Modern Telecommunication Systems
Lecture 9

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Satellite Orbits

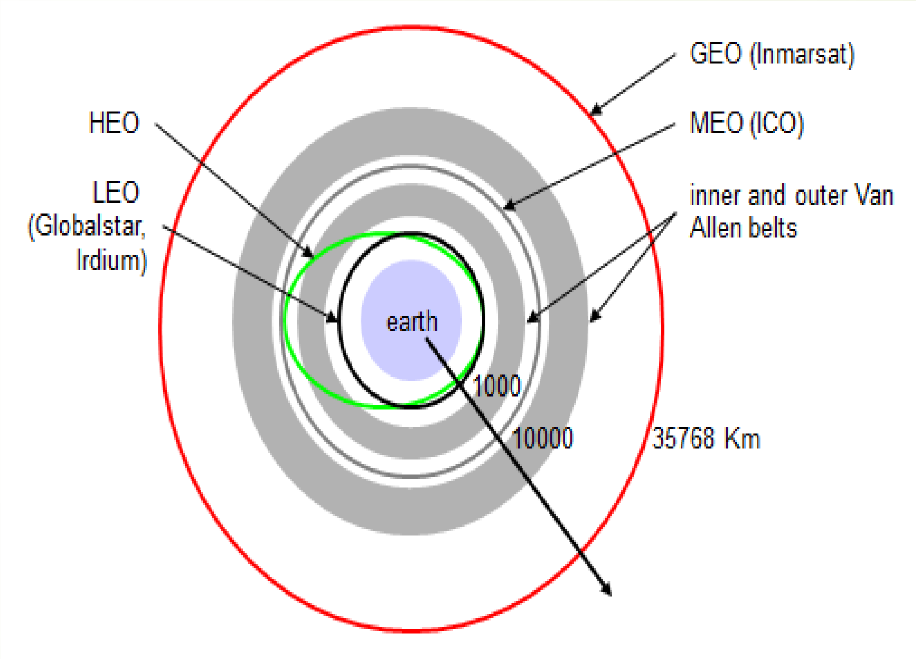
- When a satellite is launched, it is placed in orbit around the Earth.
- The Earth's gravity holds the satellite in a certain path as it goes around the Earth, and that path is called an "orbit.“
- There is only one main force acting on a satellite when it is in orbit, and that is the gravitational force exerted on the satellite by the Earth.
- This force is constantly pulling the satellite towards the center of the Earth.

Satellite Orbits

- A satellite doesn't fall straight down to the Earth because of its velocity.
- Throughout a satellites orbit there is a perfect balance between the gravitational force due to the Earth, and the centripetal force necessary to maintain the orbit of the satellite.

Types of Orbits

- GEO: ~ 36000 km from the earth
- MEO: 6000 - 20000 km
- LEO: 500 - 1500 km
- HEO: Highly Elliptical Orbit, elliptical orbits
- Difficulties from radiation belts



Geostationary Earth Orbit (GEO)

- Objects in Geostationary orbit revolve around the earth at the same speed as the earth rotates.
- This means GEO satellites remain in the same position relative to the surface of earth.
- Because of the long distance from earth it gives a large coverage area, almost a fourth of the earth's surface.

Geostationary Earth Orbit (GEO)

- But, this distance also cause it to have both a comparatively weak signal and a time delay in the signal, which is bad for point to point communication.
- High transmit power needed and launching of satellites to orbit are complex and expensive.
- Not useful for global coverage for small mobile phones and data transmission, typically used for radio and TV.

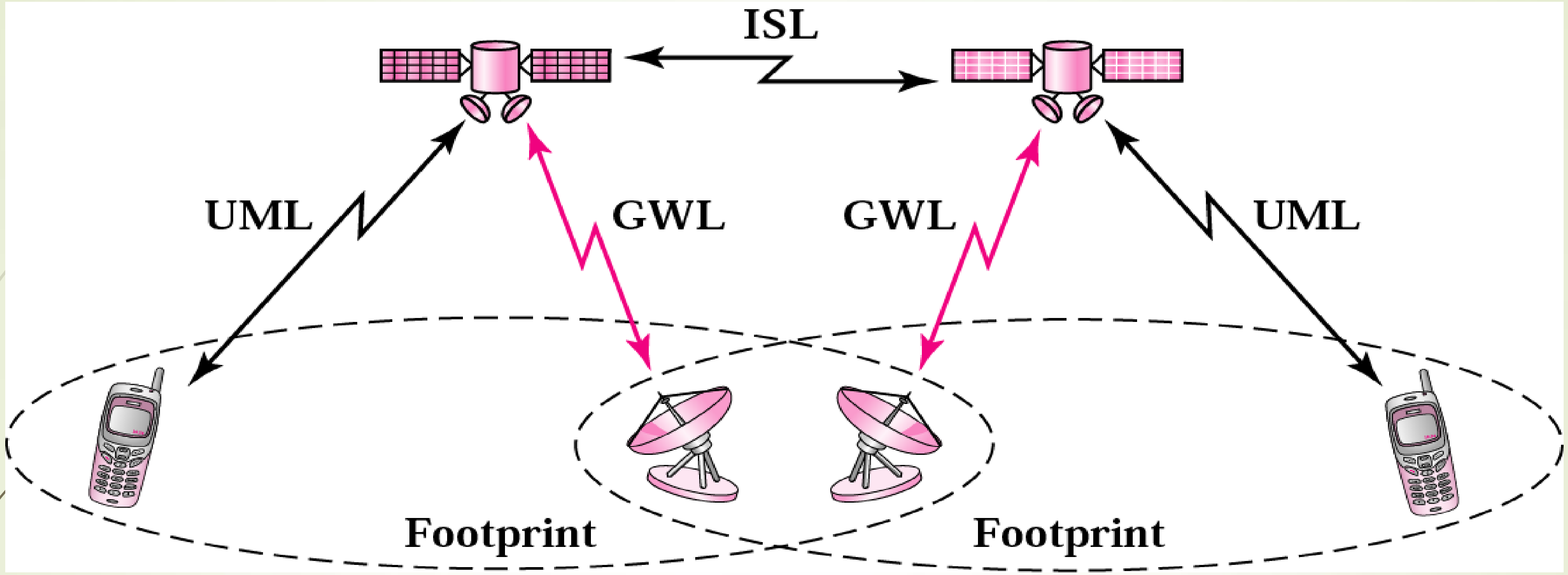
Medium Earth Orbit (MEO)

- MEO satellites have a larger coverage area than LEO satellites.
- A MEO satellite's longer duration of visibility and wider footprint means fewer satellites are needed in a MEO network than a LEO network.
- A MEO satellite's distance gives it a longer time delay and weaker signal than a LEO satellite, though not as bad as a GEO satellite.

Low Earth Orbit (LEO)

- LEO satellites are much closer to the earth than GEO satellites, ranging from 500 to 1,500 km above the surface.
- LEO satellites don’t stay in fixed position relative to the surface, and are only visible for 15 to 20 minutes each pass.
- A network of LEO satellites is necessary for LEO satellites to be useful.
- Handover necessary from one satellite to another.
- Need for routing.

LEO



- ISL Inter Satellite Link
- GWL – Gateway Link
- UML – User Mobile Link

Satellite Orbits

Principles of Satellite Orbits and Positioning:

- The ability to launch a satellite and keep it in orbit depends upon following well-known physical and mathematical laws called orbital dynamics.
- In order for a satellite to go into orbit around the earth, it must have some forward motion.
- When a satellite is launched, it is given both vertical and forward motion.

Satellite Orbits

Principles of Satellite Orbits and Positioning

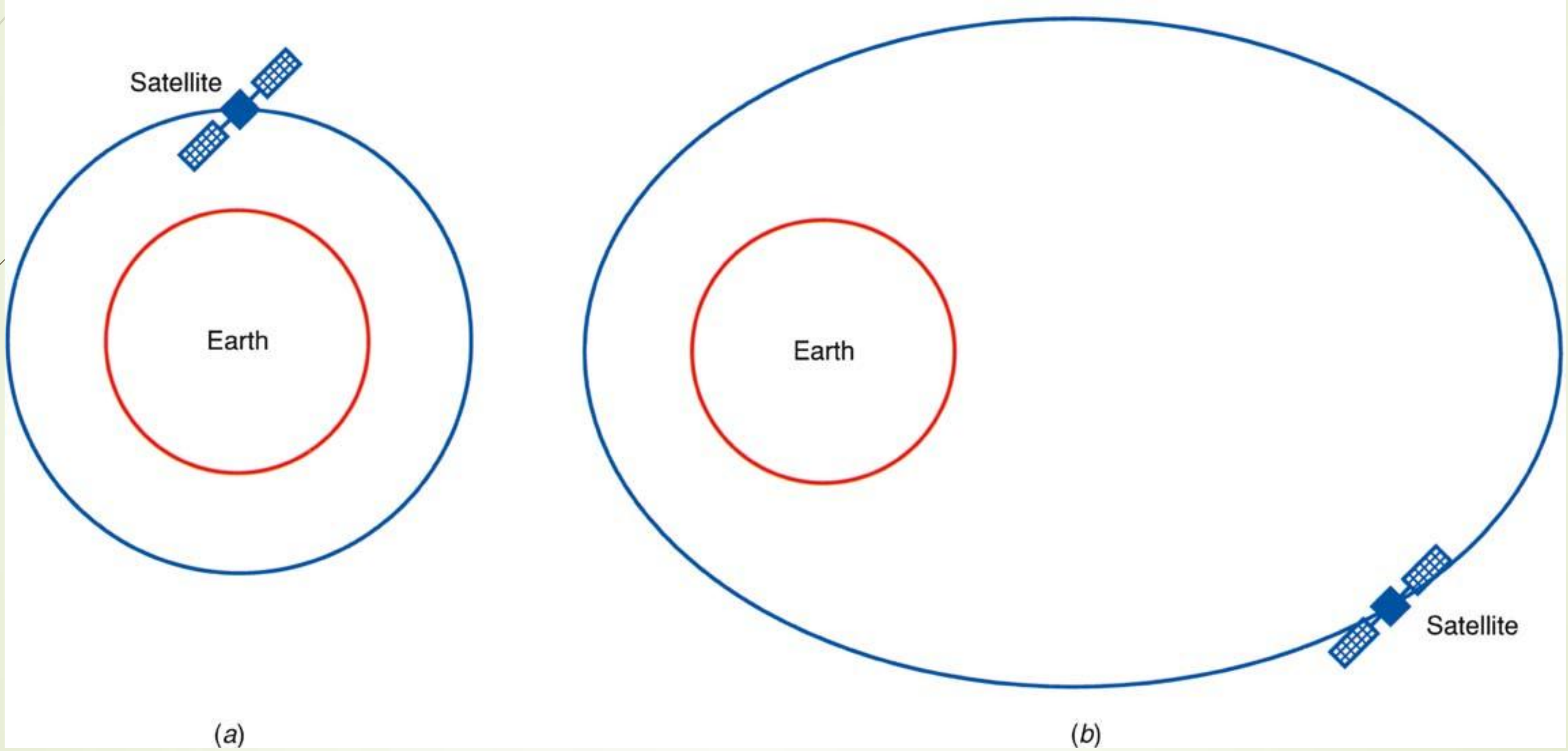
- Forward motion produces inertia, which tends to keep the satellite moving in a straight line
- Gravity tends to pull the satellite toward the earth.
- The inertia of the satellite is equalized by the earth’s gravitational pull.
- The satellite constantly changes its direction from a straight line to a curved line to rotate about the earth.

Satellite Orbits

Principles of Satellite Orbits and Positioning

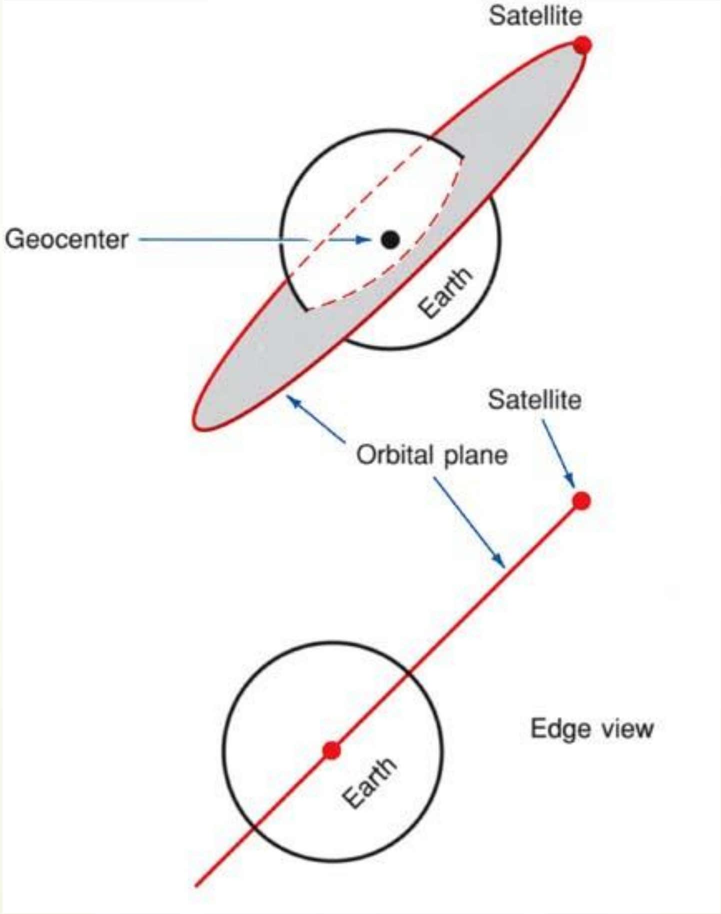
- The goal is to give the satellite acceleration and speed that will exactly balance the gravitational pull.
- Communication satellites are typically about 22,300 miles from the earth.
- A satellite needs to travel about 6800 mi/hr in order to stay in orbit at that distance.
- A satellite rotates around the earth in either a circular or elliptical path.
- A satellite rotates in an orbit that forms a plane that passes through the center of gravity of the earth called geocenter.

Satellite Orbits



Satellite orbits. (*a*) Circular orbit. (*b*) Elliptical orbit.

Satellite Orbits



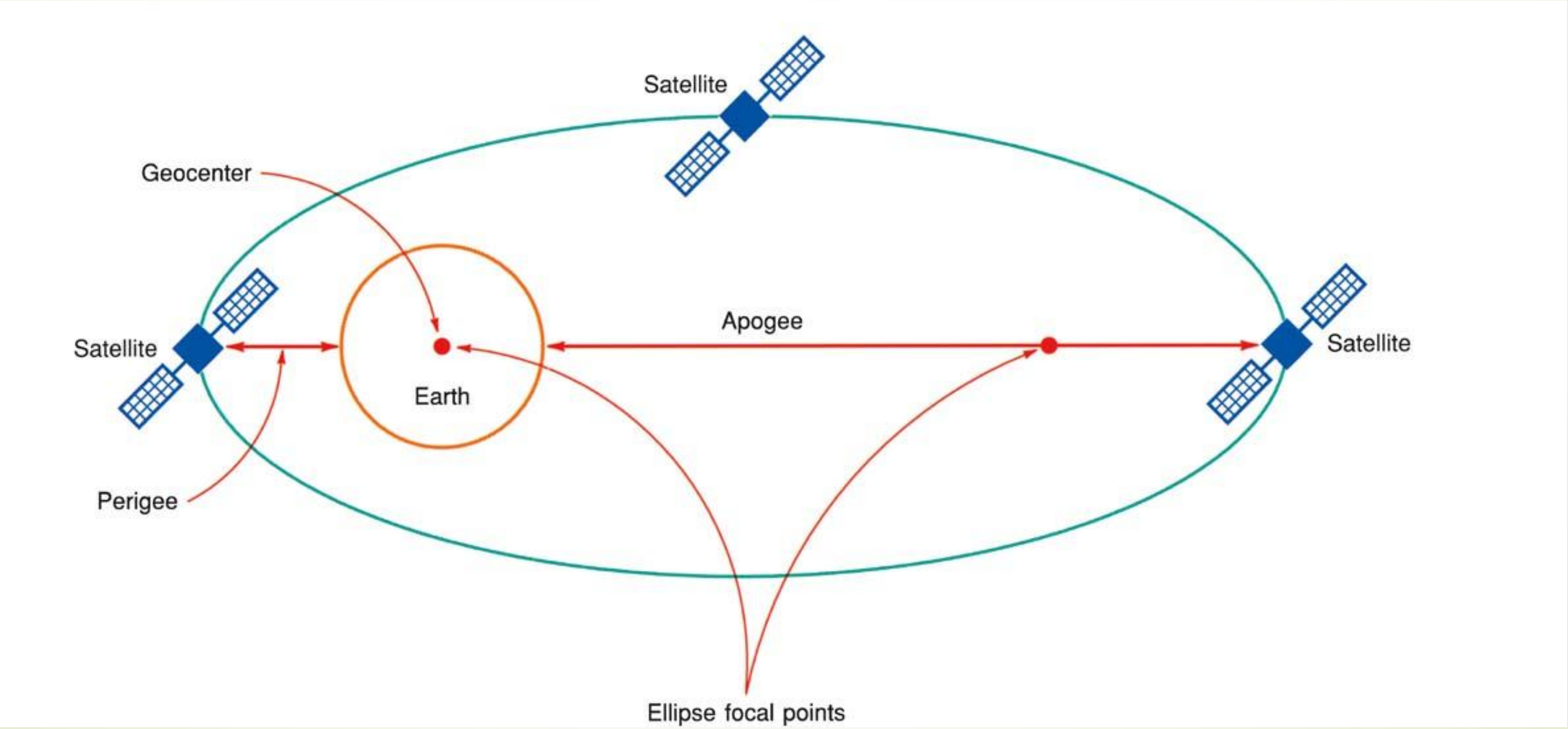
The orbital plane passes through the geocenter.

Satellite Orbits

Principles of Satellite Orbits and Positioning: Satellite Height

- In a circular orbit, the height is the distance of the satellite from the earth.
- In geometric calculations, the height is the distance between the center of the earth and the satellite.
- When the satellite is an elliptical orbit, the center of the earth is one of the focal points of the ellipse.
- The two points of greatest interest are the highest point above the earth (the apogee) and the lowest point (the perigee).

Satellite Orbits



Elliptical orbit showing apogee and perigee.

Satellite Orbits

Principles of Satellite Orbits and Positioning: Satellite Speed

- Satellite speed varies depending upon the distance of the satellite from the earth.
- For a circular orbit the speed is constant, but for an elliptical orbit the speed varies depending upon the height.
- Low earth satellites of about 100 mi in height have a speed of about 17,500 mi/hr.
- Very high satellites such as communication satellites typically travel at speeds of about 6800 mi/hr.

Satellite Orbits

Principles of Satellite Orbits and Positioning: Satellite Period

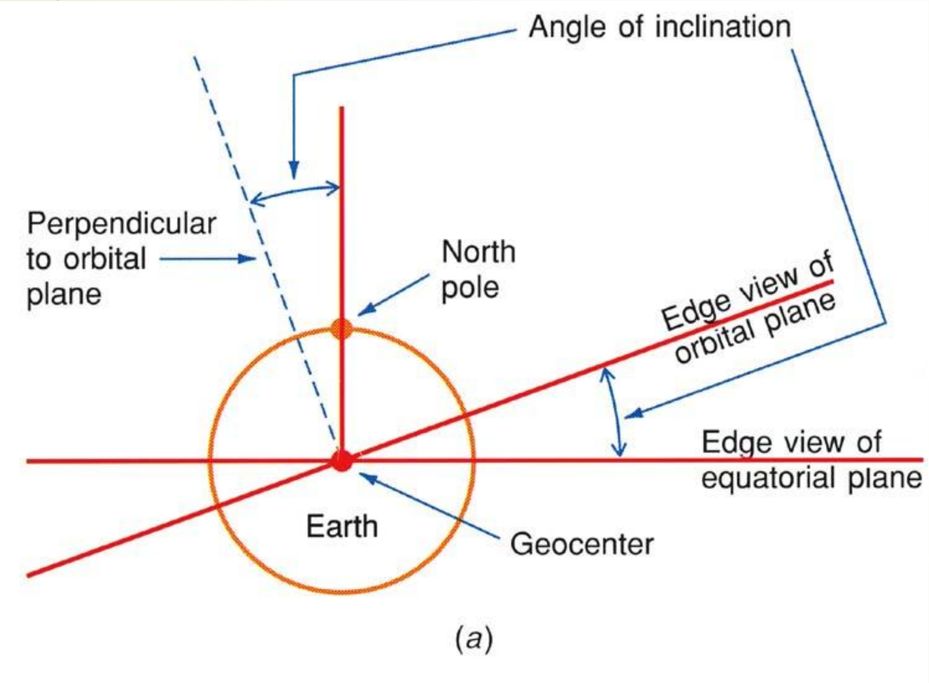
- The period is the time it takes for a satellite to complete one orbit.
- This time is also called the sidereal period.
- One revolution is the period of time that elapses between the successive passes of the satellite over a given meridian of earth longitude.
- Typical rotational periods range from about 1 ½ h for a 100-mi height to 24 h for a 22,300-mi height.

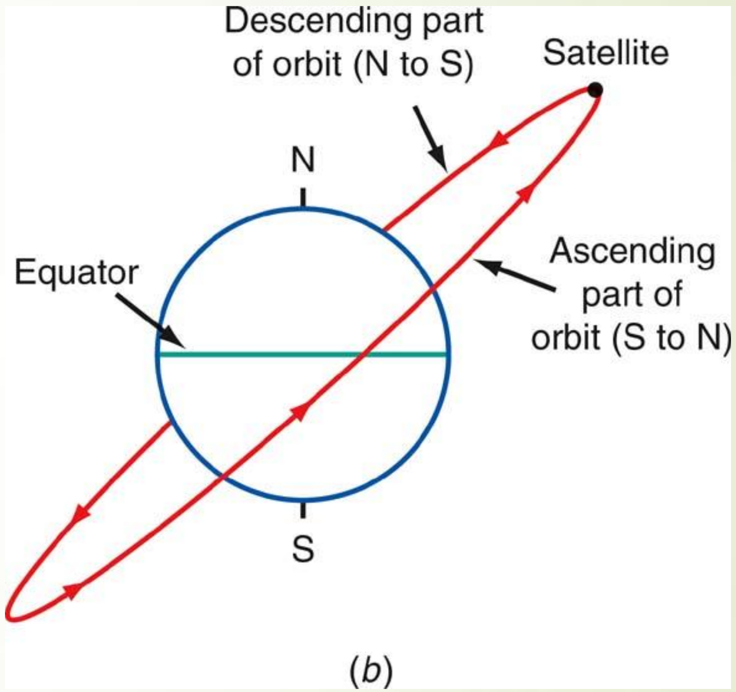
Satellite Orbits

Principles of Satellite Orbits and Positioning: Angle of Inclination

- The angle of inclination of a satellite orbit is the angle formed between the line that passes through the center of the earth and the north pole, and a line that passes through the center of the earth but that is also perpendicular to the orbital plane.
- It is also defined as the angle between the equatorial plane and the satellite orbital plane as the satellite enters the northern hemisphere.
- When the satellite has an angle of inclination, the orbit is said to be ascending or descending.

Satellite Orbits





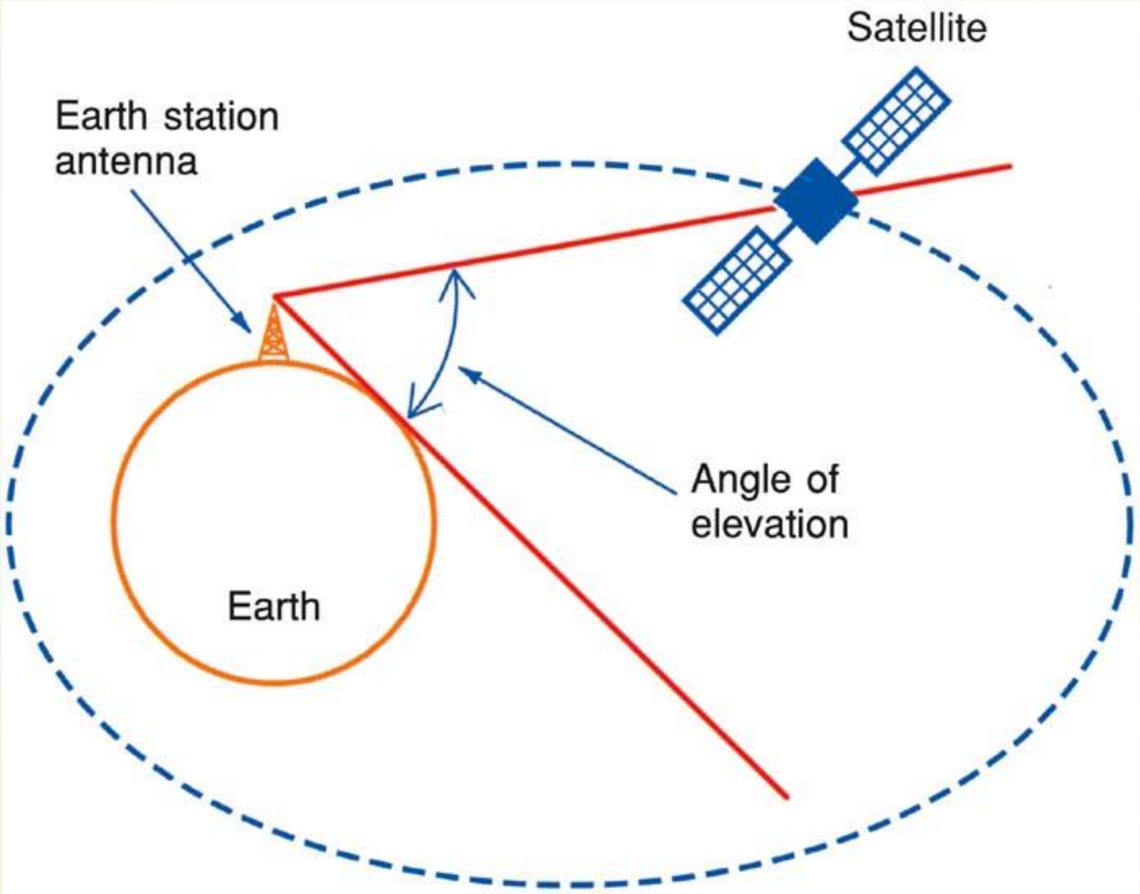
(a) Angle of inclination. (b) Ascending and descending orbits.

Satellite Orbits

Principles of Satellite Orbits and Positioning: Angle of Elevation

- The **angle of elevation** of a satellite is the angle that appears between the line from the earth station’s antenna to the satellite and the line between the earth station’s antenna and the earth’s horizon.
- Noise in the atmosphere contributes to poor performance.
- The minimum practical angle of elevation for good satellite performance is 5°.
- The higher the angle of elevation, the better.

Satellite Orbits



Angle of elevation.

Satellite Orbits

Principles of Satellite Orbits and Positioning: Geosynchronous Orbits

- To use a satellite for communication relay or repeater purposes, the ground station antenna must be able to follow or track the satellite as it passes overhead.
- Depending upon the height and speed of the satellite, the earth station is able to use it only for communication purposes for that short period when it is visible.
- The best solution to this problem is to launch a synchronous or geostationary satellite.

Satellite Orbits

Principles of Satellite Orbits and Positioning: Geosynchronous Orbits

- In a geosynchronous earth orbit (GEO), the satellite rotates about the earth in exactly 24 h.
- It appears to be fixed or stationary. The antenna is pointed at the satellite and remains in a fixed position, making continuous communication possible.
- Most communication satellites in use today are of the geosynchronous variety.

Satellite Orbits

Principles of Satellite Orbits and Positioning: Position Coordinates in Latitude and Longitude

- The satellite location is specified by a point on the earth directly below the satellite known as the sub-satellite point (SSP).
- Latitude is defined as the angle between the line drawn from a given point on the surface of the earth to the point at the center of the earth called the geo-center and the line between the geo-center and the equator.
- The prime meridian is used as a reference point for measuring longitude.

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