Design techniques of Ground Station for pollution monitoring nanosatellite

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Abstract—**Recent environmental fiascos, oil spills, regular emission of huge amount of Greenhouse gases, negligence in implementing pollution control strategies, etc. have led to drastic change in the global climate. Abrupt changing of climate and increasing sea level have posed a great threat to human existence, along with its flora and fauna. To monitor the air pollution more effectively, and to provide a precise data model of pollution level, we are implementing space technology in monitoring the Greenhouse gases over a particular region. Our nanosatellite is having a spectrometer as a payload for monitoring the greenhouse pollutants over a given region. We propose in this paper the ground station design techniques to receive the data and process it in our university campus. The Ground Station is capable of providing VHF/UHF communications in the frequency ranges of 144-146MHz and 430-440MHz, with our dedicated satellite in LEO. The proposed designed of circular polarized, crossed yagi antenna will perform autonomous tracking efficiently to acquire data from the satellite. Our ground station consists of the Antenna system including rotor interface, transceiver and terminal node controller (as the Modem system) and the Processing system.**

Keywords— Sathyabama University; Greenhouse Gases; Nanosatellite; Ground Station Subsystem; Low Earth Orbit;

I. INTRODUCTION

The Sathyabama University Nanosatellite (SNSAT) Project is a milestonetaken up by the students of Sathyabama University. The vision is to increase the awareness of climatic pollution and contribution to space science and technology. The primary objective of the Sathyabama University Nanosatellite (SNSAT) is to monitor the Greenhouse gases present in the atmosphere and create an effective pollution model. This is completely a student initiative under the aegis of Indian Space Research Organization (ISRO) and the faculties of Sathyabama University.

Some of the details about the Sathyabama University Nanosatellite (SNSAT) are:

- ✓ Weight: ~ 5Kgs
- ✓ Payload: IR Spectrometer
- ✓ Orbit: Low Earth Sun Synchronous Orbit, 750Km (approx) altitude
- ✓ Downlink and uplink at 430-440MHz
- ✓ Beacon at 144-146MHz.
- ✓ Estimated 6 months mission lifetime.

Project SNSAT is an entirely multidisciplinary project, involving students of various departments, like Mechanical, Aeronautics, Electronics & Communication, Control, Telecommunication, Electrical, etc. SNSAT will be placed in Low Earth Orbit at an altitude of about 750Km by ISRO's Polar Satellite Launch Vehicle (PSLV). In this paper, we present the high level design and specification of various components of the ground station subsystem.

The Ground station of SNSAT is situated in the campus of Sathyabama University, designed and developed by the students and faculties of Department of Electronics and Telecommunication.

II. MISSION STATEMENT

The main mission Objectives framed for the ground station are:

1. To transmit the telecommand data to the Satellite to initiate the downlink and activate the payload in the space vehicle.
2. To receive the telemetry data from the satellite to process it and generate a pollution model.
3. To receive a beacon signal on the amateur band and to track the satellite.

During the entire lifetime of the mission, the ground station will be the "ear" and control centre of the satellite. The success of this entire space mission massively depends on the success of the ground station. Therefore, we have framed a success criterion for the Ground Station separately.

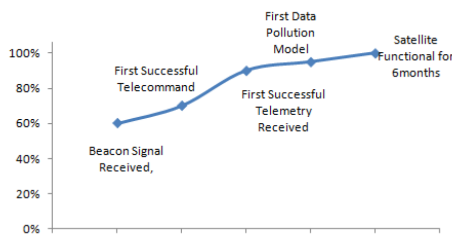

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Figure 1. Success criteria

The basic principle of the payload is:

"Various gases in the atmosphere have a unique spectrum pattern. Based on the spectral analysis, using the spectrometer, we can determine the concentration of greenhouse gases present in the atmosphere"
The output from the spectrometer will be processed in the Ground Station, and the numerical data will be plotted into a graphical pollution Model.

III. COMMUNICATION OVERVIEW

The communication system consists of a command, telemetry and beacon providing communication between satellite and ground station in the low earth orbit of about 750km.The system parameters proposed is mentioned in table[2].

TABLE I. COMMUNICATION SYSTEM PARAMETERS

Parameters	Command	Telemetry	Beacon
Frequency	437.5MHz	437.8MHz	145.7MHz
Tx Power	20W	1W	50mW
Data Rate	1200bps	9600bps	12bps
Modulation	FSK	FSK	OOK
Satellite Antenna	monopole	monopole	monopole
Minimum Gain	-4dB	4dB	4dB
Antenna Gain (GS)	Crossed Yagi 14dBi	Crossed Yagi 14dBi	Crossed Yagi 12dBi

IV. GROUND STATION SYSTEMS

The Ground station consists of three major sections:

1. Antenna and Tracking Section
2. Modem Section.
3. Data Processing Section.

The Antenna Section consists of as shown in Fig [1] two circular polarized crossed yagi antennas for telemetry, telecommand and tracking & beacon reception. The antenna is moved in alignment with the satellite in the radio window with the help of a rotor and tracking software interfaced with it. The modem section containing a terminal node controller executes the packet assembling and de-assembling of the signal. It also implements the AX.25 protocol as per programmed in the EPROM of the TNC. The ground station transceiver will implement the FSK modulation technique. Finally, the data processing section contains a system which will convert the raw spectrometer data into a pollution model using a software.

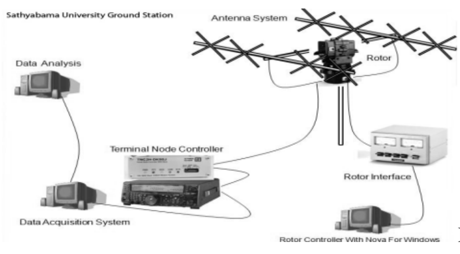

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Figure 2. The Ground Station Layout

V. ANTENNA SECTION

We propose for the receiving side antenna as a VHF circular polarized crossed yagi antenna of gain 12dBi and UHF circular polarized crossed yagi antenna of gain 14dBi. Both the antennas are placed on the same boom. The clean radiation pattern increases the F/B and forward gain.A sample radiation pattern expected for the design is shown in Fig[2].The pattern isimportant in order to match the antenna's noise temperature with modern low-noise preamps. We will also be using two different Low Noise Amplifiers for the VHF and UHF antennas and a separate lightning protection system.

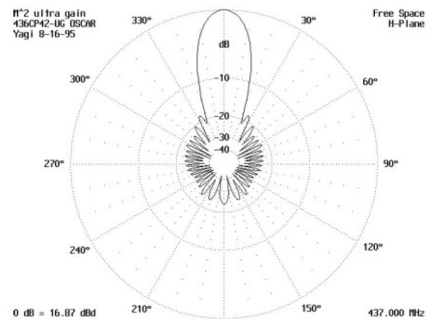

Figure 3. Radiation Pattern Of Crossed Yagi Antenna [1]

The most important aspect of the ground station antenna is that an antenna azimuth-elevation rotor is used to synchronize the antenna into perfect alignment to avoid any kind of pointing loss as well as to get the maximum exposure of the satellite. The rotor is interfaced with the satellite tracking software, to identify the path of the satellite arrival and point the antenna into that particular direction.

Apparently, we are using Nova for Windows Fig[3], as a tracking and rotor orientation software. Most importantly because it is user friendly and is compatible with the rotors YEASU 5500 and its interface GS-232A.

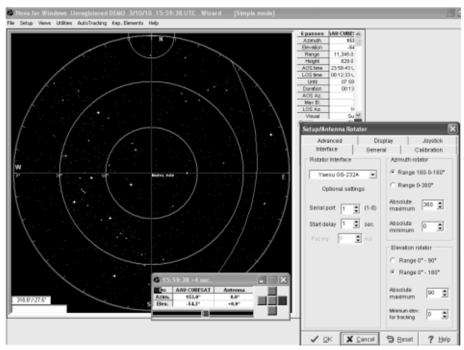

Figure 4. Nova For Windows [2]

The above Fig. 4 illustrates the details of each crossed yagi antenna. Along the boom, we will fix the antenna rotor as shown in Fig[1] , which will be interfaced to Nova for windows using a rotor interface. Yaesu G5500 and Yaesu

GS232A interface are the most compatible and appropriate rotor system for this kind of antenna. Moreover GS 232A has a spectacular facility to select the baud rate ranging from 150 to 9600 by using DIP switches in the interface box. The GS 232A has a inbuilt ROM for logging data and retrieve it later.

Figure 5. Antenna Rotor With Interface [3]

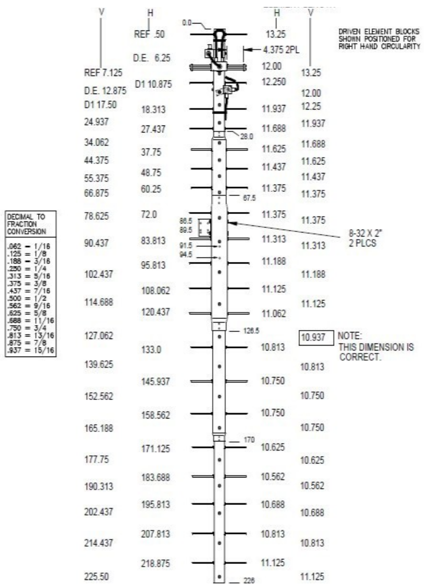

Figure 6. Antenna Specifications [1]

VI. MODEM SECTION

The modem section mainly comprises of:

- Ground Station Transceiver.
- Terminal Node Controller (TNC)

The Ground station transceiver,Kenwood TS2000 is a radio band DSP transceiver with adjustable DSP filter frequencies and digital automatic gain control.A second independent sub-receiver for the 144-146 and 430-440MHz are used. It has an in built Antenna tuner for HF/50 MHz band. Another advantage of the selected Transceiver is it has an in built Doppler shift rectification facility.Another major advantage of this transceiver is that it has an inbuilt terminal node controller (TNC)for 1200-9600bd AX.25 AFSK, FSK and BPSK. The main purpose of the TNC is to convert the data packets into frames by implementing the AX.25 protocol stored in the EPROM of the TNC. The AX.25 protocol is the most widely accepted and used packet assembling protocol used by amateur radio operators. AX.25 occupies the first, second, and often the third layers of the OSI networks model, and transfers data (encapsulated in packets) between nodes and detects errors introduced by the communications channel.

VII. DATA PROCESSING UNIT

This unit mainly for processing the received telemetry and plots it into a pollution model. The spectrometer we shall use is a Thots technologies product, Argus 1000.

Figure 7. ARGUS 1000 Spectrometer [6]

Argus can be effectively used to map the concentration of greenhouse gases. The spectrometer records infrared radiation emitted from the Earth's surface and atmosphere. By using optical absorption spectroscopy, absorption and consequently the densities of particular atmospheric gas may be obtained. Methods such as differential optical absorption spectroscopy (DOAS) are similar to computing the intensity ratio between closely associated absorption and non-absorption features[6].

The primary reason for the selection of this spectrometer is its excellent space heritage. Moreover, we can program the integration time of the spectrometer.

This gives us the advantage of programming the spectrometer according to our favourable and required observation conditions, scene altitude and orbital parameters. We can also program the integration time of the payload, for a better signal to noise to ensure a successful and proper data acquisition [6].

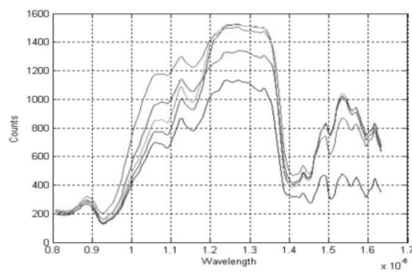

Figure 8. Example Pollution Model From Thoths Technologies INC. [6]

VIII. ORBITAL DYNAMICS

These are series of calculation that determines the number of passes of the satellite over the ground station and also the amount of time the satellite will be visible from the ground station.

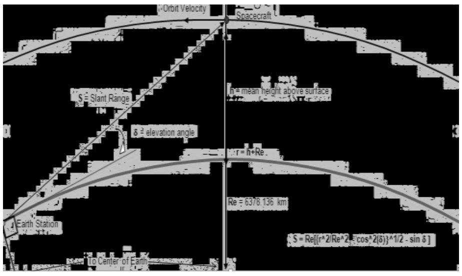

Figure 9. Path Determination

The basic equation to find out the maximum distance the satellite can attain from the ground station will be given by:

$$R= R_e[\{r^2/R_e^2 - \cos^2(\delta)\}^{1/2}- \sin(\delta)] \qquad ....(1)$$

Where, s is the distance, $R_e$is the radius of the earth, r is h+R_e, h is the mean height above the surface and δ is the elevation angle of the satellite with the ground station.

Pass prediction and visibility period is estimated by simulation using Nova for windows and Orbitron.

TABLE III. PASS PREDICTION AND VISIBILITY PERIOD

Parameters	Value
No. of passes over ground station per day.	6-7
No. of passes during day	3-4
No. of passes during night.	2-3
Average duration of each pass	9.65 min
Total time over 20deg elevation per day	21min
Total Data Transfer per day.	18.98 MB

Based on the above parameters we get an approximate value as to when the satellite arrives and from when we should transmit the command. It is wasteful to utilize a clear signal view of the satellite for transmitting command to the satellite. The basic idea is to transmit the command when the satellite is in a moderate elevation and receive when the satellite is at the most favourable elevation angle with the ground station.

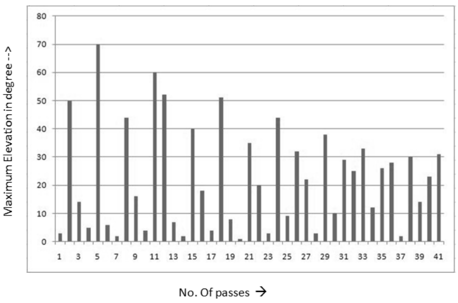

Figure 10. No of Pass Vs. Max. Elevation

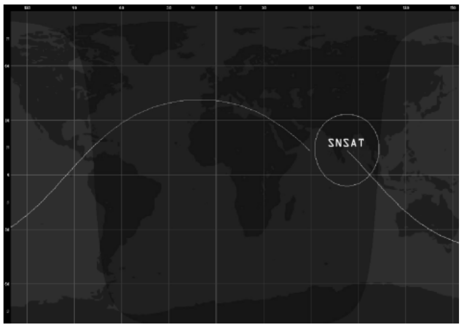

Figure 11. Orbitron For Pass Prediction

A basic idea of the working of the satellite can be briefed as below: "When the satellite enters the radio window, we will send a command from the ground station to switch on the payload and initiate the data acquisition. As it leaves the radio window, the ground station again sends a command which will shut switch off the payload. During the successive pass, we will again send a command to the satellite, which will initiate the onboard transmitter and we will receive the telemetry data. Again, the GS will send the command to satellite to switch of the transmitter. And this process takes place in a cyclic manner."

IX. CONCLUSION

We hope that this project and the launch of the satellite will give a strong boost to research in miniaturized and low cost space technology. The objectives apart from air pollution modelling were to create awareness in space science and technology as well as the climatic changes. We believe using our satellite we will be able to plot a proper air pollution model and restrict ourselvesagainst the environmental degradation and towards a sustainable environment. It also provides an excellent practical exposure of students towards space technology and increases their interest in it.

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