Advanced Electronic Communication Systems

Lecture 4

Satellite Orbits (Part 3)

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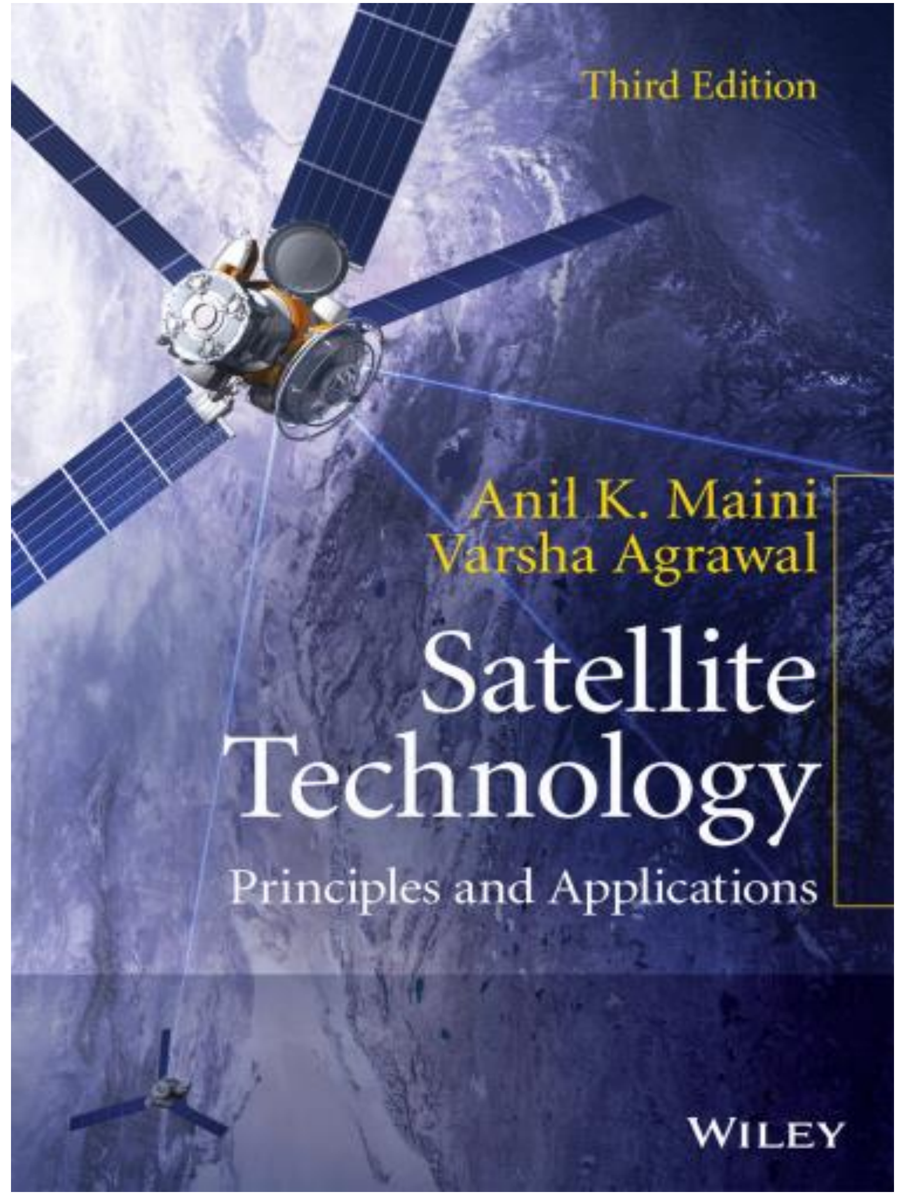
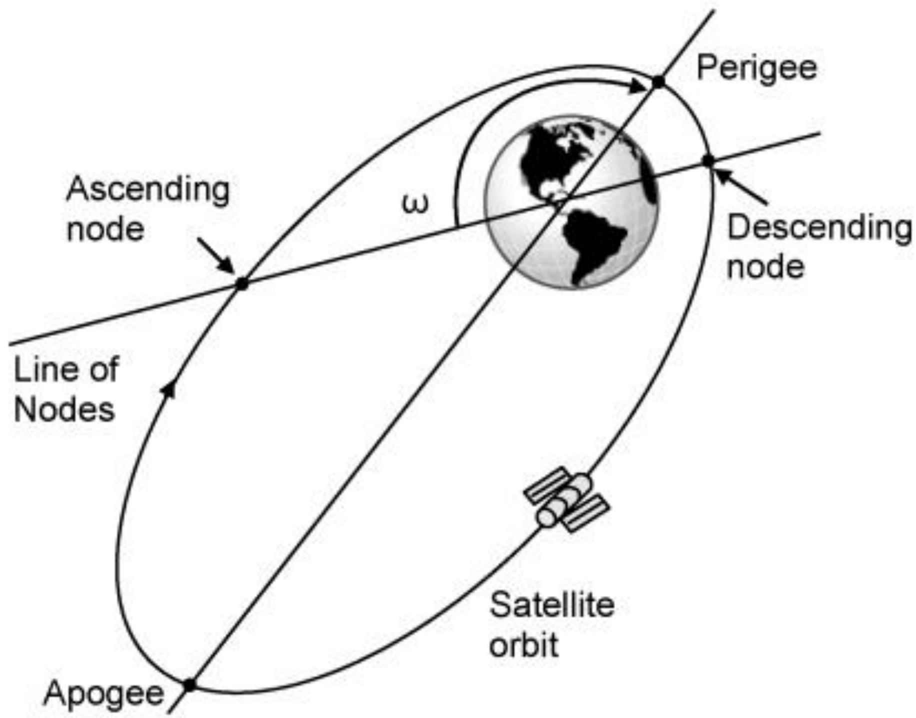
Still mostly with

Chapter (2)
Satellite Technology:
Principles and Applications



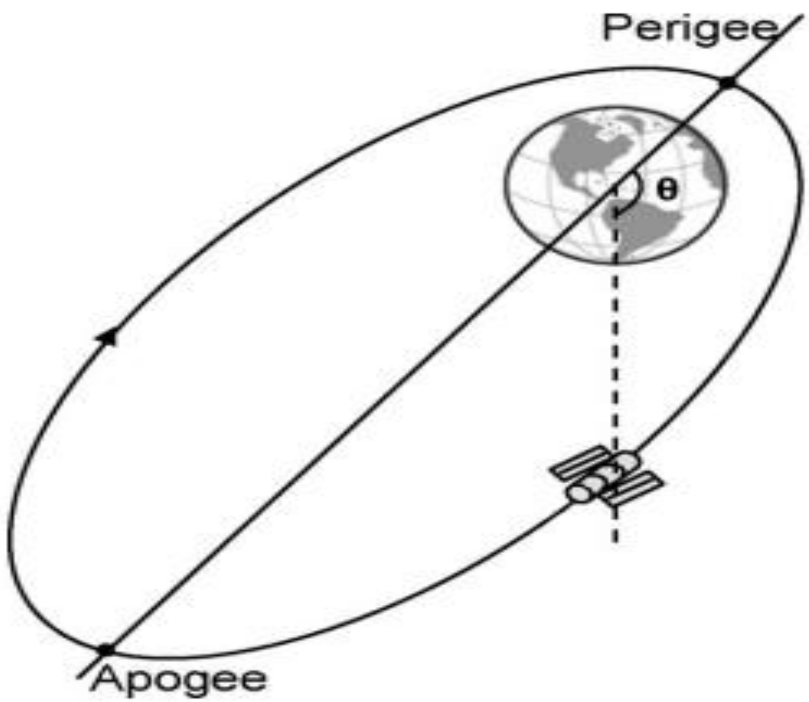
Argument of Perigee (ω°)



The angle between the line, joining the perigee and the centre of the Earth, and the line of nodes in the same direction as that of the satellite orbit (angle form ascending node to perigee)

- It measures the location of the perigee point in the orbit, or in other words it measures the orbit rotation

True Anomaly (ω^o)



- is the angle from perigee to the satellite position
- The angle between the line, joining the perigee and the centre of the Earth, with the line joining the satellite and the centre of the Earth
- This gives the true angular position of the satellite in the orbit as a function of time.

2.5 Types of Satellite Orbits

- Satellites travel around Earth along predetermined repetitive paths called orbits.
- The orbit is characterized by its elements or parameters,
- The orbital elements of a particular satellite depend upon its intended application.

- The satellite orbits can be classified on the basis of:

1. Orientation of the orbital plane
2. Eccentricity
3. Distance from Earth

2.5 Types of Satellite Orbits

2.5.1 Orientation of the Orbital Plane

- The orbital plane of the satellite can have various orientations with respect to the equatorial plane of Earth (Inclination Angle)

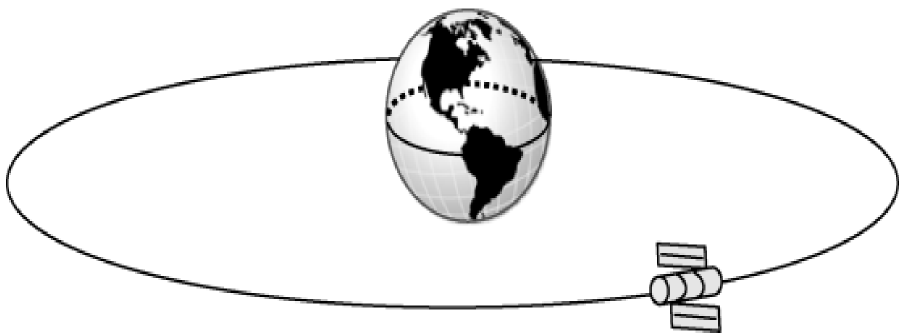


Figure 2.32 Equatorial orbit

Figure 2.33 Polar orbit

i =0°

i =90°

2.5 Types of Satellite Orbits

2.5.1 Orientation of the Orbital Plane

- The orbital plane of the satellite can have various orientations with respect to the equatorial plane of Earth (Inclination Angle)

Figure 2.34 Prograde orbit

$0^\circ < i < 90^\circ$

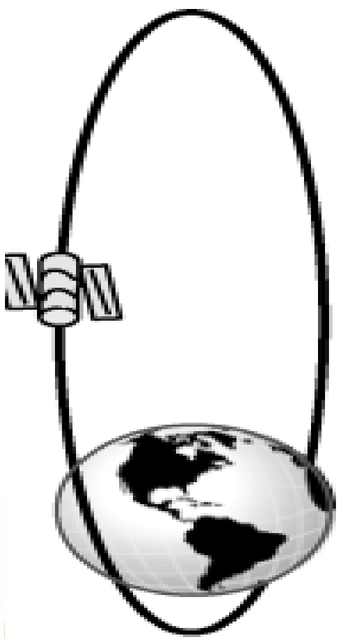
Figure 2.35 Retrograde orbit

$90^\circ < i < 180^\circ$

2.5 Types of Satellite Orbits

2.5.2 Eccentricity of the Orbit

- Orbits are classified as elliptical and circular orbits.
- Practically, all circular orbits are eccentric to some extent. For example, the eccentricity of orbit of geostationary satellite INSAT-3B, an Indian satellite in the INSAT series providing communication services, is 0.0002526.



Elliptic

Geostationary

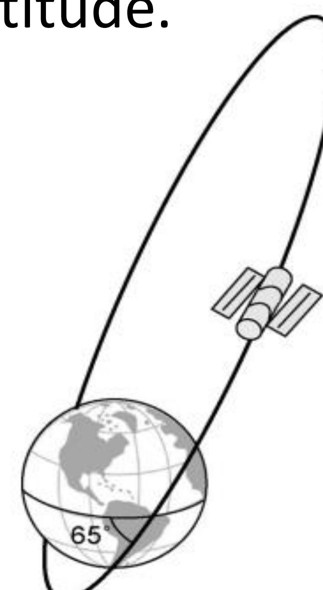
(geosynchronous circular equatorial orbit)

2.5 Types of Satellite Orbits

2.5.2.1 Highly Elliptical Orbit (HEO) or Molniya Orbit

- The Molniya orbit combines high inclination (63.4°) with high eccentricity (0.722) to maximize viewing time over high latitudes, which are otherwise not covered by geostationary orbits.
- Each orbit lasts 12 hours (Semi-Synchronous), so the slow, high-altitude portion of the orbit repeats over the same location every day and night.
- The satellite spends about 8 hours in the high latitude before diving down to a low level perigee for the high southern latitude.

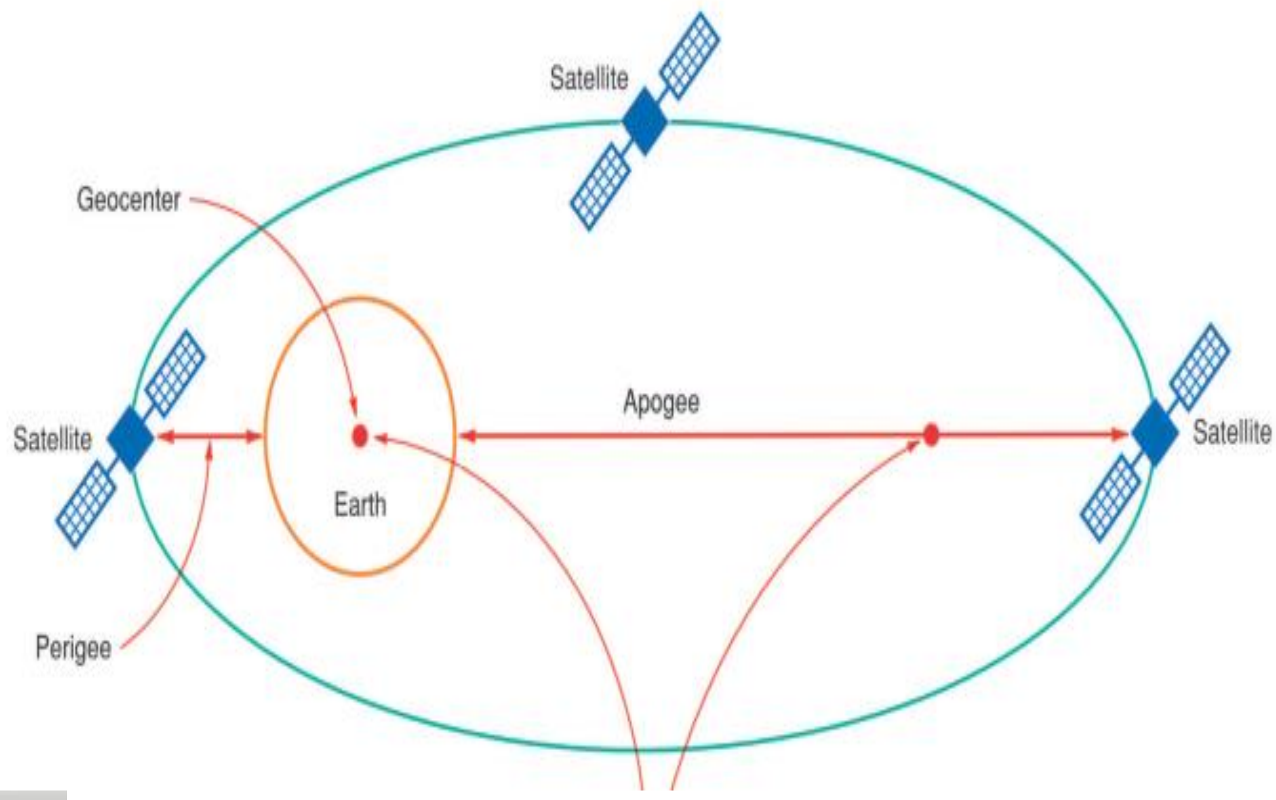
> - This type of orbit is useful for communications in the far north or south.
> - Russian communications satellites and the Sirius radio satellites currently use this type of orbit.



2.5 Types of Satellite Orbits

2.5.2.1 Highly Elliptical Orbit (HEO) or Molniya Orbit

- Since HEO is seen by ground users on high latitude areas for 2/3 of the day, a multi-satellite system is needed if we want a 24/7 coverage.
- Usually, three satellites at different phases of the same Molniya orbit are capable of providing an uninterrupted communication service.



Non-synchronous Satellites

Geo-synchronous Satellites

Semi-synchronous Satellites

Geo-Stationary Satellites

- **Geo-Synchronous Orbit:** is a prograde orbit whose orbital period equal to one sidereal day (i.e., 23 hours 56 minutes)

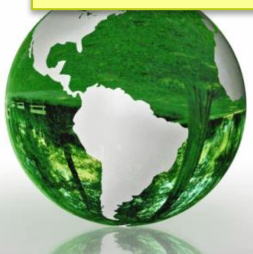
- **Sidereal Day:** the time taken by Earth to complete one full rotation around its axis with reference to distant stars.

Is every Geo-synchronous Satellite seems fixed w.r.t. a ground user all the time?

NO

Is it mandatory to have fixed LOS to a satellite to achieve communication ?

NO



Non-synchronous Satellites

- Non-synchronous satellites rotate around Earth with a speed different from that of earth rotation.

- 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 earth station antenna **tracks the satellite** from horizon to horizon.
- But at some point, the satellite disappears around the other side of the earth. At this time, it can no longer support communication.

Non-synchronous Satellites as a relay

- The interruption of communication caused by these orbital characteristics is highly undesirable in many communication applications.
- Another way to reduce interruptions is to use more than one satellite.
- Typically 3 satellites, if properly spaced in the correct orbits, can provide continuous communication at all times (but usually larger numbers are used)

However, multiple tracking stations and complex signal switching or "hand-off" systems between stations are required.

Maintaining these stations is expensive and inconvenient.

- ✓ Despite the cost and complexity of multiple-satellite systems, they are widely deployed in global telecommunication applications.
- ✓ At any given time, multiple satellites are in view anywhere on earth, making continuous communication possible (Ex. Monlnia Sate. Sys.)

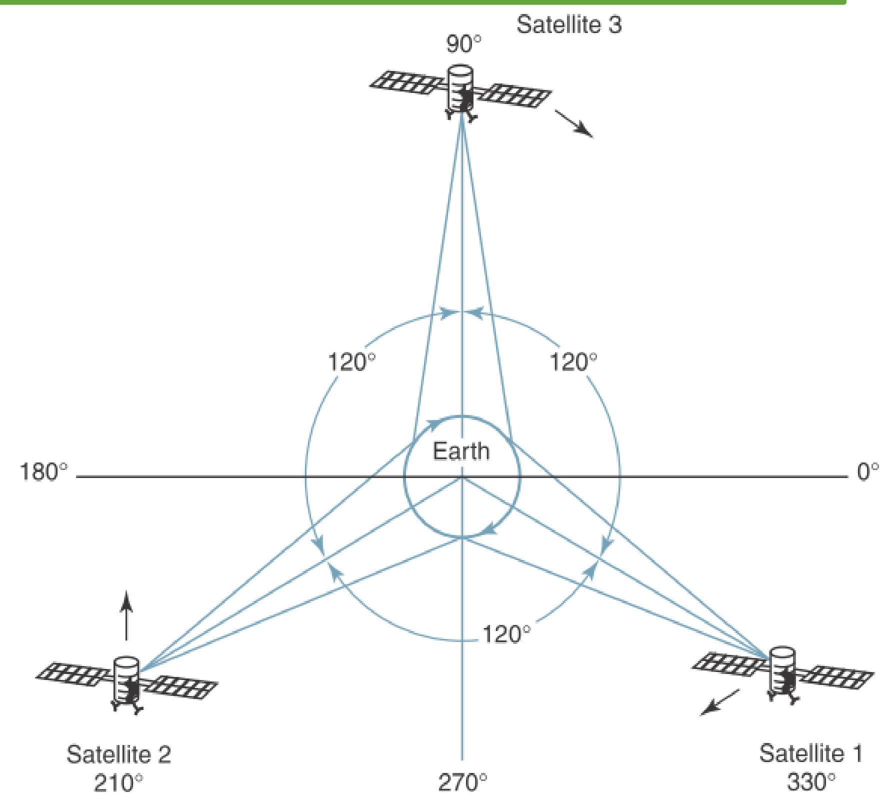
Geo-Stationary Satellites

✓ When a geo-synchronous Earth orbit satellite seems fixed (**Stationary**) w.r.t. ground user?

1. It must have a constant latitude, which is possible only at 0° latitude (at the equator).
2. The orbit inclination should be **zero**.
3. It should have a constant longitude and thus have a uniform angular velocity, which is possible when the orbit is **circular**.
4. The orbital period should be equal to 23 hours 56 minutes, which implies that the satellite must orbit at a height of **35786** km above the surface of the Earth **(Keplar's law**).
5. The satellite motion must be from west to east (**Earth rotation direction**).

Geo-Stationary Satellites (GEO)

- Since it seems stationary, No tracking antennas are required. The antenna is simply pointed at the satellite and remains in a fixed position.
- Due to the very large height (**35786 Km**), the round-trip delay is about 260 ms, which is very noticeable in voice communication (LEO: 10 ms, MEO: 100 ms).
- Higher power is required for such a great distance,
- GEO is sometimes referred to as the **Clarke orbit**, after Arthur C. Clarke, who first suggested its existence in 1945 and proposed its use for comm. satellites.

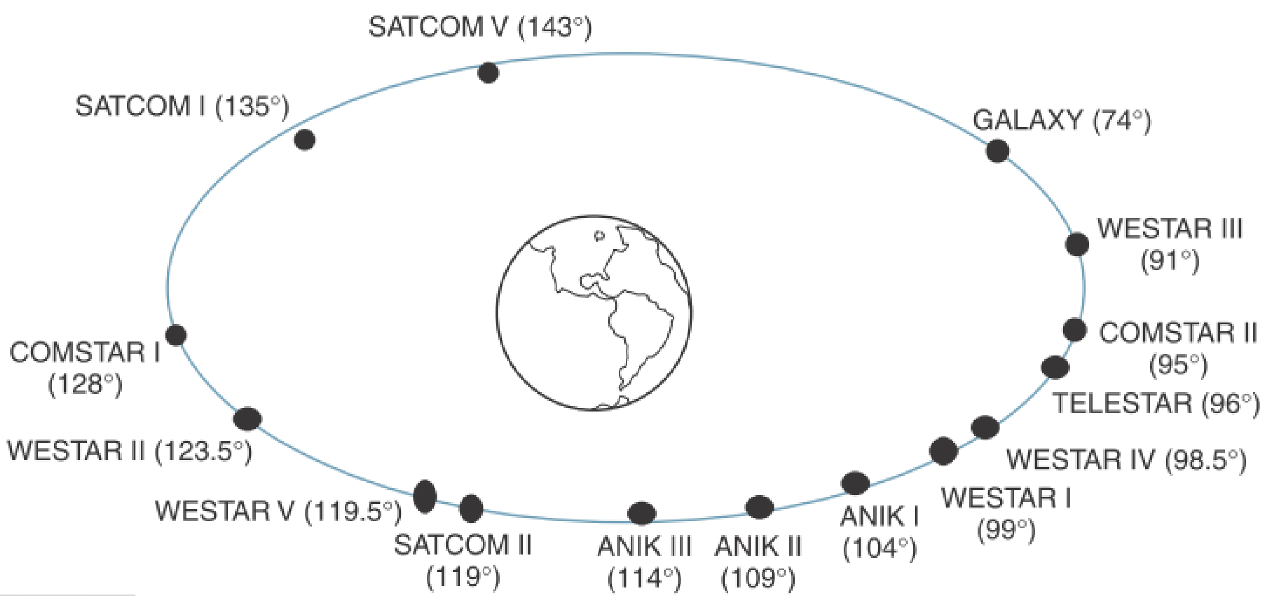


- ✓ In order to cover the globe, one satellite is not enough.
- ✓ Only three satellites are sufficient to provide connection throughout the surface of the Earth **except the two polar regions**

Geo-Stationary Satellites (GEO)

➢ GEO international agreement :

- ✓ An international agreement initially mandated that all satellites placed in the Clarke orbit must be separated by at least 1833 miles.
- ✓ This separation equates to an angular separation of 4° or more, which limits the number of satellite vehicles in a geosynchronous earth orbit to less than 100.
- ✓ Today, however, international agreements allow satellites to be placed much closer together.
- ✓ The Figure shows the locations of several satellites



Geo-Stationary Satellites (GEO)

- The radius from the centre of the earth to the satellite is:

$$35{,}786 \text{ km} + 6378 \text{ km} = 42{,}164 \text{ km}$$

- Geosynchronous Satellite Orbital Velocity

The circumference (C) of a geosynchronous orbit is

$$C = 2\pi(42{,}164 \text{ km})$$
$$= 264{,}790 \text{ km}$$

Therefore, the velocity (v) of a geosynchronous satellite is

$$v = \frac{264{,}790 \text{ km}}{24 \text{ hr}}$$
$$= 11{,}033 \text{ km/hr}$$

or $$v \approx 6840 \text{ mph}$$

Geo-Stationary Satellites (GEO)

- Round-Trip Time Delay of Geosynchronous Satellites

The round-trip propagation delay between a satellite and an earth station located directly below it is:

$$t = \frac{d}{c}$$

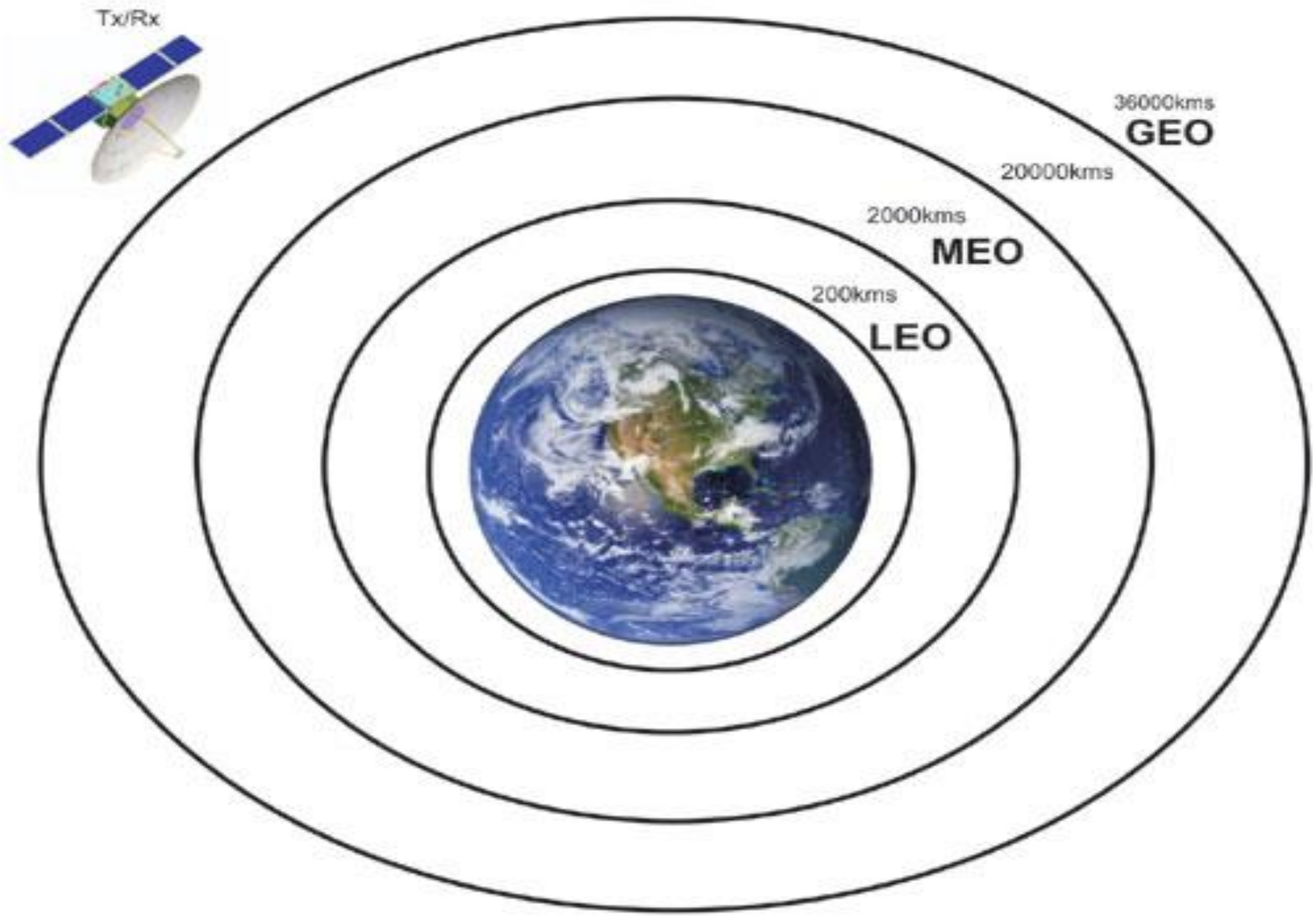
$$= \frac{2(35{,}768 \text{ km})}{3 \times 10^5 \text{ km/s}}$$

$$= 238 \text{ ms}$$

- Including the time delay within the earth station and satellite equipment, it takes more than a quarter of a second for an electromagnetic wave to travel from an earth station to a satellite and back when the earth station is located at a point on Earth directly below the satellite.
- For earth stations located at more distant locations, the propagation delay is even more substantial and can be significant with two-way telephone conversations or data transmissions.

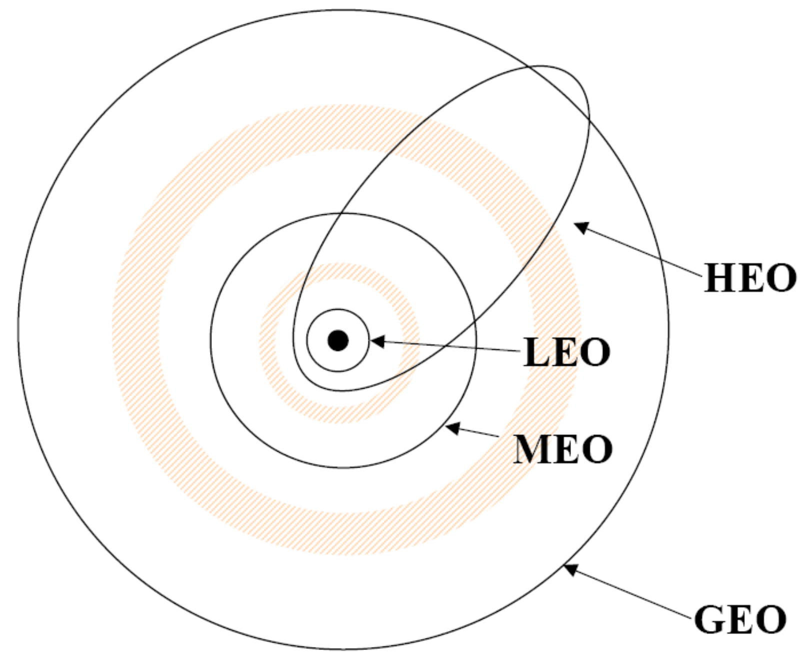
2.5.3 Distance from Earth (Satellite Elevation Categories)

- Satellite orbits are also classified in terms of the orbital height to:



Van Allen radiation belts

- Region of charged particles that can cause damage to satellite
- Orbit should avoid Van Allen radiation belts:
- Occur at
  - ~2000-4000 km and
  - ~13000-25000 km



1. LEO

- The Low Earth Orbits (LEO) satellites are located approximately between 300-1500km (this number is different in diff references)
- The speed is 5 mph (8 km/s) so one revolution is completed in only 90 minutes.
- We cannot place them closer because of the atmosphere drag which would cause the satellite to burn and decay.
- LEO satellites are usually used for Earth monitoring and as weather satellites, as well as for military purposes .
- Most LEO satellites operate in the 1.0-GHz to 2.5-GHz frequency range
- Recently, LEO satellites are being deployed as a network to provide global coverage.

Motorola's satellite-based mobile-telephone system (Iridium) is a LEO system utilizing a 66-satellite constellation orbiting approximately 480 miles (around 770 Km) above Earth's surface.

- The main advantage of LEO satellites is that the path loss between earth stations and space vehicles is much lower than for satellites revolving in medium- or high-altitude orbits, which means:
  - ✓ Lower transmit powers,
  - ✓ Smaller antennas, and
  - ✓ Less weight

Satellite Elevation Categories

2. MEO

- MEO satellites operate in the 1.2-GHz to 1.66-GHz frequency band and
- Orbit between 10,000 Km and 20,000 Km above Earth.
- These satellites move more slowly relative to the earth's rotation allowing a simpler system design (spin around the Earth between 2 and 12 hours)
- MEO can cover larger populations with fewer handovers.

- Usually used to provide the Goblal Positioning Service (GPS) maintained by the US government, GLONASS or GALILEO, Russian and European version of GPS respectively.

- The greater the height above the earth, the better the view and the greater the radio area coverage on the earth's surface.
- When the goal is broader coverage per satellite, the MEO is obviously preferred over the LEO.
- However, the higher the satellite, the higher the power required for reliable communication and the longer the delay.

Thank you