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A Review on Space-Ground Link Subsystem and Its Interfacing with Control Entities

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Abstract— With the advancement of technology in the modern era, satellite communication has become the backbone of long distance communication. Along with the use in communication purpose satellites are also used for meteorological data collection, minerals detection, Global Positioning System(GPS), ion detection at the space, dust detection and many more useful applications for day to day as well as for scientific purpose. All these application need a proper handling system known as the space system. This paper gives a review on the space segment, ground segment and the control segment of the space system along with the required Telemetry and Tele commands needed to extract the information for the control of the system.

Keywords— Space system, Ground Segment, Control Segment, Space Segment, Telemetry and Telecommand

I. INTRODUCTION

Space systems are complex pieces of equipment which are thoroughly designed to perform specific function for a specified design life. To keep a space system functioning over many years requires almost constant attention through a complex network of equipment along with the involvement of many people. This system is mainly divided into three main parts, Space Segment which consists of one or more satellites organized in the constellation for the application purpose and the launch vehicles used to deliver those satellites to orbit. Control and Command Segment include the personnel, equipment and facilities responsible for the operation and control of the satellite and also used to monitor and control all the assets in space. User segment consists of all individual and groups which use the capabilities provided by the satellite payload. This paper gives the review on the space system and it's interfacing with the terrestrial network & the control segment at the ground. Section II shows the system overview, section III contains the main subparts and their working in the space segment which flies in the space whereas section IV includes ground segment's interfacing between the payload and platform with the terrestrial network. Section V contains the commands and their functions used for telemetry, telecommand and tracking for controlling the whole system.

II. SYSTEM OVERVIEW

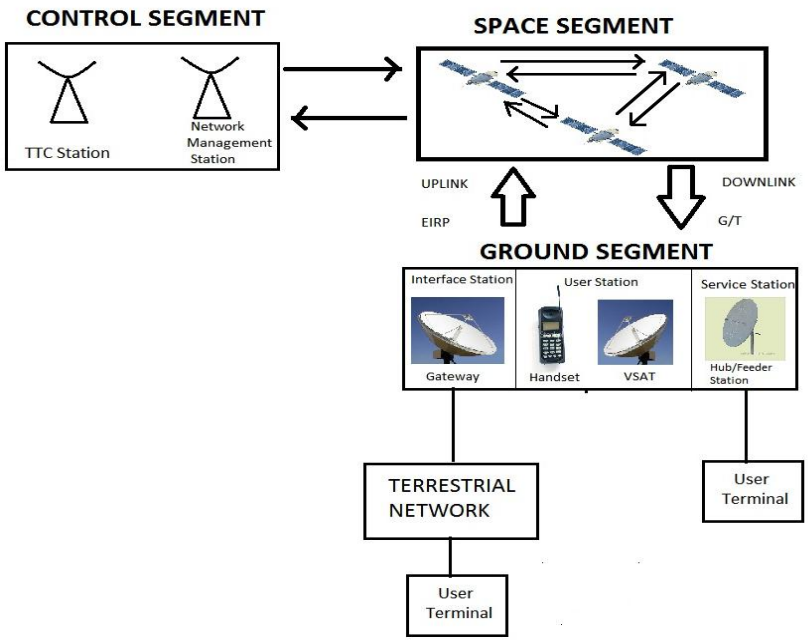

Fig. 1: Overview of satellite communication system and its interfacing with terrestrial and control entities

The figure shows all the three different segments in which the ground segment comes in three different classes, as :1) User station under which the handset, portable, mobile station and Very Small Aperture Terminal (VSATs) which allows the customer direct access to space segment. 2) Interface station known as gateways which interconnects the space segment to the Terrestrial Network. 3) The service station such as hub/feeder which collects or distributes information from and to user station via space segment. A connection between the service provider and the user goes through a hub (for collecting services) or a feeder station (ex: broadcasting services). A connection from the Gateway, Hub/feeder station to the user terminal is called a forward connection, and the reverse connection is in return connection. Both forward and reverse connection entails an uplink and a downlink. The controlling and extracting information to and from the space craft is directly handled at the control segment.

III. SPACE SEGMENT SECTION

There are numerous types of space systems which provide a wide variety of capabilities and services but there are two main principal subsystems applied to all space systems as they all have to work in the environment of space.

A. The Platform

The platform is the basic frame of the satellite and the components which allow the satellite to function in space regardless of the satellite's mission. These components are monitored and controlled by the control segment at the ground. The platform consists of:

1) Structure of satellite: The structure of the satellite holds all the components together as an integral unit and provides its interface with the launch vehicle. The structure should be light enough to not unduly restrict payload weight yet strong enough to withstand the rigors of launch.

2) Power: The power to the satellite is required to operate the electrical equipment that is on board. More power are required to the satellites which has high power sensors or transmit strong continuous signals, require more power than those which have low power sensors and radios. For example, communications satellites which receives, processes and then retransmits the signals that are sent from users on the Earth or from other satellites require more power than scientific satellite which have only few sensors and a small radio to transmit the data to researchers on the ground. The energy sources to the satellite are mainly of two types:

- **Solar energy**: The Sun is the most dependable and constant source of energy in the space. Large area of Solar cells is mounted on the payload for the production of high power. On satellites which are stable and are stabilized have their payload always face to the Earth; and the solar cells are usually mounted on panels which extend from the main body .These panels are controlled by motors which keep them oriented to face the sun. Whereas, the spinning satellites usually have solar cells mounted on the outside of the body of the satellite so that some panels are always facing the sun.
- **Chemical Energy:** Chemical energy sources include batteries and fuel cells. Short lived satellites and sounding rockets use primary batteries where they are used as a continuous source of energy and are not recharged. Most spacecraft use secondary batteries which are recharged by some other energy source to provide power during peak usage periods or when another energy source is not capable of meeting demand. Batteries are mainly required so the satellite can continue its functioning when it is in the Earth's shadow or when peak power is required for a short time.

Hence, the combination of solar and the chemical energy are used for the best power performance of the satellite.

3) *Propulsion:* Propulsion is used to achieve initial orbit and to make major changes in the position of the orbit. After reaching its initial orbit the satellite is separated from the final stage of the launcher and the final orbit is achieved by firing a kick motor to move the satellite to the final desired orbit and position. Changing the orbital plane requires more force than changes done within the orbital plane. The kick motor is mostly used to make major changes in the satellite's orbit. The need of sufficient propellant must be carried on board to last the lifetime of the satellite.

4) Stabilization and Attitude Control: The proper position and attitude of the satellite is checked with the stabilization and the attitude control. Number of forces, such as particles streaming from the Sun, meteorites, atmospheric drag, gravity gradients, gravity from the Moon and other perturbation are affected to the satellite in the space. These forces cause satellites to spin, wobble, drift, or move in other ways which are not desired. When momentum wheels and other such passive devices are unsuccessful to control the orbit, the satellite controllers send signals to the satellite to fire thrusters in short spurts to control roll, pitch and make corrects in orbital altitude by which the initial working position of the satellite can be obtained.

5) Thermal control: The temperature in a satellite is affected by both internal and external sources which causes its temperature to become too hot or too cold. Also the on board electronic equipment and other devices which consume power also generate heat. The most common heat transfer device is the passive radiator which radiates heat from the satellite into space to maintain temperatures within design parameters. Liquid or gas filled cooling system may also be require to transfer heat from internal components to the passive radiator.

6) Environmental Control: Manned spacecraft require precise environmental control to ensure that water, temperature, air quality and humidity are maintained within operating limits. Unmanned satellites do not require environmental control.

B. The Payload

The payload can be considered as the brain of the satellite and its function is unique and depends on the mission of the satellite. Many payloads are attached to a single satellite depending on the working. It is a support subsystem known as a

bus and a subsystem responsible for providing the core functionality. Most common functions of payload are in the field of:

1) Communication System: The basic payload in case of communication satellite is the transponder, which acts as the transmitter, amplifier and the receiver. A transponder can also be considered as a microwave relay channel that performs a function of frequency translation from the uplink frequency to the relative lower frequency. Hence it can be considered as the combination of the elements like sensitive high antenna gain antennas for transmit-receive functions, a subsystem of repeaters, frequency shifters, Low noise amplifier(LNA),frequency mixer, filters and power amplifier. Satellites employ L, S, C, X, Ku, Ka band for the communication purpose in which the Ka band is the latest entry. L (2GHz/1GHz), S (4GHz/2GHz) and C (6 GHz/4 GHz) bands were first employed for the satellite broadcasting due to low atmospheric absorption. The C band is most common and is mostly used for domestic and international telephone services. With advancement of technology high frequency band such as Ku and Ka are also used. These bands have the advantages of higher bandwidth and reduced antenna size.

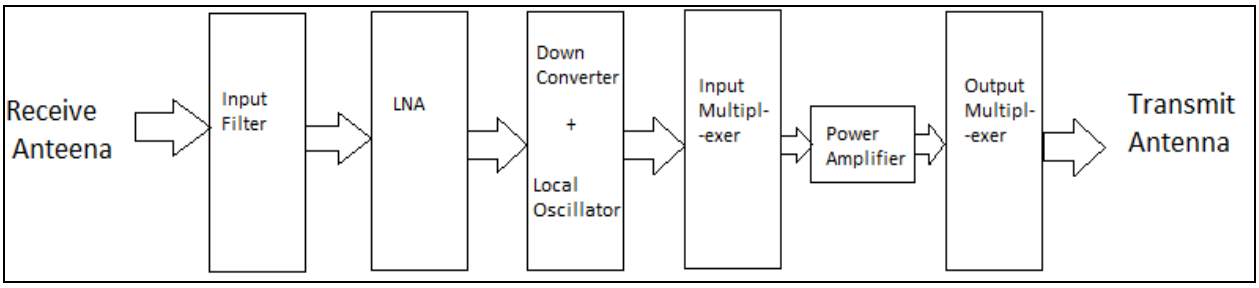

Fig. 2 Transponder

2) Weather Forecasting: The payload mostly used for weather forecasting is the Radiometer. It has the detectors sensitivity in the visible, near-IR and far-IR bands. Visible images gives the information about the amount if light reflected from the earth or clouds whereas the IR images gives the amount of sunlight being reflected from Earth or clouds whereas the IR images provide information on the temperature of the cloud cover on the Earth's surface.

3) Other Scientific Payloads: Scientific satellites have many varied payloads depending on their mission. Telescope are used to collect light from the stars and spectrograph operating over a wide range of UV wavelengths from 120 to 320nm for observing the stars. Likewise, satellite for planetary exploration has varied equipment, like the plasma detector to study the solar winds and radiation belts. The magnetometer is used to investigate the magnetic field around the Planet. Gamma Spectrometer is used to determine the radioactivity of the surface rocks. Dust detector is used for measuring the dust particles striking the instrument likewise Ion detector is used for detecting the charge, velocity, mass, directions, quantity(counts) of ions striking the payload from the sun.

III. GROUND STATION INTERFACE

The ground segment consists of the earth station; these are mostly connected to the end user's terminal by the terrestrial network or Small Stations (VSAT), directly connected to the end user's terminal. These Earth stations are distinguished by their size- which varies according to the volume of the traffic to be carried on the satellite link and the type of traffic, i.e. telephone, television or data. The figure below shows the typical architecture of the earth station with the transmission and reception.

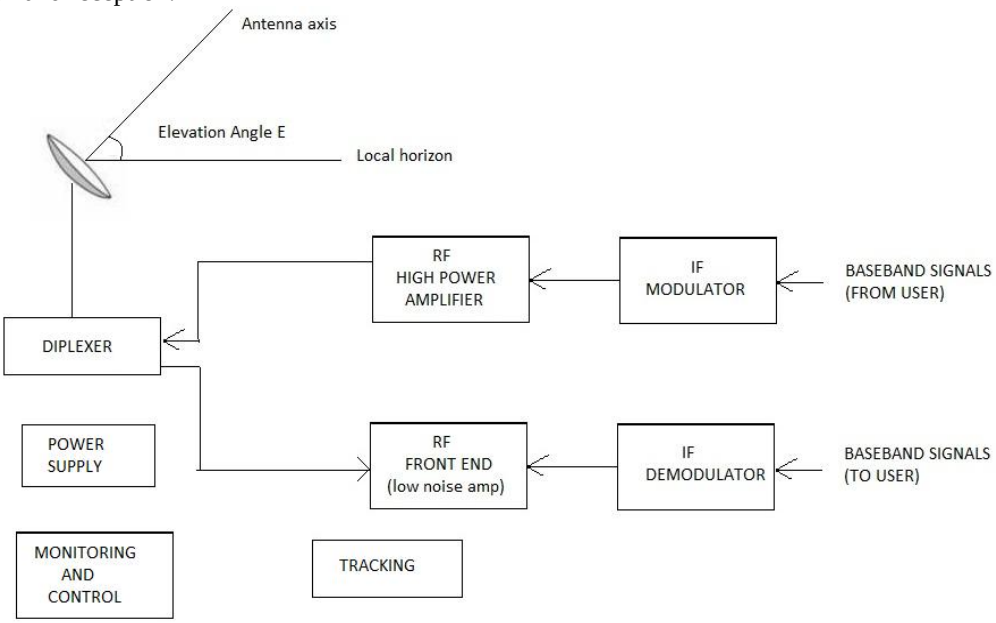

Fig. 3: Transmission and reception of the signal from Earth station

IV. TELEMETRY, TELECOMMAND AND DATA HANDLING UNDER CONTROL SEGMENT

The basic function of all spacecraft requires extensive contact with ground station for the overall control which includes platform control, payload control and the network control along with commanding, communication, data return and sufficient computer processing power to run all spacecraft subsystem within a high degree of autonomy. The platform control includes relocation manoeuvres, station keeping, and the proper functioning of onboard systems. Platform control can be accomplished for almost all satellites through telemetry, tracking and commanding (TT&C).Payload control involves operation and control of the payload on the satellite. The Data provided by the satellite and commands are sent to the satellite through TT&C. Other control function such as monitoring the health and status update of the satellite, locating and following the satellites, ON/OFF functions, extracting the results send form the satellite, etc are also used for controlling. The Connection between the space craft and the control segment is achieved by:

A. Telemetry

Telemetry parameters describes the status, configuration and the health of the space craft payload and the subsystem and are down linked to the command and Data Acquisition (CDA) station and after it is sent to the Satellite Operation and Control Centre (SOCC). To perform these functions, the T&C is composed of a single bicone antenna mounted on the spacecraft's east panel. The information provided from the spacecraft via telemetry is:

1) *On/Off status of all the equipments operated at the space such as heaters, coolers.*
2) *Temperature, voltages and pressure applied to the spacecraft.*
3) *Environmental sensed data from the Space Environment Monitor (SME) instrument*
4) *Housekeeping data for payload instrument*
5) *Each receiver Automatic Gain Control (AGC)*
6) *Output RF power for each transmitter*
7) *Voltage and power system parameters for each critical module*
8) *Altitude determination parameters (ex: Reading form stars and sun tracker or other tracking system)*

All of these measurements are collected with various sensors such as thermometers, accelerometers and transducers which provide outputs in form of measured resistance, capacitance or voltage. The use of these sensors to gather the required measurements is the first step in providing telemetry from the satellite to the command team on the ground. The second step is to process the measurements which includes conversion of analog system to digital information as well as formatting of the measurement for effective and if required reluctant, transmission to Earth.

B. Telecommand

Commands are sent from the Earth to manage the working of the satellite. These commands may include switching subsystems and components between on and off states or changing the operating mode in another manner. The commands may be used to control the space craft guidance and attitude control or deploy structures such as solar arrays or antennas. The telecommands may include:

1) *Payload On/Off*
2) *Star/Stop (of the process)*
3) *Reset Command*
4) *Analog Voltage On/Off*
5) *Digital Voltage On/Off*
6) *Set threshold*
7) *Mode 1 Setting*
8) *Calibration On/Off*

Telecommands vary as the working of the satellite varies. Commands may be executed may the satellite immediately upon the receipt or stored for later execution. Some commands are predefined and are the part of the onboard software that allows the satellite to execute certain functions autonomously when a predefined condition exists. These commands can be direct the thrusters to fire to change the orbit or may configure the payload to meet the needs on the users. There are two modes of command execution: 1) Real- time 2) Ground command word-verify. In real time mode, verification of the uplink command is halted and a flag bit is telemeter to the ground station indicating that the command must be retransmitted. In ground-command word-verify mode, the bits of the decoded command are telemeter back to the ground station for verification, and a subsequent execution message must be uplinked. The command unit outputs are completely redundant.

C. Tracking

Tracking is the act of locating and following the satellite to allow the command segment know where the satellite is and where it is going and with a high degree of precision. Geosynchronous satellites that can be 40 time further out on space than low earth orbit systems require more exacting methods to determine the range because of the greater distance involved. Fig.4 shows the Telemetry and Telecommand system.

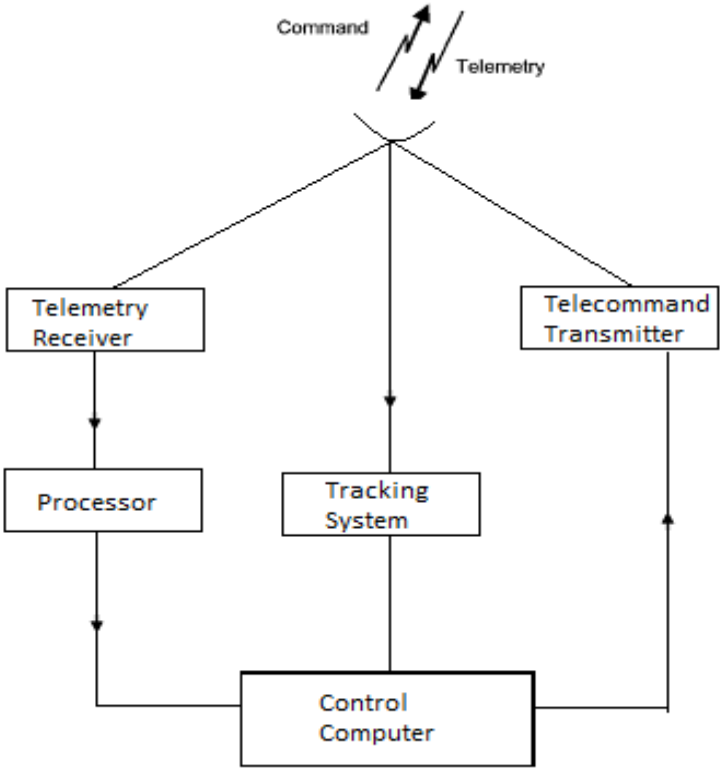

Fig. 4: Telemetry and Telcommand system

V. CONCLUSION

The satellite must be designed to operate correctly for the entire life of their mission. The important aspects of communications sub-system are antenna selection, frequency selection, proper transmitter receiver selection and link budget. If an antenna fails or the uplink and the downlink of the Telemetry are lost, the command system must act autonomously to restore communication. Which leads the Telemetry, Telecommand and Data Handling to be a critical part of ensuring whether the satellite performs as required and can react to changes in conditions at satellite (either internal or external). Thus, when modelling the space craft it is necessary to check whether every single subsystem interacts with the Command and Data Handling system in some or the other way. Also with the selection of an appropriate system architecture, the best combination of modelling, flexibility, simplicity and versatility can be obtained for a given mission.

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