Design and Development of Low Cost Ground Receiving Station for LEO Satellite Operations

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Abstract

This project describes the possibility of using Software-Defined Radio (SDR) technology for space applications by developing and setup of a low-cost VHF ground receiving station in order to support existing and future university missions. Software-defined radio is a radio communication system in which communication components are implemented by means of software on a personal computer or embedded system. The proposed solution is based on the integration of commercial low cost components available on the market. This work presents SDR based design and implementation of an educational ground station for the operation with Low-Earth Orbit (LEO) satellites. The main objective was to design and implement a SDR-based ground receiving station that satisfies the multi-mission and multi-channel (VHF and UHF bands) requirements in a resource-efficient manner. This project considered such an approach, in
order to study the operational characteristics of the ground station in a real environment that is very important to students community.

Key Words: SDR, VHF, UHF, LEO.

1. Introduction

A radio is any kind of device that wirelessly transmits or receives signals in the radio frequency (RF) part of the electromagnetic spectrum to ease the transfer of information. In today's world, radios exist in a multitude of items such as cell phones, computers, car door openers, vehicles, and televisions. Traditional hardware based radio devices limit cross-functionality and can only be modified through physical intervention. This results in higher production costs and minimal flexibility in supporting multiple waveform standards. By contrast, software defined radio technology provides an efficient and comparatively inexpensive solution to this problem, allowing multi-mode, multi-band and/or multi-functional wireless devices that can be enhanced using software upgrades. In the last several years, there has been an increased interest among academic environments in developing nanosatellites which are very small. Therefore, there is very little room to put highly sophisticated communication equipment. In practice, the majorities of currently active university satellites are placed in Low-Earth Orbits (LEO) and operate on those sections of the VHF/UHF bands, which are allocated to the amateur satellite service. In most situations, the telemetry and scientific data is transmitted using standard analogue or digital modulation schemes at low data rates. The ground segment is of primary importance for mission success and represents the health status of satellite systems in the communication link. It is responsible for tracking and communication with the LEO satellite in order to get back telemetry and experimental data or to transmit commands. These days, the concept of ground segment is evolving. Traditional ground stations lack the flexibility of changing modules and are tightened by the specifications of the hardware equipment. Software-Defined Radio communication technologies are as a new approaches and alternative for the traditional radio hardware.

A. Satellite Communication

A satellite is basically a self-contained communications system with the ability to receive signals from Earth and to retransmit those signals back with the use of a transponder—an integrated receiver and transmitter of radio signals. A satellite has to withstand the shock of a launch into orbit at 28,100 km (17,500 miles) an hour and a hostile space environment where it can be subject to radiation and extreme temperatures for its projected operational life, which can last up to 20 years. The main components of a satellite consist of the communications system, which includes the antennas, and transponders that receive and retransmit the signals.

The tracking telemetry and control (TT&C) system of a satellite is a two-way communication link between the satellite and TT&C on the ground. This allows
a ground station to track a satellite’s position and control the satellite’s propulsion, thermal, and other systems. It can also monitor the temperature, electrical voltages, and other important parameters of a satellite. Communication satellites range from microsatellites weighing less than 1 kg to large satellites weighing over 6,500 kg (14,000 pounds). Communicating with satellites in LEO and MEO requires tracking antennas on the ground to ensure seamless connection between satellites.

Satellite communication in telecommunications enables the use of artificial satellites to provide communication links between various points on Earth. Satellite communications play a vital role in the global telecommunications system. Approximately 2,000 artificial satellites orbiting Earth relay analog and digital signals carrying voice, video, and data to and from one or many locations worldwide. Satellite communication has two main components: the ground segment, which consists of fixed or mobile transmission, reception, and ancillary equipment, and the space segment, which primarily is the satellite itself. A typical satellite link involves the transmission or unlinking of a signal from an Earth station to a satellite. The satellite then receives and amplifies the signal and retransmits it back to Earth, where it is received and re-amplified by Earth stations and terminals. Satellite receivers on the ground include direct-to-home (DTH) satellite equipment, mobile reception equipment in aircraft, satellite telephones, and handheld devices.

2. Ground Receiving Station Setup

![Flow Diagram of GRS Design & Implementation]

Figure 1. Overall flow diagram of GRS design & Implementation

The main aim of this project is to generate real time facility with the available low cost materials which will give good feel to the students while doing space communication related works. This proposed work successfully implemented in the Division of Avionics, MIT Campus, Anna university, Chennai. The figure 1 represents the roadmap for the sdr based Ground Receiving Station (GRS) setup. The installation on the rooftop comprises one yagi-uda and one helical antenna operated in the VHF/UHF band. A Low-noise amplifier (LNA) is an electronic amplifier that amplifies a very low-power signal without significantly
degrading its signal-to-noise ratio. An amplifier will increase the power of both the signal and the noise present at its input. Low-noise amplifiers are designed to minimize the additional noise. Gpredict is a free, open source software, real-time satellite tracking and orbit prediction application. It can track an unlimited number of satellites and display their position and other data in lists, tables, maps, and polar plots. Gpredict can also predict the time of future passes for a satellite, and provide you with detailed information about each pass. SDR sharp software is installed in such way that is possible to visualize the each pass of the satellites exactly over the ground receiving station. WXtoImg is a free weather satellite decoding program which can decode the Automatic Picture Transmission (APT) signal received from low earth orbit satellites (here we tracked NOAA series satellites) that is integrated with SDR sharp. The exact pass of the satellites is found from the gpredict software and the signal is received to the SDR sharp from antenna and SDR dongle connected to our personal computer. Once the pass is over, the received signal is plotted using decoding software which gave weather report of our proposed GRS zone.

The antennas used for this project is of Yagi-uda and Helical type as shown in figure2 &5. The frequency response range of yagi antenna is 144-148 MHz. This antenna can be configured for either Vertical or Horizontal polarization.

![Yagiuda Antenna](image-url)

**Figure.2 Yagiuda Antenna**

The Antenna specifications are as follows:

- No of Elements: 7
- Frequency Range: 144-148 MHz
- Max Antenna Gain: 11.25 dB
- Boom Length: 7.5 ft.
- Weight:<1kg
Material: Aluminum

Figure 3. Low Noise Amplifier

LNA (Low Noise Amplifier) is an important component that is used to reduce the signal loss due to noise which is shown in figure 3. LNA Specifications are as follows:

- **Gain**: 22dB
- **Frequency Range**: 50-4000 MHz
- **Power Supply**: 12V DC.

The SDR dongle which we used is shown in figure 4. This has tuning range of 25 MHz to 1750 MHz. It can be easily connected through the USB and PC software like Seeder and SDRsharp can be used to receive and decode data. It can also be used along with Raspberry Pi. The software package used along with the SDR dongle helps to decode data received via antenna.
A helical antenna as shown in figure 5 is an antenna consisting of a conducting wire wound in the form of a helix. In most cases, helical antennas are mounted over a ground plane. The feed line is connected between the bottom of the helix and the ground plane. The antenna functions as a directional antenna radiating a beam off the ends of the helix, along the antenna's axis. It radiates circularly polarized radio waves. These are very much important for satellite communication to receive the signal irrespective of the pointing of antennas. The Antenna specifications are as follows:
operating frequency - 137Mhz

Helix diameter-697.01mm

Polarization-Circular

The figure 6 represents the snapshot of the NOAA 19 satellite pass exactly over the our installed Ground Receiving Station using Gpredict software. From this we could follow the communication parameters like look angles, Range, visibility and other parameters. These values are very much useful when we are doing visibility analysis of satellites using SGP (Simplified perturbations models) algorithms for validation purpose.

![Figure 6. Tracking of NOAA satellites using Gpredict tool](image)

**A. Implementation cost**

The overall cost spent to establish this Ground receiving station is around 49,000 rupees only(including tracking facility) and it was supported by CTDT (Centre for Technology Development and Transfer), Anna university, Chennai. The main goal of design and development of GRS was possible with this least amount and able to perform satellite tracking, decoding, mapping, and analyze the strength of signals. The availability of open source software further reduced
costs and made very much useful to students.

3. Experimental Results

In order to prove the technical reliability and feasibility of SDR based ground receiving station, number of pass considered. The following figures represents the reports taken during the raining period of last year and plotted whenever the NOAA series satellites passed overhead to GRS located in the MIT, Chennai.

The figure 7 represents the picture taken on 2nd November 2015 indicates some cloudy environment around south India. The figures 8 & 9 were very important since the pictures taken on 30/11/2015 and 01/12/2015. everybody aware of that on those days Chennai affected by historical rain fall which is clearly seen in the picture. The figure 10 (a & b) represents the different forms of image plot decoded using WXtoImg software. These graphs are useful for extracting features like object detection, location and identification of elements by considering appropriate image processing techniques.
Figure 8. Weather report on 30/11/2015
Figure 9. Weather report on 01/12/2015 at 9.00 A.M

Figure 10. (a)
4. Conclusion

The designed and implemented SDR based ground station prototype is capable of establishing satellite communications and receiving data from satellites operating in the VHF and UHF amateur radio bands employing either analog or digital modulation techniques. This design is ideal for academic environments and it will serve as a teaching and learning tool for engineering students. Further, this study helps to understand the satellite systems, orbital propagation, orbit tracking, communication techniques and also validation of certain orbital measurements.

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References


