EEEN 567 –SATELLITE ENGINEERING

TEST YOUR KNOWLEDGE ON INTRODUCTION TO SATELLITES

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1. BASIC CONCEPTS

Q1: What is an artificial satellite?

A: An artificial satellite is a human-built object intentionally placed into orbit around Earth or another celestial body. Examples include communication satellites (e.g., Starlink), navigation satellites (e.g., GPS), and Earth observation satellites (e.g., Landsat).

Q2: Define Kepler's Three Laws of Planetary Motion.

A:

1. **First Law (Elliptical Orbits):** Satellites orbit in elliptical paths with the primary body (e.g., Earth) at one focus.
2. **Second Law (Equal Area):** A satellite sweeps equal areas in equal time intervals (conservation of angular momentum).
3. **Third Law (Orbital Period):** The square of the orbital period TT is proportional to the cube of the semi-major axis aa: T2∝a3$T2 \propto a3$.

2. ORBITS

Q3: Compare LEO, MEO, and GEO orbits.
A:

- **LEO (Low Earth Orbit):** Altitude: 160–2,000 km. Short orbital period (90–120 min). Used for imaging (e.g., Hubble) and broadband (e.g., Starlink).
- **MEO (Medium Earth Orbit):** Altitude: 2,000–35,786 km. Period: 2–24 hours. Used for GPS/NAVSTAR.
- **GEO (Geostationary Orbit):** Altitude: 35,786 km. Period: 24 hours. Fixed over Earth's equator; used for weather (e.g., GOES) and TV broadcasting.

Q4: What is a sun-synchronous orbit (SSO)?
A: An SSO is a near-polar LEO orbit where the satellite passes over a location at the same local solar time daily. Enables consistent lighting for Earth observation (e.g., Landsat).

Q5: Calculate the orbital period of a satellite in GEO.
A: Using Kepler's Third Law:

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

where $\mu = 3.986 \times 10^{14} m^3/s^2$ (Earth's gravitational parameter) and $a = 42{,}164 km$ (semi-major axis).

T≈86,164seconds=23 h 56 min 4 s≈24 hours.

3. SATELLITE SUBSYSTEMS

Q6: Describe the power subsystem in a satellite.

A: Converts solar energy to electrical power using **solar panels** (photovoltaic cells) and stores energy in **batteries** (e.g., Li-ion) for eclipse periods. Power conditioning (voltage regulation) is managed by a **Power Control Unit (PCU)**.

Q7: What is attitude control, and why is it critical?

A: Attitude control maintains a satellite's orientation in space using sensors (e.g., star trackers), actuators (e.g., reaction wheels), and algorithms. Critical for:

- Pointing antennas toward Earth.
- Aligning solar panels toward the Sun.
- Stabilizing imaging payloads.

Q8: Explain thermal control in satellites.

A: Maintains temperature ranges for electronics using:

- **Passive methods:** Multi-layer insulation (MLI), heat pipes, radiators.
- **Active methods:** Heaters (for cold phases), louvers.

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4. COMMUNICATION & PAYLOADS

Q9: Define a transponder.

A: A transponder is the **communication payload** of a satellite. It receives uplink signals, amplifies/frequency-converts them, and retransmits as downlink signals. Includes:

- Low-noise amplifier (LNA).
- Frequency converter (mixer + local oscillator).
- High-power amplifier (HPA).

Q10: What frequency bands are used in satellite communication?

A: Common bands:

- **C-band:** 4–8 GHz (weather-resistant).
- **Ku-band:** 12–18 GHz (broadcast TV).
- **Ka-band:** 26–40 GHz (high-throughput broadband).

Q11: What is a link budget?

A: A link budget quantifies all gains/losses in a communication path:

Received Power (dB)=EIRP+Grx−Path Loss−LossesReceived Power (dB)=EIRP+Grx−Path Loss−Losses

where:

- **EIRP:** Effective isotropic radiated power (transmit power × antenna gain).

- **Path Loss:** Free-space loss ($20\log_{10}(4\pi d/\lambda)20\log 10(4\pi d/\lambda)$).
- **Losses:** Atmospheric attenuation, rain fade, pointing errors.

Q12: Compare FDMA, TDMA, and CDMA.

A:

- **FDMA (Frequency Division):** Users share bandwidth via frequency slots.
- **TDMA (Time Division):** Users share time slots on the same frequency.
- **CDMA (Code Division):** Users share frequency/time but use unique codes for separation.

5. APPLICATIONS

Q13: How do GPS satellites enable positioning?

A: GPS satellites transmit precise timing signals. A receiver calculates distance to ≥4 satellites using **time-of-arrival**, then trilaterates its position.

Q14: Name three remote sensing applications.

A:

1. **Agriculture:** Crop health monitoring (using NDVI).
2. **Disaster Management:** Flood mapping.
3. **Climate Science:** Ice-sheet tracking.

6. ELECTRICAL ENGINEERING FOCUS

Q15: Why are phased array antennas used in modern satellites?

A: Phased arrays electronically steer beams without moving parts, enabling:

- Rapid re-targeting (e.g., Starlink user links).
- Multiple simultaneous beams (spatial multiplexing).

Q16: What is Doppler shift in LEO communication?

A: Relative motion between LEO satellites and ground users causes frequency drift. Mitigated via:

- Predictive frequency compensation.
- Dynamic channel allocation.

Q17: How does error correction (e.g., LDPC) improve satellite links?

A: Low-Density Parity Check (LDPC) codes add redundancy to detect/correct errors caused by noise, improving reliability in low-SNR environments (e.g., deep-space links).

Q18: Why are GaN amplifiers replacing TWTA in satellites?

A: Gallium Nitride (GaN) amplifiers offer:

- Higher efficiency (>30% vs. 10–15% for TWTAs).
- Wider bandwidth.

- Lower mass/volume.

7. ADVANCED TOPICS

Q19: What is station keeping?

A: Orbital maintenance using thrusters to counteract perturbations (e.g., atmospheric drag in LEO, gravitational forces in GEO).

Q20: Explain the "spacecraft bus" concept.

A: The bus is the standardized platform hosting subsystems (power, propulsion, etc.), while the payload is mission-specific (e.g., comms, sensors).

Q21: How do CubeSats reduce mission costs?

A: CubeSats use modular, off-the-shelf components and share launch space, enabling low-cost R&D, education, and rapid deployment.

8. CHALLENGES & FUTURE TRENDS

Q22: What is orbital debris? Why is it a problem?

A: Defunct satellites/rocket parts in orbit. Collisions risk damaging active satellites (Kessler Syndrome). Mitigated via deorbiting protocols.

Q23: How does atmospheric attenuation affect Ka-band signals?

A: Ka-band suffers high rain fade (~10 dB loss in heavy rain). Compensated via adaptive coding/modulation or site diversity.

Q24: What is optical satellite communication?

A: Uses lasers (instead of radio) for high-bandwidth, low-latency links. Challenges: precise pointing and atmospheric scattering.

9. NUMERICAL PROBLEMS

Q25: Calculate free-space path loss for a GEO satellite at 36,000 km using Ku-band (12 GHz).
A:

Path Loss (dB)= $20log_{10}\left(\frac{4\pi d}{\lambda}\right)$

$$\lambda = \frac{c}{d} = \frac{3 \times 10^8}{12 \times 10^9} = 0.025m$$

$d = 36000 \times 10^3$m

Substituting, we get

Path Loss (dB)= $20log_{10}\left(\frac{4\pi \times 3.6 \times 10^7}{2.5 \times 10^{-2}}\right)$ = 205.7 dB

Q26: A satellite has a solar array output of 2 kW. If batteries must power a 500 W load for 45 minutes during eclipse, what battery capacity (kWh) is needed at 80% discharge depth?
A:

Energy Required= 500W X 0.75h = 375 Wh

Battery capacity = $\frac{375}{0.8}$ = 468.75 Wh = 0.475 kWh

10. DESIGN & ETHICS

Q27: Why is radiation hardening critical for satellite electronics?
A: Space radiation (cosmic rays, solar flares) can cause bit flips or hardware failure. Mitigated via:

- Radiation-hardened semiconductors.
- Error-correcting memory.
- Redundant systems.

Q28: What is spectrum scarcity, and how does it impact satellite design?
A: Limited radio spectrum drives competition between satellite/terrestrial networks. Satellites use:

- Higher frequencies (e.g., Ka/V-band).
- Spectral reuse via spot beams.
- Efficient modulation (e.g., 256-QAM).

11. HISTORICAL CONTEXT

Q29: What was Sputnik 1?
A: The first artificial satellite (launched by USSR, 1957). It transmitted radio pulses, initiating the space race.

Q30: Describe the significance of the Clarke Orbit.
A: Proposed by Arthur C. Clarke (1945), it describes the geostationary orbit where a satellite matches Earth's rotation—foundational for global communications.