EEEN 567 – SATELLITE ENGINEERING

GEOSTATIONARY ORBIT (GEO) SATELLITES – STUDY GUIDE/REVISION

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1. INTRODUCTION TO GEOSTATIONARY SATELLITES

Definitions

A geostationary satellite orbits Earth at ~35,786 km (22,236 miles) directly above the equator, matching Earth's rotational period (24 hours).

Key Properties of Geostationary Satellites

- Fixed position relative to Earth (appears stationary).
- Covers ~1/3 of Earth's surface (global coverage with 3 satellites).
- Used for communications, broadcasting, and weather monitoring.

2. ORBITAL MECHANICS & KEPLER'S LAWS

- **Kepler's Laws**:
  1. **First Law**: Satellites orbit in an elliptical path with Earth at one focus.
  2. **Second Law**: Equal area swept in equal time (angular velocity varies).

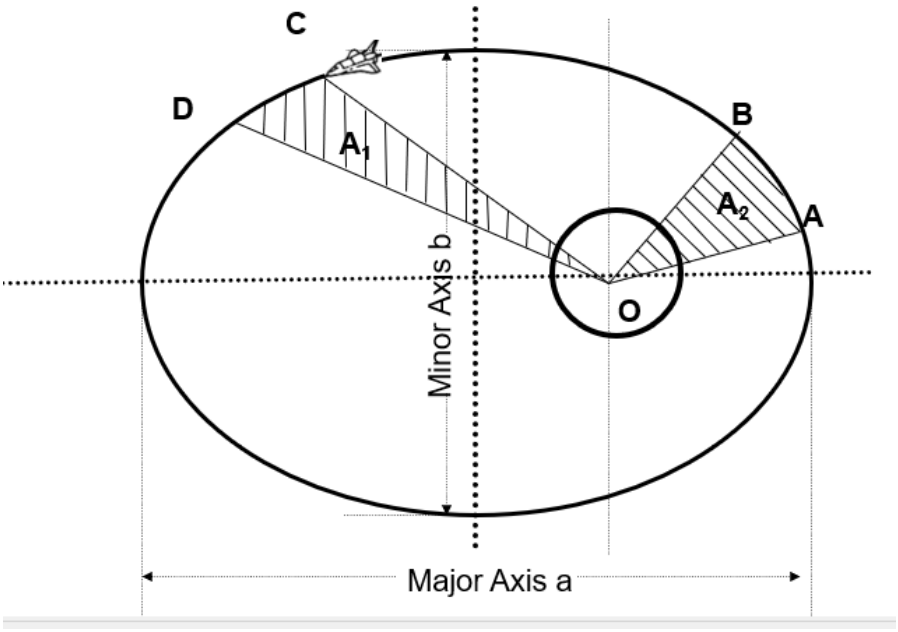

Figure 1. Kepler's 2nd Law: If the satellite travels from A to B in time t and during the same time travels from C to D, then the area under O.B is equal to area OCD.

3. **Third Law**: Orbital period^2 $\propto$ semi-major axis.

$$T^2 = \frac{4\pi^2 a^2}{GM}$$

Where

T = Orbital period (86,164 s for GEO).

a = Semi-major axis (orbital radius from Earth's centre).

GM = Earth's gravitational parameter (3.986×10^5 km^3/s^2).

Solving for a, we get:

$$a = \left(\frac{GMT^2}{4\pi^2}\right)^{1/3}$$

Substituting vales, we get

$$a \approx 42{,}164 \text{ km}$$

Subtracting Earth's radius (r = 6,378 km), we get

Altitude, h = a-h = 42164 -6378 = 35,786

- **Geostationary Orbit (GEO) Calculations**:

For satellite to remain in orbit, we must have

Centripetal force = Gravitational force

$$\frac{mv^2}{r} = \frac{GMm}{r^2} \quad \text{or} \quad v = \sqrt{\frac{GM}{r}}$$

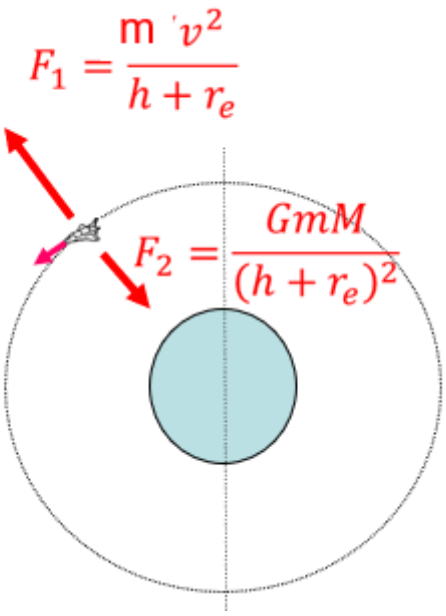

Figure 1. Gravitational force is equal to centripetal force.

- Orbital period T=2πr3GM$T = 2\pi\sqrt{\frac{r^3}{GM}}$ (must match Earth's rotation).

3. Satellite Communication System Components

- **Space Segment**:
  - Satellite (transponder, antennas, power systems, propulsion).
  - Payload (communication repeaters, amplifiers).
- **Ground Segment**:
  - Earth stations (transmit/receive antennas, modems).
  - Tracking, Telemetry, and Command (TT&C).

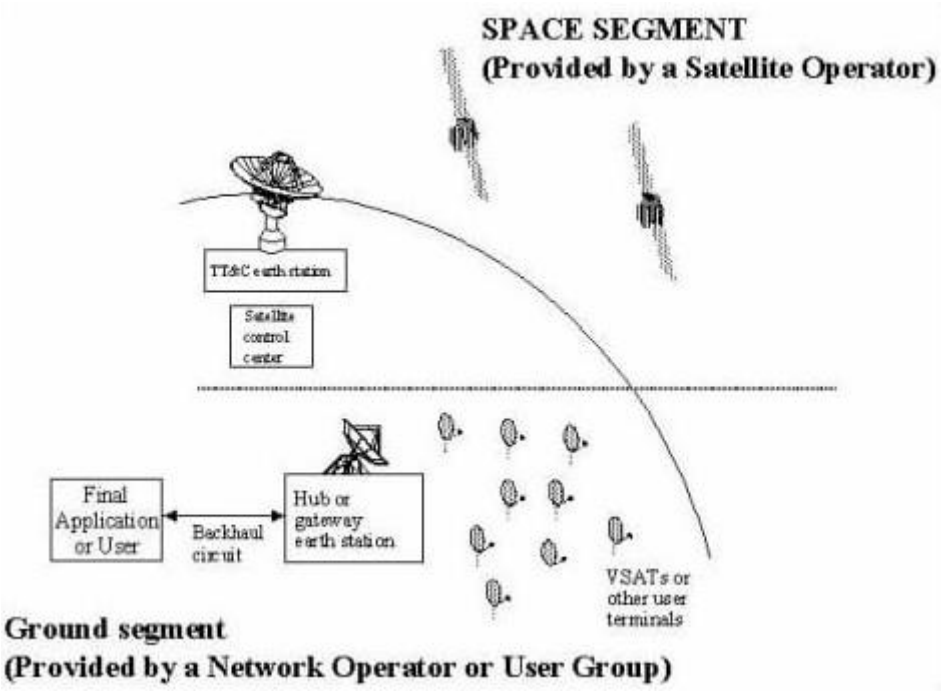

Figure 3. Satellite segments for Geostationary satellites

4. FREQUENCY BANDS IN SATELLITE COMMUNICATION

Band	Frequency Range	Applications
L-band	1–2 GHz	Mobile comms, GPS
C-band	4–8 GHz	Weather, TV broadcasting
Ku-band	12–18 GHz	DTH TV, broadband
Ka-band	26–40 GHz	High-speed internet

5. LINK BUDGET ANALYSIS

- **Key Parameters**:
  - **EIRP (Effective Isotropic Radiated Power)**:

$$EIRP = P_t G_t$$

  - **Path Loss (Free Space Loss)**:

$$L_p = \left(\frac{4\pi d}{\lambda}\right)^2$$

  - **Received Power**:

$$P_r = EIRP + G_t + G_t - L_p$$

    Where L_p is the free-space loss

  - **Noise Power**: N=kTB where k = Boltzmann's constant, T = noise temp, B = bandwidth.
  - **Carrier-to-Noise Ratio (C/N)**:

$$\frac{C}{N} = \frac{P_r}{N}$$

6. MODULATION & MULTIPLE ACCESS TECHNIQUES

- **Modulation Schemes**:
  - **Analog**: FM, AM.
  - **Digital**: QPSK, 8PSK, 16-QAM
- **Multiple Access Methods**:

- **FDMA (Frequency Division)**: Different users on different frequencies.
- **TDMA (Time Division)**: Users share frequency but transmit in time slots.
- **CDMA (Code Division)**: Users share frequency and time but use unique codes.

7. CHALLENGES IN GEO SATELLITE COMMUNICATION

- **Propagation Delays**: ~250 ms round-trip latency.
- **Atmospheric Losses**: Rain fade (especially in Ku/Ka bands).
- **Orbital Slot Congestion**: Limited positions in GEO.
- **Interference**: Adjacent satellite interference (ASI), cross-polarization.

8. APPLICATIONS OF GEO SATELLITES

- **Broadcasting**: Direct-to-Home (DTH) TV (e.g., DISH, DirecTV).
- **Telecommunications**: VSAT networks, backhaul for mobile networks.
- **Military & Defense**: Secure comms, reconnaissance.
- **Weather Monitoring**: GOES, Meteosat.

9. EMERGING TRENDS & FUTURE TECHNOLOGIES

- **High-Throughput Satellites (HTS)**: Increased capacity via spot beams.
- **Optical Satellite Communication**: Laser links for higher data rates.
- **LEO Constellations**: Starlink, Kuiper, OneWeb (competition to GEO).

10. PRACTICE PROBLEMS

1. Calculate the orbital radius of a geostationary satellite.
2. A satellite has an EIRP of 50 dBW. If the free-space path loss is 200 dB, find the received power if the ground station antenna gain is 40 dB.
3. Compare FDMA, TDMA, and CDMA in terms of spectral efficiency.