

# Weather Pattern Monitoring Using SDR

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**Abstract** – This paper provides a notion about weather station accomplished of receiving and processing satellite signal, in order to produce an image to assist in observing weather conditions. To achieve this, a Quadrifilar Helix antenna (QFH), a receiver and a PC sound card is used in the hardware part. The output from the sound card is recorded as a wave file. This wave file is decoded using processing techniques in various software environments. This paper provides a comprehensive report on antenna construction procedures and signal processing techniques used to achieve a complete readable weather image. Also using these decoded images, how far application oriented information can be retrieved is analysed.

**Keywords** – Quadrifilar helix antenna, FUNcube Dongle, HSDR, WXtoImg

## I. INTRODUCTION

Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR) where; EMR is a form of energy that reveals its presence by exhibiting observable effects as it strikes the matter. It is measured as wave radiation and characterized by frequency or wavelength. These wavelengths may be separated by filters or by the use of instruments that are sensitive to particular wavelengths, including light from frequencies beyond the visible light range, such as infrared. A multispectral image is one that captures image data at specific frequencies across the electromagnetic spectrum. Spectral imaging can allow extraction of additional information the human eye fails to capture with its receptors for red, green and blue. It was originally developed for space-based imaging. Multispectral images are the main type of images acquired by remote sensing (RS) radiometers. These radiometers are accommodated by weather satellites.

Here, the focus is on the satellites directed from NOAA. There are 4 operational satellites of NOAA in

orbit; NOAA-15, NOAA-16, NOAA-17 and NOAA-18. The satellite uses cameras to scan the visible spectrum as well as the infrared spectrum and take strips of images that would span approximately 3000 km. By repeated process we can make a continuous image [1]. These weather satellites deal with two categories of image services, a digital high resolution data (HRPT) and an analogical lower resolution data (APT). In this paper, the focus is on the reception of the Automatic Picture Transmission (APT) weather satellites pictures [4]. Where, this image is transmitted at 137 MHz and received at the ground station. This signal can be received through the antenna while the satellite is overhead. The Quadrifilar Helix antenna (QFH) is regarded as one of the best omni-directional circularly polarized antennas that suit this system [1]. The radio receiver demodulates the FM carrier and leaves an AM sub-carrier data signal that is processed to display an image.

In the present work, NOAA satellite imagery is done with the help of a Quadrifilar helix antenna and the FUNcube Dongle SDR. The antenna is fixed in a particular position for getting better signal reception from the satellite. The FUNcube Dongle is a SDR receiver which is tuned to the frequency of the satellite with the help of FUNcube Dongle interface software. The spectrum analysis is done with the HSDR program and the signal from the satellite is recorded as WAV files. Also, the waterfall display of HSDR shows the signal intensity in the tuned frequency. As the satellite passes, a direct image recording is done with the help of WXtoImg software. The brief description about the whole process is given in the coming sections.

## II. EXPERIMENTAL SETUP

A basic direct ground station typically contains the following components:

- Antenna

- Radio receiver
- A method to predict when the satellite will be in view of the ground station
- Demodulator software to "decode" the satellite signal
- Display system to view the satellite imagery (typically a personal computer)
- Computer software to manipulate the imagery (image enhancement)

### III. HARDWARE

For recording the images from weather satellites, the first main component is an antenna. A Quadrifilar helix antenna is used in this work. Now the SDR receiver comes after the antenna. Here a FUNcube Dongle SDR receiver is used. These are the hardware components needed for this project. FUNcube Dongle interface software is needed in order to drive the FCD.

#### 3.1 Antenna

An antenna is an electrical device which converts radio waves into electric current or vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter applies an oscillating radio frequency electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals that is applied to a receiver to be amplified. An antenna can be used for both transmitting and receiving.

Antennas can be designed to transmit or receive radio waves in one direction or all directions. Antennas that can receive or transmit radio waves in all directions are called as omnidirectional antennas and in one direction are called as directional antennas. The antenna for the APT (Automatic Picture Transmission) satellite system should be omnidirectional and circularly polarized beam. In this work, Quadrifilar Helix Antenna is used. This antenna has same directivity in all directions and thus a better reception is possible. Also the circularity is great in any direction and it covers horizon to horizon.

The Quadrifilar helix is one of the most popular designs because of its relatively compact size. It is used for narrow bandwidth application requiring a broad beam width, cardioids shaped radiation pattern and excellent circular polarization. The Quadrifilar helix antenna generically they employ two bifilar helix antennas with orthogonal radius fed in phase quadrature

with a folded balun to feed the antenna, with the two ports connected to a hybrid coupler to produce circular polarization. The 90-degree phase relationship between bifilars needed to feed two identical orthogonal bifilars with a quadrature hybrid using a balun. The 90-degree phase difference is realized at the expense of losing power to the hybrid, adding the hybrid weight to the system and requiring two cables to feed the two bifilar.[4]

The quadrifilar antenna improves APT antenna performance in two means. 1) Due to circular polarisation, the quadrifilar antenna exactly matches the antenna pattern from the satellite and also rejects linearly polarized earth based signals. 2) The gain pattern of a quadrifilar almost matches the received signal level from the satellite, resulting in approximately constant received signal quality from horizon to horizon.[4]



Fig. 3.1.1: Quadrifilar Helical Antenna

After the reception of the signals with the help of antenna, the data is recovered using radio receivers

#### 3.2 Radio Receiver

A radio receiver practices the radio frequency signal from an antenna in order to produce operational information such as audio. There are many radio receivers available in the market. In order to make the system cost effective, we have tried with both FUNcube Dongle (FCD), RTL-SDR-2832.

A software-defined radio receiver can be tuned to any frequency band and decode different modulations/encoding schemes across a large frequency spectrum by means of a programmable hardware, which is controlled by software. For a better reception, a good receiver is needed which has the correct IF bandwidth. The FCD is a fully integrated, wide band, high performance Software Defined Receiver with a greater potential. It is a simple USB receiver covering

approximately 60MHz to 1,700MHz range of the frequency.[6]

The Dongle is designed to allow anyone to try their hand at reception of satellites like FUNcube anywhere on Earth as part of a global educational collaboration project collecting information from space. The FUNcube Dongle is similar to a USB TV Dongle. This can be simply connected to the computer's USB port and thus it appears as a USB Audio Device running at full speed. In our computer, we can use various SDR interface software to adjust the parameters to our requirements.[13]



Fig. 3.2.1 : An FCD connected to a PC [28]

The basic working steps of the FUNcube Dongle are as follows:

- First the analog RF data enters the Elonics silicon tuner, where it undergoes down-conversion to complex I/Q baseband.
- Then it enters the audio codec where it is digitized using an ADC.
- The resulting digital audio stream is passed to the PIC, which forwards it via USB to the host PC. The PIC also controls the tuner and codec.

This hardware parameters are controlled using the various spectrum analyzer software, which is been discussed.

#### IV. SOFTWARE

After getting this, now our next aim is to track the satellites. For this, Orbitron satellite tracking software is used. After tracking this signal from the satellite is received with the help of software called HSDR. This helps in the spectrum analyzing. The image is directly recorded with WXtoImg software. Now each one is discussed in detail.

##### 4.1 HSDR

HSDR (High Definition SDR) is real time spectrum analyser software and it is a versatile program

designed to work with multiple SDR hardware platforms. It takes the I/Q data from an SDR, displays waterfall and spectrum graphs, and demodulates the signals. Spectrum analyser measures the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to measure the power of the spectrum of known and unknown signals. It has a number of significant features, all implemented in software. Before starting to work with HSDR, we must organise the required information regarding the satellite. In order to decode the data from the signal received, we need to collect the satellite pass list. As the user knows which satellite is going to pass overhead then he should select the desired channel. If the satellite is not known, then the receiver should be set to scan all of the channels. Once a signal is detected the user should press the record button on the computer to record the signal until the signal is no longer present. After recording the received data is stored in the form of a .wav file. This is further being processed by various decoding software. HSDR runs in a Microsoft Windows environment, including XP, Vista, and Windows7. Many other spectrum analysers are also available. Also the tutorials can be downloaded from internet. [18]

##### 4.2 WXtoImg:

High quality satellite image is decoded from the recorded wave file using WXtoImg. WXtoImg is a fully automated APT and WEFAX weather satellite (wxsat) decoder. The software supports recording, decoding, editing, and viewing on all versions of Windows, Linux, and Mac OS X. WXtoImg supports real-time decoding, map overlays, advanced colour enhancements, 3-D images, animations, multi-pass images, projection transformation, text overlays, automated web page creation, temperature display, GPS interfacing, wide-area composite image creation and computer control for many weather satellite receivers, communications receivers, and scanners. WXtoImg makes use of the 16-bit sampling capabilities of soundcards to provide better decoding than is possible with expensive purpose-designed hardware decoders. WXtoImg comes in a basic freeware version that provides a large range of features. Improved automation, new enhancements, a wider variety of options, projection transformations and improved quality images from communications receivers and scanners are available by upgrading the software. WXtoImg is feature-laden program that decodes NOAA data in real-time, saving the raw data as WAV files. The program can be made to process these WAV files into images in a variety of projections, and can create a color composite of numerous types. Output is in JPEG, PNG, BMP, PBM (PGM/PPM/PNM), or AVI format. WXtoImg software is used in this paper

work. The direct recording of the satellite signals is possible with this software and thus we get images of the ground station location.

V. RESULTS AND DISCUSSION

In this particular work, I have captured signal from NOAA-18. NOAA-18 is a weather forecasting satellite which was launched on May 20, 2005, into a sun-synchronous orbit at an altitude of 854 km above the Earth, with an orbital period of 102 minutes. It hosts the AMSU-A, MHS, AVHRR and High Resolution Infrared Radiation Sounder (HIRS) instruments, as well as the SBUV/2 ozone-monitoring instrument.

5.1 NOAA-18 Satellite Reception

The satellite frequency of 137.912 MHz is tuned manually using a receiver FUNcube Dongle with the help of interface software as shown below:

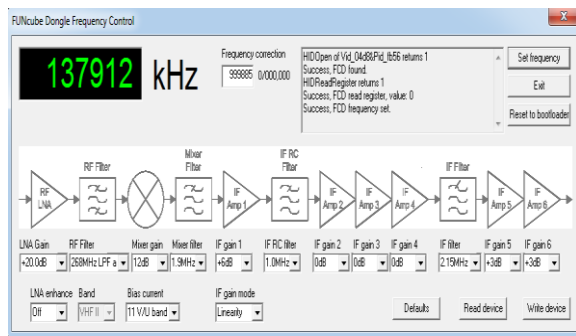


Fig. 5.1.1 : Screen shot of FCD interface software [15]

Now the FUNcube Dongle software is driven and this will work as a soundcard in laptop. In HSDR software, we are selecting input as soundcard i.e. FUNcube Dongle and we can do recording of both RF and AF signal. The sampling rate of output signal is 11025 KHz. The RF means the fully input signal and AF means audio-demodulated signal.

Now the recorded wavefile is opened in WXtoImg software for decoding. Various enhancements are done on the output image (figure 5.1.1). The yellow plus mark shows the ground station location, Coimbatore. In this image the bar code can also be seen. But the image is not much clear because of narrow IF bandwidth. This contains two images. One is visible channel image and other is infrared (IR) channel image.

5.2 Image Enhancements

Various enhancements are done on the original image. At first, contrast A enhancement is done. This contrast enhancement is performed only on the NOAA channel A image i.e. Visible channel image. This image is obtained by the sunlight that is reflected and recorded by the satellite.

In Visible channel image, clouds, snow and ice reflect the most light and appear whitest in these images i.e. the objects with higher albedo (ability to reflect sunlight) appear brighter on the satellite image. Thin clouds reflect less sunlight and appear darker.

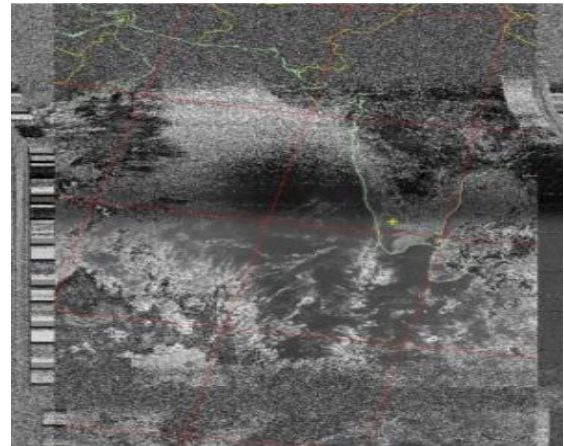


Fig. 5.2.1 : Contrast A enhancement

Next enhancement done by WXtoImg is contrast B enhancement. This contrast enhancement is performed only on the NOAA channel B image. This is contrast enhancement of channel B image i.e. infrared (IR) channel image.

In these images the source of radiation is not the sun, but features of the Earth and atmosphere themselves. Black in these images represents the greatest radiation flux at this wavelength, and white indicates the least flux. Since water (both bodies of water and water droplets) and land essentially act as blackbodies, we can judge their temperature from how much radiation they emit. Warmer objects emit more radiation, and colder objects emit less. Thus, the warmer land and water areas appear darkest in these images, while objects that are higher up in the atmosphere and colder will appear whiter.

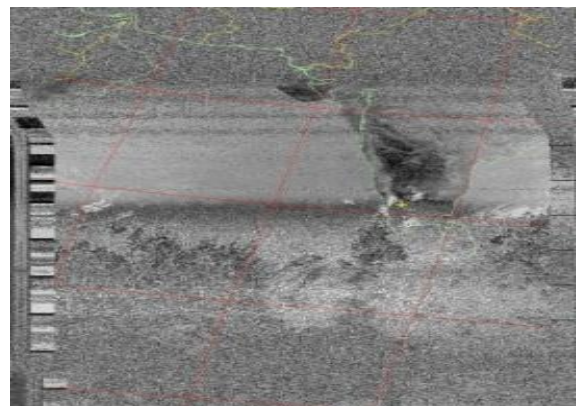


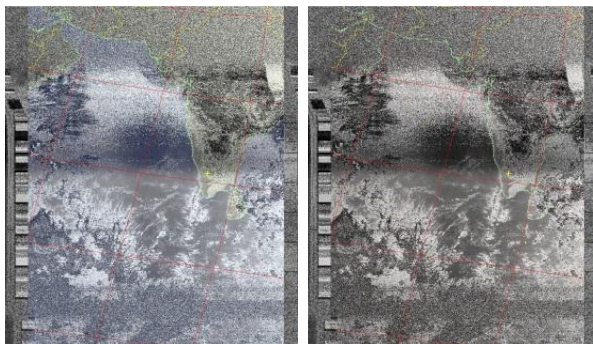
Fig. 5.2.2: Contrast B enhancement



Next enhancement is MCIR Map Color enhancement. This will color the NOAA sensor 4 IR image using a map to color the sea blue and land green. Also high clouds appear white and lower clouds gray or land or sea colored. Clouds generally appear lighter. But land/sea and low cloud may be difficult to distinguish. Darker colors will indicate warmer regions.



Fig. 5.2.3 : MCIR Map Color



(a) (b)

Fig. 5.2.4 (a) HVCT False color enhancement (b) HVC False color enhancement

## VI. CONCLUSION

Here we have utilised weather satellite signals from NOAA series of satellites. These signals are captured using quadrifilarhelix antenna which is of one dimensional format. Thereafter, it is converted to audio (.wav) file with the help of a radio receiver -FUNcube Dongle and its related interface software -HSDR, which is again one dimensional. Also using decoding techniques, these audio files are converted to colour images which is two dimensional. On these images various enhancements are done such that we can perform various weather related analysis. Cloud type classification on this image is going to be performed as

future work. Thereby we can do various applications related to weather forecast.

## VII. REFERENCES

- [1] KawayaSwana Eric Mbaka, Mark Roland,Vijo Varghese, Bill Dower, "Jayhawk Engineering Laboratory Weather Satellite Imaging System". Final Report for EECS 502, Spring 2006 21 May 2006..
- [2] Ambily Joseph, Jaini Sara Babu, K. P. Soman, "Communication with less hardware." Centre for Computational Engineering and Networking, Amrita Vishwa Vidyapeetham, Coimbatore, India
- [3] A document named "NOAA Weather with FCD and WXtoImg" available online at <http://www.ne.jp/asahi/hamradio/je9pel/fcdwximg.htm>
- [4] N. Benabadji, A. Hassini and A. H. Belbachir, "Hardware and Software Considerations to use NOAA Images", Rev. Energ. Ren. Vol.7 (2004)1-11
- [5] Document named "User's Guide for Building and Operating Environmental Satellite Receiving Stations", U.S. DEPARTMENT OF COMMERCE, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, February 2009.
- [6] Andy, DL4AND, "Satellite Weather Pictures First-Hand, Part 1" available online at [http://www.alice-dsl.net/andreas-schulze/English/NOAA/NOAA\\_English\\_1](http://www.alice-dsl.net/andreas-schulze/English/NOAA/NOAA_English_1).
- [7] A document called "Chapter 22, The Quadrifilar Helix Antenna" available online at <http://w2du.com/r2ch22.pdf>
- [8] R.W. Hollander, "TECHNOTE 1999 - 1, WORKING GROUP SATELLITES, Resonant Quadrafilar Helical Antenna.
- [9] Scotty Cowling, WA2DFI 2008 Dayton Hamvention SDR Forum, "Hands-On Software Defined Radio.
- [10] Umair Naeem, Nabeel Ahmed Durrani, "DIGITAL RECEIVER FOR SALSA", Group of Advanced Receiver Development (GARD) Radio and Space Science with Onsala Space Observatory, CHALMERS UNIVERSITY OF TECHNOLOGY Göteborg, Sweden 2010
- [11] Thad B. Welch and Travis Kent, Cameron H. G. Wright, Michael G. Morrow, "An affordable software defined radio", January 1<sup>st</sup> 2009.
- [12] Document on "Using SpectraVue with SDR-IQ RF hardware for potential frequency selection".
- [13] Document on "FUNcube Dongle-An Introduction".
- [14] Document on "FUNcube-UK Amateur Radio Educational Satellite"

- [15] Mark J Culross KD5RXT, "Initial setup of the FUNcube Dongle – 20110604".
- [16] Document on "Test bench measurement of FUNcube Dongle receiver"
- [17] Dr.David Morgan, "Experiments with Software Defined Radio Telescope".
- [18] Steve Belter, "Using HSDR with the FUNcube Dongle", available online at [http://www.hamradio.co.uk/userfiles/file/funcube\\_hdsdr.pdf](http://www.hamradio.co.uk/userfiles/file/funcube_hdsdr.pdf).
- [19] David J. Taylor, Edinburgh, SATSIGNAL: "Satellite Signal Decoder", version- 3.8.14.381, 2002 June 25.
- [20] Katherine B. Kidwell, "NOAA Polar Orbiter Data User's Guide", November 1998.
- [21] Eric, K. S. *et al.* (2006), "Weather satellite imaging system" [On-line]. Available: <http://www.markroland.com/engineering/APT>.
- [22] Gower, J. F. R. *et al.* (1989), "A precise APT receiver for cloud and sea surface Temperature Imaging", Geoscience and Remote Sensing Symposium, International Volume 4, pp. 2463-2465.
- [23] Hollander, R. and Jansen, R. (1999). The resonant Quadrifilar Helix antenna. Remote Image Group Journal, Issue No 58, September 1999, pp. 14-29.
- [24] Islam, M. R. and Exell, R. H. B. (1996). Solar Radiation Mapping from Satellite Image Using a Low Cost System. Solar Energy, Volume 56, Number 3, March 1996, pp. 225- 237.
- [25] National Aeronautics and Space Administration. (1998). Calibration of AVHRR Data, NOAA Polar Orbiter Data (POD) User's Guide Section 3.3, [On-line], Available: <http://www2.ncdc.noaa.gov/docs/podug/html/c3/sec3-3.htm>.
- [26] National Aeronautics and Space Administration. (2007). NOAA Satellite Operation Status and Information, NOAA Satellite Status Information, [On-line]. Available <http://www.oso.noaa.gov/poesstatus>.
- [27] VanlintC. (1996). "A portable/Collapsible Quadrifilar Helix Antenna for the 137 MHz APT band". Remote Image Group Journal, Issue No 44, March 1996, pp. 8-13.
- [28] <http://1.bp.blogspot.com/bwLwxG5s1dg/TXyVaQ9Af3I/AAAAAAAAAIC0/mJQgrbeMip8/s1600/P1020406.JPG>

