reliability of the decoded satellite images.
  - **Method:** Compare processed images with known reference images or assess them based on signal-to-noise ratio (SNR) and pixel clarity.
- **Geolocation-Specific Performance**
  - **Purpose:** Understand how environmental factors like atmospheric conditions and signal obstructions affect reception at the specific geographic site.
  - **Method:** Perform testing at different times of the day and in varying weather conditions to analyze signal reception quality.

Functional Requirements Summary: These focus on the core operations of the project, such as capturing satellite signals from NOAA polar-orbiting satellites using an MSI2500 SDR receiver, tracking satellite visibility, decoding raw RF signals into images, and storing processed data. A key aspect is the comparison of two antenna designs—QFH and V-Dipole—to evaluate performance in the given geolocation, ensuring effective signal reception and image quality validation.

Non-Functional Requirements Summary: These highlight the system’s performance and usability, emphasizing signal consistency, scalability, cost-effectiveness, and user-friendly operation. The design ensures portability, durability in varying environmental conditions, and accuracy in decoded images, making the system reliable and efficient for further analysis or weather forecasting tasks.

This combination of requirements ensures a robust, scalable, and accessible solution for real-time satellite data acquisition.

### 3.1.4 Context Diagram



WEDGE #1	WEDGE #2	WEDGE #3	WEDGE #4	WEDGE #5	WEDGE #6	WEDGE #7	WEDGE #8
1	2	3	4	5	6	7	8
Zero Modulation Reference	Thermistor Temp. #1	Thermistor Temp. #2	Thermistor Temp. #3	Thermistor Temp. #4	Patch Temp.	Back Scan	Channel I.D. Wedge
9	10	11	12	13	14	15	16

Notes:

- 1) Each telemetry frames consists of 16 points
- 2) Telemetry frame rate is 1 frame per 84 seconds
- 3) Each telemetry point is repeated on 8 successive APT video lines

Figure 3.2: NOAA APT Image Format

The NOAA satellite sends weather data in a special way. It divides the information into two picture streams (called Video A and Video B), plus extra data to help organize and describe the pictures. All this data is packed into rows, like lines on a page. Each row is 2080 tiny dots (pixels) long. Out of these, 909 dots are used for each picture, and the rest are for the extra data. The satellite sends two of these rows every second, which means it sends 4160 dots per second. This speed is also called 4160 baud.

### 3.1.5 Data Flow Diagram of SDR

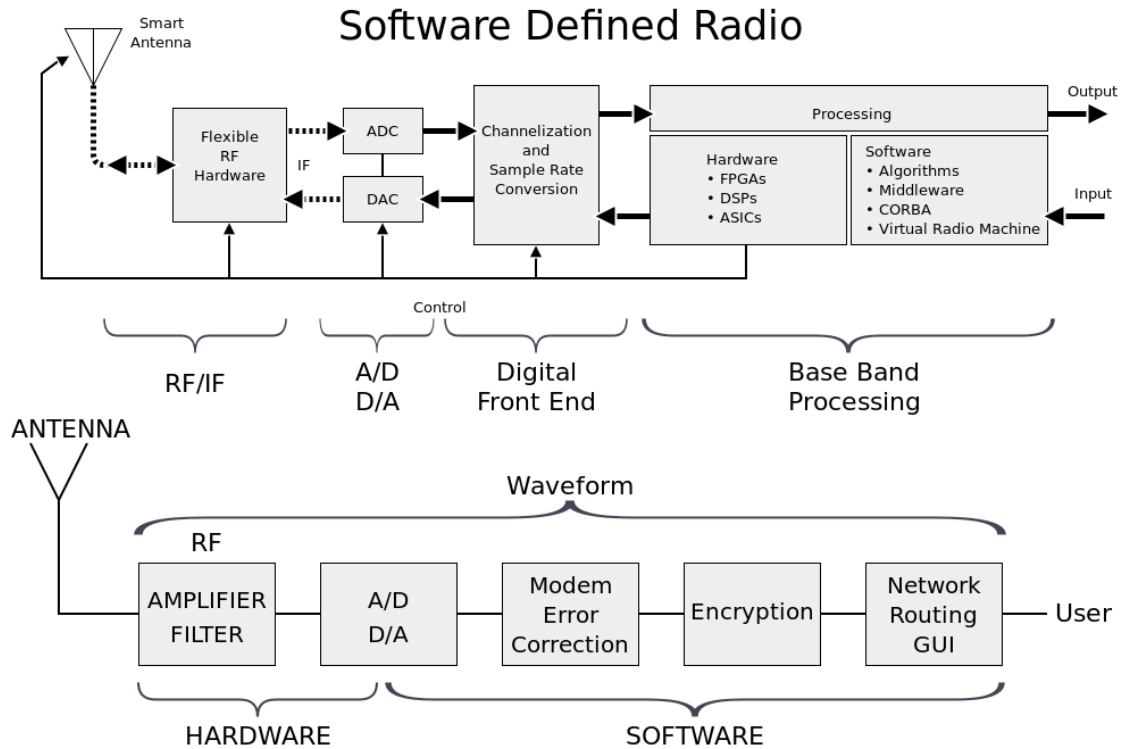


Figure 3.3: SDR Data Flow

The Data Flow Diagram (DFD) for a Software Defined Radio (SDR) represents the step-by-step process of transforming raw signals into meaningful outputs. The flow begins with signal reception via an antenna, where incoming radio frequency (RF) signals are captured. These signals are then passed to an SDR receiver, which performs Analog-to-Digital Conversion (ADC) to transform the analog RF signals into digital format. The digital signals are further processed by SDR software, which handles tasks such as filtering, demodulation, and frequency correction. Finally, decoding software interprets the processed digital data to produce usable outputs, such as satellite images or audio files, enabling valuable insights for various applications. This streamlined process emphasizes flexibility, accuracy, and the adaptability of SDR technology.

## 3.2 Detailed Methodology and Design

First I collect the antenna materials. My first priority was building the QFH Antenna. The instructions are followed:

### 1. Collecting the elements.



Figure 3.4: Components for Making QFH Antenna

#### Materials Needed:

- Copper pipe ( $\frac{1}{2}$  to 1 inch diameter)
- PVC pipe (for the antenna's frame and structure)
- PVC T-joint or similar connectors
- Coaxial cable (for connecting the antenna to the SDR receiver)
- Balun (for impedance matching)
- Tools: Pipe cutter, drill, soldering iron, wire stripper, measuring tape

## 2. Making the antenna:

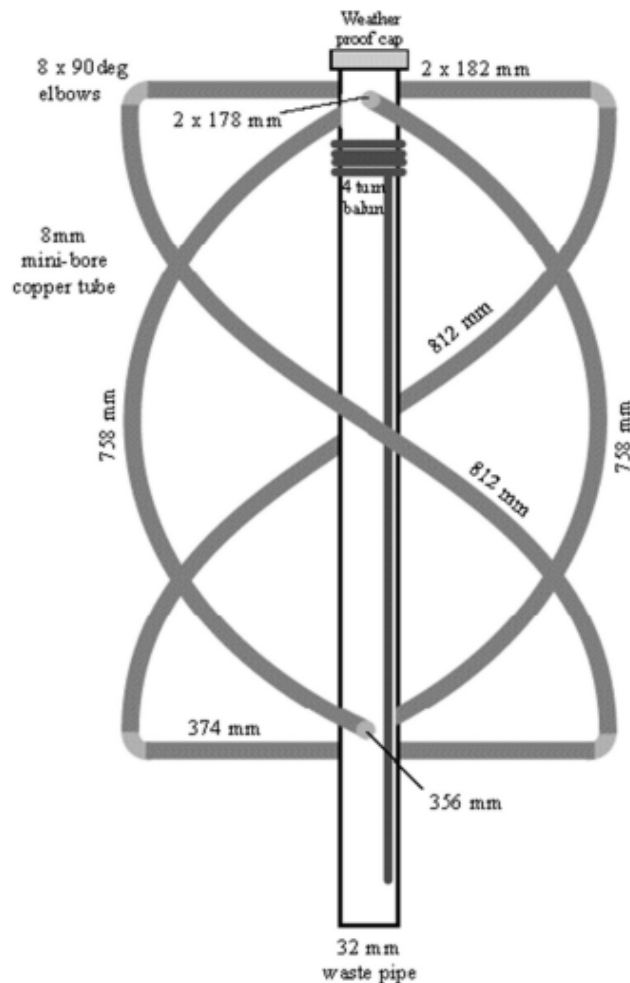


Figure 3.5: QFH Measurements

### Copper Pipe Distribution:

- (2) 812mm
- (2) 758mm
- (1) 374mm
- (1) 356mm
- (2) 182mm
- (2) 178mm

### Step-by-Step Construction:

1. **Cut the Copper Pipe:** Cut the copper pipe into four equal lengths, each one representing a quarter of the helix. For example, at a frequency of 137 MHz, the length of each section should be approximately 20.5 cm.
2. **Prepare the PVC Pipe:** The PVC pipe serves as the central hub for mounting the copper pipes. Cut the PVC to a suitable length to support the antenna structure, and drill holes at the top of the pipe for inserting the copper pipes.
3. **Form the Helix:** Bend each copper pipe into a helical shape using a pipe bender.

Each section should form a quarter-wavelength of the antenna.

4. **Construct the Antenna Frame:** Use the PVC T-joint or other connectors to create a stable base for the antenna. Ensure the frame can support the copper pipes without sagging.
5. **Connect the Coaxial Cable:** Attach the coaxial cable to the antenna. Solder the center conductor of the coaxial cable to one of the copper pipes and the shield to the other for ground.
6. **Install the Balun:** Attach the balun to the antenna to ensure impedance matching between the antenna and the receiver.

### Instruction for V-Dipole antenna

1. **Determine the Element Lengths:** Calculate the length of each dipole arm using the formula:

$$L = \frac{300}{4f}$$

For  $f = 137.5$  MHz:

$$L = \frac{300}{4 \times 137.5} \approx 54.5 \text{ cm.}$$

Cut two pieces of wire, each  $54.5$  cm in length.

2. **Prepare the Support Structure:** Use a PVC pipe as the center support and drill a small hole at the center. Attach the two wires at a  $120^\circ$  angle to form the 'V' shape.
3. **Connect the Coaxial Cable:** Strip the coaxial cable to expose the center conductor and shield:
  - Connect the **center conductor** to one dipole arm.
  - Connect the **shield** to the other dipole arm.

Solder the connections securely.

4. **Mount the Antenna:** Fix the antenna horizontally or slightly tilted. Ensure the antenna is placed in an open area with minimal obstructions.

To achieve optimal signal reception from NOAA satellites, follow these guidelines for positioning a V-Dipole antenna:

- **Angle Between Elements:**

The two arms of the V-Dipole antenna should be positioned at an angle of  **$120^\circ$  to  $135^\circ$** . This improves signal reception, especially for low-earth-orbit (LEO) satellites.

- **Orientation:**

Mount the antenna in a **vertical orientation** with the dipole arms angled upwards. Align the antenna to face the expected satellite pass direction for maximum reception.

- **Height Above Ground:**

Install the antenna **3–5 meters above ground** or surrounding obstructions to minimize interference and ensure clear sky visibility.

- **Alignment with Satellite Path:**

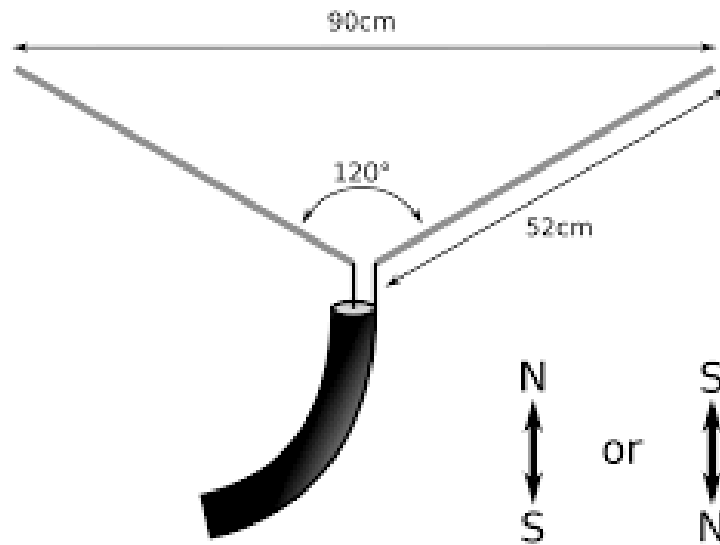


Figure 3.6: V-Dipole Measurements

Use *satellite tracking software* (e.g., Gpredict, Orbitron) to determine the satellite's azimuth (horizontal) and elevation (vertical) angles. Align the antenna accordingly.

- **Minimize Interference:**

Place the antenna away from **metal structures, walls, trees, and electrical devices** to reduce signal obstructions and noise.

Table 3.1: Summary of V-Dipole Antenna

Parameter	Recommended Position
Angle Between Arms	120° to 135°
Orientation	Vertical, with arms angled upwards
Height Above Ground	3–5 meters
Alignment	Face satellite pass direction
Interference Avoidance	Away from obstructions, metal, and electronics

### 3.3 Project Plan and Task Allocation

Table 3.2: Project Plan

Milestone	Task	Responsible Person	Estimated Timeframe
1. Planning Phase	Project planning, defining objectives, and setting timeline	Myself	1 week
2. Research and Material Acquisition	Gather materials for antenna, SDR, software, etc.	Myself	2 weeks
3. Antenna Construction	Build QFH antenna using copper pipes and PVC	Myself	2 weeks
4. Setting Up SDR System	Set up SDR hardware and install SDR software (e.g., SDRplay, WXtoImg)	Myself	1 week
5. Data Collection	Record signals from NOAA satellites and capture data	Myself	3 weeks
6. Signal Processing and Image Decoding	Process signals using WXtoImg and analyze satellite images	Myself	2 weeks
7. Evaluation and Testing	Evaluate system performance	Myself	1 week

### 3.4 Summary

The methodology of this project integrates innovative techniques and robust tools to establish a functional satellite ground station for receiving and decoding NOAA APT weather satellite images. By constructing and testing two custom antennas, QFH and V-Dipole, and leveraging the capabilities of MSI2500 SDR hardware, the project ensures optimized performance tailored to its geolocation. The use of advanced software like WxToImg and SDRplay, combined with a systematic testing and evaluation approach, distinguishes this effort from similar works. The results aim to fill gaps in existing research, such as the application of multiple antenna systems and modern SDR technology, setting a strong foundation for future environmental monitoring and data analysis applications.

# Chapter 4

## Implementation and Results

This is where the real works begin, after all the proposed plan has been in mind and written paper, this is where I show how I did all the things in real life, meaning setup the environment, testing and evaluation, result and discussion about the result.

### 4.1 Environment Setup

#### 4.1.1 Making Antenna

##### QFH Build

Building a Quadrifilar Helix (QFH) antenna involves a step-by-step process that emphasizes accurate measurements and careful assembly to ensure effective signal reception. The construction begins with selecting good-quality materials, such as copper wires, which are cut to specific lengths based on the desired operating frequency, typically 137 MHz for receiving weather satellite signals. These wires are bent into two interlaced helices, which are carefully arranged to maintain the correct polarization and impedance for optimal performance.

The helices are mounted on a sturdy, non-metallic support structure, such as PVC pipes or similar materials, to hold them in place and maintain the required shape. At the base of the antenna, a coaxial cable is connected to the helices through a feed point, ensuring a reliable connection and minimizing signal loss. Proper soldering and insulation are applied, along with waterproofing measures, to protect the antenna from environmental factors.

The final stage involves fine-tuning the antenna by adjusting the helix dimensions, spacing, or angles to achieve resonance and reduce signal loss. Testing with a receiver verifies the antenna's performance in capturing clear signals from polar-orbiting satellites like NOAA. This process highlights the importance of precision and attention to detail in creating an efficient and reliable antenna for satellite signal reception.



(a) Bending the QFH elements



(b) Curved Elements Installment



(c) Top of the QFH



(d) After Connecting

Figure 4.1: Construction of QFH

After done constructing the QFH antenna, this is the final view of QFH antenna. This is the end of building QFH Antenna.



Figure 4.2: Final view of QFH Antenna

### **V-Dipole Building**

Building a V-Dipole antenna is a straightforward process that requires precision to achieve optimal performance. The construction starts by selecting conductive materials such as

copper or aluminum rods, which are cut into two equal lengths based on the operating frequency, typically around 137 MHz for receiving weather satellite signals. These rods form the two arms of the dipole.

The arms are attached to a central insulator at a specific angle, usually between 90 and 120 degrees, to create the characteristic "V" shape. This angle enhances the reception of circularly polarized signals from satellites. At the center of the dipole, a coaxial cable is connected to the two arms, ensuring proper impedance matching and minimizing signal loss. Careful soldering and insulation are applied to secure the connections and protect them from environmental factors.

The assembled V-Dipole is then mounted on a support structure, such as a mast or pole, at an elevated position to ensure clear line-of-sight reception. Fine adjustments are made to the angle and orientation of the arms to optimize signal reception.

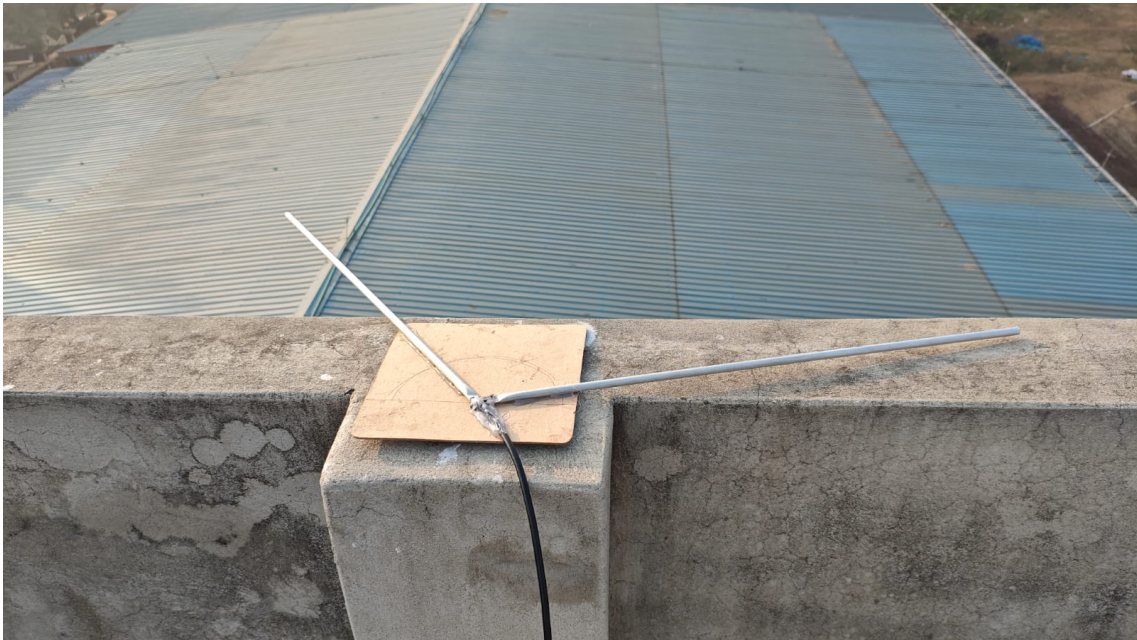


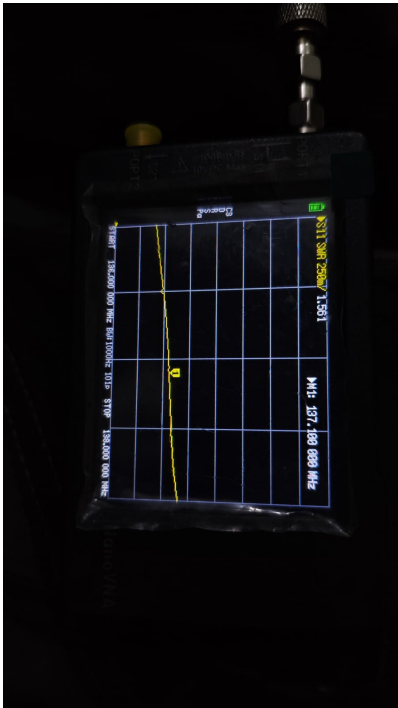
Figure 4.3: Final view of V-Dipole Antenna

## 4.2 Testing and Evaluation

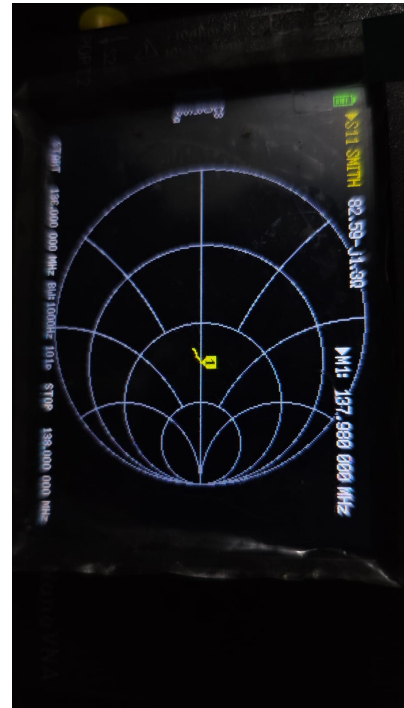
This is where the real works begin, after all the proposed plan has been in mind and written paper, this is where I show how I did all the things in real life, meaning setup the environment, testing and evaluation, result and discussion about the result

### 4.2.1 Antenna Testing:

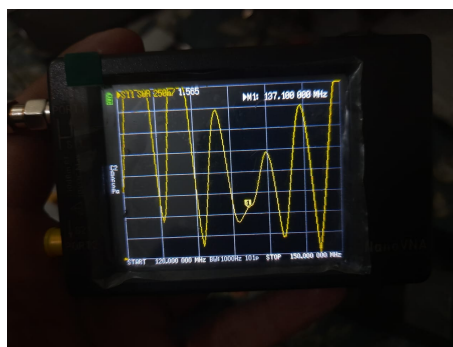
The QFH Resulted back with those SWR Result.



(a) QFH Antenna SWR



(b) QFH Antenna SmithChart



(c) V-dipole SWR

Figure 4.4: QFH and V-Dipole Antenna SWR Test

### 4.3 Results and Discussion

The Result are shown here Sequentially:

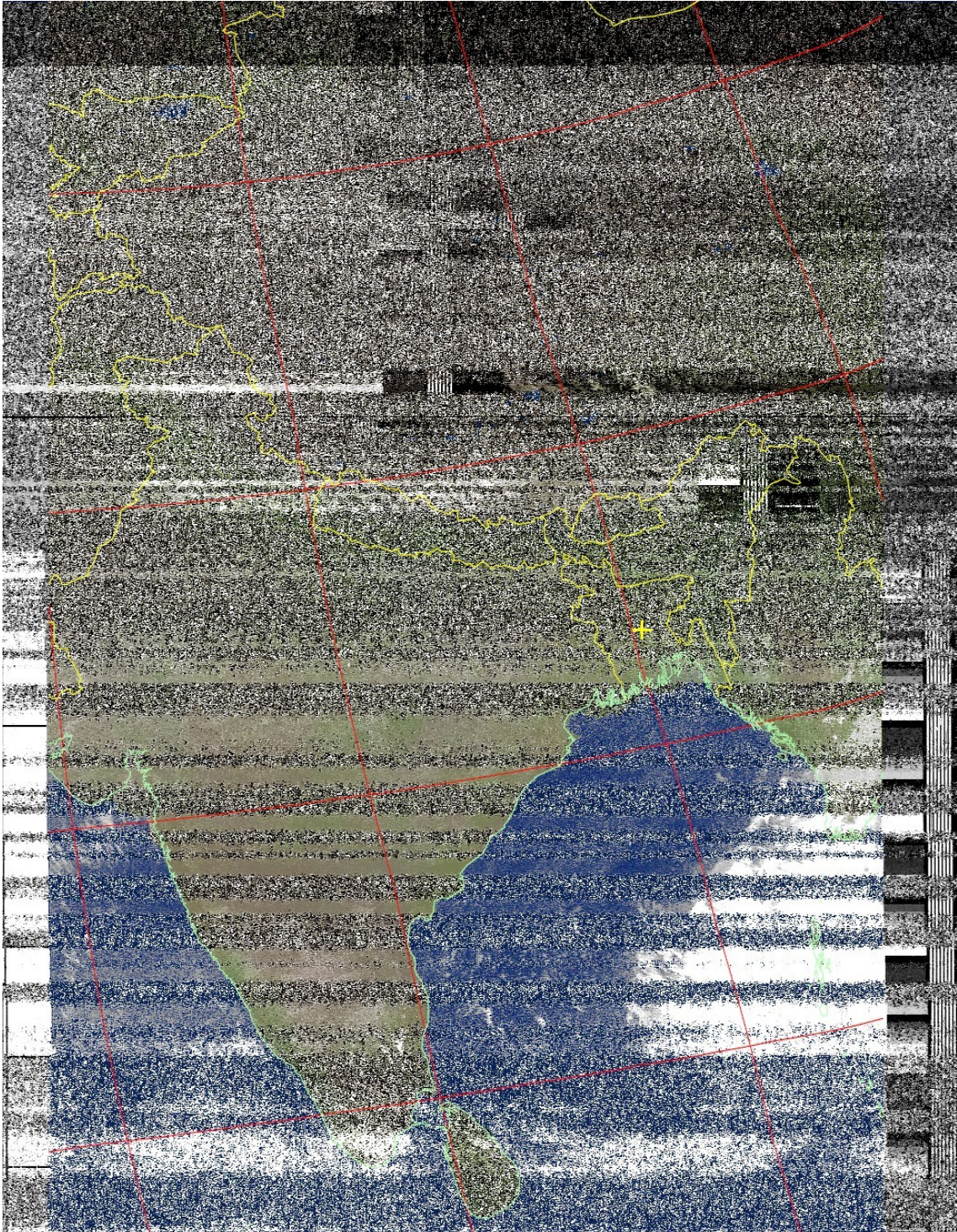


Figure 4.5: First Attempt with QFH Antenna with Noise

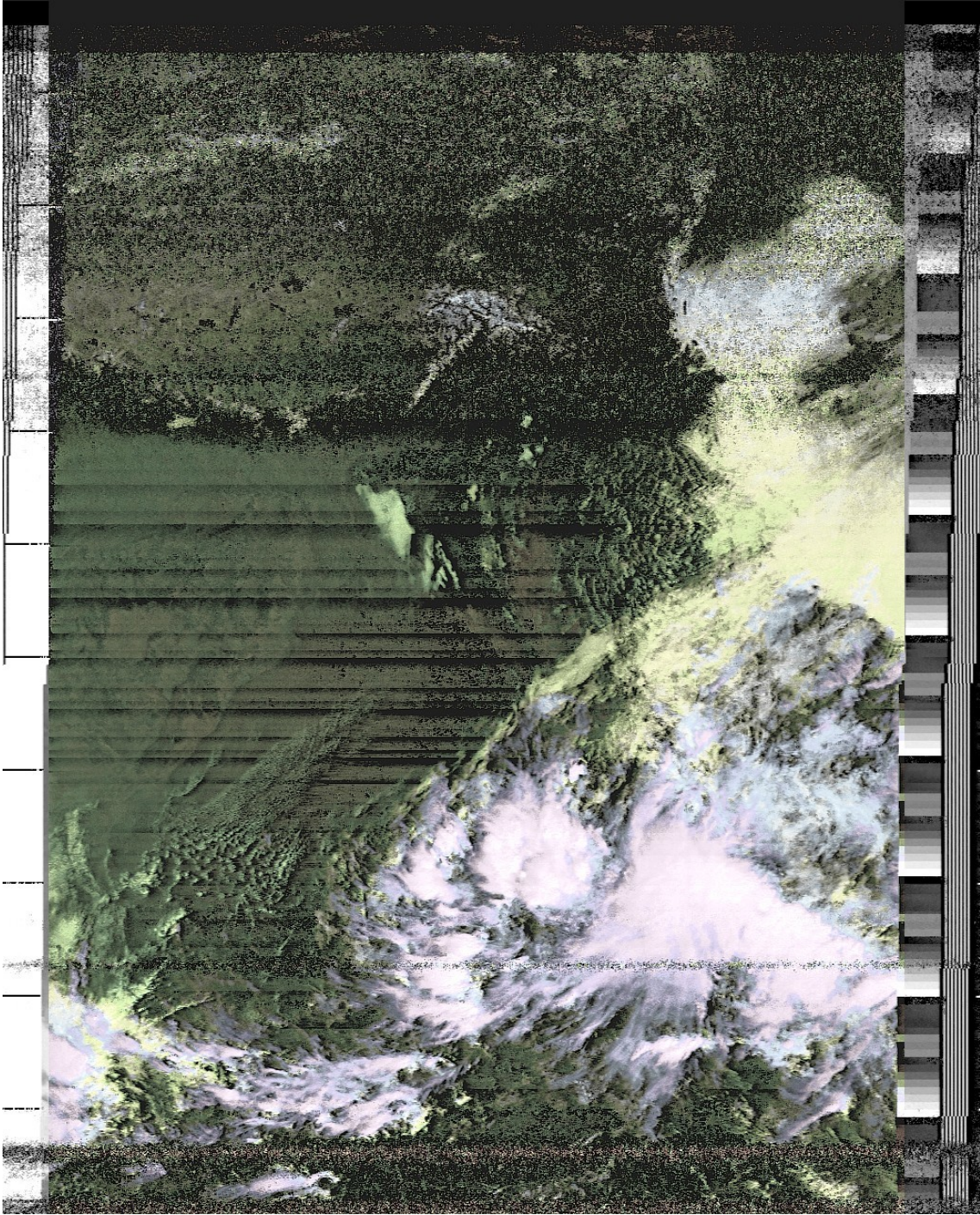


Figure 4.6: 2nd Attempt Result with Less Noise

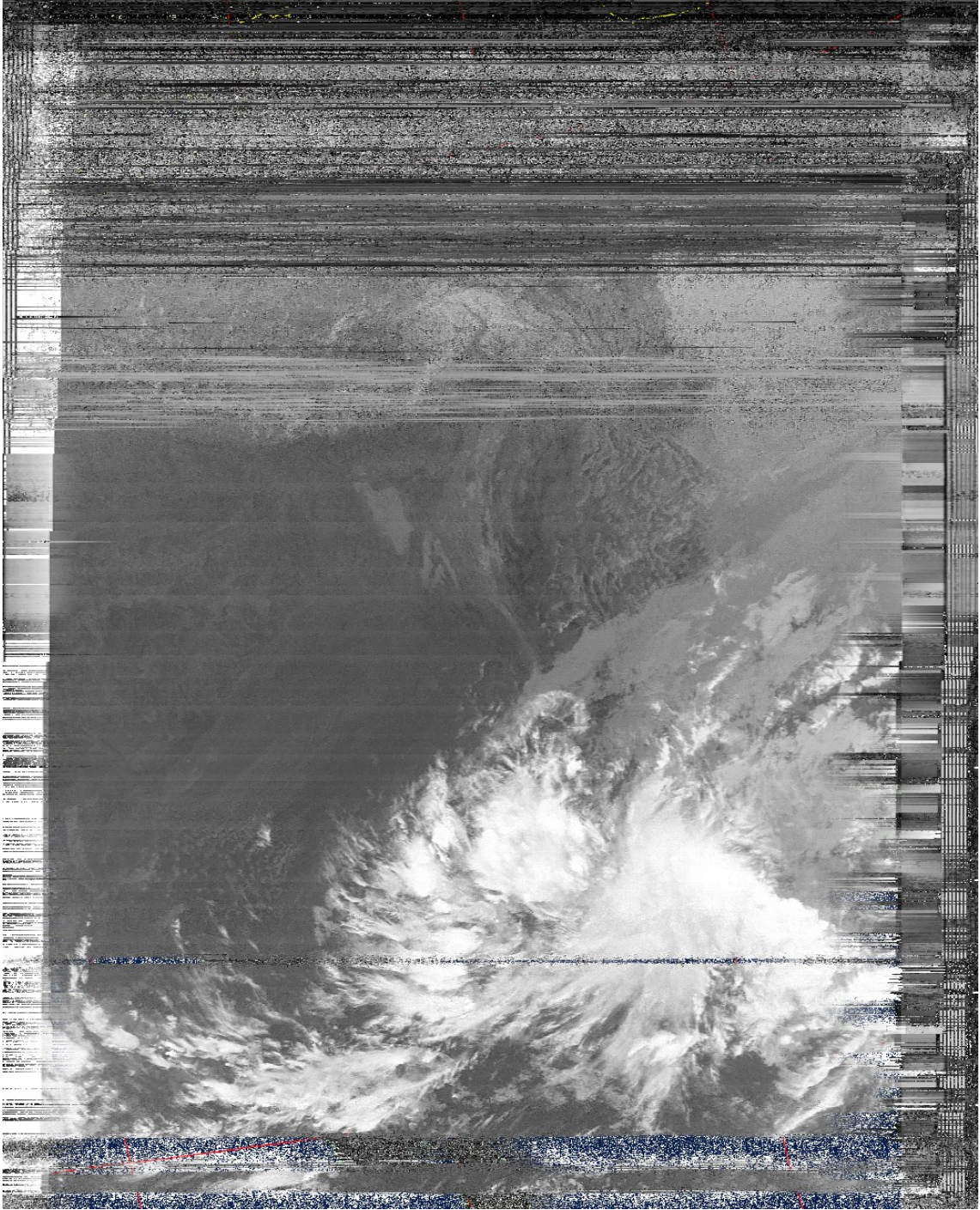


Figure 4.7: Near Infrared Picture of 2nd Attempt

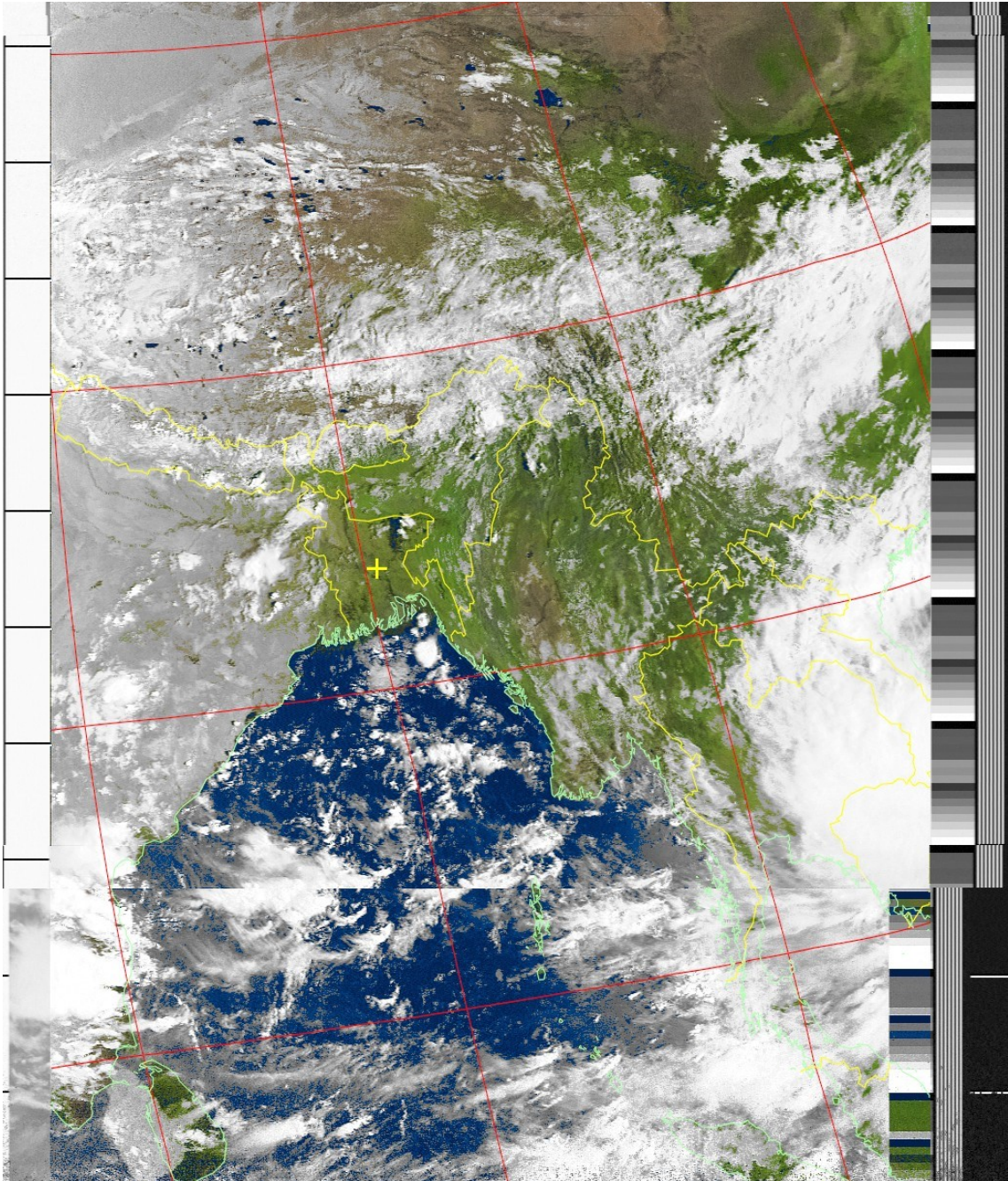


Figure 4.8: NOAA18, Final Image with another Satellite Pass

## 4.4 Summary

The Result signal reception and image decoding involved three iterations with the QFH antenna. The first attempt yielded an image with significant noise, highlighting areas for improvement in the setup. Adjustments were made in the second attempt, which resulted in reduced noise but still fell short of optimal clarity. Finally, after further fine-tuning of the antenna position and system calibration, the third attempt produced a clear and detailed satellite image, showcasing the effectiveness of the QFH antenna and the signal processing pipeline. This iterative process underscores the importance of refinement in achieving high-quality results.

# Chapter 5

## Engineering Standards and Design Challenges

This chapter outlines the software and hardware standards, communication protocols, societal and environmental impacts, ethical considerations, financial analysis, and project management strategies, along with addressing complex engineering challenges encountered during the project.

### 5.1 Compliance with the Standards

Only mention the standards that are related to your project. This list is not complete. For each of the standards discuss the alternatives with pros and cons and rationale of selection.

#### 5.1.1 Software Standards

In this project, several software tools were employed for signal processing, satellite tracking, and image decoding. These tools were selected based on their compatibility, ease of use, and suitability for achieving the project objectives. Below is a detailed discussion of the software used, along with their alternatives, pros and cons, and the rationale behind their selection.

- **HSDR:** HSDR (version 2.81) was chosen for signal processing due to its freeware nature and user-friendly interface.[11] It proved effective for tuning, demodulating, and recording signals from NOAA satellites.

**Alternatives:**

**SDRSharp:** This software is user-friendly but supports limited hardware. It does not support the MSI2500 SDR used in this project.

**SDRUno:** While user-friendly, it posed challenges due to its user interface, which I found less intuitive for efficient operation.

**GNURadio:** Known for its high customizability, GNURadio requires advanced technical expertise and is better suited for projects with complex signal processing needs.

**SDR Console:** Although feature-rich, it has a steep learning curve and lacks effective audio output for APT signals.

**Rationale for Selection:** HSDR's simplicity and compatibility with the MSI2500 SDR made it the most practical choice for this project, balancing functionality and

ease of use.

- **VB-Cable:** This virtual audio cable software was used for routing audio signals between HSDR and image decoding software.[12] Its ability to seamlessly transfer signals without external hardware made it an indispensable tool.

**Alternatives:**

Alternatives like Virtual Audio Cable (VAC) exist but are paid solutions, whereas VB-Cable is a free and straightforward option.

**Rationale for Selection:**

VB-Cable’s no-cost licensing and easy setup made it ideal for this project.

- **WxToImg:** WxToImg was employed for decoding and enhancing satellite image data from Automatic Picture Transmission (APT) signals.[13] Its specialized features, such as map overlays and image enhancement filters, ensured high-quality output.

**Alternatives:** Limited alternatives exist for APT decoding, however, WxToImg remains a preferred choice for its extensive feature set and freeware availability.

**Rationale for Selection:**

The software’s focus on NOAA APT image processing and enhancement capabilities aligned perfectly with the project’s objectives.

- **Gpredict:** Gpredict provided real-time satellite tracking and azimuthal predictions, aiding in the accurate alignment of the ground station for optimal reception.[14] Features like automatic TLE updates further streamlined operations.

**Alternatives:** Alternatives include Orbitron, which offers similar functionalities but lacks automatic TLE updates, requiring manual maintenance.

**Rationale for Selection:** Gpredict’s combination of accuracy, user-friendly interface, and automatic TLE updates made it the most suitable tool for this project.

Table 5.1: Software Used in the Project and Alternatives

Software Used	Version	Alternatives
HSDR	2.81	SDRSharp, SDRUno, GNURadio, SDR Console
VB-Cable	1.0.3.5	Virtual Audio Cable (VAC)
WxToImg	2.10.11	APTDecoder, SATdump
Gpredict	2.2.1	Orbitron, Heavens-Above

The software suite used in this project was carefully selected to balance functionality, ease of use, and compatibility with low-cost hardware. Each tool was evaluated against alternatives, ensuring that the final choices aligned with the project’s goals and constraints.

### 5.1.2 Hardware Standards

The hardware components selected for this project were carefully chosen based on their suitability for receiving and processing NOAA satellite signals. Below is an overview of the key hardware used in the project, along with alternative options, their pros and cons, and the rationale for the selection of each component.

#### MSI2500 SDR Receiver

The **MSI2500 SDR receiver** was selected for its cost-effectiveness and reliability in receiving NOAA satellite signals. It provides a balance of performance and affordability, making it well-suited for this project. The MSI2500 offers enhanced frequency stability, ensuring that weak satellite signals are captured with sufficient clarity for processing.[15]

##### Alternatives:

- **HackRF One:** Offers a wider frequency range (1 MHz to 6 GHz)[16], making it versatile for various SDR applications. However, it is more expensive than the MSI2500 and may be overkill for this project.
- **RTL-SDR V3:** A popular and affordable SDR receiver[17], but slightly less sensitive compared to the MSI2500, which could affect signal clarity for weak satellite signals.
- **FunCube Dongle Pro+:** A compact solution with a limited frequency range, suitable for specific satellite reception but not as versatile as the MSI2500.
- **Airspy Mini:** Offers higher sensitivity, but at a higher price point, which may not have been necessary for this project.

**Rationale for Selection:** The **MSI2500 SDR receiver** was chosen for its balance between affordability, performance, and compatibility with NOAA APT signal decoding. It offered the necessary sensitivity to receive signals effectively without introducing unnecessary complexity.

#### Antenna Standards

Two antenna designs were employed to ensure optimal signal reception from NOAA satellites. Both antennas were tested to determine their performance in receiving weak signals from polar-orbiting satellites.

#### QFH Antenna

The **QFH (Quadrifilar Helix) antenna** was chosen for its ability to provide circular polarization, which is essential for consistent reception of NOAA APT signals. It was designed to operate at a frequency of 137 MHz, optimized for NOAA satellites.

## V-Dipole Antenna

The **V-Dipole antenna** was selected as an alternative due to its simple design and omnidirectional characteristics. It provides a broad reception angle, making it a good backup for the QFH antenna.

### Alternatives:

- **Turnstile Antenna:** A simple antenna design that is easy to construct but less efficient at low elevations. This could have been used as a secondary option, though it might not provide the same level of performance as the QFH antenna.
- **Yagi-Uda Antenna:** A highly directional antenna, suitable for focused signal reception but more complex to design and less ideal for capturing signals from multiple angles.

**Rationale for Selection:** The **QFH antenna** was selected for its superior circular polarization, crucial for receiving stable signals from NOAA satellites. The **V-Dipole antenna** was chosen as a secondary option to provide flexibility in signal reception and serve as a backup antenna for optimal performance.

## RG6 Coaxial Cable

The **RG6 coaxial cable** was used to connect the antenna to the MSI2500 SDR receiver. RG6 is a 75-ohm cable commonly used for television and satellite reception. Although **50-ohm cables** are generally preferred for radio frequency (RF) applications, the use of RG6 was acceptable in this project due to its suitability for a receive-only ground station.

### Alternatives:

- **LMR-400:** A 50-ohm cable that offers superior performance with lower loss and higher shielding, but it is more expensive than RG6 and may not be necessary for the requirements of this project.
- **RG58:** A 50-ohm cable, more flexible but with higher loss compared to other options like LMR-400.
- **LMR-240:** Flexible but with slightly higher loss than LMR-400, though it is more affordable.

**Rationale for Selection:** **RG6** was chosen primarily for its cost-effectiveness and sufficient performance in a **receive-only** setup. Since the project did not require high-performance transmission capabilities, RG6 was adequate for the purpose.

## Computer System

An **Intel 8th Gen laptop** with 8GB of RAM was used for processing the satellite signals and generating the decoded images. While a **Raspberry Pi** could have handled basic tasks, the laptop was preferred for its better processing power, which allowed for more efficient signal processing and faster image generation. Additionally, the laptop's larger memory and broader software compatibility made it a more practical solution for this project.

### Alternatives:

- **Raspberry Pi:** A low-cost, compact option that could run basic signal processing software like SATdump. However, it lacks the processing power needed for real-time decoding and image generation at the scale required for this project.
- **Intel NUC:** A small, energy-efficient computer with better performance than the Raspberry Pi but at a higher cost. It could have been a good alternative for a more compact system.
- **Desktop PC:** A desktop PC with higher performance would have been more powerful but would compromise portability, making it less suitable for a ground station setup.

**Rationale for Selection:** The **Intel 8th Gen laptop** was chosen for its combination of performance, portability, and compatibility with the necessary software tools. It provided sufficient processing power to handle real-time signal processing and image generation, making it the most suitable option for this project.

Table 5.2: Summary of the Hardware Standards

Hardware Used	Alternatives
MSI2500 SDR Receiver	<ul style="list-style-type: none"><li>- <b>HackRF One:</b> More versatile but expensive.</li><li>- <b>RTL-SDR V3:</b> Popular but slightly less sensitive.</li><li>- <b>FunCube Dongle Pro+:</b> Compact but limited frequency range.</li><li>- <b>Airspy Mini:</b> More sensitive but pricier.</li></ul>
QFH Antenna	<ul style="list-style-type: none"><li>- <b>Turnstile Antenna:</b> Simple but less efficient at low elevations.</li><li>- <b>Yagi-Uda Antenna:</b> More directional, but more complex and less omnidirectional.</li></ul>
V-Dipole Antenna	<ul style="list-style-type: none"><li>- <b>Turnstile Antenna:</b> Simple to design, less efficient at low elevations.</li><li>- <b>Log-periodic Antenna:</b> Offers broadband capabilities but more complex design.</li></ul>
RG6 Coaxial Cable	<ul style="list-style-type: none"><li>- <b>LMR-400:</b> 50-ohm cable, higher quality and low loss but more expensive.</li><li>- <b>RG58:</b> 50-ohm, flexible but higher loss.</li><li>- <b>LMR-240:</b> Flexible but with higher loss compared to LMR-400.</li></ul>
Intel 8th Gen Laptop	<ul style="list-style-type: none"><li>- <b>Raspberry Pi:</b> Low-cost and portable but less powerful.</li><li>- <b>Intel NUC:</b> Compact and energy-efficient but more expensive.</li><li>- <b>Desktop PC:</b> Higher performance but larger and less portable.</li></ul>

As my project title said it would be a cost effective project, so the the selected hardware provides a balance between performance and cost-effectiveness for this project. Alternatives were considered, with the chosen components offering the best compatibility and reliability for signal reception and processing

### 5.1.3 Communication Standards

The communication standards used in this project were primarily focused on the reception and processing of signals from NOAA polar-orbiting satellites. The key standard employed was the **Automatic Picture Transmission (APT)**, which is an analog signal transmission format commonly used by NOAA weather satellites.

- **NOAA APT Protocol:** This protocol operates at a frequency of 137 MHz, transmitting analog signals that carry weather imagery data from polar-orbiting satellites. APT is widely used for low-cost satellite reception and is supported by a variety of receivers and decoding software. The **MSI2500 SDR receiver** and **QFH/V-Dipole**

**antennas** were selected for their compatibility with this standard, ensuring effective reception of these signals.

- **Alternatives:**
  - **Low Rate Picture Transmission (LRPT):** Offers better image quality with higher resolution, but requires more complex receivers.
  - **High Rate Picture Transmission (HRPT):** Provides real-time data at high resolution, but demands more expensive and complex equipment.
- **Rationale for Selection:** The **APT protocol** was chosen due to its simplicity, wide availability, ease of decoding, and compatibility with the hardware selected for this project. It allowed for effective and reliable signal reception without the need for specialized or costly equipment.
- **Frequency Standards:** Operates in the 137–138 MHz VHF band, allocated for meteorological satellite communication by the **ITU (International Telecommunication Union)** and **BTRC (Bangladesh Telecommunication Regulatory Commission)**.
- **Rationale for Selection:** Compliance with both ITU and BTRC regulations ensures legal operation within global and national standards, minimizing interference and maintaining lawful satellite communication.[18]
- Additionally, **Software Defined Radio (SDR)** communication standards were employed for signal processing and interfacing with decoding software. These standards enable flexibility in processing various types of signals, and **HDSDR software** was used to interface with the SDR hardware. The software was chosen for its compatibility with the **MSI2500 SDR** and its ease of use in tuning and demodulating APT signals.

## 5.2 Impact on Society, Environment and Sustainability

### 5.2.1 Impact on Life:

This project demonstrates how affordable technology can bridge the gap between advanced scientific tools and everyday users. It provides practical benefits in education, research, and community awareness.

**Educational Benefits:** This project simplifies satellite signal processing, making it accessible for students, educators, and hobbyists. It encourages STEM learning by providing a cost-effective way to explore space technology.

**Useful for Research:** Local researchers and environmentalists can use the system to gather weather and satellite data, enabling studies and disaster preparedness even in underprivileged regions.

**Inspiring Creativity:** Using low-cost tools and innovative methods, this project motivates experimentation and innovation in communication and satellite technology.

**Raising Awareness:** By accessing real-time weather data, individuals can better understand and respond to environmental challenges, promoting broader awareness of global climate issues.

### 5.2.2 Impact on Society & Environment:

This project plays a vital role in environmental monitoring and awareness by utilizing satellite data to provide an efficient and affordable method for assessing environmental changes.

**Environmental Monitoring:** The processed satellite images allow users to track weather patterns, deforestation, and urbanization, contributing to a better understanding of climate change impacts and natural resource management.

**Reduced Waste Through Software-Defined Radios:** Unlike traditional hardware-intensive systems, this project employs software-defined radios (SDRs), which are versatile and minimize electronic waste. Their reusable nature supports eco-friendly practices.

**Promotion of Green Awareness:** The project promotes green initiatives by enabling communities to identify and respond to environmental issues efficiently, using accurate satellite data.

This project demonstrates environmental monitoring while minimizing its ecological footprint through efficient technology choices.

### 5.2.3 Ethical Aspects

This project not only emphasizes technological innovation but also sticks to strong ethical considerations, ensuring responsible and equitable use of resources and data.

**Open Access to Knowledge:** By utilizing open-source software and affordable hardware, this project democratizes access to satellite data and weather monitoring tools. It ensures that even underprivileged communities can benefit from advanced technology without significant financial barriers.

**Privacy and Data Ethics:** The system is designed to process publicly available satellite data, ensuring compliance with data privacy laws and ethical standards. By avoiding sensitive or restricted information, the project respects global regulations and promotes transparency in data usage.

**Sustainability and Environmental Responsibility:** The project’s focus on software-defined radios (SDRs) aligns with sustainable practices by reducing the need for specialized hardware and minimizing electronic waste. This conscious choice highlights a commitment to environmental ethics.

**Avoidance of Dual-Use Risks:** While enabling technological experimentation, the project actively discourages the misuse of satellite data for harmful purposes. By promoting educational and environmental applications, it aligns with ethical principles and discourages unintended dual-use risks.

#### 5.2.4 Sustainability Plan

The project’s design and implementation promote sustainability through low-cost technology and long-term usage benefits.

**Economic Accessibility** Using low-cost SDR hardware ensures that environmental monitoring tools are accessible to a wider audience, fostering inclusive participation in sustainable development efforts.

**Scalability and Future-Proofing** The flexibility of SDR and the adaptability of the selected software ensure that the system can evolve with technological advancements, avoiding obsolescence.

**Low Resource Consumption** The project’s reliance on a single lightweight ground station setup reduces the energy and resource demands compared to conventional large-scale monitoring systems.

In conclusion, the project integrates sustainability into its core by ensuring economic, environmental, and technological balance.

### 5.3 Design Constraints

Throughout the development of this project, I encountered several design constraints that required careful consideration and decision-making. These challenges, ranging from budget limitations to ethical and sustainability concerns, played a key role in shaping the final approach and the hardware and software choices made during the project.

#### 5.3.1 Economic Constraint

The radio-related devices required for this project can be costly, especially for high-performance hardware. Due to budget limitations, I had to choose more affordable alternatives, such as the MSI2500 SDR receiver and QFH/V-Dipole antennas, ensuring that the project remained within a manageable budget while still meeting the performance requirements.

### 5.3.2 Ethical Constraint

Although there is access to high-resolution satellite imagery from various sources, many of these data sets are restricted due to regulatory and licensing constraints. As a result, I was limited to publicly available NOAA APT signals, which are less detailed but still provide valuable environmental information without violating data usage regulations.

### 5.3.3 Sustainability

The antenna for the project was made from copper, which is prone to degradation when exposed to outdoor conditions for extended periods. While copper is a good conductor, it does not offer long-term sustainability when exposed to weather elements, leading to potential corrosion. This constraint necessitates regular maintenance and potential replacement to ensure the antenna remains functional over time.

## 5.4 Project Management and Financial Analysis

Project management for this project emphasizes the efficient use of low-cost resources while achieving the goal of satellite signal processing and image generation. The project follows a structured approach, involving defining clear objectives, conducting signal reception, designing antennas, configuring hardware, and processing satellite images. Since this project is carried out individually, all tasks were planned and executed by myself, ensuring efficiency and quality at every stage.

In this project, affordable hardware and software solutions were utilized to achieve the desired results without compromising performance. The estimated cost for the project is kept between 99,000 and 108,900 BDT, with careful resource allocation and prioritization to minimize unnecessary expenses. The breakdown of costs includes hardware, software, signal reception, documentation, and contingency allowances.

Table 5.3: Estimated Cost

<b>Components</b>	<b>Estimated Cost (BDT)</b>
Hardware/Infrastructure	7,000–10,000
Components for Antenna	1,500–2,000
Visiting Stakeholders	Free of Cost
Software	Free of Cost
Documentation and Report Writing	Free of Cost
Miscellaneous	1,000–2,000
Contingency (10% of total)	800–1,000
<b>Total Estimated Cost</b>	<b>10,500–15,000</b>

## 5.5 Complex Engineering Problem

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### 5.5.1 Complex Problem Solving

This project addresses complex problem-solving criteria by integrating technical expertise, hardware, software, and stakeholder collaboration to achieve its objectives. Below is an analysis of how the project aligns with the relevant elements.

**EP1: Depth of Knowledge** The project showcases in-depth expertise in satellite signal reception, antenna construction, and software-defined radio (SDR) technology. Advanced methodologies for signal decoding and weather data visualization reflect a strong grasp of relevant technical domains.

Table 5.4: Mapping with complex problem solving.

EP1 Dept of Knowl- edge	EP2 Range of Con- flicting Require- ments	EP3 Depth of Analysis	EP4 Familiarity of Issues	EP5 Extent of Applicable Codes	EP6 Extent of Stake- holder Involve- ment	EP7 Inter- dependence
√	√	√	√		√	√

**EP2: Range of Conflicting Requirements** By balancing cost-efficiency, hardware compatibility, and reception quality, the project navigates the trade-offs between performance and affordability. The selection of the MSI2500 SDR and QFH/V-Dipole antennas exemplifies this balance.

**EP3: Depth of Analysis** Comprehensive testing and analysis of signal clarity, image quality, and antenna performance highlight the rigorous approach undertaken. Evaluations of various SDR software options further reinforce the analytical depth.

**EP4: Familiarity of Issues** The project addresses typical challenges such as signal interference, hardware limitations, and environmental factors affecting reception. These issues are mitigated through robust equipment choices and optimization techniques.

**EP6: Extent of Stakeholder Involvement** The project integrates feedback from educators and technical advisors, enhancing its practical application and usability for environmental monitoring and educational purposes.

**EP7: Interdependence** The project unifies hardware, software, and regulatory compliance into a cohesive system. The interdependence of the SDR receiver, decoding software, and antenna design ensures seamless operation and high-quality results.

## Mapping with Knowledge Profile for EP1

This table 5.5) is designed to map the EP1 to the Knowledge Profile.

Table 5.5: Mapping with knowledge Profile.

K3 Engineering Fundamentals	K4 Specialist Knowledge	K5 Engineering Design	K6 Engineering Practice	K8 Research Literature
√	√	√	√	√

This project aligns with various knowledge profiles essential for engineering problem-solving. Below is an analysis of how the project reflects these knowledge areas.

**K3: Engineering Fundamentals** The project demonstrates a strong foundation in engineering fundamentals by focusing on core concepts like radio frequency communication, satellite signal reception, and antenna design principles.

**K4: Specialist Knowledge** Specialist knowledge is showcased through the selection and optimization of SDR hardware, antennas (QFH and V-Dipole), and decoding software tailored for NOAA APT signals.

**K5: Engineering Design** The design of the ground station, including the integration of SDR receivers, antennas, and decoding tools, exemplifies efficient engineering design. The focus on balancing performance and cost-effectiveness aligns with this knowledge area.

**K6: Engineering Practice** By applying practical techniques such as SDR-based signal processing, antenna construction, and signal decoding using industry-standard tools, the project fulfills the engineering practice requirement.

**K8: Research Literature** The project incorporates research into satellite communication, antenna theory, and decoding techniques. Insights from ITU and BTRC regulations, along with industry best practices, ensure a solid foundation and regulatory compliance.

### 5.5.2 Engineering Activities

In this section, provide a mapping with engineering activities. For each mapping add subsections to put rationale (Use Table 5.6).

This project demonstrates alignment with complex engineering activities through several key aspects.

Table 5.6: Mapping with complex engineering activities.

EA1 Range of re- sources	EA2 Level of Interac- tion	EA3 Innovation	EA4 Consequences for society and environment	EA5 Familiarity
✓	✓		✓	✓

**EA1: Range of Resources** The project utilizes a diverse range of tools and resources, including SDR hardware, decoding software, and antenna designs, to construct an effective and low-cost ground station for NOAA APT signal reception. This integration ensures robust performance while adhering to the project’s cost-effective approach.

**EA2: Level of Interaction** A high level of interaction is achieved between SDRs, antennas, and decoding software. The seamless integration of these components ensures efficient signal processing and accurate satellite image generation, highlighting the inter-connected nature of the system.

**EA3: Innovation** The extension of this project from other project would be the multiple antenna alignment at the same time, but by far that would not consider as innovation, So for my project EA3 is not applicable.

**EA4: Consequences for Society and Environment** This project contributes positively to society and the environment by promoting environmental monitoring and awareness. By processing satellite data, it enables the tracking of weather patterns and environmental changes, providing valuable insights for addressing ecological challenges.

**EA5: Familiarity** The project leverages well-established tools and standards, ensuring a balance between reliability and innovation. This familiarity with existing methods allows for tailored solutions in signal decoding and system optimization, creating an effective and practical implementation.

## 5.6 Summary

This project follows well-established engineering standards to deliver a reliable and efficient solution for satellite signal reception and processing. By combining various hardware and software components, it achieves a seamless and innovative integration while addressing key challenges like compatibility, antenna performance, and signal decoding efficiency. The design prioritizes cost-effectiveness without compromising on functionality, ensuring it meets the requirements of a low-cost ground station. Additionally, the project’s contribution to weather monitoring and its eco-conscious approach reinforce its significance as a practical and sustainable initiative.

# Chapter 6

## Conclusion

In the chapter 4 I already discuss about the result. Is the result matches my expected outcome? If not what was the limitation, if yes or not what could be done with this project in future for enhancement? this is what discussed in this Conclusion chapter.

### 6.1 Summary

This project successfully developed a low-cost ground station to receive and process signals from NOAA polar-orbiting satellites. Utilizing a combination of software-defined radio (SDR) technology, QFH and V-dipole antennas, and open-source software, the project focused on capturing Automatic Picture Transmission (APT) signals. The processed data allowed for the generation of satellite imagery that can be used for environmental monitoring. Through this project, various standards were adhered to, including communication, hardware, and environmental sustainability. The overall approach demonstrated the feasibility of using cost-effective methods to capture and decode satellite signals, providing valuable insights without the need for expensive equipment. Additionally, the data generated can serve as a valuable resource for data scientists who can further analyze the data for advanced applications.

### 6.2 Limitation

While the project achieved its primary objectives, several limitations were encountered. One of the key constraints was the use of a 75-ohm RG6 cable for signal transmission, which, while functional, was not ideally suited for radio standards. Additionally, the reliance on APT signals, which have a lower resolution compared to HRPT or LRPT, limited the quality of the images generated. The system was also restricted to receiving signals from NOAA satellites, and the signal reception range was constrained by geographical and environmental factors.

- **Signal Transmission**
- **Resolution Limitations**
- **Geographical and Environmental Constraints**
- **Hardware Limitations**

Furthermore, the processing power was limited by the hardware chosen, which, while

adequate, could have been optimized for more efficient processing of higher-resolution data.

### 6.3 Future Work

- **Exploration of LRPT and HRPT**
- **Advanced Signal Processing**
- **Collaboration with Data Scientists**
- **Improved Hardware Setup**
- **Optimization for Large-Scale Data**

Future work for this project includes expanding the scope to include higher-resolution signals such as Low Rate Picture Transmission (LRPT) and High Rate Picture Transmission (HRPT). These transmission protocols offer superior image quality and real-time data, which would significantly enhance the utility of the satellite data for environmental and weather monitoring. Additionally, improvements can be made to the antenna design and signal processing techniques to further optimize performance. Exploring the use of alternative hardware such as more specialized SDR receivers could help enhance signal sensitivity and reception quality. Expanding the project to include multi-satellite reception and automated image analysis could also be considered to increase the scope and applicability of the system. With the data collected, data scientists can also engage in more advanced analysis, such as predicting weather patterns, climate change effects, and identifying key environmental trends.

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