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Internal Assessment Test 1 – Sept. 2025

Subject/Code: BEC515D – Satellite and Optical Communication				
Date:11-10-2025	Duration: 90 mins	Max. Marks: 50	Semester: 05	Branch: ECE

Sl.	Answer any FIVE FULL Questions	Marks	CO	RBT
1	Explain Kepler laws of Planetary motion. Also derive the expression for orbital period.	10	CO1	L3
2	Explain briefly any six orbital parameters required to determine a satellite orbit.	10	CO1	L2
3	A satellite is orbiting Earth in a uniform circular orbit at a height of 630 km from the surface of Earth. Assuming the radius of Earth and its mass to be 6370 km and 5.98×10^{24} kg, respectively, determine the velocity of the satellite. (Take gravitational constant $G = 6.67 \times 10^{-11}$ Nm^2/kg^2).	10	CO1	L3
4	Explain the solar energy-driven power supply system of a satellite.	10	CO2	L3
5	Describe the telemetry, telecommand, and tracking control monitoring system of a communication satellite.	10	CO2	L3
6	What is a transponder? Explain the various types of transponders.	10	CO2	L3

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Questions with Answers:

1. Explain Kepler laws of Planetary motion. Also derive the expression for orbital period.

Answer:

Orbiting Satellites – Basic Principles

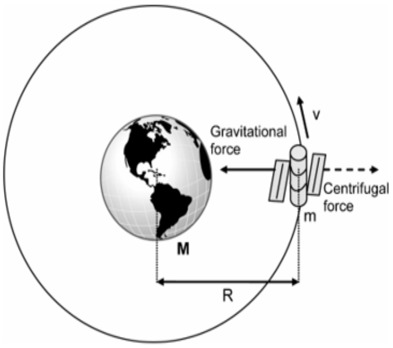


Fig: Gravitational force and the centrifugal force acting on bodies orbiting Earth

Newton's Law of Gravitation

- Newton's law of gravitation, every particle irrespective of its mass attracts every other particle with a gravitational force whose magnitude is directly proportional to the product of the masses of the two particles and inversely proportional to the square of the distance between them.

$$F = \frac{Gm_1m_2}{r^2}$$

where

$m1$, $m2$ = masses of the two particles

r = distance between the two particles

G = gravitational constant = 6.67 × 10^{-11} $m^3/kg\ s^2$

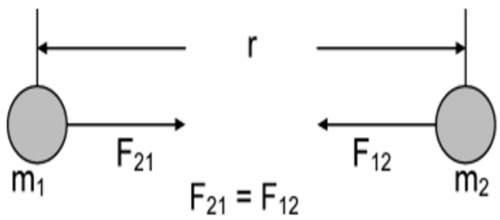
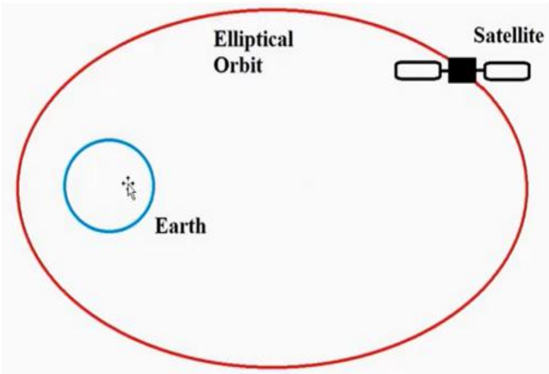


Fig: Newton's law of gravitation

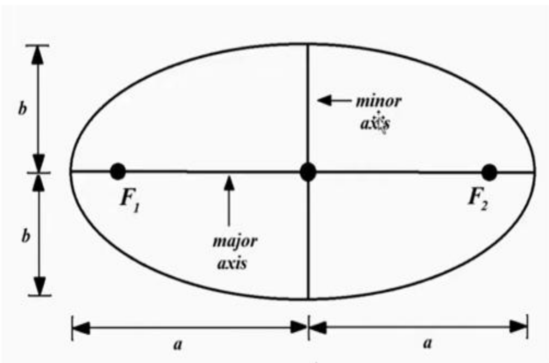
Kepler's Laws

- *Johannes Kepler* gave a set of *three empirical expressions* that explained *planetary motion*.
- They are called as '*Kepler's Laws Of Planetary Motion*'.



Kepler's First Law

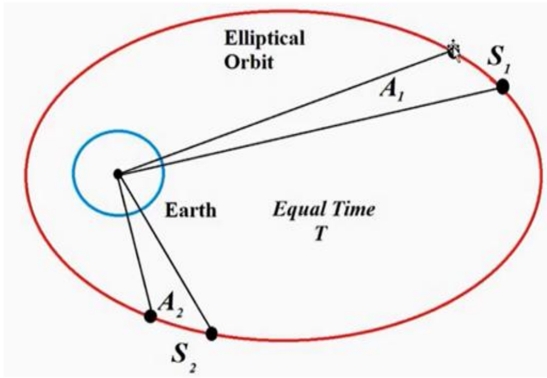
- According to *Kepler's First Law, the path followed by a satellite around Earth will be an ellipse.*
- The *center of the Earth* will lie on *one of the foci of the ellipse.*
- A *circular orbit* is a *special case* of an *elliptical orbit.*



Kepler's Second Law

- *Kepler's second law* states that, ***a satellite will cover equal areas in its orbital plane for equal time intervals***.

- The ***line joining the satellite and the centre of the Earth sweeps out equal areas*** in the ***orbital plane*** in ***equal time intervals***.



- Suppose in a given period of time, *T*, the satellite covers distances S_1 and S_2 respectively and covers areas A_1 and A_2 respectively.

- Then, according to Kepler's second law,

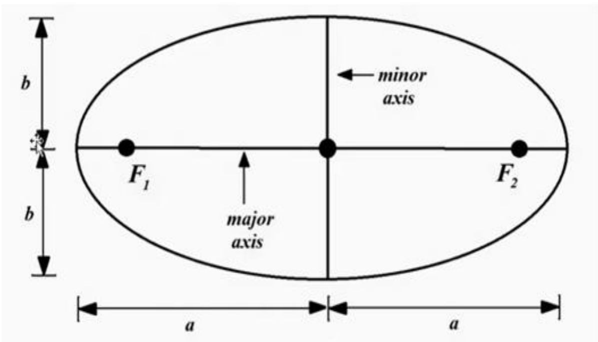
$$\boxed{A_1 = A_2}$$

Kepler's Third Law

- In *Kepler's third law*, it is stated that ***the square of the time period of any satellite is proportional to the cube of the semi-major axis of its elliptical orbit***.

- So,

$$\boxed{T^2 \, \alpha \, a^3}$$



- For elliptical orbits,

$$\boxed{T = \frac{2\pi}{\sqrt{\mu}} a^{3/2}}$$

- For circular orbits,

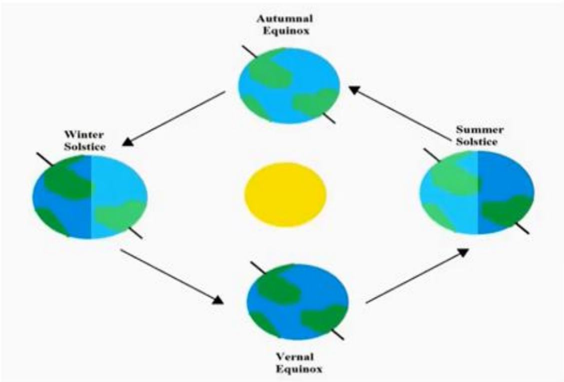
$$\boxed{T = \frac{2\pi}{\sqrt{\mu}} r^{3/2}}$$

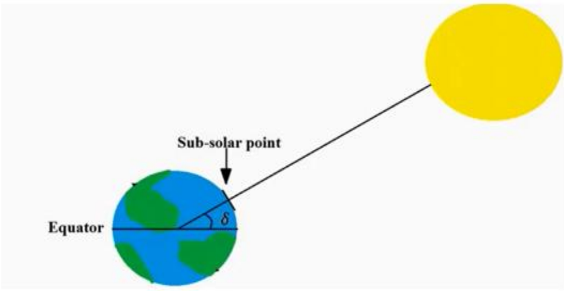
2. Explain briefly any six orbital parameters required to determine a satellite orbit.

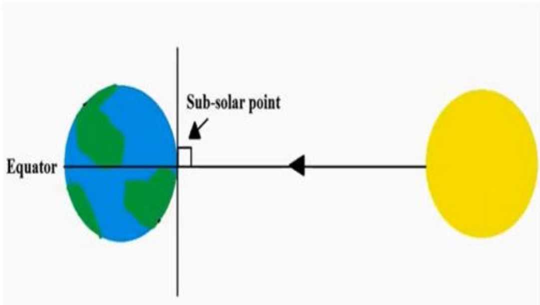
Answer:

Sub-solar Point

- A sub-solar point is a location of a planet , at some time of a year, ***comes directly under the sun*** or ***the sun is at the zenith***.
- At the sub-solar point ***sunlight hits the surface, perpendicularly***.
- The sub-solar point is the location of the planet closest to the sun.





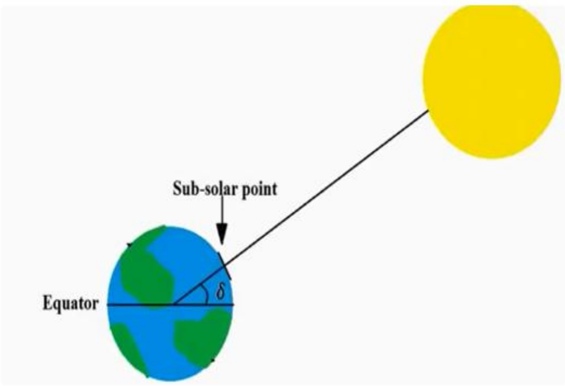


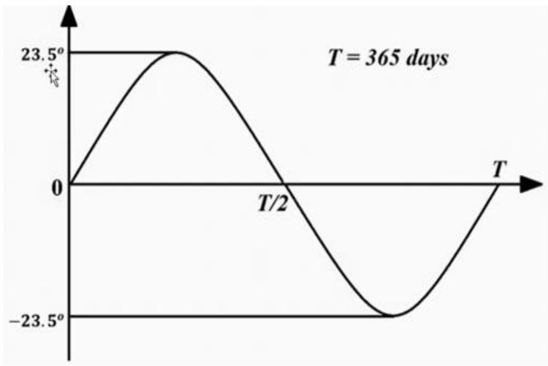
Solar Declination Angle

- The declination of the sun is the ***angle between the equator and a line drawn from the centre of the Earth to the centre of the sun.***
- The ***declination angle, δ varies seasonally due to the tilt of the Earth on its axis of rotation and the movement of the Earth around the sun.***
- The ***solar declination angle follows a sinusoidal variation*** and ***completes one cycle of sinusoidal variation over a period of 365 days.***
- It is given by,

$$\delta = 23.5\, sin\,(\frac{2\pi t}{T})$$

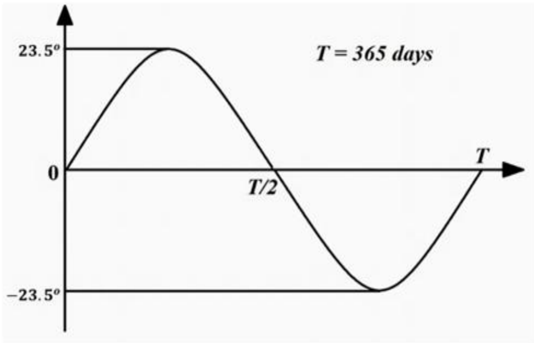
$$T = 365\ days$$

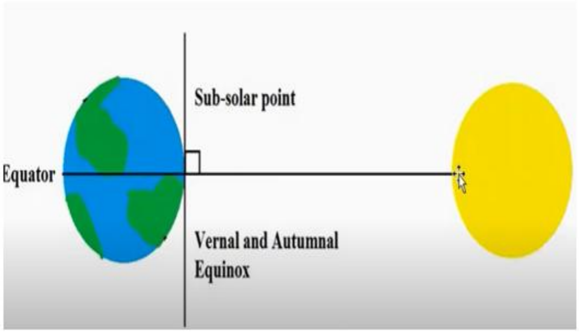




Equinox

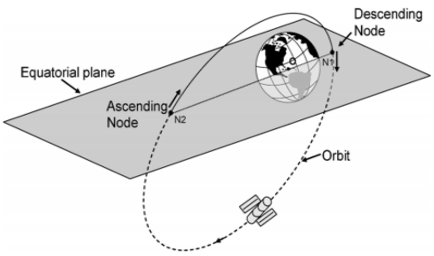
- An equinox is an event in which ***a planet's subsolar point passes through its equator***.
- The equinoxes are the only time ***when both the Northern and Southern Hemisphere experience roughly equal amounts of daytime and nighttime***.

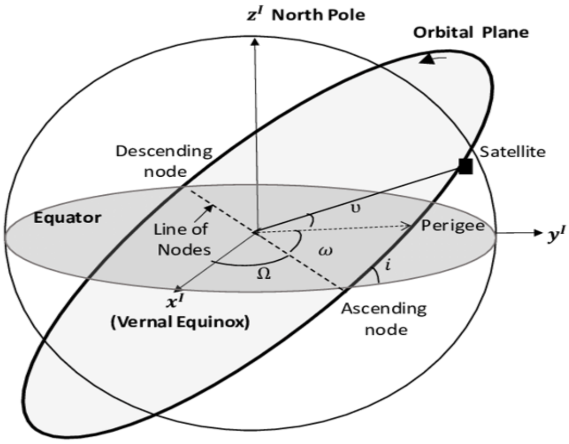




- At equinox, ***solar declination angle is zero***.
- It happens at ***t = T/2, twice a year*** called as ***vernal (spring) equinox (20-21 March)*** and ***autumnal equinox (22-23 September)***.
- The ***two equinoxes are spaced six months apart***.

Ascending and descending nodes

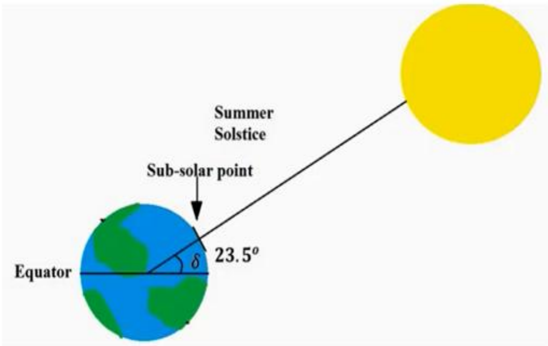


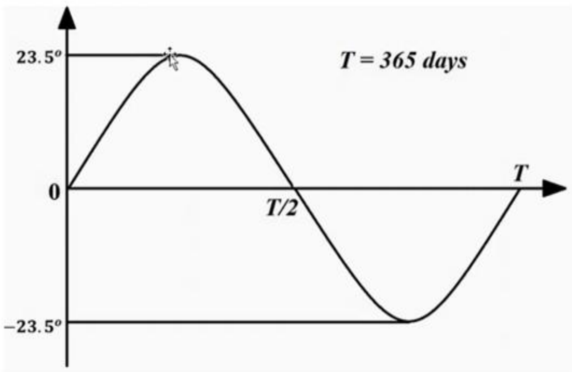


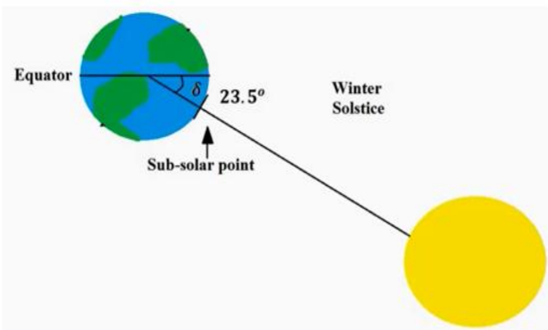
- The ascending node and descending node are the points where an orbiting object crosses from one side of a reference plane to the other. The ascending node is where the object moves from below the reference plane to above it, while the descending node is where it moves from above the reference plane to below it.

Solstice

- ***Solstices*** are the times when the ***solar declination angle is at its maximum i.e.,*** 23.5°
- These also ***occur twice during a year*** on ***20-21 June, called the summer solstice*** and ***21-22 December, called the winter solstice.***

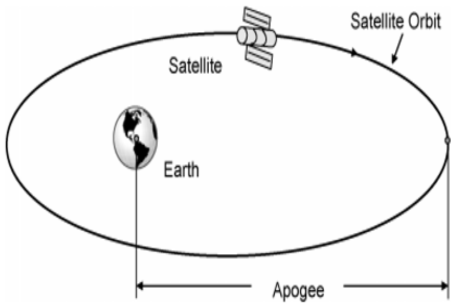






Apogee

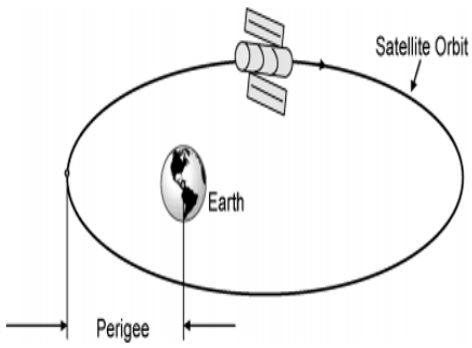
Apogee is the point on the satellite orbit that is at the farthest distance from the center of the Earth.
Apogee distance, A = a (1 + e)



Perigee

Perigee is the point on the orbit that is nearest to the center of the Earth.

Perigee distance, $P = a\,(1 - e)$



3. A satellite is orbiting Earth in a uniform circular orbit at a height of 630 km from the surface of Earth. Assuming the radius of Earth and its mass to be 6370 km and 5.98 × 10^{24} kg, respectively, determine the velocity of the satellite. (Take gravitational constant G = 6.67 × 10^{-11} Nm^2/kg^2).

Answer:

Given data:

- Height of satellite above Earth, $h = 630\ \mathrm{km} = 6.30 \times 10^5\ \mathrm{m}$
- Radius of Earth, $R = 6370\ \mathrm{km} = 6.37 \times 10^6\ \mathrm{m}$
- Mass of Earth, $M = 5.98 \times 10^{24}\ \mathrm{kg}$
- Gravitational constant, $G = 6.67 \times 10^{-11}\ \mathrm{N}\backslash\mathrm{cdotp}\mathrm{m}^2/\mathrm{kg}^2$

Formula for orbital velocity:

$$v = \sqrt{\frac{GM}{R+h}}$$

Step 1: Compute $R + h$

$$R + h = 6.37 \times 10^6 + 6.30 \times 10^5 = 7.00 \times 10^6\ \mathrm{m}$$

Step 2: Substitute values

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{7.00 \times 10^{6}}}$$

$$v = \sqrt{\frac{3.9866 \times 10^{14}}{7.00 \times 10^{6}}}$$

$$v = \sqrt{5.695 \times 10^{7}}$$

$$v \approx 7.55 \times 10^{3} \text{ m/s}$$

✅ **Final Answer:**

$$\boxed{v = 7.55 \text{ km/s}}$$

4. Explain the solar energy-driven power supply system of a satellite.

Answer:

Solar Energy Driven Power Systems

The major components of a solar power system are the solar panels (of which the solar cell is the basic element), rechargeable batteries, battery chargers with inbuilt controllers, regulators and inverters to generate various d.c and a.c voltages required by various subsystems.

- Power systems for satellite applications have been developed based on the use of solar energy, chemical energy and nuclear energy.
- Heat generators make use of heat energy in solar radiation to generate electricity.
- This mode of generating power is completely renewable and efficient if the satellite remains exposed to solar radiation.
- Heat generators, however, are very large and heavy and are thus appropriate only for large satellites.

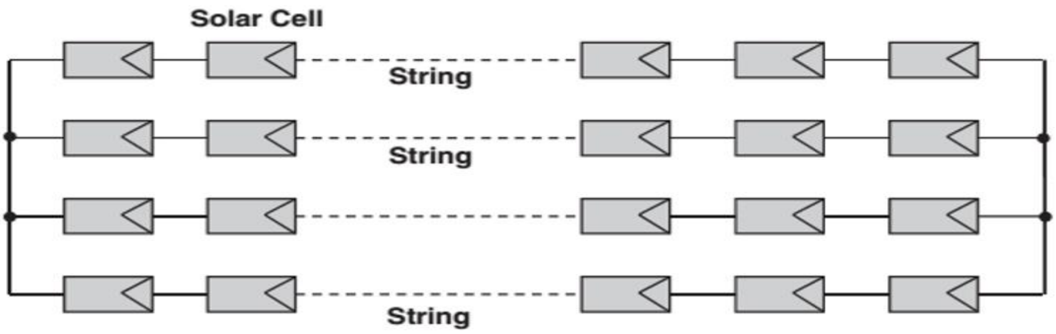


Fig: (a) Series–parallel arrangement of solar cells and (b) solar panel

- Major components are the solar panels and the batteries.
- During the sunlight condition, the voltage of the solar generator and also the bus is maintained at a constant amplitude with the voltage regulator connected across the solar generator.
- The battery is decoupled from the bus during this time by means of a battery discharge regulator (BDR) and is also charged using the battery charge regulator (BCR) as shown in the figure.
- During the eclipse periods, the battery provides power to the bus and the voltage is maintained constant by means of the BDR.

Solar Panels

- Solar panel is nothing but a series and parallel connection of a large number of solar cells.
- The voltage output and the current delivering capability of an individual solar cell are very small for it to be of any use as an electrical power input to any satellite subsystem.
- The series–parallel arrangement is employed to get the desired output voltage with the required power delivery capability.
- A large surface area is therefore needed in order to produce the required amount of power.

5. Describe the telemetry, telecommand, and tracking control monitoring system of a communication satellite.

Answer:

Tracking, Telemetry and Command Subsystem

- The tracking, telemetry and command (TT&C) subsystem monitors and controls the satellite right from the lift-off stage to the end of its operational life in space.
- The tracking part of the subsystem determines the position of the spacecraft and follows its travel using angle, range and velocity information.
- The telemetry part gathers information on the health of various subsystems of the satellite. It encodes this information and then transmits the same towards the Earth control centre.

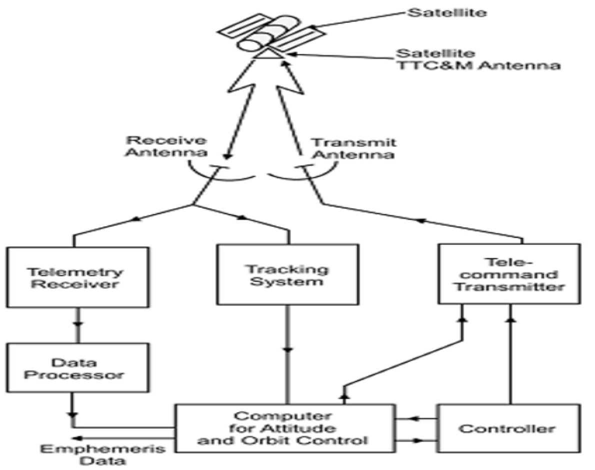


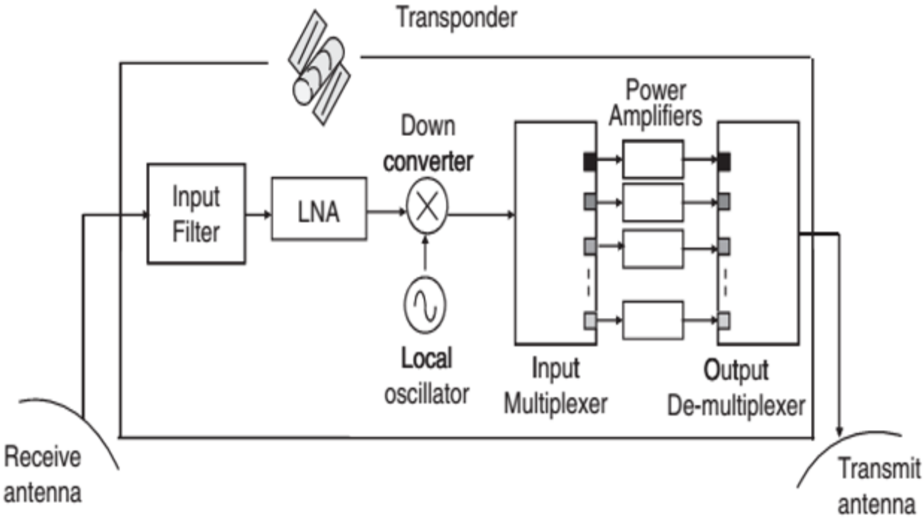
Fig: Block schematic arrangement of the basic TT&C subsystem

- The command element receives and executes remote control commands from the control centre on Earth to effect changes to the platform functions, configuration, position and velocity.
- Tracking is used to determine the orbital parameters of the satellite on a regular basis.
- This helps in maintaining the satellite in the desired orbit and in providing look-angle information to the Earth stations.
- During the orbital injection and positioning phase, the telemetry link is primarily used by the tracking system to establish a satellite-to-Earth control centre communications channel.
- Its primary function is to monitor the health of various subsystems on board the satellite.
- It gathers data from a variety of sensors and then transmits that data to the Earth control centre.
- With the modulation signal as digital, various signals are multiplexed using the time division multiplexing (TDM) technique.
- The bit rates involved in telemetry signals are low, it allows a smaller receiver bandwidth to be used at the Earth control centre with good signal-to-noise ratio.
- The command element is used to receive, verify and execute remote control commands from the satellite control centre.
- The functions performed by the command element include controlling certain functions during the orbital injection and positioning phase, including firing the apogee boost motor and extending solar panels, during the launch phase.
- The control commands received by the command element on the satellite are first stored on the satellite and then retransmitted back to the Earth control station via a telemetry link for verification.

6. What is a transponder? Explain the various types of transponders.

Answer:

Payload



The payload in a communication satellite mainly refers to the transponders, which handle the reception, frequency conversion, amplification, and retransmission of signals.

1. **Receive Antenna**
    1. Collects the weak signals transmitted from the Earth station.
    2. These signals are usually in the **uplink frequency band** (e.g., 6 GHz for C-band).
2. **Input Filter**
    1. Removes unwanted noise and out-of-band signals.
    2. Ensures only the desired frequency range is processed.
3. **Low Noise Amplifier (LNA)**
    1. Amplifies the very weak uplink signals received from Earth.
    2. Specially designed to add as little noise as possible, hence called "low noise."
4. **Down Converter**
    1. Converts the uplink frequency to a lower **intermediate frequency (IF)** or to the **downlink frequency band**.
    2. Uses a **local oscillator** to mix with the received signal and shift it to the desired frequency.
5. **Input Multiplexer (IMUX)**
    1. Separates different channels (multiple carriers or signals) received together.
    2. Directs each signal to its respective transponder path.
6. **Power Amplifiers**
    1. Each separated channel is amplified to a sufficient power level for retransmission.
    2. Typically, **Traveling Wave Tube Amplifiers (TWTA)** or **Solid-State Power Amplifiers (SSPA)** are used.
7. **Output Demultiplexer (OMUX)**
    1. Combines the amplified signals back into a composite signal.
    2. Ensures proper frequency allocation for each channel without interference.
8. **Transmit Antenna**
    1. Sends the amplified and frequency-shifted signals back to Earth.
    2. This is the **downlink signal** (e.g., 4 GHz in C-band).