Acquiring Automatic Picture Transmission of NOAA 18 & 19 using V-Dipole Antenna for Philippine Cloud Cover Monitoring

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Abstract– The National Oceanic and Atmospheric Administration (NOAA) of the United States invests heavily in launching and operating satellites for weather and climate forecasts, as well as environmental data gathering for oceanic, coastal, and land monitoring. NOAA 18 and NOAA 19 Satellites are one of many series of weather forecasting satellites that transmit automatic picture transmission (APT), allowing any user station to receive local data from these satellites. Gathering data for cloud cover is important in the field of Meteorology and weather analysis as it describes meteorological phenomena, and it impacts climate and weather conditions. Using a computer-based radio scanner with a wide frequency range and a dipole V-shape horizontal antenna paired with a low-noise amplifier, this simple setup is sufficient to receive the APT transmitted at 137 MHz. Optimal conditions for acquiring automatic picture transmissions through the V-Dipole Antenna are simulated in the MMANA-GAL. The APT received from NOAA 18 and NOAA 19 Satellites, containing cloud cover images of the country twice a day, was decoded using SatDump. In conclusion, the processed picture transmissions of the archipelago were able to produce visible and infrared spectrum channels that created MCIR composite and rain composite imageries that are fit for visualizing cloud cover monitoring which accounted for the ± 20.687 kHz of Offset shifting the frequency of NOAA 18 and NOAA 19 to a varying range of 137.892 MHz to 137.933 MHz and 137.079 MHz to 137.121 MHz respectively. Moreover, the results indicated that the height and maximum elevation of the satellite pass have an established relationship with maximizing the gain of the antenna, for which the V-Dipole antenna, having a gain of 7.88 dBi and 7.9 dBi should be placed with a height of 8 meters, maximizing its efficiency. Other factors, such as exploring the gain-height relationship of the antenna, reducing the frequency offset, and using other composite filters, are highly suggested.

Keywords– *NOAA, Dipole Antenna, Automatic Picture Transmission, 137-Mhz, Polar Orbiting Satellite*

INTRODUCTION

Cloud cover is an important factor in both weather and climate as it impacts the precipitation conditions and surface temperatures (National Geographic Society Data and Information Service, 2023). The NOAA Polar-orbiting Operational Environmental Satellites (POES) are polar weather orbiting satellites that accurately gather data to improve weather analysis, including cloud coverage, environmental forecasting, and global climate monitoring (Klaes et al., 2007). These satellites have an analog image transmission system called Automatic Picture Transmission (APT) that enables any user station on the surface to access the weather satellite image data. The weather satellites orbit the Earth about 14 times every day with two passes above the user, travelling from one pole to another, sufficient to provide weather data such as the cloud coverage (National Environmental Satellite Data amd Information Service, 2022).

The NOAA Satellites carry Advanced Very High-Resolution Radiometer (AVHRR) for multipurpose imagery and earth observation, enabling these satellites to capture the cloud covering and to measure the cloud optical depth, top height, temperature, leaf area index, and normalized difference vegetation index, sea surface temperature, and sea ice cover (World Meteorological Organization, 2022). Since the APT signals from the NOAA Satellites are right-handed circularly polarized, a realistic option to generate a satisfactory signal reception is a linearly polarized dipole antenna.

This paper analyzed the hardware and software implementation, emphasizing the antenna designed to receive and decode the APT signal from NOAA 18 and NOAA 19 weather satellites for monitoring cloud cover over the Philippine Archipelago. The type of antenna, as one of the hardware, is a simple V-dipole antenna configured to receive a 137-Megahertz (MHz) APT Signal. The use of this antenna design to receive signals from NOAA weather satellites was proposed and practically tested by Adam 9A4QZ with excellent and promising results. The dipole is arranged into a horizontal 'V' shape and spread apart by 120 degrees opening southward or northward so that it will be optimal for NOAA Satellites traveling north to south or vice versa. A USB dongle, most known as Realtek Software Defined Radio (RTL-SDR), which utilizes an RTL2832U chipset, is used for computer-based radio receiving and was attached to a low-noise amplifier with a 20 dB signal gain. The tracking software is called GPredict, and the decoding program, known as SatDumb, is a versatile data processing application featuring real-time decoding, map overlays, advanced color enhancements, three-dimensional imagery, animations, multi-pass imaging, text overlays, and projec-

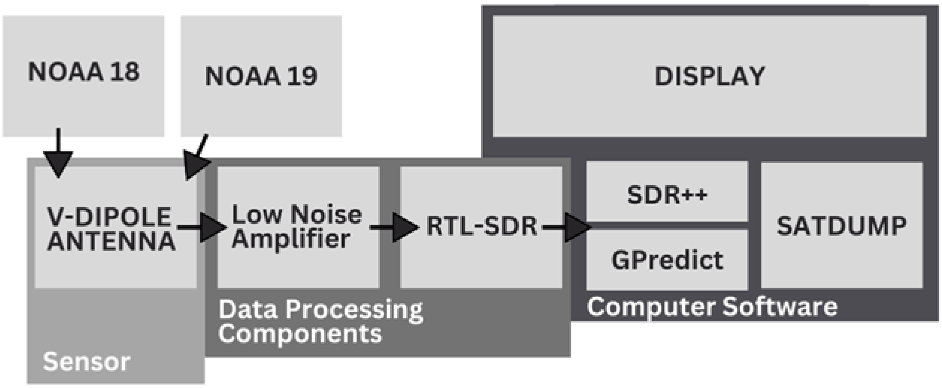

Figure 1 Block Diagram of the Data Acquisition for Satellite Image

Table 1 V-Dipole Antenna Measurement Results of 137.9125 MHz (NOAA 18)

R (Ω)	jX (Ω)	SWR 50	Ga dBi	F/B dB	Ground	Heights
107.7	220.7	11.6	2.01	0.05	Free	–
125.7	268.3	11.6	5.6	0.07	Real	0.5 m
109.2	193.9	9.42	6.47	0.26	Real	1.0 m
116.7	209.4	10.2	6.89	0.3	Real	2.0 m
11.4	221.8	11.2	7.35	0.29	Real	4.0 m
105.6	223.6	12.0	7.88	0.27	Real	8.0 m
109.6	220.6	11.4	7.78	0.28	Real	16.0 m

tion transformations (such as Mercator).

METHODOLOGY

In this study, the data acquisition for satellite image consisted of a computer installed with software for tracking the satellite and decoding the APT, RTL-SDR, female-to-female connector connecting the RTL-SDR and low noise amplifier, 75-Ohms coaxial cable, and V-dipole antenna.

Figure 1 describes the process of data acquisition linearly specifying each part. The V-dipole antenna receives an APT signal from the NOAA Satellites, and this signal is then transferred to the low noise amplifier through the coaxial cable. The low-noise amplifier amplifies the very low-power APT signal, supplying it with significant power gain. The amplified signal is now received by the RTL-SDR, directing it to the computer's software-defined radio program SDR++. The GPredict tracks the satellite, displaying tracking data in lists, maps, and polar circular maps. The received APT signal is then recorded by SDR++ and then decoded by SatDump, turning it into an image with various filters and overlays, and enhancements such as sea temperature, contrast enhancements, MCIR map color in infrared, thermal, and vegetation for scientific applications.

The V-Dipole Antenna proposed and tested by Adam-9A4QZ was modified, so its legs, with a length of 53.4 centimeters and 120 degrees apart, are in the horizontal direction, enhancing the satellite signals directed towards the front, side, and top of the antenna. Moreover, the horizontally polarized antenna has the advantage of reducing the interference of terrestrial signal with vertical polarization to 20 decibels. The antenna is facing north or south due to the direction of the NOAA satellites orbiting from north to south direction, or south to north (Fathurahman et al., 2019). The V-Dipole Antenna is a suitable antenna to receive the circularly polarized radio waves of the NOAA satellites at about 137 megahertz.

The antenna was mounted to a telescopic tripod to adjust the height accordingly. It was placed on a rooftop with a plain view of the horizon facing south. The Legs of the antenna are 5mm aluminum rods attached to the elements of the coaxial cable using bolts and nuts. RTL-SDR is directly attached to the USB port of the laptop while also connected to the low-noise amplifier via a connector.

RESULTS AND DISCUSSION

A. *V-Dipole Antenna Analysis*

Figure 2 shows the v-dipole antenna modeled in the antenna analyzing software MMANA-Gal. The antenna analysis from the software was focused on the frequencies of NOAA 18 and NOAA 19, with height as the independent variable. Table 1 presents the antenna measurement results of NOAA 18. The resistance (R) and the reactance (jX) indicate significant fluctuation in impedance as the height varies while the SWR with values ranging from 9.42 to 12.0 have a noticeable impedance mismatch at 50 ohms feedline. The gain measured in dBi increases as the height increases,

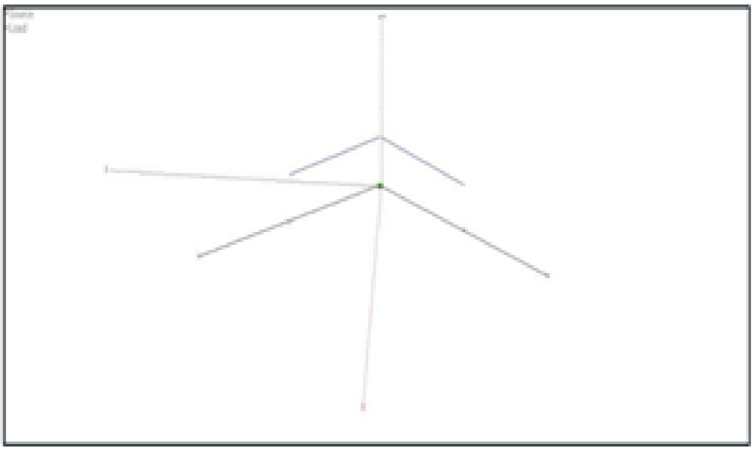

Figure 2 V-Dipole Antenna Geometrical View in MMANA-Gal

Table 2 V-Dipole Antenna Measurement Results of 137.1000 MHz (NOAA 19)

R (Ω)	jX (Ω)	SWR 50	Ga dBi	F/B dB	Ground	Heights
105.0	215.3	11.2	2.01	0.05	Free	–
121.5	261.3	14.0	5.61	0.07	Real	0.5 m
107.4	188.1	9.09	6.42	0.25	Real	1.0 m
114.3	203.9	9.9	6.86	0.29	Real	2.0 m
111.8	216.4	11.0	7.36	0.29	Real	4.0 m
102.1	216.5	11.6	7.9	0.26	Real	8.0 m
106.5	215.2	11.2	7.79	0.28	Real	16.0 m

with a maximum measured value of 7.88 dBi in 8.0 meters. The Front-to-Back Ratio also increases directly proportional to the height with a maximum value of 0.29 dB at 16 meters. Table 2 shows the antenna measurement results for NOAA 19. The resistance (R) and the reactance (jX) also indicate significant impedance fluctuation and the SWR with values ranging from 10.2 to 12, indicating impedance mismatch at 50 Ω. The gain and the F/B also have a direct proportion to height, with a maximum gain of 7.9 at 8 meters and a maximum value of 0.29 at 4 meters for Front-to-Back Ratio. Both tables show that the gain of both frequencies improves with high placement of the antenna, while low placement degrades its directionality.

B. *Frequency Offset*

The frequency offset refers to the minor deviation in radio frequency caused by discrepancies between the transmitter and receiver oscillators, as well as the Doppler effect resulting from the transmitter's motion (Moose, 1994). The RTL-SDR consisted of a low-quality crystal oscillator with a ± 150 PPM offset, which corresponds to a 20.687 kHz frequency offset. The NOAA 19, with a working frequency of 137.1000, which deviated from its non-offset frequency of 137.079 MHz, and the NOAA 18, with a working frequency of 137.9125 MHz, which deviated from its non-offset frequency of 137.892 MHz. The deviations caused by the offset in the frequency on NOAA 18 and NOAA 19 is caused by the RTL-SDR's low-quality crystal oscillator and by environmental factors, specifically temperature (Wiryadinata et al., 2018).

C. *Acquisition Results*

1. NOAA 18 Satellite Pass

The path of NOAA 18 in its pass at coordinates of 4°33' N, 121°06' E and a time of 10:52 AM at Philippine Standard Time (PhST) on May 22, 2024, started from the north with an initial azimuth of 11.76 degrees, transversing the horizon with a maximum elevation of 88 degrees on the western horizon and ending to the south with an azimuth of 194.22 degrees. The recording lasted 8 minutes and 45 seconds while the pass lasted 13 minutes. The antenna height was 0.5 meters to take advantage of the high elevation pass of the satellite.

2. NOAA 19 Satellite Pass

The path of NOAA 19 in its pass at coordinates of 4°33' N, 121°06' E and a time of 9:11 AM PhST on May 23, 2024, started from the north with an initial azimuth of 12.57 degrees, transversing the horizon with a maximum elevation of 89 degrees on the eastern horizon and ending to the south with an azimuth of 193.24 degrees. The recording duration lasted for 8 minutes and 35 seconds, while the pass lasted again for 15 minutes. The antenna height was 0.5 meters, the same as NOAA 18, to take advantage of the high elevation pass of the satellite.

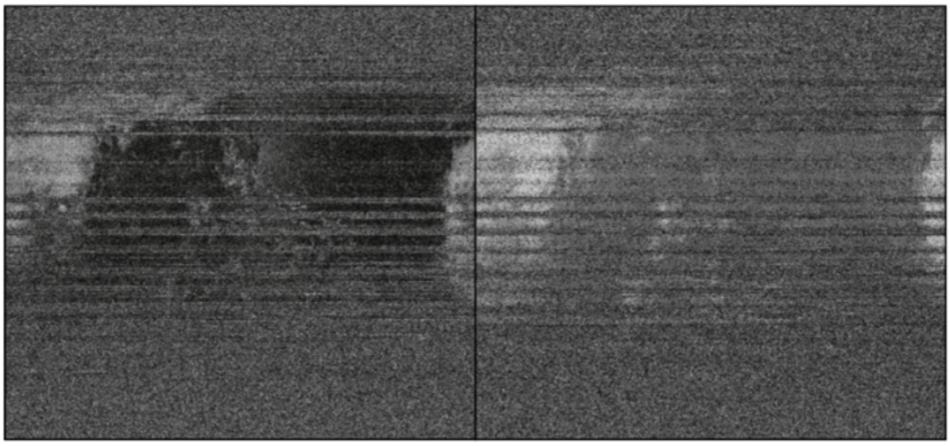

Figure 3 Channel A (Left) and Channel B (Right) of NOAA 18

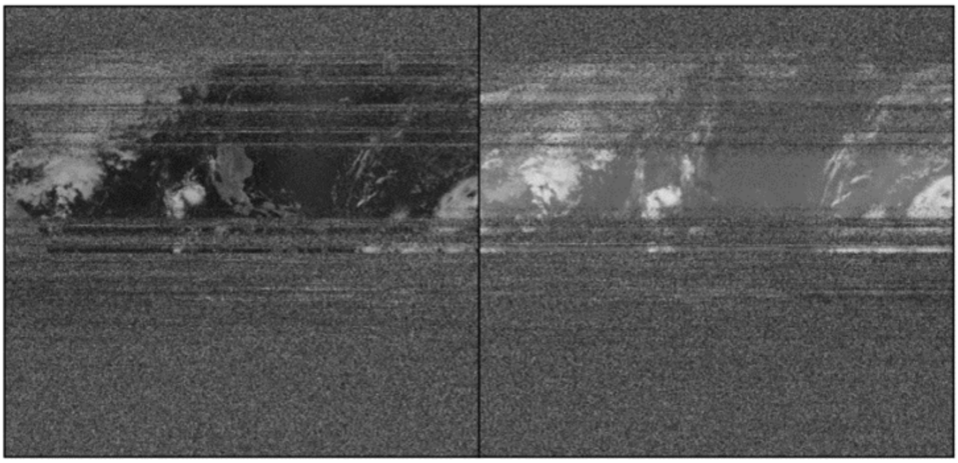

Figure 4 Channel A (Left) and Channel B (Right) of NOAA 19

3. Processed Image

The images data (Figures 3 & 4) from NOAA 18 and NOAA 19 consist of two channels, which are channel A and channel B. Channel A is for visible light, whereas channel B is for infrared. These channels were produced by the 2400 Hz pixel values embedded in the audio file received by the antenna. The Advanced Very High-Resolution Radiometer (AVHRR) employed by NOAA Satellites is a wide-field-of-view spaceborne sensor with a spatial resolution of 4 km, producing maps with 1:8000 scale and is corrected for a nearly constant geometric resolution to free the image of distortion due to the curvature of the earth (National Environmental Satellite Data amd Information Service, 2022).

Processed Channels A and B produced different RGB Composite imagery to highlight the presence of meteorological phenomena, specifically cloud cover (Stowe et al., 1991). MCIR composite (Figure 5) enhances the clouds in the composites appearing as white and progressively less transparent as the cloud thickens, preserving more cloud data. MCIR Rain composite (Figure 6) shows the likelihood of precipitation appearing green, yellow, red and black.

CONCLUSION

This paper analyzed the V-dipole Antenna from the designs of Adam 9A4QZ tuned in 137 Mhz as an inexpensive antenna for receiving automatic picture transmission (APT) signals from NOAA 18 and NOAA 19. The V-dipole Antenna with RTL-SDR as its software-defined radio receiver was able to receive APT signals from the NOAA 18 and 19 satellites and was able to decode and process the signal into an image using the decoding software SatDump. Employed with an MCIR filter, the images highlighted meteorological phenomena, enhancing the resolution of the cloud coverage during the passes and gathering substantial meteorological data for analysis and cloud cover prediction. The processed picture transmissions of the archipelago were able to produce visible and infrared spectrum channels. An offset ±20.687 kHz was observed, which is due to low low-quality crystal oscillator utilized by the RTL-SDR and other chemical-induced factors such as temperature. This offset shifted the frequency of NOAA 18 and NOAA 19 to a varying range of 137.892 MHz to 137.933 MHz and 137.079 MHz to 137.121 MHz, respectively. Moreover, modeling the V-Dipole antenna in MMANA-Gal provided numerical

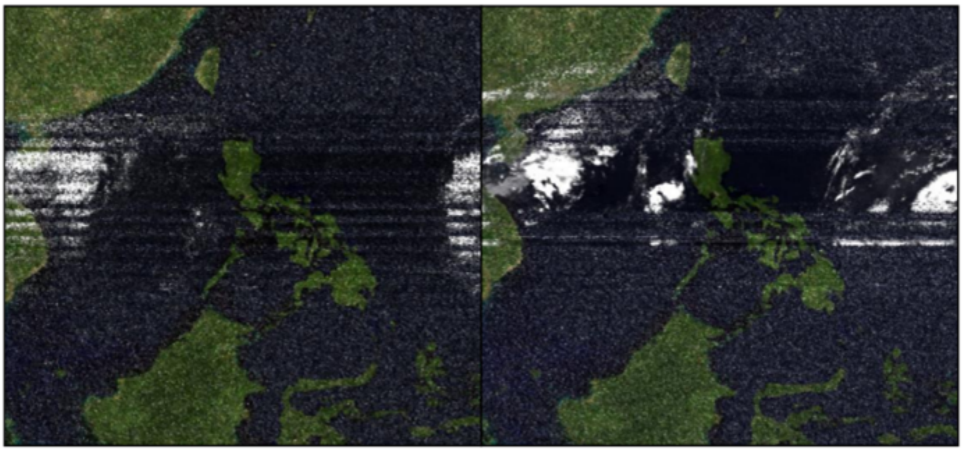

Figure 5 MCIR Composite of NOAA 18 (Left) and NOAA 19 (Right)

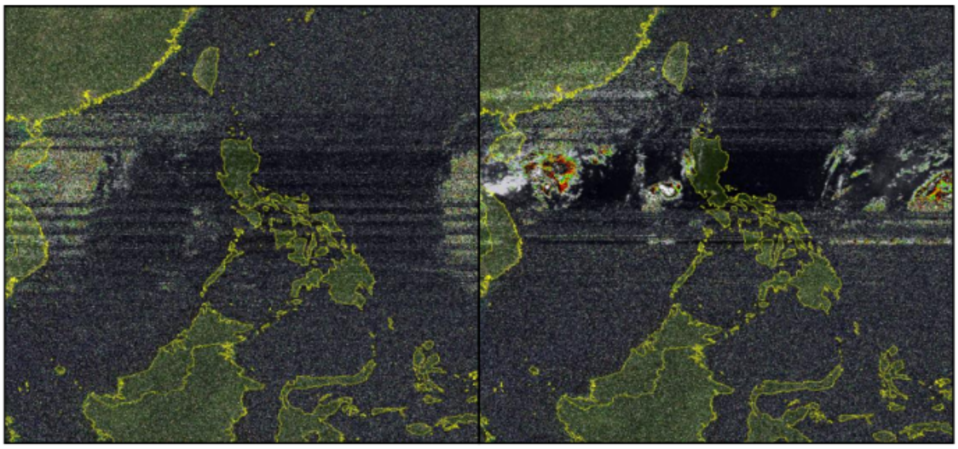

Figure 6 MCIR Composite of NOAA 19 (Left) and NOAA 19 (Right)

interpretation presenting the relationship between the gain and placement of the antenna. The efficient placement of the V-Dipole antenna for its gain of 7.88 dBi for NOAA 18 and 7.9 dBi of gain for NOAA 19 is for both placements of 8 meters.

Other factors that affect the signal reception from NOAA satellites should be explored such as the pass height of the satellite and the Front-to-Back Ratio of the antenna, extensive signal reception in different heights to improve the image quality and reducing the frequency offset using other software-defined radio that is superior to RTL-SDR could also improve the image quality. In addition, extending the composite filters to show algal bloom, sea surface temperature monitoring, and forest fire detection is highly suggested.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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