Satellite Subsystems

Reference: Satellite Communications by Dennis Roddy

Learning Outcomes: To Explain the importance and working of the attitude and orbit control subsystem of the satellite

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Attitude Control

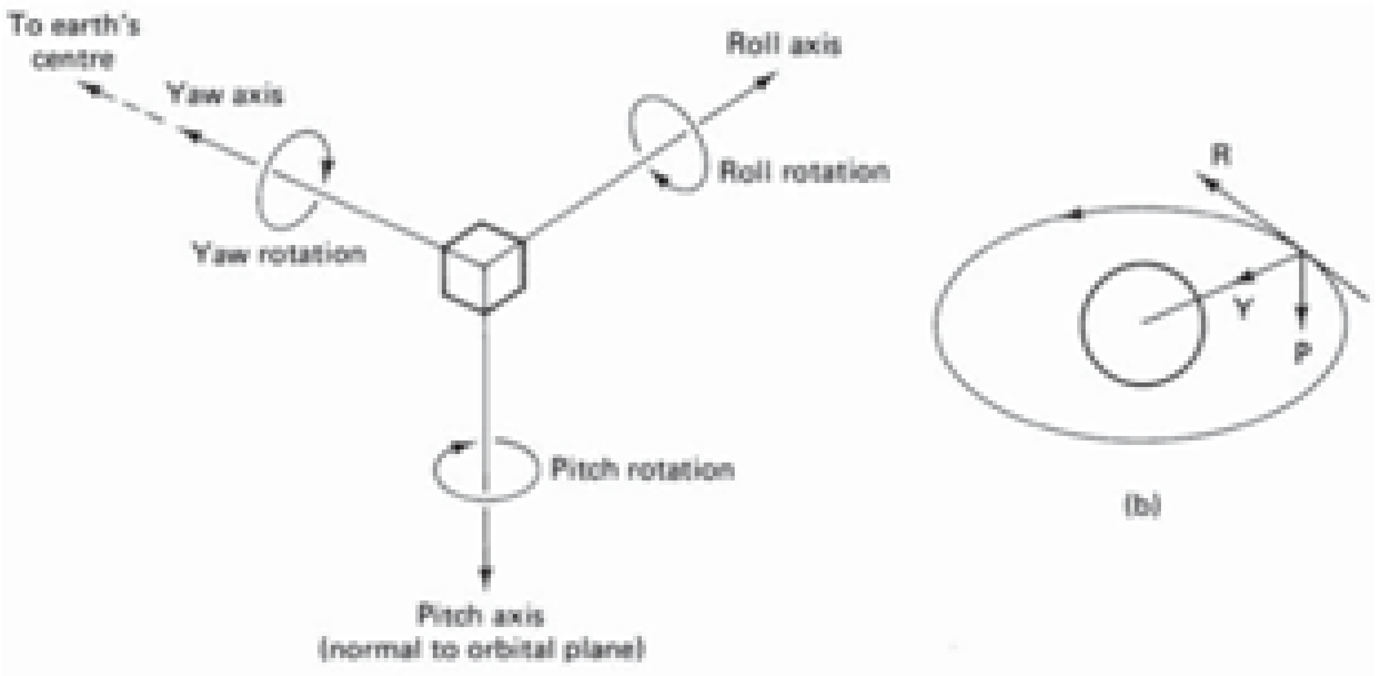
- The attitude of a satellite refers to its orientation in space.
- Much of the equipment carried aboard a satellite is there for the purpose of controlling its attitude.
- Attitude control is necessary, to ensure that directional antennas point in the proper directions.
- In the case of earth environmental satellites, the earth-sensing instruments must cover the required regions of the earth, which also requires attitude control.
- A number of forces, referred to as disturbance torques, can alter the attitude, some examples being the gravitational fields of the earth and the moon, solar radiation, and meteorite impacts.

Attitude Control vs Station keeping

- Station keeping, which is the term used for maintaining a satellite in its correct orbital position.
- Attitude Control corresponds to the orientation of the satellite.

Roll, pitch, and yaw axes

- The three axes which define a satellite's attitude are its roll, pitch, and yaw (RPY) axes.
- The yaw axis is directed toward the earth's center, the pitch axis is normal to the orbital plane, and the roll axis is perpendicular to the other two.
- RPY axes for the geostationary orbit. Here, the roll axis is tangential to the orbit and lies along the satellite velocity vector .



Mechanism of attitude control

Passive Control

Active Control

Passive attitude control

- Passive attitude control refers to the use of mechanisms which stabilize the satellite without putting a drain on the satellite's energy supplies;
- For example, When thruster jets are impulsed to provide corrective torque.
- Examples of passive attitude control are spin stabilization and gravity gradient stabilization. The latter depends on the interaction of the satellite with the gravitational field of the central body and has been used, with the Radio Astronomy Explorer-2 satellite, which was placed in orbit around the moon (Wertz, 1984).
- For communications satellites, spin stabilization is often used.

Spinning Satellite Stabilization

- Spin stabilization may be achieved with cylindrical satellites.
- The satellite is constructed so that it is mechanically balanced about one particular axis and is then set spinning around this axis.
- For geostationary satellites, the spin axis is adjusted to be parallel to the N-S axis of the earth, as illustrated in Fig.
- Spin rate is typically in the range of 50 to 100 rev/min. Spin is initiated during the launch phase by means of small gas jets.
- In the absence of disturbance torques, the spinning satellite would maintain its correct attitude relative to the earth.
- Disturbance torques are generated in a number of ways, both external and internal to the satellite. Solar radiation, gravitational gradients, and meteorite impacts are all examples of external forces which can give rise to disturbance torques. Motor-bearing friction and the movement of satellite elements such as the antennas also can give rise to disturbance torques.
- The overall effect is that the spin rate will decrease, and the direction of the angular spin axis will change. Impulse-type thrusters, or jets, can be used to increase the spin rate again and to shift the axis back to its correct N-S orientation.

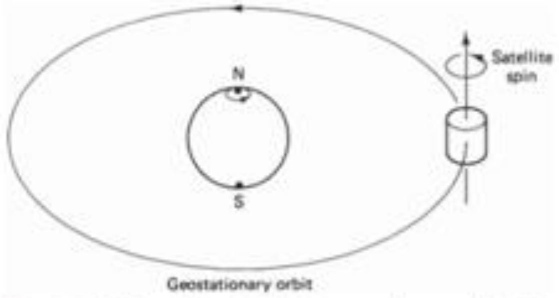


Figure 7.5 Spin stabilization in the geostationary orbit. The spin axis lies along the pitch axis, parallel to the earth's N-S axis.

Three Axis Stabilization

- Satellites have small spinning wheels, called reaction wheels or momentum wheels, that rotate so as to keep the satellite in the desired orientation in relation to the Earth and the Sun.
- If satellite sensors detect that the satellite is moving away from the proper orientation, the spinning wheels speed up or slow down to return the satellite to its correct position.
- Some spacecraft may also use small propulsion-system thrusters to continually nudge the spacecraft back and forth to keep it within a range of allowed positions.
- An advantage of 3-axis stabilization is that optical instruments and antennas can point at desired targets without having to perform “despin” maneuvers.

Station Keeping

- In addition to having its attitude controlled, it is important that a geostationary satellite be kept in its correct orbital slot.
- The equatorial ellipticity of the earth causes geostationary satellites to drift slowly along the orbit, to one of two stable points, at 75°E and 105°W.
- To counter this drift, an oppositely directed velocity component is imparted to the satellite by means of jets, which are pulsed once every 2 or 3 weeks.
- This results in the satellite drifting back through its nominal station position, coming to a stop, and recommencing the drift along the orbit until the jets are pulsed once again.
- These maneuvers are termed east-west station-keeping maneuvers.
- Satellites in the 6/4-GHz band must be kept within 0.1° of the designated longitude, and in the 14/12-GHz band, within 0.05°.

Station Keeping

- A satellite which is nominally geostationary also will drift in latitude, the main perturbing forces being the gravitational pull of the sun and the moon.
- These forces cause the inclination to change at a rate of about 0.85°/year. If left uncorrected, the drift would result in a cyclic change in the inclination, going from 0° to 14.67° in 26.6 years and back to zero, at which the cycle is repeated.
- To prevent the shift in inclination from exceeding specified limits, jets may be pulsed at the appropriate time to return the inclination to zero. These maneuvers are termed north-south station-keeping maneuvers.
- East-west and northsouth station-keeping maneuvers are usually carried out using the same thrusters as are used for attitude control.

Reference

1. Timothy Pratt Charles W. Bostian, Jeremy E. Allnutt: Satellite Communications: WileyIndia. 2nd edition 2002

2. Tri T. Ha: Digital Satellite Communications: Tata McGraw Hill, 2009

3. Dennis Roddy: Satellite Communication: 4th Edition, McGraw Hill,2009