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NOAA SATELLITE RECEIVER SYSTEM USING RASPBERRY PI

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Abstract: **–** This paper analyzes the design and construction of a satellite receiver station whose purpose is to receive meteorological signals transmitted from NOAA (National Oceanic and Atmospheric Administration) Satellites. This is done through an arrangement consisting of an SDR (Software Defined Radio), an adaptive antenna on the VHF band and web and FTP servers for analysing the obtained images remotely. The SDR maintains connection with the satellite in the specified time period. The paper also further analyzes the decoding of the thus obtained image. The enhanced image is further studied. These images can be used for clear meteorological monitoring with the only intention of effectively analysing and preventing climatic events in particular regions.

Keywords - **satellite, SDR, antenna, NOAA, enhanced image, atmospheric parameters**

I. INTRODUCTION

NOAA (National Oceanic and Atmospheric Administration) is an agency from the USA which has one of its branches extended towards monitoring the weather at a large scale. It has 19 satellites with the objective of monitoring the ocean and weather at a tremendous scale. The Satellites currently in active mode are the NOAA LEO (Low Earth Orbit) 15, 18, and 19. These satellites have automatic picture transmission format APT (Automatic Picture Transmission). The NOAA LEO satellites 15, 18 and 19 are in sun synchronous orbit, i.e. they are synchronized with day hours and are at an average height of 854km over the surface of the Earth.[5]

The satellites traversal can be predetermined as the transmission time for its type of orbit is at the same time or hour daily. The system in order to synchronize its orbit moves a degree per day. A full loop to Earth lasts about 100 minutes.

The station designed in this paper is a satellite receiver station used to capture signals from the NOAA (National Oceanic and Atmospheric Administration) satellites.[1] The design of the receiver system consists of an omnidirectional antenna called a Quadrifilar Helix Antenna (QFH). This connects to a processing system, an SDR (Software Designed Radio). The so obtained transmitted signal will then be decoded into an image by using WX to Img software. The obtained image is then enhanced .The enhanced images are then studied

II. RELATED WORK

2.1 Literature survey

The survey from few papers gives us an overview on the existing system and its advantages and disadvantages.

1. "System for receiving NOAA meteorological satellite images using software defined radio" proposed by C. Bosquez, A. Ramos, and L. Noboa explains reception of radio signals using a NIUSRP-2920 SDR and reception intensity between different NOAA satellites is studied.
2. "Design and implementation of a satellite communication ground station" as explained by A. Done, A. M. Cailean, C. E. Lesanu, M. Dimian, and A. Graur emphasizes the importance of ground stations and construction of a ground plane antenna.
3. "Hardware and software implementation of weather satellite imaging earth station" proposed by C. Patil, T. Chavan, and M. Chaudhari explains receiver system using a personal computer and directly decoding in the system.
4. "Considerations on ground station antennas used for communication with LEO satellites" written by the team of A. Done, A. M. Cailean, C. E. Lesanu, M. Dimian, and A. Graur stating the directivity of various antennas with their polarizing nature and various observations.
5. "THE NOAA SATELLITE OBSERVING SYSTEM ARCHITECTURE STUDY" by D. Di Pietro, N. Goddard, and S. Flight explains the importance of NOAA satellites and states its various advantages.

2.2 Technical Background

The satellites use Advanced Very High Resolution Radiometer (AVHRR) as a primary scanning instrument. The instrument is designed in such a way that it can detect five energy channels radiating from the Earth's surface. These five channels range from the visible spectrum, the near-infrared spectrum and to the infrared spectrum. Data from these channels are transmitted directly. The transmission happens in a digital format at high speed and this is known as High Resolution Picture Transmission (HRPT). An analog Automatic Picture Transmission (APT) signal is derived from the original data. This Automatic Picture Transmission signal is then multiplexed so that only two of the original channels appear in the APT format. This is accomplished on the satellite by using every third scan line of the digital High-Resolution Picture Transmission (HRPT).A carrier frequency of 137 MHz is used by the broadcast signal in order to perform frequency modulation. A 2.4KHz amplitude modulated sub carrier is used for the transmission of the Automatic Picture Transmission signal on the 137 MHz carrier. The design of the analog APT system is such that it can produce real-time video images that can be received and reproduced by satellite ground station that are of low cost. The data stream of the transmitted signals is produced by Amplitude modulation of a 2400 Hz sub-carrier with the 8 most significant bits of the 10-bit digital AVHRR data produces the data stream of the transmitted signal. This results in an analog signal that has amplitude varying as a function of the original AVHRR digital data. Two of the six possible AVHRR spectral channels are multiplexed so that the first channel APT data is obtained from one spectral channel of the first AVHRR scan line and another channel from another spectral channel contained in the second AVHRR scan line. The third AVHRR scan line is omitted from the APT before the process is repeated. The two spectral channels are determined by ground command .These spectral channels are not selectable by the user.

2.2 Proposed system

The proposed system looks to replace noise and null patterns from the existing system. It also makes use of a Raspberry Pi system, making it compatible. It reduces the cost drastically by replacing expensive SDR with a cost effective SDR model.

III. SYSTEM DESIGN

In this proposed system the block diagram (fig 3.1) shows the complete methodology of working of a satellite receiver system.

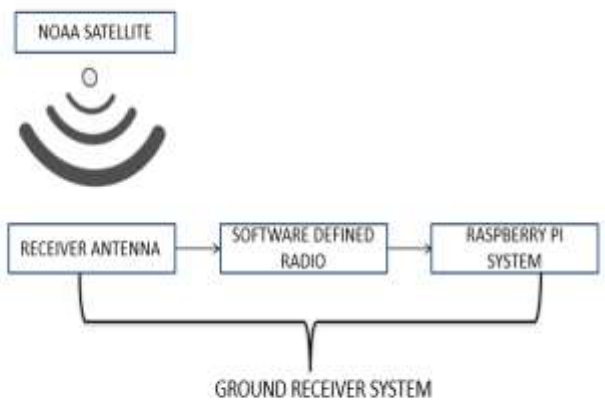


Fig 3.1

The figure 3.1 shows the stages of the Earth station. The first stage has an antenna. The omnidirectional antenna used is a Quadrifilar Helix antenna (QFH). This considerably decreases the fading that might arise in the signals that are transmitted across the layers of the Earth's atmosphere.

FM demodulation is then performed on the signal that is received by the Quadrifilar Helix (QFH) Antenna. Further processing that is to be done by the obtained image is performed by the computer. This demodulation is done using an SDR(Software Defined Radio).The demodulated image is then enhanced .

3.1 QUADRIFILAR HELIX ANTENNA

A number of antennas can be designed in order to accomplish adequate APT reception. These antennas are designed considering the frequencies, signal strength, and polarization factors of the transmissions. The antenna used here is a Quadrifilar Helix Antenna. It is an omnidirectional antenna. An omnidirectional antenna is a class of antenna that radiates power of equal radio power in all directions perpendicular to an axis, with power varying with angle to the axis, declining to zero on the axis. Quadrifilar Helix Antenna (QFH) is the same antenna that is used on board NOAA satellites for the transmission of the APT signals and as a result of this, it is a good antenna to be used for receiving signals transmitted from NOAA. The advantage with using a Quadrifilar Helix antenna is that it provides a much better radiation pattern than as compared to other APT antennas. It also does not suffer from the loss of signal strength exhibited in other alternate antennas such as the simple turnstile antennas. The Quadrifilar Helix usually consists of four ½- turn helices. These are equally spaced around the circumference of a common cylinder. The radiation pattern is omnidirectional in the plane perpendicular to its main axis. Radiation of the signal is nearly circularly polarized over the hemisphere irradiated .This makes it ideal for receiving signals from polar orbiting weather satellites. Quadrifilar Helix Antennas often exhibit inherent gain from 3dB to 5 dB if it is well designed. The Quadrifilar antenna will provide virtually noise free reception once the antenna reaches an elevation of 5-10 degrees above the horizon. The turnstile antenna provides slightly less performance levels. The QHA constructed is a self phasing antenna. It consists of a smaller loop and a larger loop. The dimensions of the antenna decide the resonant frequency. The input impedance of the antenna is determined by the diameter of the conductor used to form the loops. PVC pipes are used to form the mast and the arms of the antenna. The pipes are used to form the skeleton of the antenna and give it rigidity and keeps the filars of the antenna in desired helical shape. The two vertical loops are formed by an RG 6 coaxial cable in infinite balun configuration. To use the coaxial cable as a single conductor, simply short circuit the centre conductor and the braiding. Not only the proper construction but also environmental factors play a great role in the working of the antenna. The construction of a Quadrifilar Helix Antenna (QFH) can be done using simple household materials such as PVC pipes and coaxial cables, which is another advantage to using a Quadrifilar Helix Antenna. The calculations done for the Quadrifilar Helix Antenna are of essence and calculators can be found online.

3.2 SOFTWARE DEFINED RADIO

Software Defined Radio(SDR) is a radio communication system where components that have been traditionally implemented in hardware are instead implemented by means of a software on a personal computer or embedded system. Traditional hardware-based radio devices limit cross-functionality. They can also only be modified through physical intervention. The result of this is higher production costs and minimal flexibility in supporting multiple waveform standards. A major point of concern in any receiver is the quality of the signal. The processing of the signal happens entirely in the digital domain. As a result of this the quality of the signal is creditable. The software defined radio is used for observing a wide range of frequencies .It is made more attractive to amateur radio operators by implementing it on a chip making it portable. The SDR used for the implementation of the receiver system is Nooelec mini SDR-2.

3.3 RF FRONT END

The Software defined radio is a USB dongle .The hardware component requires a software counterpart that can control its software defined parameters such as modulation techniques, filter orders, gain, easy to adjust receiver centre frequencies and a UI that makes observation of a wide range of frequencies an easy job. There are some open source software that satisfy the requirements of an SDR.

3.5 SATELLITE TRACKING

The NOAA satellites are LEO satellites. That is they are Low Earth Orbiting satellites. As a result of this they orbit the Earth around 4 to 5 times a day. This necessitates the fact that they need to be tracked. Only when the satellite and receiver system are in line of sight is the APT signal available. There should also be some minimum elevation level. The task of locating the satellite traversal may be complex, but there are several software that can be used for the prediction. Some software that are used for this purpose are predict and orbitron. Orbitron is used for satellites that have significant doppler shift in their transmission frequencies. Continuous adjustments to SDR receiver centre frequency are not required, as the doppler shift is quite small.

IV. HARDWARE IMPLEMENTATION

Connection of hardware components shows in fig 4.1

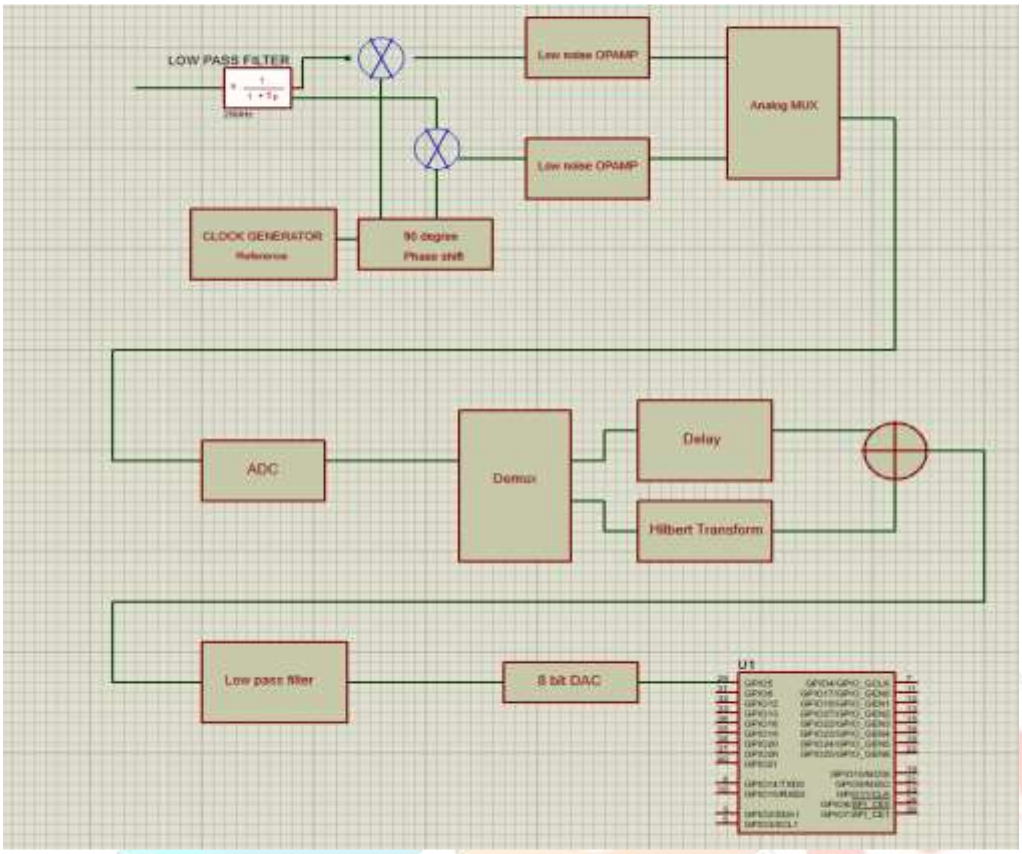
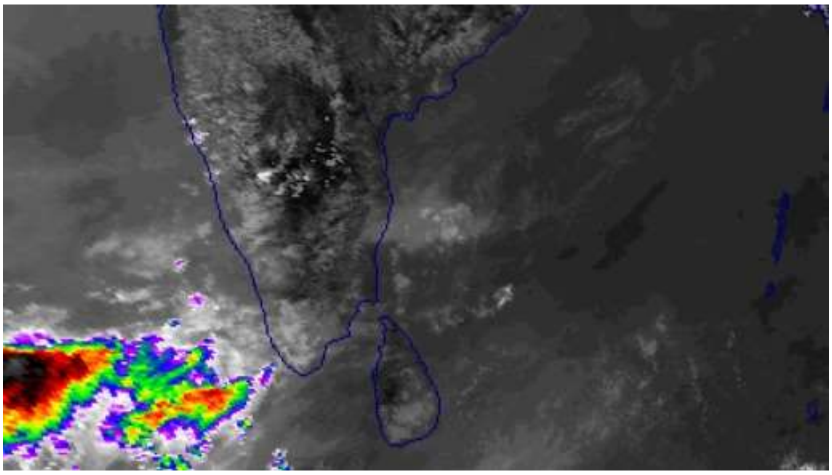


Fig 4.1 circuit connection diagram.

Initial connections from the antenna are given to SDR which is basically a device which has hardware components embedded has software, thus making it compatible. It performs operations of a low pass filter, ADC/DAC, delay, Mux/Demux. This is then connected to a Raspberry PI system which is a microcomputer. Connections between the device is through a coaxial cable. A coax connection is given from antenna to the SDR and then from SDR to the Raspberry PI. Coaxial cable is used for the transmission of radio signals from one end to another without the loss of information.

IV. OUTCOMES AND CONCLUSION

Thus by simple construction methods we are able to access the NOAA satellite and gather informative signals. We are able to arrive at a terrestrial image which is then enhanced and studied to observe various information.



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