Implementation of Antenna in Satellite Ground Station for Cubesat

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Abstract. The functionality of the Satellite depends on the payload, which contributes to the majority of work in extracting the data in a satellite. The purpose of the satellite payload is to support national security initiatives, advance space exploration, monitor the Earth, collect scientific data, or provide communication services, it is specifically designed to meet these goals. A transponder (Communication device) is responsible for establishing a communication link with the ground station. Ground Station is a basic communication element that receives data/signal transmitted by the transponder of the satellite. In the project, we proposed to build a student-level Ground Station to receive data from source Satellites such as Weather satellites and ISS (International Space Station). A Ground Station is a terrestrial radio station that is designed for extra-planetary and other Satellite communication purposes. The Ground Stations communicate with spacecraft by transmitting and receiving radio waves in VHF (30 to 300 MHz) and UHF (300 MHz to 3 GHz). The major components that are involved in building a Ground Station are SDR, Raspberry Pi, Antenna. There are many antennas used for receiving a signal such as the Yagi-Uda antenna, Patch antenna, Log-Periodic antenna, Helical antenna, and V-Dipole antenna. In this project, a Log periodic antenna that works at 100 MHz to 500 MHz is proposed to receive the signals from NOAA-15 (National Oceanic and Atmospheric Administration) [1] at the frequency of 162.400–162.550 MHz for broadcasting weather information.

Keywords: Ground Station Satellite · Antenna · Payload

1 Introduction

A Ground station is also known as an Earth station or tracking station. The Ground stations are the critical link between Earth and space, enabling seamless communication, data exchange, and control of spacecraft and satellites [1]. Ground stations receive data collected by satellites or spacecraft, such as scientific measurements, weather data, and other satellite-tracked data. The establishment of an intricate network of ground stations represents a remarkable

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feat in modern space communication technology. These ground stations serve as vital lifelines, enabling a continuous flow of data and information between Earth and distant spacecraft, no matter where they may be positioned within the vast expanse of space [2]. A central feature of these ground stations is their exceptional capability to receive data from a wide array of spacecraft, including compact and innovative Cubesat. These miniature satellites have ushered in a new era of space exploration, and the ground stations are adept at capturing the streams of data they transmit back to Earth. Satellite Ground Stations (SGS) are built for collecting and streaming remote sensing satellite data to a variety of users and applications. Ground stations are establishments situated on Earth with the purpose of facilitating instantaneous communication with satellites [3]. In addition to receiving data transmissions from the satellite (downlink) and sending radio signals to it (uplink), the crew at these stations occasionally acts as the satellite network's command and control center [17].

1.1 Hardware Design

A basic ground station can be constructed using off-the-shelf components that are commonly available such as a simple omnidirectional antenna to more complex multi-rotor antennas. The reference design contains a Raspberry Pi + RTL-SDR dongle + Antenna.

1. **Raspberry Pi:** Raspberry Pi is a credit-card-sized single-board computer design. Raspberry Pi is a versatile and affordable computer that can perform various tasks. Its compact size and low cost make it accessible to anyone. Using a Raspberry Pi imager installation of Raspberry OS is simple and easy.
2. **SDR:** SDR stands for Software-Defined Radio, which refers to a communication system where traditional hardware components in a radio system. It enables seamless integration of different wireless standards, dynamic spectrum allocation, and improved spectrum efficiency.

In the realm of weather satellite communications, the choice of an optimal frequency range is crucial to ensure reliable and efficient data transmission between satellites and ground stations. In this context, a frequency range spanning from 100 MHz to 500 MHz has emerged as a particularly suitable option. This choice takes into account the specific transmission frequencies employed by weather satellites, as well as the availability of radio spectrum for ground-based communication systems. Weather satellites commonly utilize frequencies within the UHF (Ultra High Frequency) and VHF (Very High Frequency) bands due to their advantageous propagation characteristics, which facilitate communication through various atmospheric conditions.

1.2 Related Work

Atharva College Ground Station: One of the receiving stations used to receive and process Pratham's data is Atharva Ground Station. The satellite weighs close to 10 kg and is made to fit inside a cube with 30-cm sides. Pratham will help with tsunami warnings, scientific research, and fixing GPS communication issues. The team's shared enthusiasm for satellite communication and space technology has motivated them to conduct research on satellite tracking and to share their knowledge on everything from antenna design to signal decoding [15]. The Ground Station innovative student team at Atharva College of Engineering has successfully established a functional receiving Ground Station for the PRATHAM satellite of IIT Bombay, marking a significant accomplishment (Fig. 1).

Fig. 1. On September 26, 2016, at 9:00 a.m., the student satellite Pratham was successfully launched by ISRO's four-stage Polar Satellite Launch Vehicle (PSLV) at Sriharikota's Satish Dhawan Space Centre [15]. The satellites known as Pratham were launched. As part of the project, Atharva College students worked with project guides Prof. Samuel Jacob and Prof. Archana Chaudhary to develop a fully functional satellite tracking system, with ongoing support from Atharva College Management.

Norway, Design of Low-Cost Ground Stations for Satellite Communications: The ongoing investigation in Norway is centered around the ambitious goal of crafting an uncomplicated and cost-effective ground station. This facility is envisioned to serve as a dynamic laboratory, catering to the needs of both researchers and aspiring students interested in the intricate domains of satellite communication advancements and space technology. The scope of the system design is impressively comprehensive, encompassing several vital aspects [9]. The ground station is primed to undertake the pivotal task of tracking signals emitted by an array of satellites, spanning low earth orbit satellites and diminutive nano-satellites. Additionally, the ground station will provide an invaluable platform for error correction methodologies, frame synchronization techniques, and digital signal processing [14]. This venture in Norway aspires to catalyze significant advancements in these cutting-edge fields while nurturing the minds that will shape their future trajectories.

2 Design Flow of Antenna

The ground station's antenna is designed to receive signals from the satellite. As the satellite orbits the Earth, the antenna needs to be able to capture signals coming from various directions. These signals may contain information such as telemetry data, images, or other types of data transmitted by the satellite. A ground station is a point of contact between the spacecraft and the earth [7]. The design of antennas and their working environment will decide the effectiveness of any provided ground station.

Ground stations use radar, telescopes, and other tracking instruments to continuously track the satellite's trajectory. This information is crucial for maintaining communication with the satellite and ensuring collision avoidance with other space objects. This information helps operators assess the satellite's health and performance, diagnose issues, and make informed decisions about its operation.

Software Defined Radio (SDR) is a technology that allows for the flexible and reconfigurable reception and processing of radio signals using software. SDR is responsible for receiving the signals captured by the antenna and tracking the received signals' characteristics. The decoding ratio is a metric that indicates how many of the transmitted data packets from the satellite are successfully decoded and received by the ground station. The SDR processes the received signal to decode these packets.

Once the SDR decodes the packets, a Raspberry Pi (a small computer) starts processing the data. This processing might involve various tasks, such as error correction, data formatting, or extracting useful information from the received packets.

Processed data from the Raspberry Pi is sent to a server via similar communication system. The server will be hosted locally or remotely and act as a central repository for collecting data from various ground stations.

Data retrieval involves collecting the processed data from the server [8]. This data could be raw telemetry, images, scientific measurements, or any other type of information transmitted by the satellite [13]. Different satellites may operate in different modes to accommodate varying communication requirements, data rates, and interference considerations.

For a ground station to successfully communicate with a satellite, its communication equipment must be compatible with the satellite's designated modes. This means that the ground station's antenna, SDR hardware and software must be capable of receiving and decoding signals transmitted by the satellite using the specified frequencies and modulation schemes [16]. The ground station needs to be equipped to send and receive signals within the specified parameters for effective communication with satellites orbiting the Earth.

3 Results and Analysis

To receive pictorial data from NOAA APT Signals and SSTV Signals [10], the weather satellites. Ground stations are necessary for mission control and data communication in satellite space missions. Satellite technology facilitates telecommunications, security, and technological development [11]. During the constellation design process, at least one satellite can be connected at all times for the transmission between the source node satellite and the source node ground station, and the ground-to-satellite link is always connected.

The final results obtained are (Fig. 2):

Fig. 2. Result of NOAA-15 (National Oceanic Atmospheric Administration) satellite which was tracked on 17th of June 2023. The process begins with capturing raw images from the NOAA-15 satellite. These images may contain various types of noise, such as electronic noise, and atmospheric interference.

A V-dipole antenna, often referred to as a V-dipole or simply a dipole antenna, is a type of antenna commonly used for receiving signals from satellites and other sources in space. A V-dipole antenna consists of two straight elements arranged in a V shape. The two arms of the V are typically equal in length, and they are oriented in opposite directions. The angle between the arms of the V is often around 120 to 150°, although variations exist (Fig. 3).

Fig. 3. V-dipole antenna is used to track the satellite. This antenna design is popular for satellite tracking due to its simplicity, omnidirectional properties, and effectiveness in receiving signals from various directions.

Denoising is a technique used to remove noise or unwanted artifacts from an image, enhancing its quality and making it more suitable for analysis or

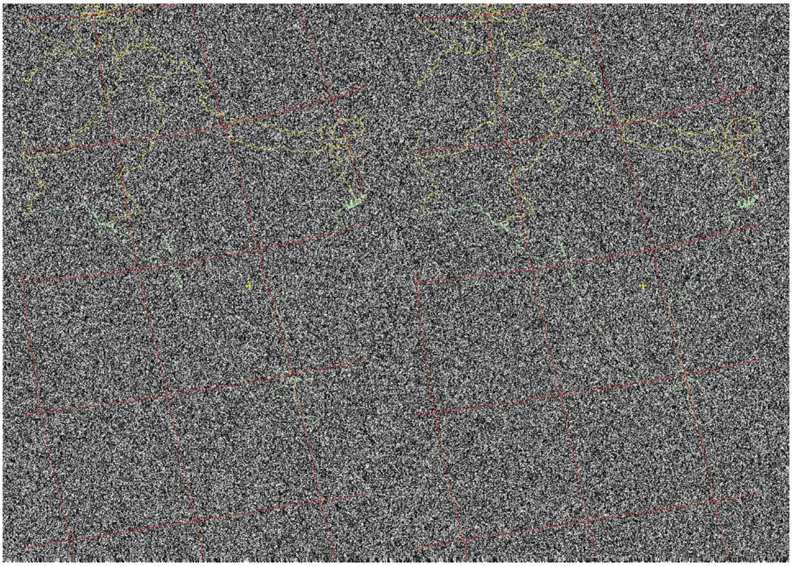

Fig. 4. The Raw image is preprocessed to correct any inherent issues, such as geometric distortions, radiometric corrections, and noise occurrence. This step aims to ensure that the data is in a standardized and accurate form for further analysis.

interpretation. In the context of satellite imagery, denoising can be crucial for obtaining accurate and clear information from the captured data (Figs. 4 and 5).

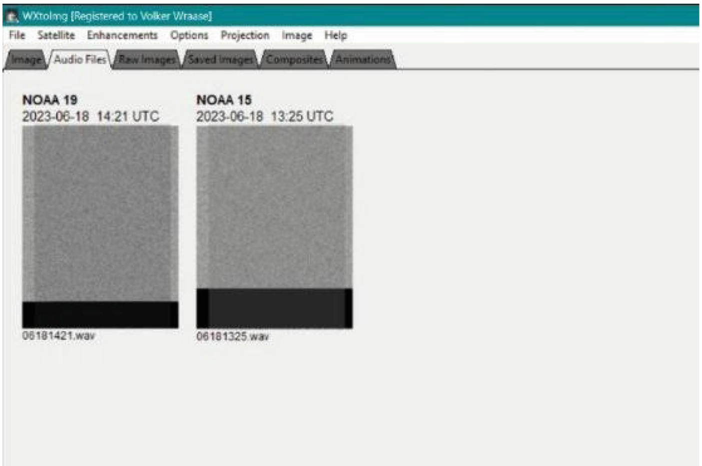

Fig. 5. The different satellites of NOAA-15, NOAA-19 are tracked.

Tracking involves identifying the satellite's position over time, predicting its future location, and possibly correlating this information with other data sources (Fig. 6).

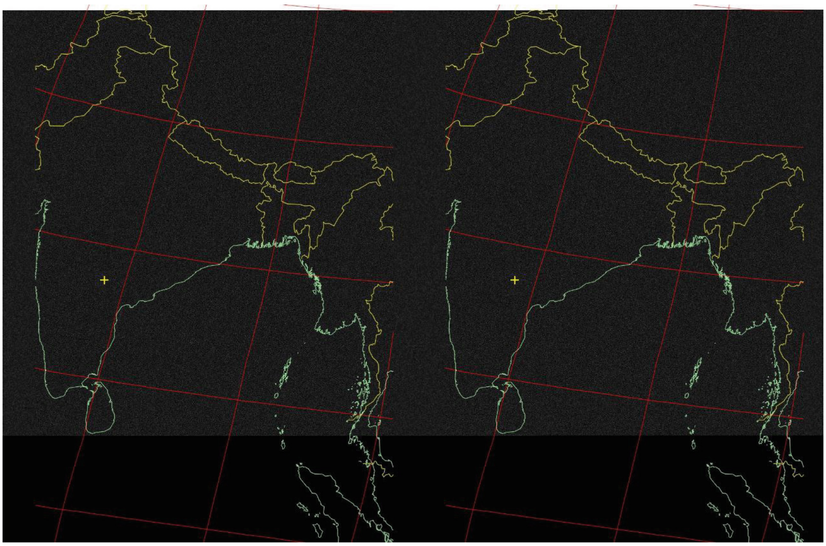

Fig. 6. The above figure shows the target and reduces the noise while preserving important features. The final output of the denoising process is a set of clear, noise-reduced images of the NOAA-15 satellite. This image is more suitable for accurate performance, analysis, and interpretation. This tracked image is used for weather monitoring, and also environmental studies.

4 Conclusion

Low earth orbit (LEO) satellite systems, with their low launch, satellite, and transmission latency costs, are a key component of the next generation of global communication systems [5]. The present system used for ground stations is satisfying the industry need but is lacking in a few sectors due to the current trend in CubeSat and small satellite advancement there is a great need for a ground station for data processing [6]. Data processing should be done fast and accurately, so switching to a hybrid model where IoT helps to swift the process and is very cost-efficient compared to a traditional setup. This model helps to track the Satellite information easily and it is completely student-based level. Every student can access the tracked data from Satellites at different locations [12]. Research is being done on a basic, reasonably priced satellite ground station system for satellite communication and space technology development. The goal of the project is to create a satellite ground station system that can serve as a learning environment and a testing ground for novel wireless technologies with potential applications.

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