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ABSTRACT

This project is about reception of weather satellite images from NOAA satellites. The image of the surface of the earth is obtained using two types of antennas namely, V-Dipole antenna and QFH antenna using RTL-SDR. The audio signals generated by the SD-sharp software was decoded into an image as per the APT format using WXtoImg and NOAA-APT softwares. This project gives experience on the usage of hardware and handling of different types of antennas. Based on the nature of the signal received by the antenna, the required parameters such as bandwidth, frequency and gain are set in the softwares for proper reception of the signal. In this project let us see how to get the images from the NOAA satellites.

INTRODUCTION

One of the interesting data protocols developed in the last century is APT (Automatic Picture Transmission). It is used to transmit images of the Earth's surface from space, and what is much more interesting for us, receiving APT signals is feasible to radio amateurs.

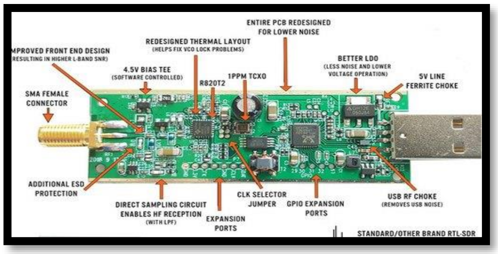
The NOAA meteorological satellites belong to the TIROS (Television InfraRed Observation Satellite) series, the first of which was launched in 1960. There are currently 3 satellites in operation (NOAA-15, NOAA-18 and NOAA-19, the oldest of which, NOAA-15 works since 1998). The satellites orbit around the Earth at an altitude of about 850 km and make one revolution in about 1.5 hours. There are various sensors onboard, but we will be interested in receiving meteorological images. And there are two options available. The simplest way of reception is to get an analogue signal in the APT Format at a frequency of 137 MHz.

According to international conventions, all meteorological data is open, and anyone can receive NOAA signals.

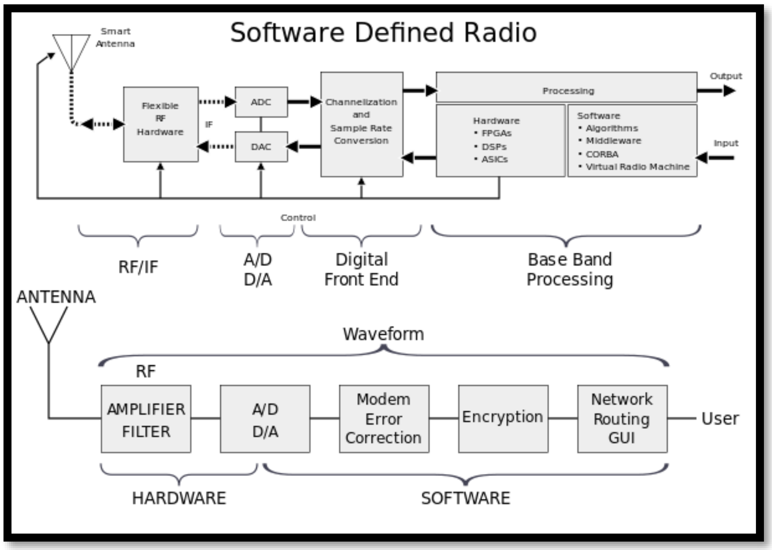
REQUIREMENTS AND SET UP

We are setting up the RTL-SDR dongle and SDR Sharp. We will also need to install audio pipes for transmission of Audio. Audio pipelines will allow audio from SDRSharp to be transferred to the WxtoImg. We use a VB cable for audio pipes.

RTL SDR



We used **RTL-SDR** Blog R820T2 RTL2832U 1PPM TCXO SMA Software Defined Radio



SDR represents **Software-defined radio**. It is a radio communication system where components that were traditionally used in hardware (e.g., mixers, filters, loudspeakers, modulators / demodulators, thumbnails, etc.) are instead made using software on a personal computer or embedded system.

ANTENNA

NOAA APT weather satellites broadcast their signal at about 137 MHz, and their signals also have a circular polarized right hand (RHCP), which means you will need a circular right antenna to receive signals correctly. Satellite antennas are also designed to get the best out of space signals from the sky. The below antennas can be used for implementation.

Turnstile Antenna

A turnstile antenna is a polarized circular antenna. It can be built in two ways, normal and axial. To get satellite reception we need it in axial mode.

Quadrifilar Helix (QFH) Antenna

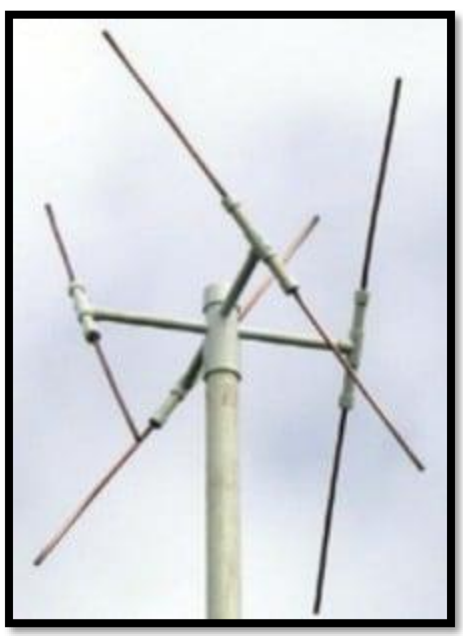
Quadrifilar Helix (QFH) is a circularly polarized antenna that can be made of PVC pipe and coax cable. The QFH antenna has a slightly higher reception compared to the turnstile.

V-Dipole

It was recently discovered by 9A4QV Adam that a simple dipole arranged in a horizontal 'Vee' shape made the satellite antenna have very good and very simple weather. This is probably the most basic beginner antenna to pick as it has only two wires and coax cable.

Double Cross Antenna (DCA)

Another effective antenna with NOAA APT satellites is a double cross antenna (DCA). Basically, four dipoles are arranged in a certain way to produce circular polarization.



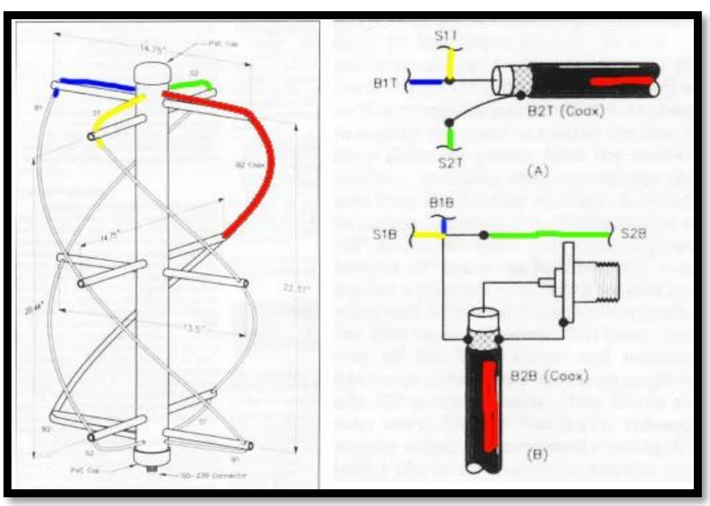
So, in this project we implemented using QFH and DIPOLE ANTENNA

QFH ANTENNA

The Quadrifilar Helix Antenna (QFH) is a suitable antenna for receiving APT at 137 MHz. Not only in theory, but also in practical application, it works perfectly when properly constructed. As long as the system is satisfied, the antenna operates in the expected way from theoretical considerations, i.e., the sensitivity of the circularly polarized right hand (RHCP) from horizontal to horizontal.
Unfortunately, it is not always clear whether the QFH is properly constructed, on the basis of "well-received". In order to achieve maximum performance, distortion estimates must be made, which will determine whether the required phase shift relationship in both loops is achieved or not. A QHA where a category change relationship is wrong, will often still present a rough picture, because in the absence of RHCP selections, problems will only occur whenever powerful indicators are met.

We have made our Quadrifilar Helix Antenna 137 MHz and 380-430 MHz frequency band. These antennae are designed to operate on the UHF satellite band. Due to the hemispherical shape of the beam width this antenna is also known as a hemispherical antenna. These antennas are ideal for amateur satellite communication and GPS tracking. RP-SMA A female connector is mounted at the end of the Antenna to facilitate feed communication.

CONSTRUCTION:
For dimensions we calculated in jcoppens.com . The antenna's helices diameter and pitch distance are dependent and the number of turns must be more than 1.25. We used the RG-58 COAXIAL CABLE with 50-ohm impedance, PVC Pipes and Some connectors and connecting wires.



From the image above you can see the connections of QFH Antenna.

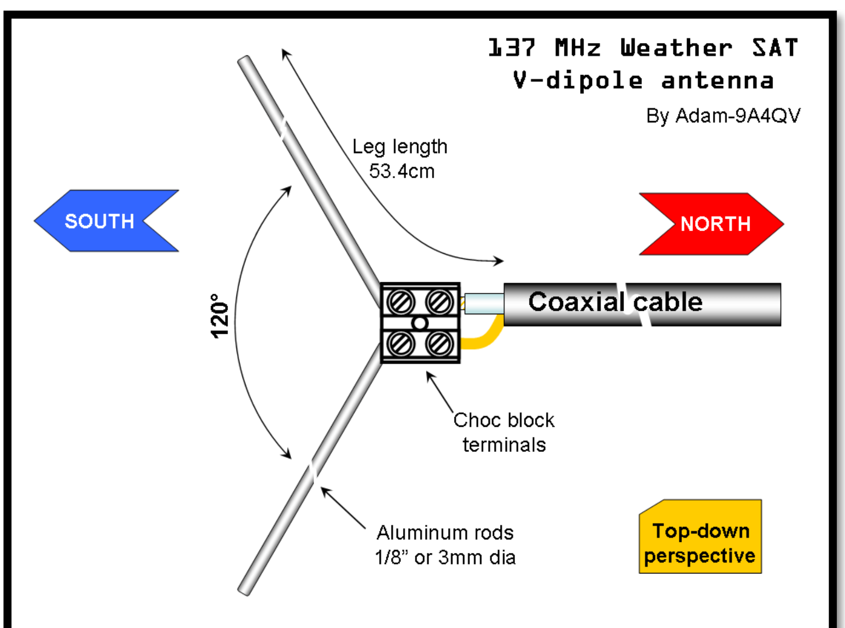
In our team we made 3 QFH antenna in total:

ANTENNA 1:

ANTENNA 2:

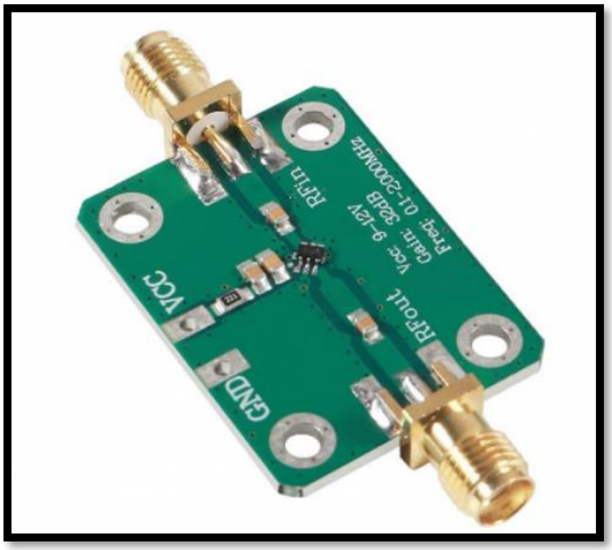
ANTENNA 3:

DIPOLE ANTENNA



We also tried implementing the Dipole Antenna. There are some conditions to properly set up the antenna, the length of the antenna must be 53.4cm and the angle between them is 120 degrees and that should be faced horizontally toward south or north which depends on the satellite.

LOW NOISE AMPLIFIER

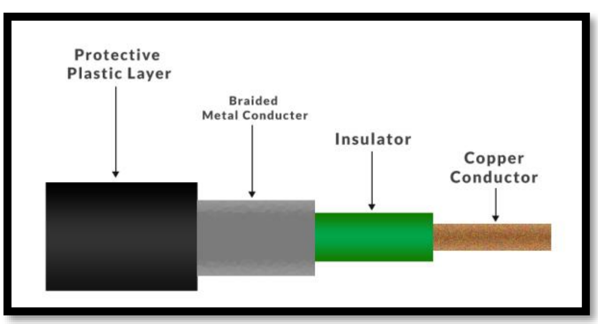


LNA Boosts the received signal to a sufficient level above the noise floor so it can be used for additional processing and it is capable for Wide frequency range and used for High Gain, it has Low Noise Figure. Noise-Figure Limits the sensitivity of the LNA

The power supply can be given in range of 6v to 12 volt And it's Max gain is 32db

COAX CABLES

A coaxial cable is an electrical cable with a copper conductor and a protective shield around it and a twisted metal mesh that prevents signal interference and conversation. Coaxial fiber is also known as coax.



The main copper conductor is used to transmit signals and the insulator is used to provide an insulator to the copper conductor and the protection is surrounded by a metal conductor that helps prevent electrical signal interference and prevents misalignment. All of these setups are also covered with a protective layer of plastic to provide additional security for the cable.

We used RG-58 COAX CABLE

<u>CONNECTORS USED</u>

- ❑ RG-58 CABLE for construction of antenna, it has impedance of 50 ohm
- ❑ RG-316 CABLES for connecting between RTL SDR and antenna
- ❑ SMA MALE TO MALE WIRE (To connect with LNA having female pins on both side) SMA FEMALE TO MALE WIRE
- ❑ RP-SMA FEMALE TO SMA MALE
- ❑ RG-58 CO AXIAL CABLE IS CONNECTED WITH RP-SMA MALE

SOFTWARES USED

1. **SD-SHARP**

   This software is used to visualize the FFT plot and waterfall plot for the source signal obtained from the RTL-SDR. We set the specific bandwidth, gain and frequency (Tune it according to the frequency of the signal emitted by the satellite passing through the geographical location. This frequency is obtained from WXtoImg software). The audio obtained in this software must be connected to the WXtoImg software. This is achieved by a driver named VB-Cable. Hence, the output audio of this software is set to VB-Cable.

2. **WXTOIMG**

   This software is useful for determining the
   - Ground-station location: Exact latitudes and longitudes where we live
   - Next choose the input soundcard for the software as VM-Cable. So, the SD-Sharp software and this software are connected.
   - Active APT Satellites: Here we should select the currently active APT Satellites (Namely, NOAA 15, NOAA 18, NOAA 19)
     Then we should update this table whenever we update the Keplers.
   - Next we should check the internet options whether the celestrak website is chosen. The WXtoImg software gets the data of orbiting satellites, their UTC time of arrival, duration upto which they reside in a location.

- On updating Keplers, this software stores those data within it.
- Then we can take the satellite pass list, which looks like the image below.

2022-01-29 UTC

Satellite	Dir	MEL	Long	Local Time	UTC Time	Duration	Freq
NOAA 15	S	54W	73E	01-29 08:07:37	02:37:37	11:06	137.6200
NOAA 19	S	36W	69E	01-29 08:23:02	02:53:02	10:46	137.9125
NOAA 18	S	89W	78E	01-29 10:25:35	04:55:35	11:54	137.1000
NOAA 15	N	47E	83E	01-29 19:11:36	13:41:36	10:49	137.6200
NOAA 19	N	88E	78E	01-29 19:32:35	14:02:35	11:52	137.9125
NOAA 18	N	35E	86E	01-29 21:36:16	16:06:16	10:41	137.1000

- Then on clicking record option from file menu and give auto-record. This will record the image once the satellite arrives at the desired location.

3. NOAA

In this software, the input will be an audio file(which is recorded using SDR sharp). So the audio files will be loaded into it. Then we should choose the satellite number like NAOO15, NAOO16, NAOO18. Then we should mention the starting time and date. Sometimes the satellite number and time and date will be recognized correctly but not every time. Then we can click on “add false color” for the colorful images. Also, we can click on “draw map overlay” to get the national borders. Then when we process it, we will get the output image. Then we can save it.

APT FRAMES

APT means Automatic Picture Transmission. This system was developed to transmit low resolution analog images for weather satellites. A complete APT image takes around 12 minutes to be built up at a rate of 2 lines per second. The data is broadcasted by the satellite. The stream is obtained by the AVHRR/3 instrument. Two channels with a low resolution are emitting all the time using VHF signals at reduced rates (around 120 lines/minutes).

The two channels are composed of:

- Channel A: A visible frequency range channel providing APT imagery during the day.
- Channel B: An IR channel providing APT imagery at any time of the day and the night.

CHARACTERISTICS OF APT

1. The frequencies range is 137-138 MHz (audible frequencies) and specifically 137.100 MHz for NOAA 19, 137.9125 MHz for NOAA 18, 137.620 MHz for NOAA 15.
2. The overall RF bandwidth is equal to 34 kHz. The modulation mode is NFM (NarrowBand Frequency Modulation) and a 2.4 kHz AM (Amplitude Modulation) subcarrier is modulated on FM carrier.

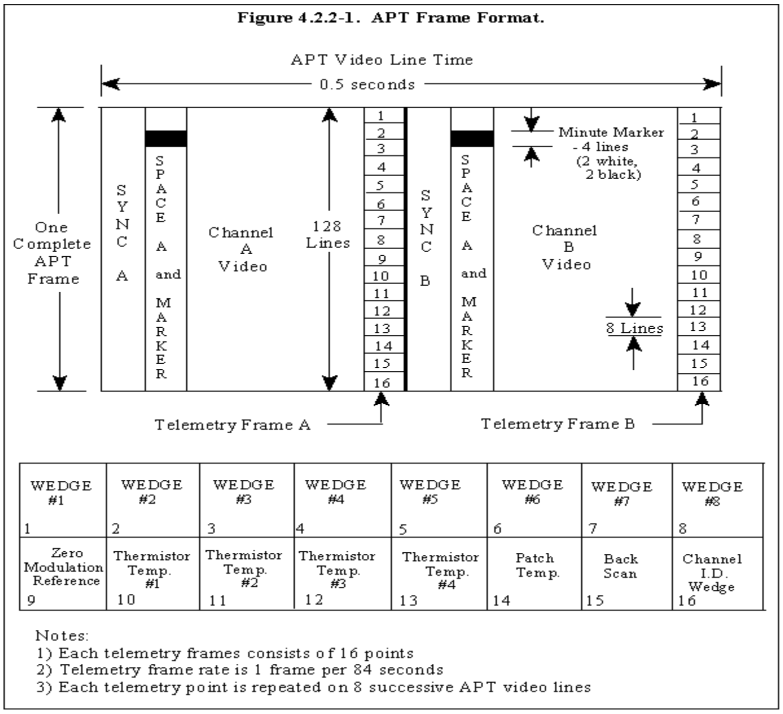
3. A circularly polarized antenna is usually needed (RHCP) but other types have also been used.
4. The data resolution is 4 km/pixel at a line rate of 120 lines/minute or 2 lines/second anad the transmitted power: 5W (37 dBm).

APT FRAME FORMAT

The broadcasted transmission is made of two channels for the image, synchronization and telemetry information. A complete APT Video Line Time is 2080 pixels long (990 pixels for each image). One APT line is composed of one line for Channel A video followed by one line for Channel B video.

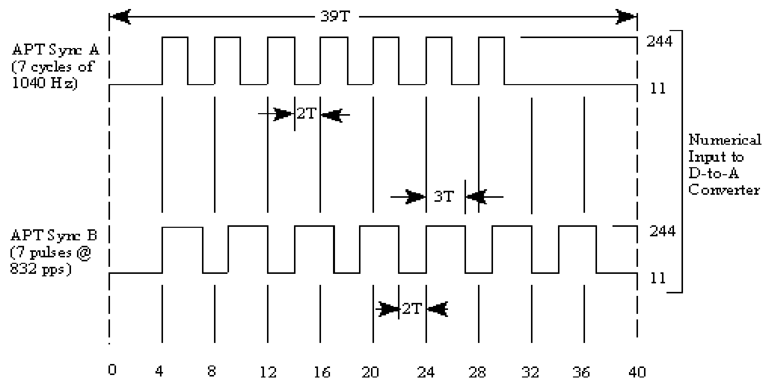
- Telemetry frame:
  Each video channel A and B have their own telemetry frame
  Each telemetry frames consists of 16 points (wedges): height of 128 video lines
  Telemetry frame rate is 1 frame per 64 seconds
  Each telemetry point is repeated on 8 successive APT lines
- Space and minute marker:
  Time between two successive markers is one minute
  Minute markers are repeated on 4 successive lines, with 2 lines black and 2 lines white
  B video is always an IR channel (Ch. 4 usually), so spaces are white and minute markers black
  When A Video is a visible channel, spaces are black and minute markers white; otherwise, it appears like B video

Figure 4.2.2-1. APT Frame Format.



- APT Synchronization:
  Sync A precedes Channel A data. Is a 1040 Hz square wave - 7 cycles
  Sync B precedes Channel B data. Is an 832 pps pulse train - 7 pulses

Figure 4.2.3-3. APT Synchronization details.

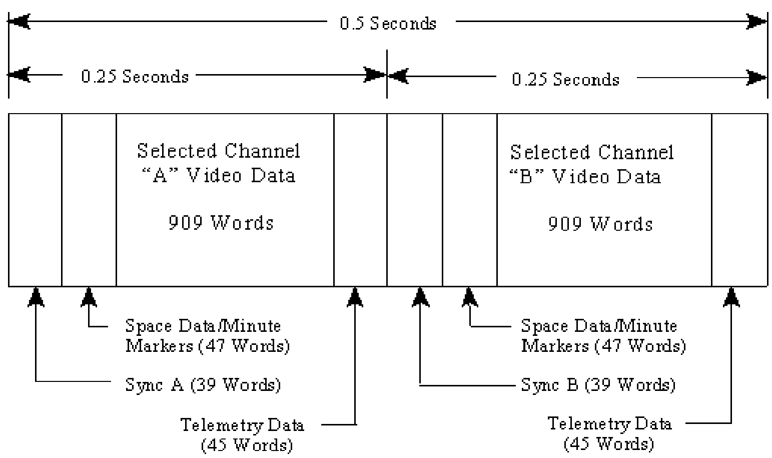


Notes:

1) T=1/4160 second
2) Sync A precedes Channel A data
3) Sync B precedes Channel B data

APT Video Line Format

Figure 4.2.3-2. APT Video Line Format.

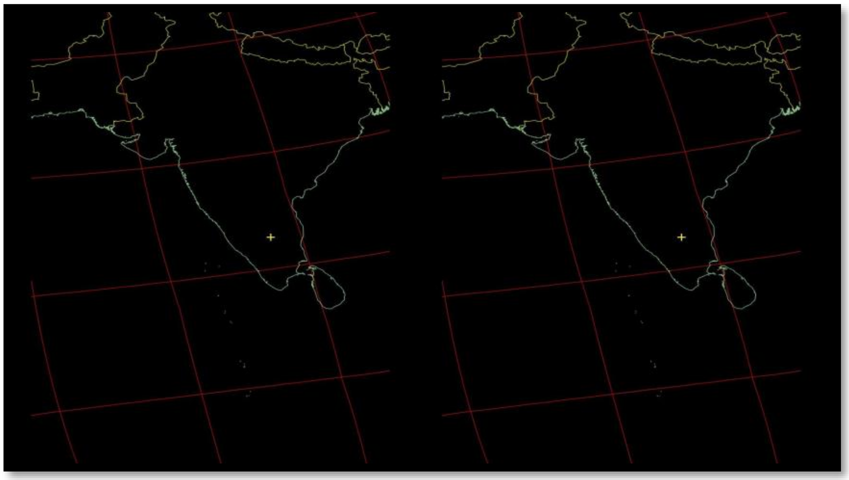


Notes:

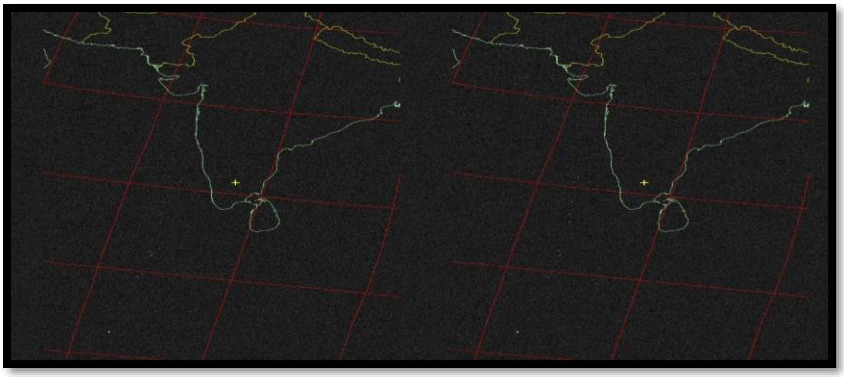
1) Equivalent output digital data rate is 4160 words/second
2) Video line rate - 2 lines/second
3) APT frame size - 128 lines
4) Any two of the five (six for group 505) AVHRR channels may be selected for use
5) Sync A is a 1040-Hz square wave - 7 cycles
6) Sync B is an 832-pps pulse train - 7 pulses
7) Each of the 16 telemetry points is repeated on 8 successive lines
8) Minute markers are repeated on 4 successive lines, with 2 lines black and 2 lines white

RESULTS AND OUTPUT

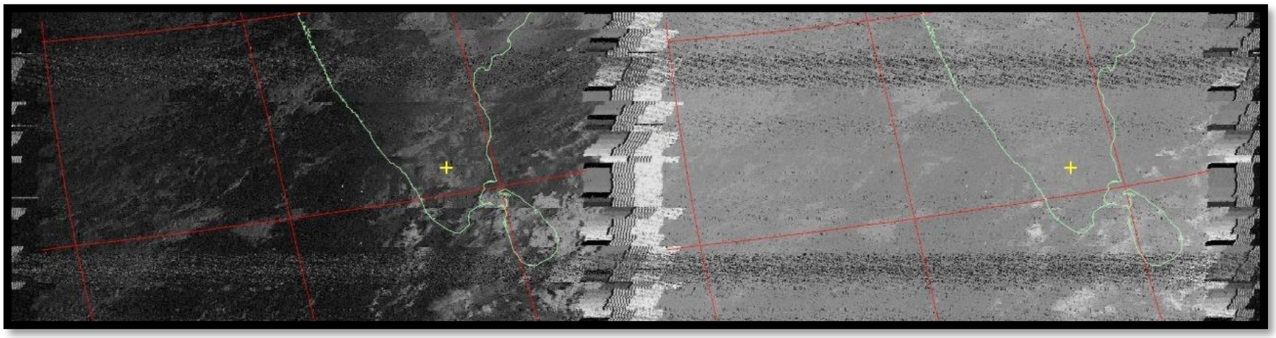
We have used SDR sharp and NAOO-APT in this project. We have got the output from each one, but the outputs are different in each. Sometimes we got a very good output and sometimes we got a very poor image. So let's see them.



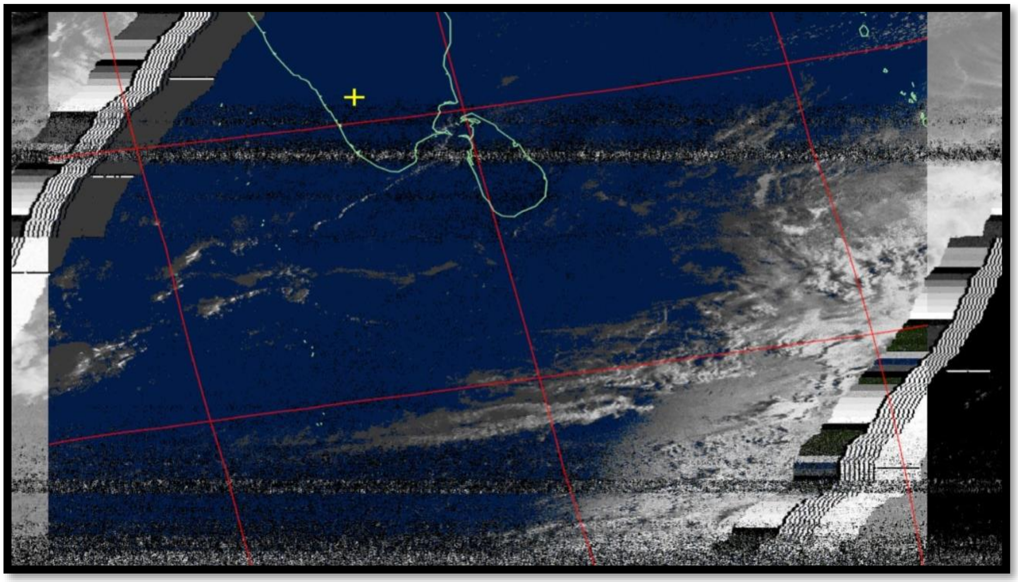
From the above picture we can observe that we got the outline of INDIA but we didnt get the land and water area. Also, we got the location from where we accessed.



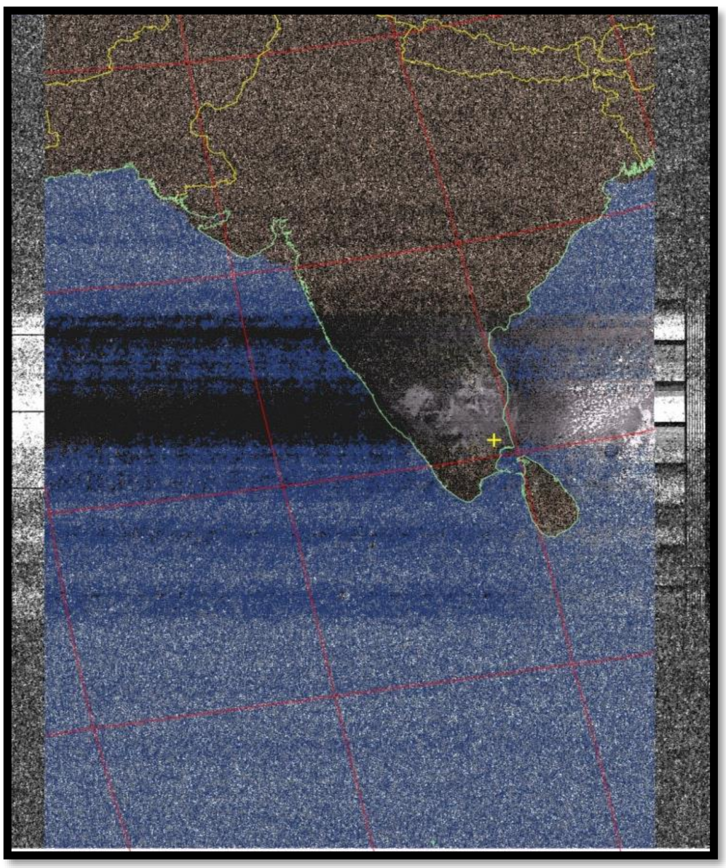
In the above picture, we can observe we have received very few pixels.



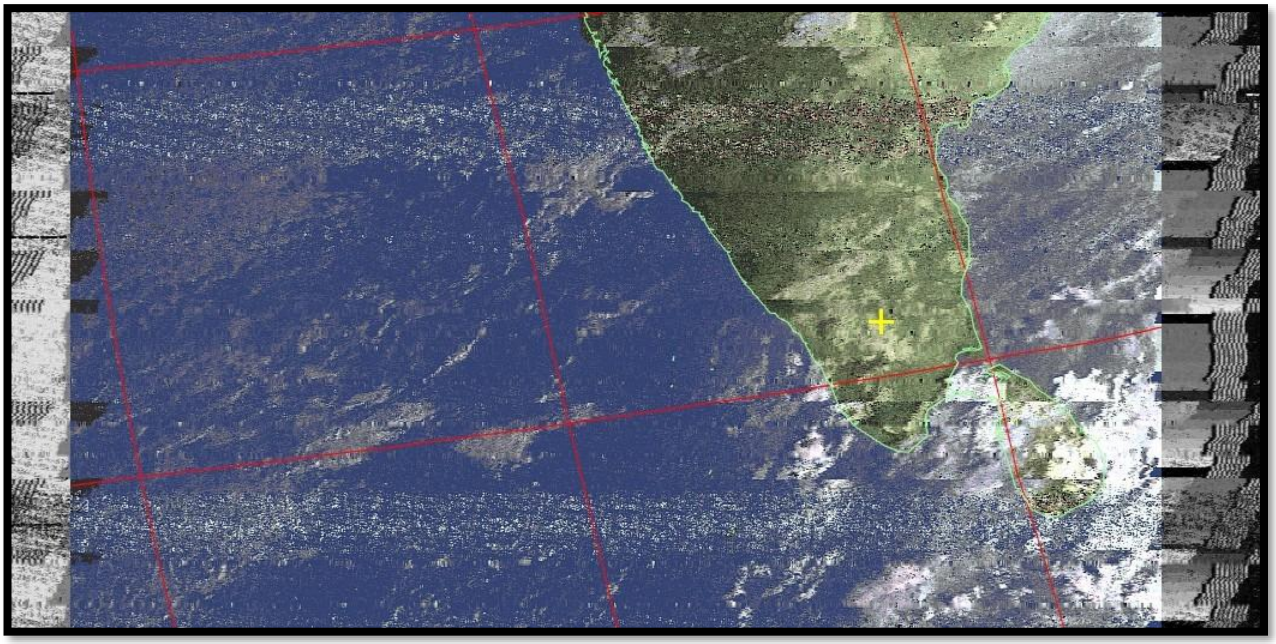
In the above picture, we can observe some clouds, water(ocean) and land part. Which mean we have received more signal than before.

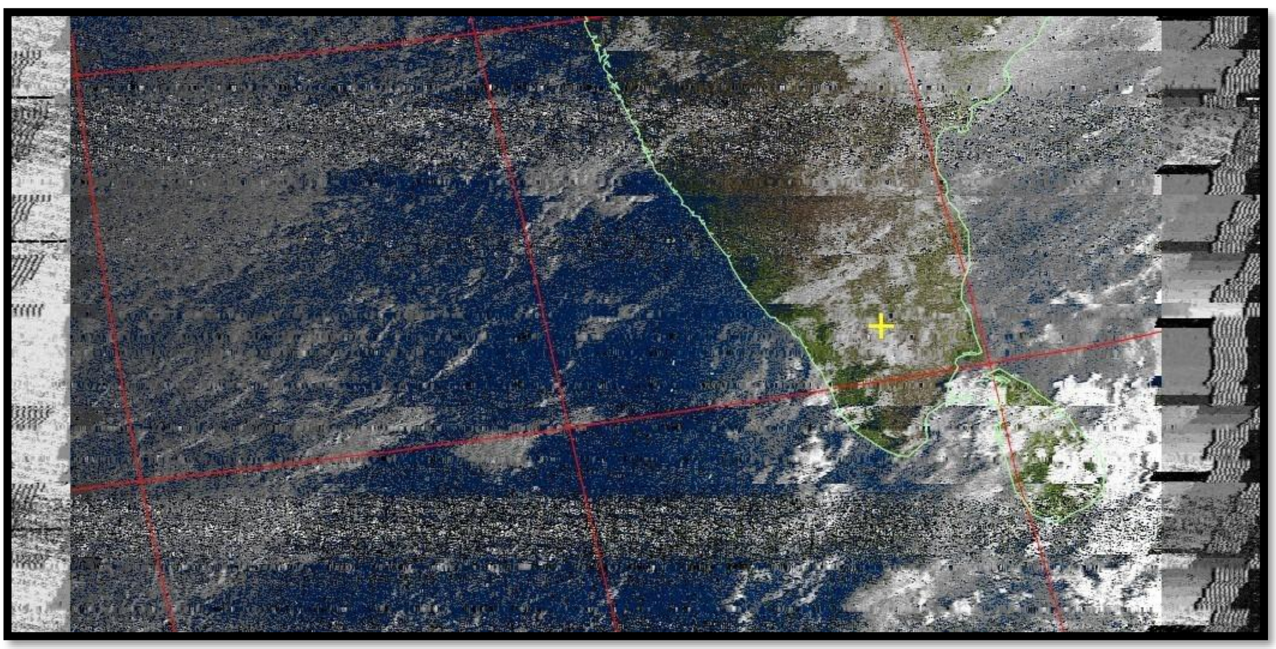


Here we can observe some clouds and water but the way it is located is wrong. Which means we received some signal from the satellite.



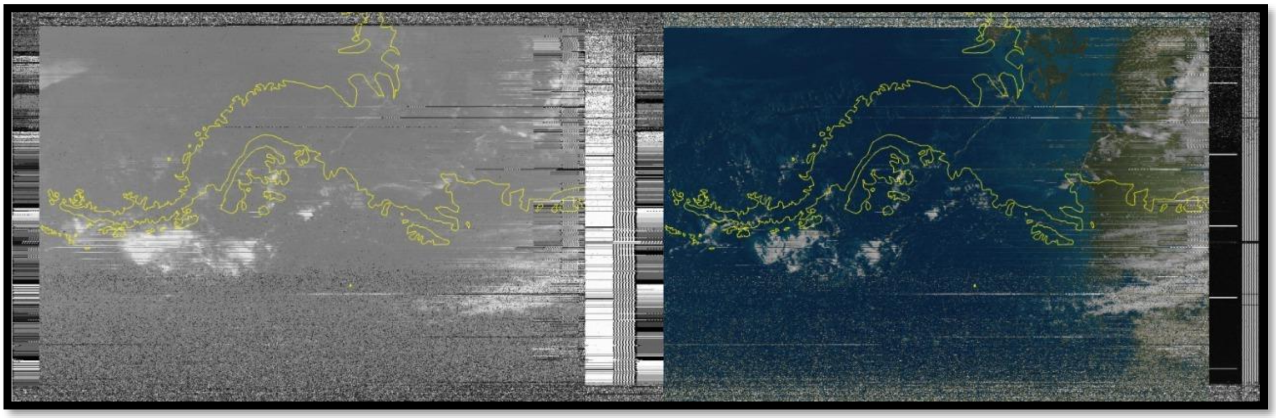
Here we got the water part correctly in the picture and some clouds.



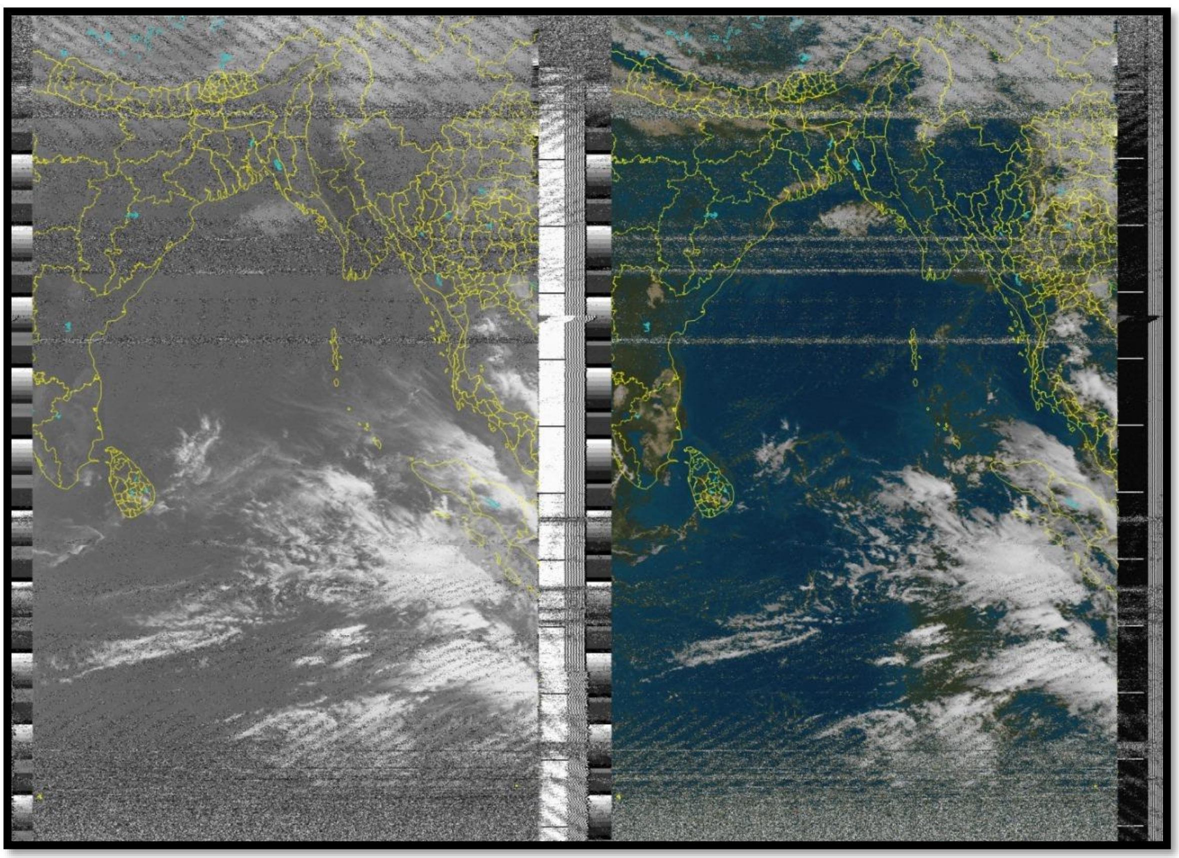


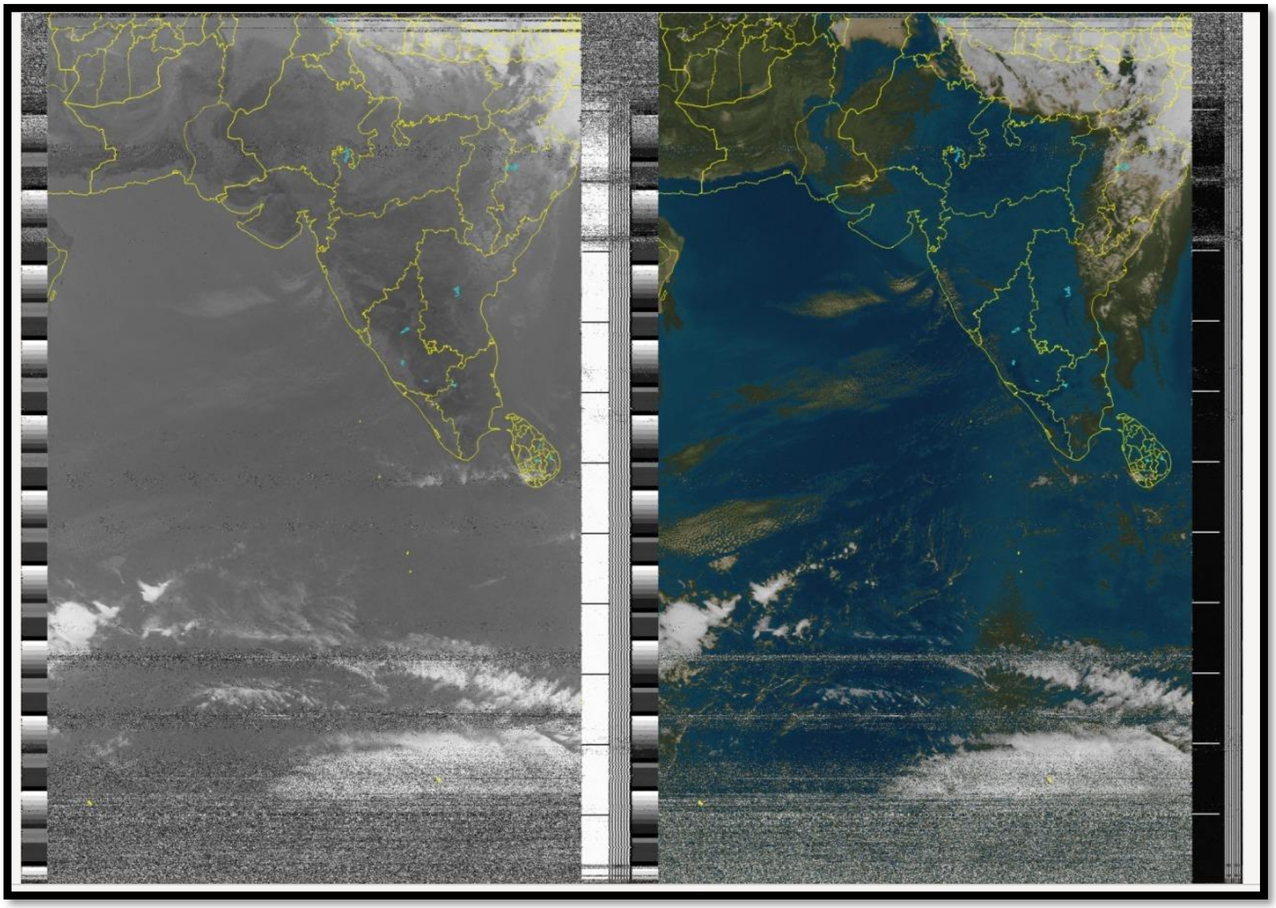
In these last 2 images we can observe the land, clouds, and water area correctly.

Now let’s see some output from NAOO-APT.



This is one of the worst pictures we received.





In these two pictures, we have received more signals as compared to the before picture.

Here we got some pictures no matter good or bad. In each and every picture we have received some signal. So basically, the picture quality is based on the signal received. So the signal is received better in open space.

CONCLUSION

Thus, in this project we have received the APT signals from NOAA satellites and decoded into the images using APT format by using different software's. Different kinds of quality of images were obtained. On doing the experiment for about a month we arrived at a perfect image from the satellite. This project gives us ideas about the various techniques of reception of the signals from the satellites. We learnt the properties of the signal and the strength of the signal received based on the change of parameters like gain, bandwidth and many more. This project can be extended in future for reception of meteorological images even.

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