Receiving APT Signal of NOAA Satellites Using V-Dipole Antenna

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by

Akhil Selvakumar (14ET12)
Pathan ShahidKhan AkhtarKhan (14ET33)

Under the guidance of

Prof. Siraj Pathan

Department of Electronics and Telecommunication Engineering
Anjuman-I-Islam's Kalsekar Technical Campus,
Sector 16, New Panvel , Navi Mumbai
(Affiliated to University of Mumbai)
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Anjuman-I-Islam's
Kalsekar Technical Campus
(Affiliated to the University of Mumbai)
Plot 2 and 3,Sector 16, Khandagaon, Near Thana Naka, New Panvel, Navi Mumbai 410206.

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This is to certify that, the dissertation titled

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is a bonafide work done by

Akhil Selvakumar (14ET12)
Pathan ShahidKhan AkhtarKhan (14ET33)

and is submitted in the fulfillment of the requirement for the degree of

Bachelor of Engineering
in
Electronics and Telecommunication Engineering
to the
University of Mumbai.

Guide Project Coordinator

Head of Department Principal

Certificate of Approval by Examiners

This is to certify that the dissertation entitled **"Receiving APT Signal of NOAA Satellites Using V-Dipole Antenna "** are a bonafide work done by **Akhil Selvakumar and Pathan ShahidKhan AkhtarKhan** under the guidance of **Mr. Siraj Pathan**. This dissertation has been approved for the award of **Bachelor's Degree in Electronics and Telecommunication Engineering**, University of Mumbai.

Examiners:

Name: Name:

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Abstract

Weather forecasting has always been an essential part of man's numerous activities including day-to-day agriculture, seafaring, deep sea fishing. Over the past several decades, weather forecasting has been carried out using satellite, internet other sophisticated equipment. But, this may not be accessible in remote places like hilly regions deep seas. However, huge expenses, poor resolution of the images, and very low availability of useful information from them have always been among the top issues faced. Fine reception of these images and extraction of relevant information is easier said than done. This project aims to decrease the cost of imaging substantially, and greatly improve availability of such images. By making use of locally available raw materials, an antenna will be constructed and tested with good results that would receive fine APT signals from NOAA 15, 18, 19. Using sync pulses, the audio signals will be decoded into an image in WXtoIMG. Filtering, cross correlation and noise reduction are some of the steps that will be implemented to form the image. This system thus provides a comprehensive solution for receiving satellite images with a Software Defined Radio, an appropriate antenna and various application environments for decoding the audio signals into an intelligible image. It requires very less processing power thus making weather forecasting quite convenient for the common man. It is therefore a low cost and a homebrew elucidation of a technique that is otherwise regarded as quite sophisticated by space enthusiasts.

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Chapter 1

Introduction

1.1 Introduction

We will be receiving APT signals which are Right Hand Circular Polarized. The idea is that by arranging a dipole into a horizontal V shape, the radiation pattern will be directed skywards in a figure 0 (zero) pattern. This will be optimal for satellites travelling in front, above and behind the antenna. Since polar orbiting satellites always travel North to South or vice versa, we can take advantage of this fact simply by orienting the antenna North/South. There is also another advantage to Adams design. Since the antenna is horizontally polarized, all vertically polarized terrestrial signals will be reduced by 20 dB. Most terrestrial signals are broadcast in vertical polarization, so this can help significantly reduce interference and overloading on your RTL-SDR. Overloading is a big problem for many trying to receive weather satellites as they transmit at 137 MHz, which is close to the very powerful FM broadcast band, air band, pagers and business radio.

- Weather forecasting : Weather forecasting has always been an essential part of mans numerous activities including day-to-day agriculture, seafaring, deep sea fishing. Over the past several decades, weather forecasting has been carried out using satellite, internet other sophisticated equipment. But, this may not be accessible in remote places like hilly regions deep seas. However, huge expenses, poor resolution of the images, and very low availability of useful information from them have always been among the top issues faced. Fine reception of these images and extraction of relevant information is easier said than done. This project aims to decrease the cost of imaging substantially, and greatly improve availability of such images. By making use of locally available raw materials, an antenna will be constructed and tested with good results that would receive fine APT signals from NOAA 15, 18, 19. Using sync pulses, the audio signals will be decoded into an image in WXtoIMG. Filtering, cross correlation and noise reduction are some of the steps that will be implemented to form the image. This system thus provides a comprehensive solution for receiving satellite images with a Software Defined Radio, an appropriate antenna and various application environments for decoding the audio signals into an intelligible image. It requires very less processing power thus making weather forecasting quite convenient for the common man. It is therefore a low cost and a homebrew elucidation of a technique that is otherwise regarded as quite sophisticated by space enthusiasts.

1.2 Motivation

Monitoring weather patterns and interpreting satellite images is one of the most widely utilized applications of remote sensing. Weather forecasting is a very important requirement for applications like Agriculture, Deep Sea Fishing, etc Weather forecasting can be done using Internet, but it cannot be made available in remote areas like hilly regions, oceans, etc. To overcome this problem, we will construct an antenna which will be easily portable and of low cost.

Chapter 2

Literature Survey

2.1 Receiving Automatic Picture Transmission Signals

Satellite Image Acquisition is one of the most explored domains in satellite communications since the start of the space age. Satellite images provide us with a wealth of information regarding cloud formations, precipitation, surface temperatures and air pollutants among many others. Presently, getting weather forecasts is limited to accessing governmental websites that show satellite images encompassing quite a large chunkof land. Access to localized weather images and their interpretation to decipher the information hidden in them is thus the need of the hour. There is a widespread misconception that for receiving satellite images, firstly an authorized license is required and secondly, huge parabolic dishes with specialized RF receivers are necessary. This is however, not the case. With a simple Quadrifilar Helical Antenna , and a cheap Software Defined Radio dongle, satellite images of quite good resolution can be obtained. The Automatic Picture Transmission (APT) signal is an analog image transmission signal used by weather satellites. National Oceanic and Atmosphere Administration (NOAA) uses 137.5 MHz APT signal to broadcast data. NOAA's satellites focus on the conditions of the oceans and the atmosphere. Antennas of simple and low cost construction are enough to capture these signals.

2.1.1 Cross Polarization

As the name says, it is the polarization orthogonal to the polarization of the interest, that we are using. If we are using the vertical polarization, the cross polarization is the horizontal and vice versa. Same goes for the circular polarization, if we are using the RHCP, the cross polarization is LHCP. Why is this important for us? Simply, if you choose the wrong polarization the cross polarization will be infinite, in theory. In practice, we can not construct the antenna ideally to radiate just vertical or just the horizontal polarization hence the cross polarization will not be infinite do imperfections but will have the values of 20-30dB. You can check that easily. Try to listen some radio using the vertical whip antenna and turn the whip then horizontally. There should be difference in the signal strength at least 20dB. Same way, if you miss to wind your helix antenna in proper direction the cross-polarization will be 20-30dB and you will end up with poor signal reception. Polarization relationship regarding cross polarization :

X-polarization	Vertical	Horizontal	RHCP	LHCP
Vertical	0dB	-20dB	-3dB	-3dB
Horizontal	-20dB	0dB	-3dB	-3dB
RHCP	-3dB	-3dB	0dB	-20dB
LHCP	-3dB	-3dB	-20dB	0dB

2.1.2 Problems faced while receiving signals

- Weather conditions : The most prominent one is wind. Wind in itself doesn't effect the RF signal but it does put an external force (wind loading) on the antenna system that can cause it to move or come out of alignment. Moisture such as fog, rain, and snow (depending on its water content) adds attenuation to the signal's path. Fog, although dense, has very low moisture when it comes to its effect on RF signal. With snow it all depends on its density. Snow typically has less moisture content than actual rain. Rain depends on the amount of rainfall (measured in mm/h) and the size of the raindrops. Heavier the raindrops and the higher velocity of rainfall the higher the attenuation.

- Noise : Noise due to equipment, wrong polarization, change of angle between dipole legs.

2.2 Problem Statement

Receiving Automatic Picture Transmission signals for weather forecasting needs to be done in a cheap and simple way which will provide people in remote areas with good quality weather predictions.

2.3 Project Overview

Monitoring weather patterns and interpreting satellite images is one of the most widely utilized applications of remote sensing. Satellites have been used over the past several decades to obtain a wide variety of information about the earth's surface. Inspite of that, huge expenses, poor resolution of the images, and very low availability of useful information from them have always been among the top issues faced by satellite enthusiasts. Fine reception of these images and extraction of relevant information is easier said than done. This project aims to decrease the cost of imaging substantially, by designing a cheap, yet reliable V-dipole antenna. The idea is that by arranging a dipole into a horizontal V shape, the radiation pattern will be directed skywards in a figure 0 (zero) pattern. This will be optimal for satellites travelling in front, above and behind the antenna. Since polar orbiting satellites, like the NOAA group of satellites always travel north to south or vice versa, we can take advantage of this fact simply by orienting the antenna North/South.

Chapter 3

Technical Details

3.1 Methodology

At the moment there are three NOAA satellites available transmitting the APT weather pictures in LRPT format. They are operating in the frequency range of 137 MHz till 138 MHz. The satellites are transmitting the RHCP (Right Hand Circular Polarized) signal on the following frequencies:

NOAA-15	137.620 MHz
NOAA-18	137.912 MHz
NOAA-19	137.100 MHz

Beside this three NOAA satellites there is also the Russian METEOR M N2 satellite transmitting weather pictures on 137.900 MHz. The band (137-138 MHz) is crowded with the other satellite signals. Usually you can find several strong ORBCOMM signals and wideband ORBCOMM 57k6 signal on 137.560 MHz, just below the NOAA-15 frequency. Do not be confused with the aeronautical VDL MODE 2 signal on 136.975 MHz.

3.2 Selecting the right antenna

The satellite transmits the RHCP signal. Ideally, this signal should be received with the RHCP antenna. If we made a mistake winding the helix in a wrong direction creating the LHCP the received signal will be lower at least 20dB if not more than it should be received using the RHCP antenna. This will result in a poor signal quality, not acceptable. Sacrificing a few dB for the simple antenna design we can select on of the linearly polarized antenna. First we decide the polarization we prefer, vertical or horizontal. A simple vertical whip or even a ground plane vertical antenna may be a cheap and simple to build antennas. What are the pros for the vertical antenna? Simple design, omnidirectional pattern not requiring the antenna rotator, easy to achieve 50 ohms impedance, low radiation angle that can give us good reception when the satellite is low and distant on horizon. Almost perfect antenna for our satellite reception one may say, but let se the cons for such a design. The biggest problem is coming from the fact that most of the professional radio services and networks are using the vertical polarization too. The most of the users will use the standard DVB-t dongle grade SDR receiver lacking both, the selectivity and dynamic range. This problem can be solved partially by turning the gain down a bit, with drawback through increased noise figure and reduced S/n ratio. Nearby aeronautical radio service is also using the vertical polarization on the AM. Definitely the planes are the biggest blockers. They are simply 10-12km above us and transmitting usually 25W. You may note that problem through the raised noise floor resulting with the noise strips on the received picture. A vertical antenna will have a donuts shape radiation diagram where the signals above the antenna will be attenu- ated a lot. At high elevations the satellites are close enough and this drawback may be compensated a bit by shorter distance. Horizontal polarization and pros for the simple dipole antenna. Cheap and simple to build also, but there is another advantage. If we look back to the polarization relationship between the vertical and horizontal polarization we can notice the crosspolarization of 20dB. This free of charge feature will attenuate all vertically polariyed signals from the commercial radios and aeronautical service for 20dB too. We can turn back the gain on our dongle resulting the better reception and picture. The QFH antenna will not give you this advantage. Checking the same crosspolarization table, we may note the difference of only 3dB to the vertical polarization if the circularly polarized antenna is used. So far,so good. Let’s see the cons using a simple dipole for the antenna. The main drawback is the dipole radiation diagram. Horizontal dipole is not omnidirectional antenna where radiation diagram is figure 8 shaped with the deep side nulls. All signals coming perpendicularly to the dipole are going to be attenuated a lot. Rotating a dipole for the best signal is not what makes dipole a simple antenna for our needs. Both polarization have the problems with the radiation diagram where the vertical suffer from the strong commercial signals too. Considering all, the horizontal dipole is a better option.

3.2.1 Improving a dipole for the NOAA satellite reception

The theoretical radiation diagram of horizontal dipole is figure 8 shaped with deep side nulls.

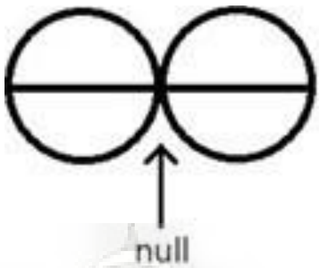

Figure 3.1: Deep side nulls in horizontal dipole

In practice, the side null are not so deep and the signal coming orthogonal to the dipole can be received too, but weaker comparing to the front coming signals. To overcome this problem we can bend the dipole in a wing shape configuration with the angle of 120 degrees between the dipole legs. Such a configuration will result with the figure 0 (zero) radiation diagram and enhanced signal level coming orthogonal to the dipole. This can be good enough for our purpose.

Horizontal V-dipole

Ones we know how the antenna should look like just a simple dipole antenna calculations should be applied. Using the simple formula for the wavelength dipole we get the following:

L(m) = 147 / F(MHz)

L(m) = 147 / 137.5

L = 1.068 m = 106.8cm

Each leg = 53.4 cm

Important: The length of the each leg should include the connecting wire's length up to the coaxial connector or coax.

Keep this length as short as possible but it will be difficult to stay bellow 1.5 cm. For a dipole legs I did use the 1/8 (3.25mm) aluminum rods. Do not use a ferromagnetic materials due to increased losses caused by the skin effect. The center of the dipole is

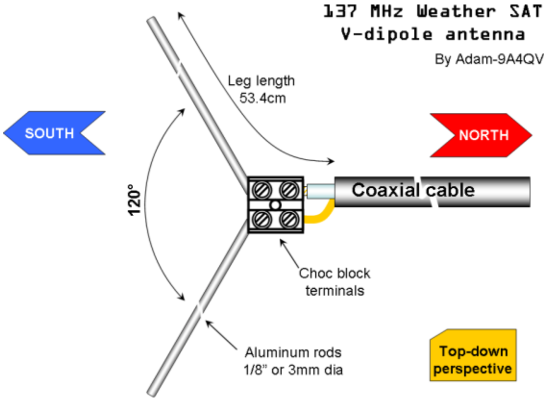

Figure 3.2: Horizontal V-Dipole Antenna

Figure 3.3: Outdoor Setup

made of Choc block terminals where the aluminum rods are secured on one side and the coax from the other side of the terminal. The center hole on the Choc block is used to secure the Choc block to the /mast bracket so the antenna can be easily mounted on the mast/pole. Run the 50 or 75 ohms coaxial cable to your receiving equipment. Bend the dipole legs to create a 120 degrees angle and point the antenna to the North-South direction. You are ready for the NOAA WX sat reception.

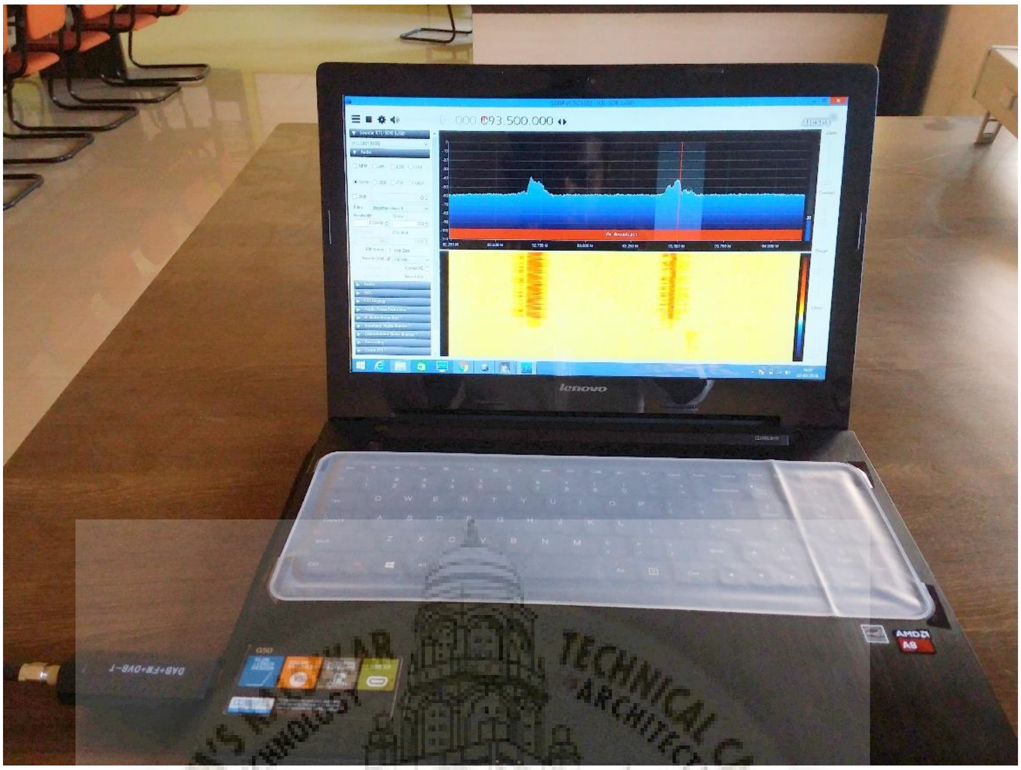

Figure 3.4: Outdoor Setup

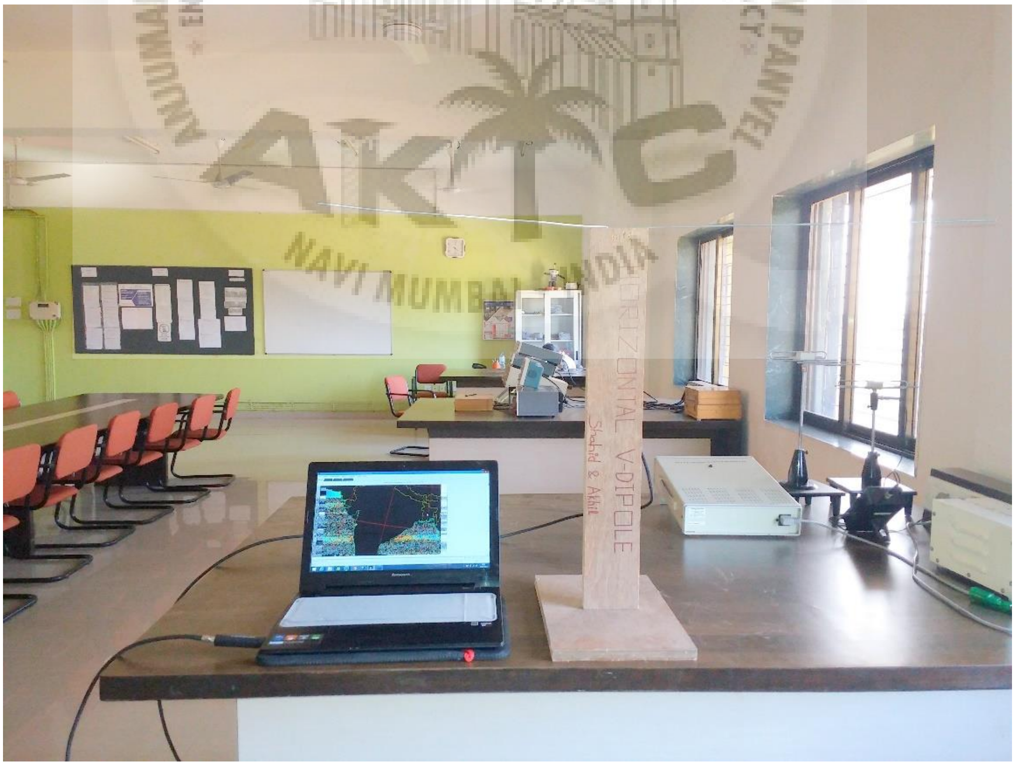

Figure 3.5: Complete Setup

3.3 Project Requirements

3.3.1 Software Requirements

- gpredict - Track the location of satellites
- SDRSharp - Receiver software that does all the radio stuff
- WXtoImg - Take that all transmission and turn it into an actual picture

3.3.2 Hardware Requirements

- Coax Cable roughly 10 meters in length
- SDR Card/Adapter
- Choc block
- Aluminium rod (3mm diameter)

Chapter 4

Results, Conclusion and Future Scope

4.1 Results

Our location is not perfect but still very good for the satellite reception. We have a clear horizon to the North but hills and a high voltage power lines to the South limiting the North elevation to 7 degrees. The antenna is fixed on the roof antenna pole, 8 meters above the ground. First test made was including the barefoot setup, usually used by the beginners to receive the weather satellite pictures. Starting from the antenna (V-dipole) there was 10 meters of RG-213 cable / N connector followed by N/N adapter and 12 meters of H- 2000 cable. Another N/N adapter followed by 10 meters of RG-214 cable with another N/PL259 adapter. Finally, there was 1mtr of flexible but lossy RG-58 cable and BNC/SMA adapter to match the RTL.SDR dongle connector. All together, there was 25 meters of the mixed quality cables and 4 coaxial adapters. On the dongle side there was also SMA/SMA DC block used to isolate the DC from the dongle bias-t. I was really pleased with the received picture quality despite the mentioned limitations. There is a noise in the picture present close to the horizon due to obstacles in the South and a weaker signals on the North. These are really remote parts of the World and the air masses from that areas are not affecting the weather at our antenna location. It was found out that the Signal to noise ratio (S/n) required for the noise free picture is close to 22dB. Below that, the picture starts to be noisy, resulting a black strips across the received picture.

The results are:

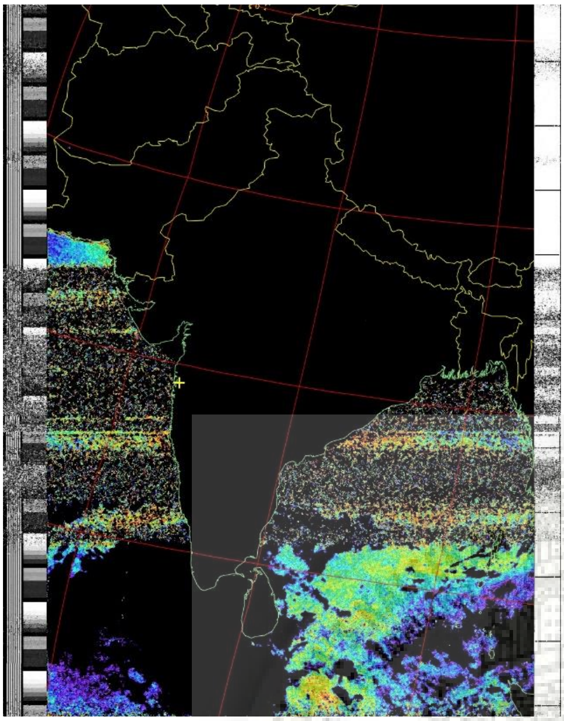
Figure 4.1: Sea surface temp

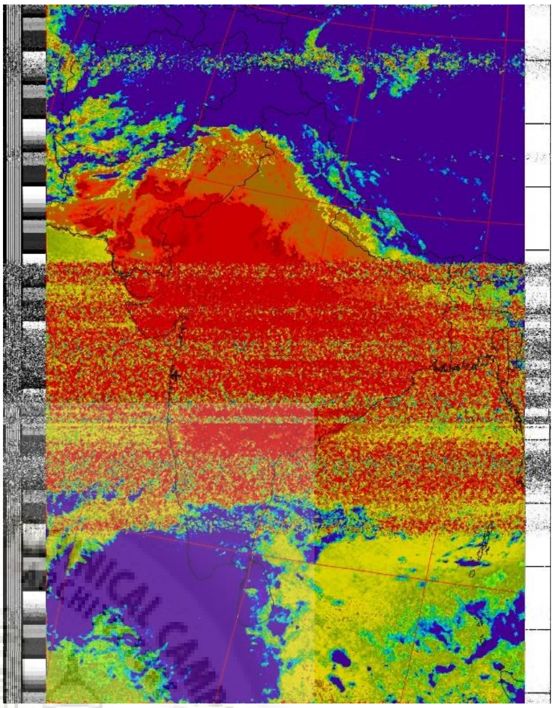
Figure 4.2: Thermal (13-03-18)

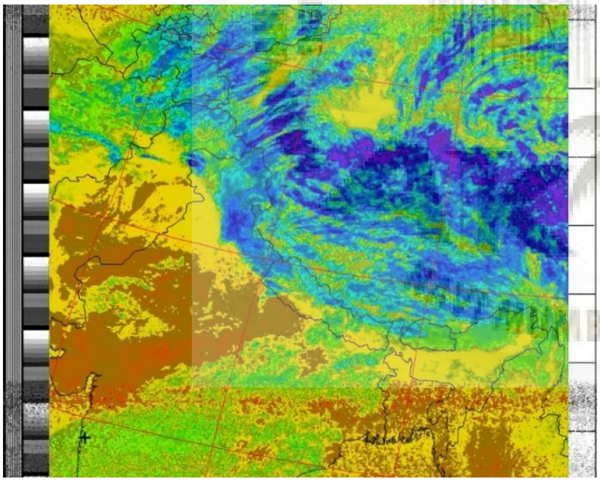
Figure 4.3: Thermal (15-03-18)

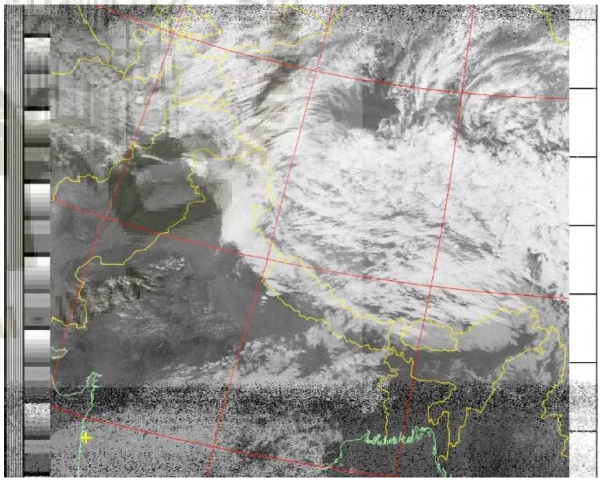
Figure 4.4: Contrast enhance

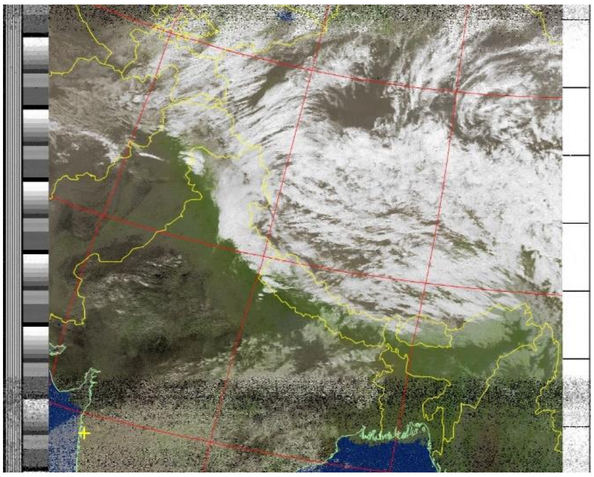
Figure 4.5: Map colour IR

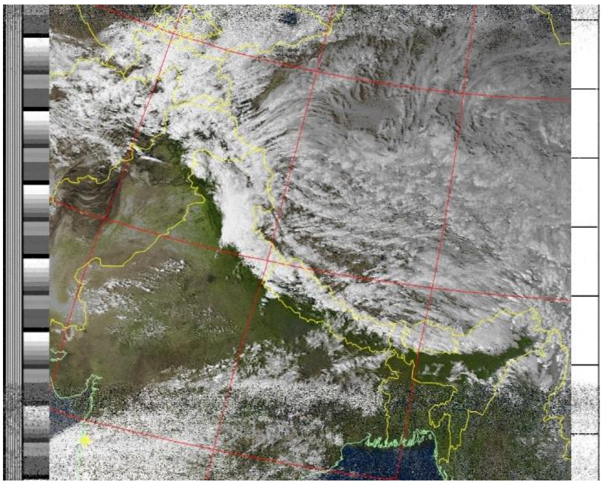
Figure 4.6: Multispectral analysis

4.2 Conclusion

Although satellites have been used over the past several decades to obtain a wide variety of information about the earth's surface, the sector of satellite imaging has always been monopolized by government or privately funded organizations. The population in urban cities more or less, use satellites for the sole purpose of navigation. The use of satellites for capturing images which could be used for weather analysis remains unexplored by the large masses.
The rural population, farmers and fishermen are the ones who require such interpretations of weather data the most. But the widespread misconception that huge parabolic dishes and dedicated RF receivers along with some kind of authorization is mandatory for satellite communication is generally quite hard to dispel.

4.3 Future Scope

The future prospects of this weather analysis satellite imaging station are quite promising. They can be briefly put down in the following way:

- This weather analysis satellite imaging station can be made more compact and portable with the help of Microstrip Patch Antenna technology.
- The continuous collection of temperature values from almost three passes on each day can form an impressive database. If this dataset is used for training unsupervised neural networks with enough interconnections to guarantee better interpolation, a

temperature predictor can be implemented.

- Similar to temperature, the cloud precipitation levels that can be obtained from these images can also be used to form rainfall maps.
- Cloud cover and its patterns can be analyzed over a period of time to determine the effect of wind and pressure on other weather parameters.
- A truly portable solution can be accomplished by migrating the entire software setup onto a Raspberry Pi which can be accessed and controlled through Internet. Owing to its small size, the Raspberry Pi board can be attached below the antenna making it convenient to handle.

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