



ECE 514E – RADAR & SATELLITE ENGINEERING

GEOSTATIONARY ORBIT (GEO) SATELLITES – STUDY GUIDE/REVISION

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).

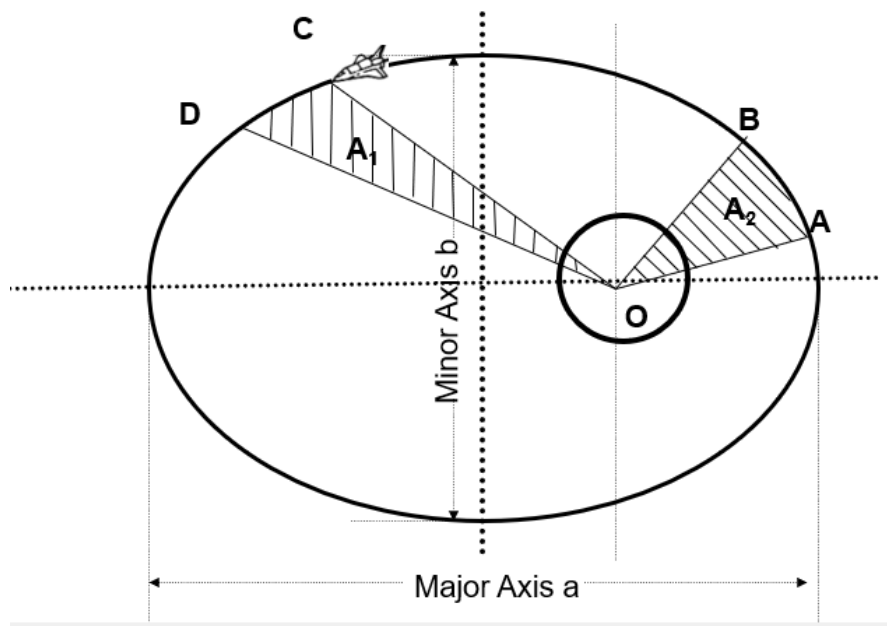


Figure 1. Kepler's 2nd Law: If the satellite travels from A to B in time t and during the same time travels from C to D, then the area under O.B is equal to area OCD.

3. **Third Law:** Orbital period² \propto semi-major axis.

$$T^2 = \frac{4\pi^2 a^3}{GM}$$

Where

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

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

GM = Earth's gravitational parameter ($3.986 \times 10^5 \text{ km}^3/\text{s}^2$).

Solving for a, we get:

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

Substituting values, we get

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

Subtracting Earth's radius ($r = 6,378 \text{ km}$), we get

$$\text{Altitude, } h = a - r = 42164 - 6378 = 35,786$$

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

For satellite to remain in orbit, we must have

Centripetal force = Gravitational force

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

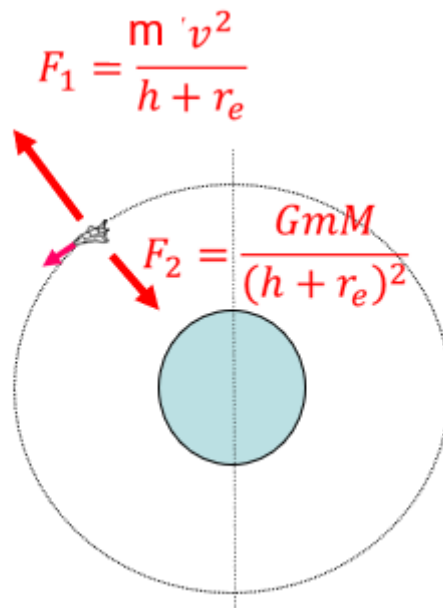


Figure 1. Gravitational force is equal to centripetal force.

- Orbital period $T = 2\pi r^3 / GM = 2\pi GM / r^3$ (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).

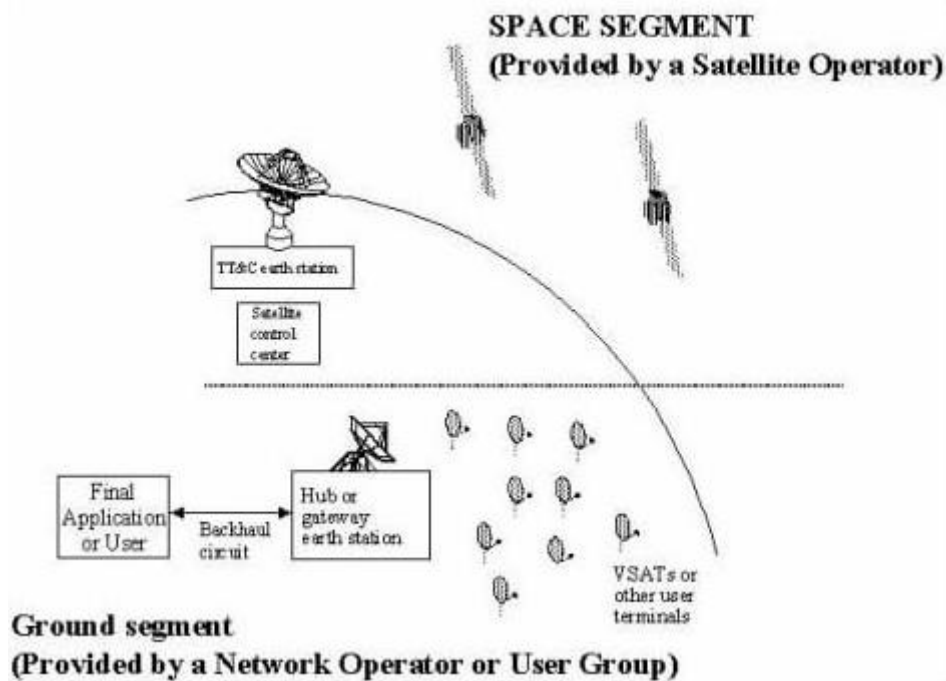


Figure 3. Satellite segments for Geostationary satellites

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:**

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

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.