Satellite Communication

5EC5-14

Unit # 3

Satellite Sub-Systems

3.1 Study of Architecture and Roles of various sub systems of a satellite system such as Telemetry, tracking, command and monitoring (TTC & M).
3.2 Attitude and orbit control system (AOCS).
3.3 Communication sub-system, Power sub-systems etc.

3.1 Telemetry, Tracking, Command and Monitoring (TTC & M): Telemetry, Tracking, Commanding and Monitoring **(TTCM)** subsystem is present in both satellite and earth station. In general, satellite gets data through sensors. So, Telemetry subsystem present in the satellite sends this data to earth station(s). Therefore, TTCM subsystem is very much necessary for any communication satellite in order to operate it successfully.

It is the responsibility of satellite operator in order to control the satellite in its life time, after placing it in the proper orbit. This can be done with the help of **TTCM subsystem**.

Telemetry and Monitoring Subsystem:

The word **'Telemetry'** means measurement at a distance. Mainly, the following operations take place in 'Telemetry'.

- Generation of an electrical signal, which is proportional to the quantity to be measured.
- Encoding the electrical signal.
- Transmitting this code to a far distance.

3.1.1 Telemetry subsystem present in the satellite performs mainly two functions −

- Receiving data from sensors, and
- Transmitting that data to an earth station.

Satellites have quite a few sensors to monitor different parameters such as pressure, temperature, status and etc., of various subsystems. In general, the telemetry data is transmitted as FSK or PSK.

Telemetry subsystem is a remote controlled system. It sends monitoring data from satellite to earth station. Generally, the **telemetry signals** carry the information related altitude, environment and satellite.

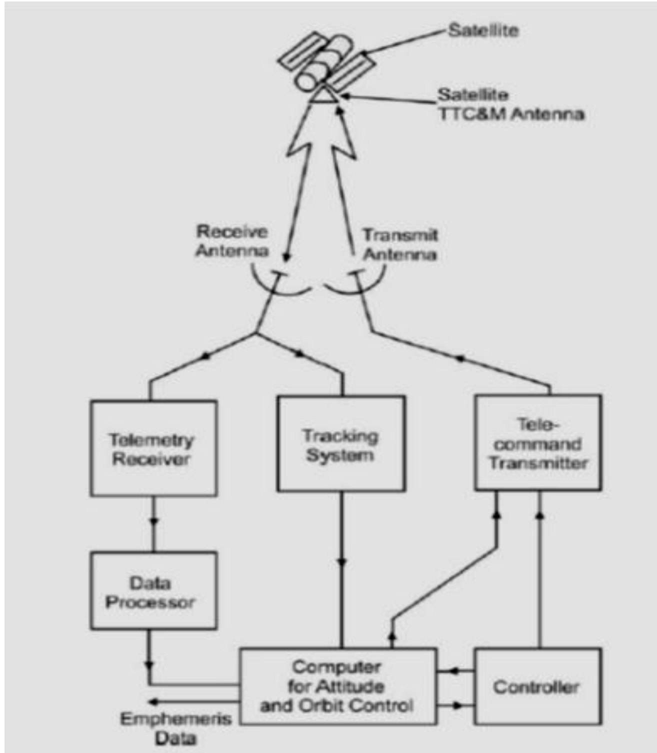

Figure 3.1: Telemetry, Tracking & Control System of Satellite Communication

3.1.2 Tracking Subsystem:

Tracking subsystem is useful to know the **position of the satellite** and its **current orbit**. Satellite Control Center **(SCC)** monitors the working and status of space segment subsystems with the help of telemetry downlink. And, it controls those subsystems using command uplink.

We know that the **tracking subsystem** is also present in an earth station. It mainly focuses on range and look angles of satellite. Number of techniques that are using in order to track the satellite. For **example**, change in the orbital position of satellite can be identified by using the data obtained from velocity and acceleration sensors that are present on satellite.

The **tracking subsystem** that is present in an earth station keeps tracking of satellite, when it is released from last stage of Launch vehicle. It performs the functions like, locating of satellite in initial orbit and transfer orbit.

3.1.3 Commanding Subsystem:

Commanding subsystem is necessary in order to launch the satellite in an orbit and its working in that orbit. This subsystem adjusts the altitude and orbit of satellite, whenever there is a deviation in those values. It also controls the communication subsystem. This **commanding subsystem** is responsible for turning ON / OFF of other subsystems present in the satellite based on the data getting from telemetry and tracking subsystems.

In general, control codes are converted into command words. These command words are used to send in the form of **TDM frames**. Initially, the validity of command words is checked in the satellite. After this, these command words can be sent back to earth station. Here, these command words are checked once again.

If the earth station also receives the same (correct) command word, then it sends an execute instruction to satellite. So, it executes that command.

Functionality wise, the Telemetry subsystem and commanding subsystem are opposite to each other. Since, the first one transmits the satellite's information to earth station and second one receives command signals from earth station.

3.1.4 Monitoring Subsystem:

- The **monitoring system** collects data from many sensors within the satellite & analyzes these data to the controlling earth station.
- **Monitoring parameters**: pressure, temperature, and voltage, current.
- Evaluation of each component in the ground station is a very crucial process so as to **maintain optimal level** in the performance of each of the components.
- **Alarms** can also be sounded if any vital parameter goes outside allowable limits.
- **Attitude maintenance** sighting devices are monitored via telemetry link.
- In failure case the satellite points in the wrong direction. The **faulty unit** must then be disconnected and a spare brought in, via the command system, or some other means of controlling attitude devised.
- These comparisons are done to take **corrective or preventive action** whenever required to prevent failure or delays in the mission timelines.

➢ Parameters measured: **AGC** & **BER**

AGC: It is the plot between time and power. It helps us to determine the satellite anomalies.

BER: The figure of merit for a digital radio link is its Bit Error Rate

3.2 Attitude and orbit control system (AOCS):

We know that satellite may deviates from its orbit due to the gravitational forces from sun, moon and other planets. These forces change cyclically over a 24-hour period, since the satellite moves around the earth.

Altitude and Orbit Control **(AOC)** subsystem consists of rocket motors, which are capable of placing the satellite into the right orbit, whenever it is deviated from the respective orbit. AOC subsystem is helpful in order to make the antennas, which are of narrow beam type points towards earth.

We can make this AOC subsystem into the following **two parts**.

- Altitude Control Subsystem
- Orbit Control Subsystem

Now, let us discuss about these two subsystems one by one.

Altitude Control Subsystem

Altitude control subsystem takes care of the orientation of satellite in its respective orbit. Following are the **two methods** to make the satellite that is present in an orbit as stable.

- Spinning the satellite
- Three axes method

Spinning the Satellite:

In this method, the body of the satellite rotates around its **spin axis**. In general, it can be rotated at 30 to 100 rpm in order to produce a force, which is of gyroscopic type. Due to this, the spin axis gets stabilized and the satellite will point in the same direction. Satellites are of this type are called as **spinners.**

Spinner contains a drum, which is of cylindrical shape. This drum is covered with solar cells. Power systems and rockets are present in this drum.

Communication subsystem is placed on top of the drum. An electric motor drives this communication system. The direction of this motor will be opposite to the rotation of satellite body, so that the antennas point towards earth. The satellites, which perform this kind of operation are called as **de-spin**.

During launching phase, the satellite **spins** when the small radial gas jets are operated. After this, the **de-spin** system operates in order to make the TTCM subsystem antennas point towards earth station.

Three Axis Method:

In this method, we can stabilize the satellite by using one or more momentum wheels. This method is called as **three-axis method**. The advantage of this method is that the orientation of the satellite in three axes will be controlled and no need of rotating satellite's main body.

In this method, the following **three axes** are considered.

- **Roll axis** is considered in the direction in which the satellite moves in orbital plane.
- **Yaw axis** is considered in the direction towards earth.
- **Pitch axis** is considered in the direction, which is perpendicular to orbital plane.

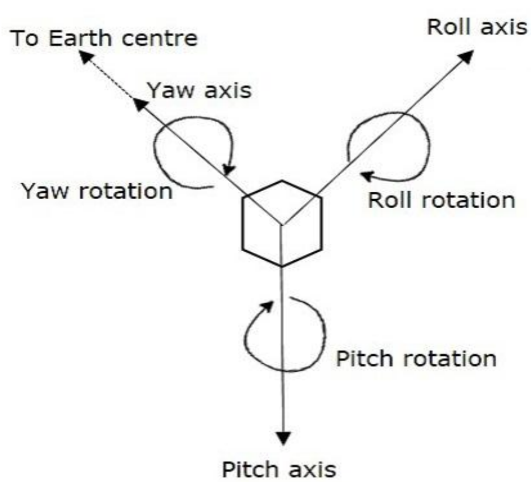

Figure 3.2.1: Three Axis Method

These three axes are shown in below **figure**.

Let X_R, Y_R and Z_R are the roll axis, yaw axis and pitch axis respectively. These three axis are defined by considering the satellite's position as **reference**. These three axes define the altitude of satellite.

Let X, Y and Z are another set of Cartesian axes. This set of three axis provides the information about orientation of the satellite with respect to reference axes. If there is a change in altitude of the satellite, then the angles between the respective axes will be changed.

In this method, each axis contains two gas jets. They will provide the rotation in both directions of the three axes.

- The **first gas jet** will be operated for some period of time, when there is a requirement of satellite's motion in a particular axis direction.
- The **second gas jet** will be operated for same period of time, when the satellite reaches to the desired position. So, the second gas jet will stop the motion of satellite in that axis direction.

Orbit Control Subsystem:

Orbit control subsystem is useful in order to bring the satellite into its correct orbit, whenever the satellite gets deviated from its orbit.

The TTCM subsystem present at earth station monitors the position of satellite. If there is any change in satellite orbit, then it sends a signal regarding the correction to Orbit control subsystem. Then, it will resolve that issue by bringing the satellite into the correct orbit.

In this way, the **AOC subsystem** takes care of the satellite position in the right orbit and at right altitude during entire life span of the satellite in space.

3.3 Communication sub-system, Power sub-systems:

3.3.1 Communication Sub-System:

A satellite communication system can be broadly divided into two segments, a ground segment and a space-segment. The space system includes Satellite.

Space segment: The space segment consists of the satellite, which has three main systems: (a) fuel system; (b) satellite and telemetry control system; and (c) transponders. The fuel system is responsible for making the satellite run for years. It has solar panels, which generate the necessary energy for the operation of the satellite. The satellite and telemetry control system is used for sending commands to the satellite as well as for sending the status of onboard systems to the ground stations. The transponder is the communication system, which acts as a relay in the sky. The transponder receives the signals from the ground stations, amplifies them, and then sends them back to the ground stations. The reception and transmission are done at two different frequencies. The transponder needs to do the necessary frequency translation.

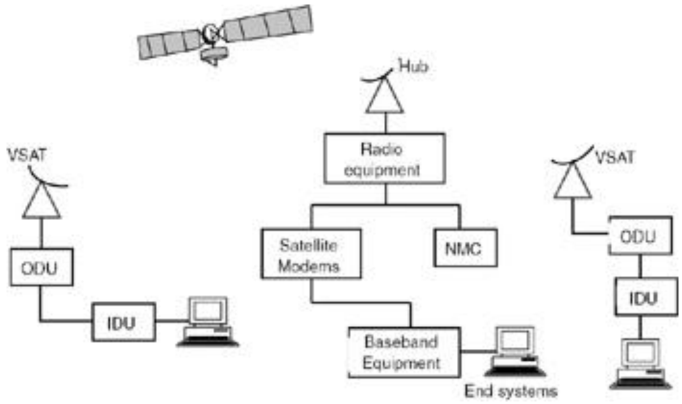

Figure 3.3.1: Architecture of Satellite Communication

Ground Segment: The ground segment consists of a number of Earth stations. In a star configuration network, there will be a central station called the hub and a number of remote stations. Each remote station will have a very small aperture terminal (VSAT), an antenna of about 0.5 meter to 1.5 meters. Along with the antenna there will an outdoor unit (ODU), which contains the radio hardware to receive the signal and amplify it. The radio signal is sent to an indoor unit (IDU), which demodulates the signal and carries out the necessary baseband processing. IDU is connected to end systems, such as a PC, LAN, or PBX.

The central station consists of a large antenna (4.5 meters to 11 meters) along with all associated electronics to handle a large number of VSATs. The central station also will have a Network Control Center (NCC) that does all the management functions, such as configuring the remote stations, keeping a database of the remote stations, monitoring the health of the remotes, traffic analysis, etc. The NCC's main responsibility is to assign the necessary channels to various remotes based on the requirement.

The communication path from a ground station to the satellite is called the uplink. The communication link from the satellite to the ground station is called the downlink. Separate frequencies are used for uplink and downlink. When a remote transmits data using an uplink frequency, the satellite transponder receives the signal, amplifies it, converts the signal to the downlink frequency, and retransmits it. Because the signal has to travel nearly 36,000 km in each direction, the signal received by the satellite as well as the remote is very weak. As soon as the signal is received, it has to be amplified before further processing.

3.3.2 Power Sub Systems:

We know that the satellite present in an orbit should be operated continuously during its life span. So, the satellite requires internal power in order to operate various electronic systems and communications payload that are present in it.

Power system is a vital subsystem, which provides the power required for working of a satellite. Mainly, the solar cells (or panels) and rechargeable batteries are used in these systems.

Solar Cells:

Basically, the **solar cells** produce electrical power (current) from incident sunlight. Therefore, solar cells are used primarily in order to provide power to other subsystems of satellite.

We know that individual solar cells generate very less power. So, in order to generate more power, group of cells that are present in an array form can be used.

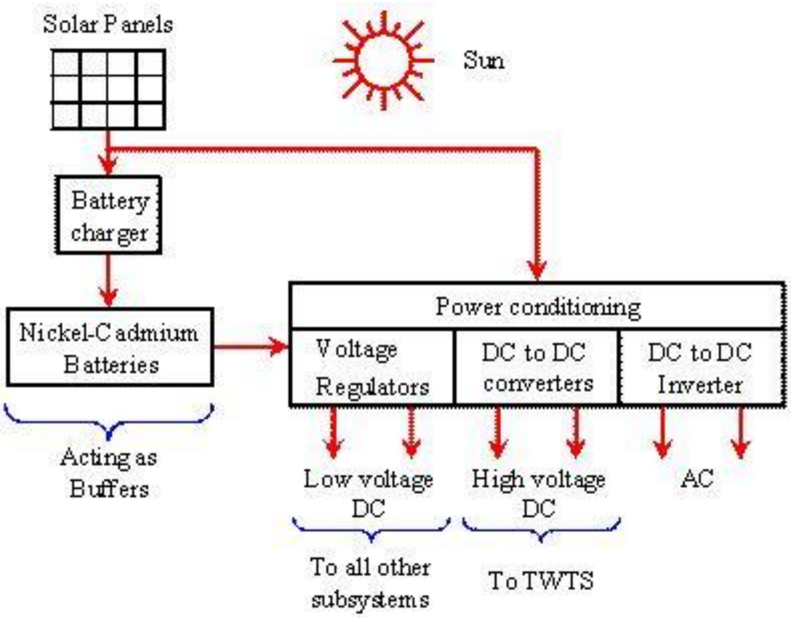

Figure 3.3.2 Power Sub Systems of satellite

Solar Arrays:

There are two **types of solar arrays** that are used in satellites. Those are cylindrical solar arrays and rectangular solar arrays or solar sail.

- **Cylindrical solar arrays** are used in spinning satellites. Only part of the cylindrical array will be covered under sunshine at any given time. Due to this, electric power gets generated from the partial solar array. This is the drawback of this type.
- The drawback of cylindrical solar arrays is overcome with **solar sail**. This one produces more power because all solar cells of solar sail are exposed to sun light.

Rechargeable Batteries:

During eclipses time, it is difficult to get the power from sun light. So, in that situation the other subsystems get the power from **rechargeable batteries**. These batteries produce power to other subsystems during launching of satellite also.

In general, these batteries charge due to excess current, which is generated by solar cells in the presence of sun light.