Advanced Electronic Communication Systems

Lecture 4

Satellite Orbits (2)

Dr.Eng. Basem ElHalawany

Orbital (nonsynchronous) Satellites (cont.)

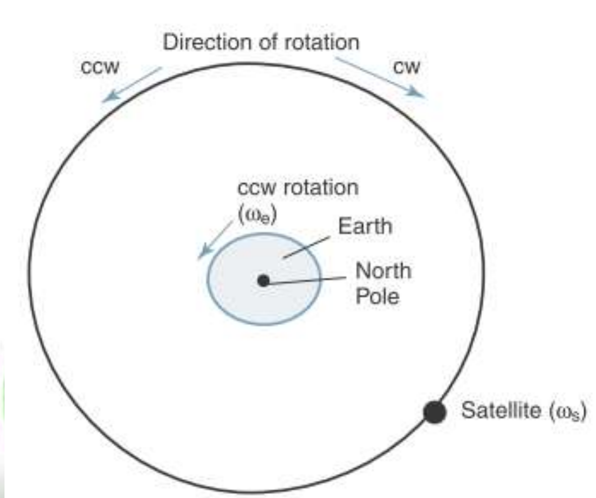
➢ Posigrade orbit or Prograde:

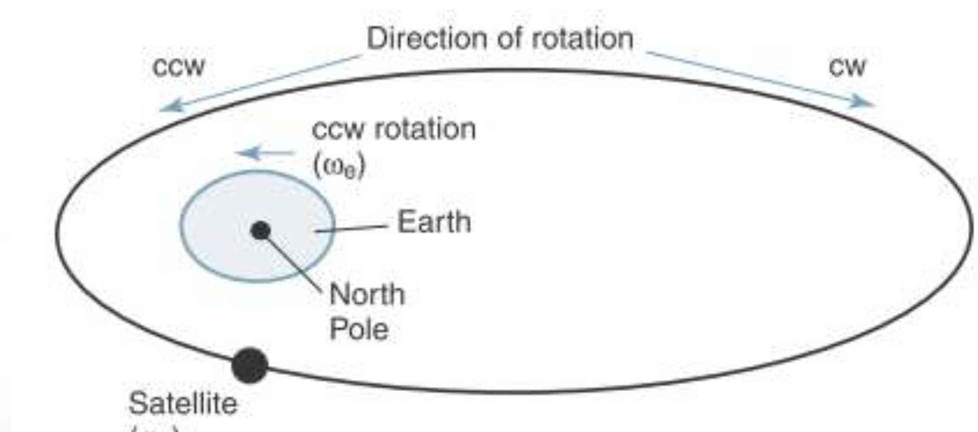
- If the satellite is orbiting in the same direction as Earth's rotation (counterclockwise) and at an angular velocity greater than that of Earth ($\omega_s > \omega_e$)

➢ Retrograde orbit :

- If the satellite is orbiting in the opposite direction as Earth's rotation or in the same direction with an angular velocity less than that of Earth ($\omega_s < \omega_e$)

✓ Most nonsynchronous satellites revolve around Earth in a prograde orbit.
✓ Therefore, the position of satellites in nonsynchronous orbits is continuously changing in respect to a fixed position on Earth.





(b)

Orbital (nonsynchronous) Satellites (cont.)

Disadvantage of orbital Satellites

- Nonsynchronous satellites have to be used when available, which may be as little as 15 minutes per orbit.
- Need a complicated and expensive tracking equipment at the earth stations so they can locate the satellite as it comes into view on each orbit and then lock its antenna onto the satellite and track it as it passes overhead.

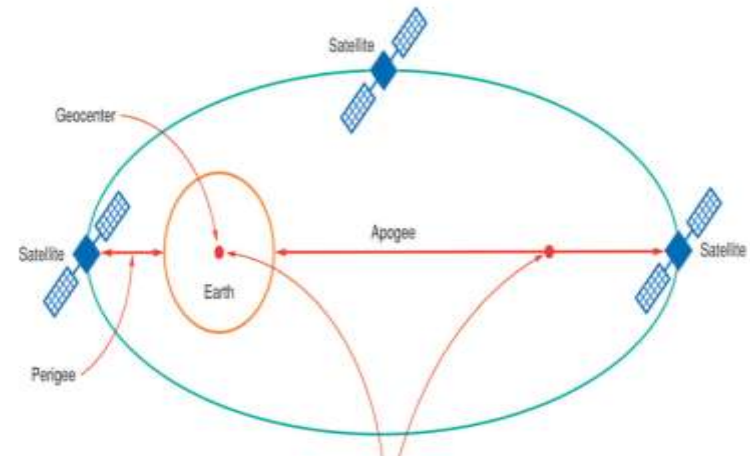
Advantage of orbital Satellites

- Propulsion rockets are not required on board the satellites to keep them in their respective orbits.

Orbital (nonsynchronous) Satellites as relay

- 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.

- One solution to this problem is to launch a satellite with a very long elliptical orbit so that the earth station can "see" the apogee.
- In this way, the satellite stays in view of the earth station for most of its orbit and is useful for communication for a longer time.



Orbital (nonsynchronous) Satellites as a relay

- The interruption of communication caused by these orbital characteristics is highly undesirable in many communication applications.
- One way to reduce interruptions is to use more than one satellite.
- Typically 3 satellites, if properly spaced in the correct orbits, can provide continuous comm s are used)

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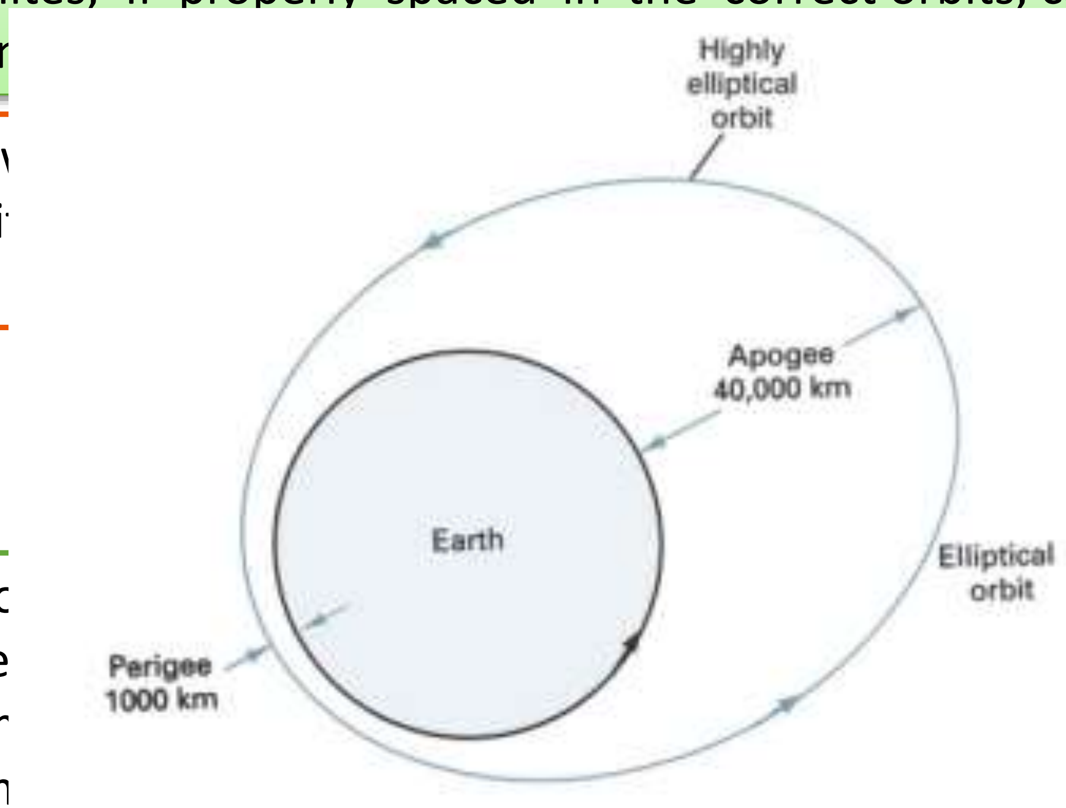

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- ✓ At any given tir rth, making continuous con

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Orbital (nonsynchronous) Satellites as a relay

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- One 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.)

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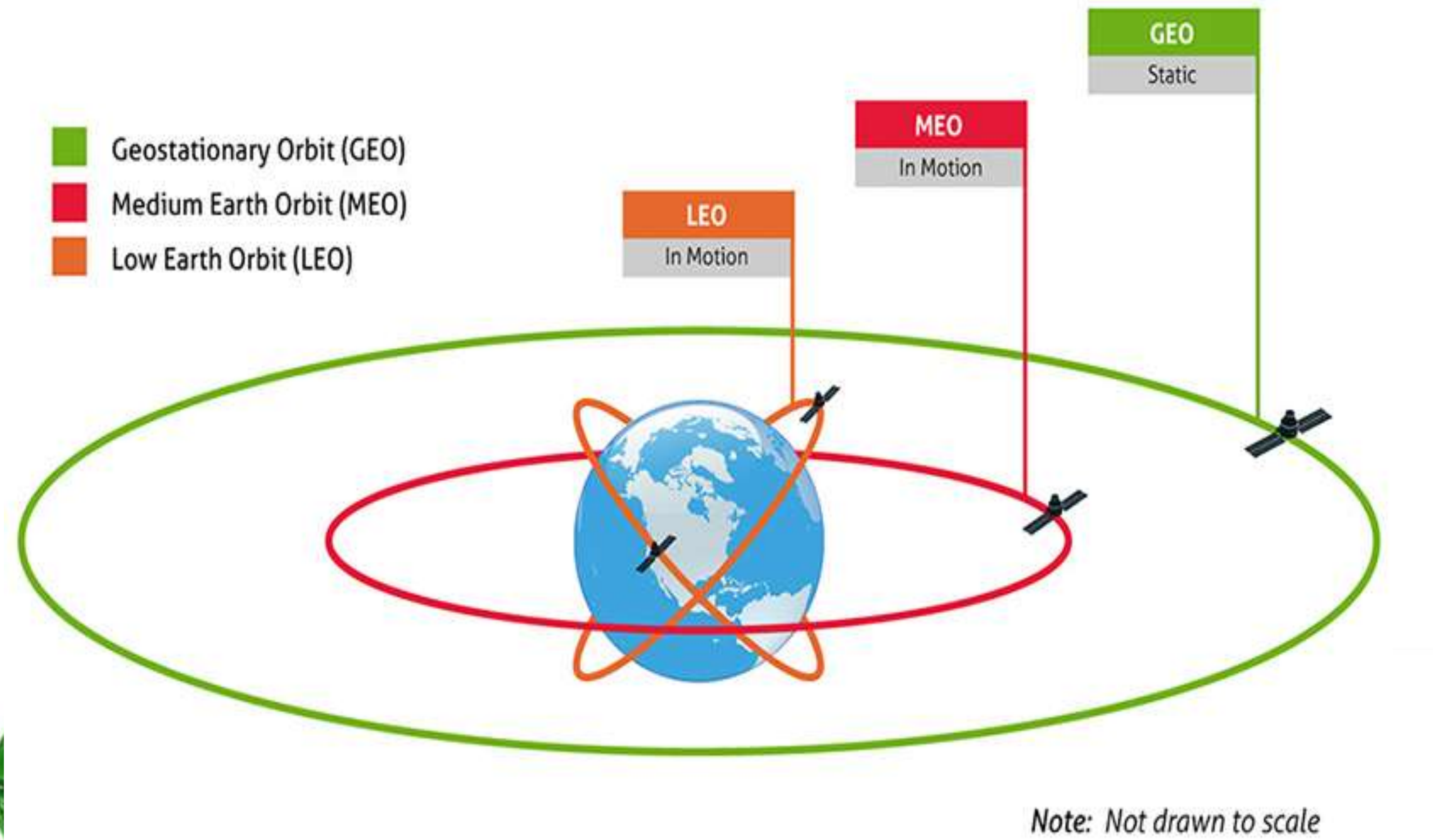
Satellite Elevation Categories

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



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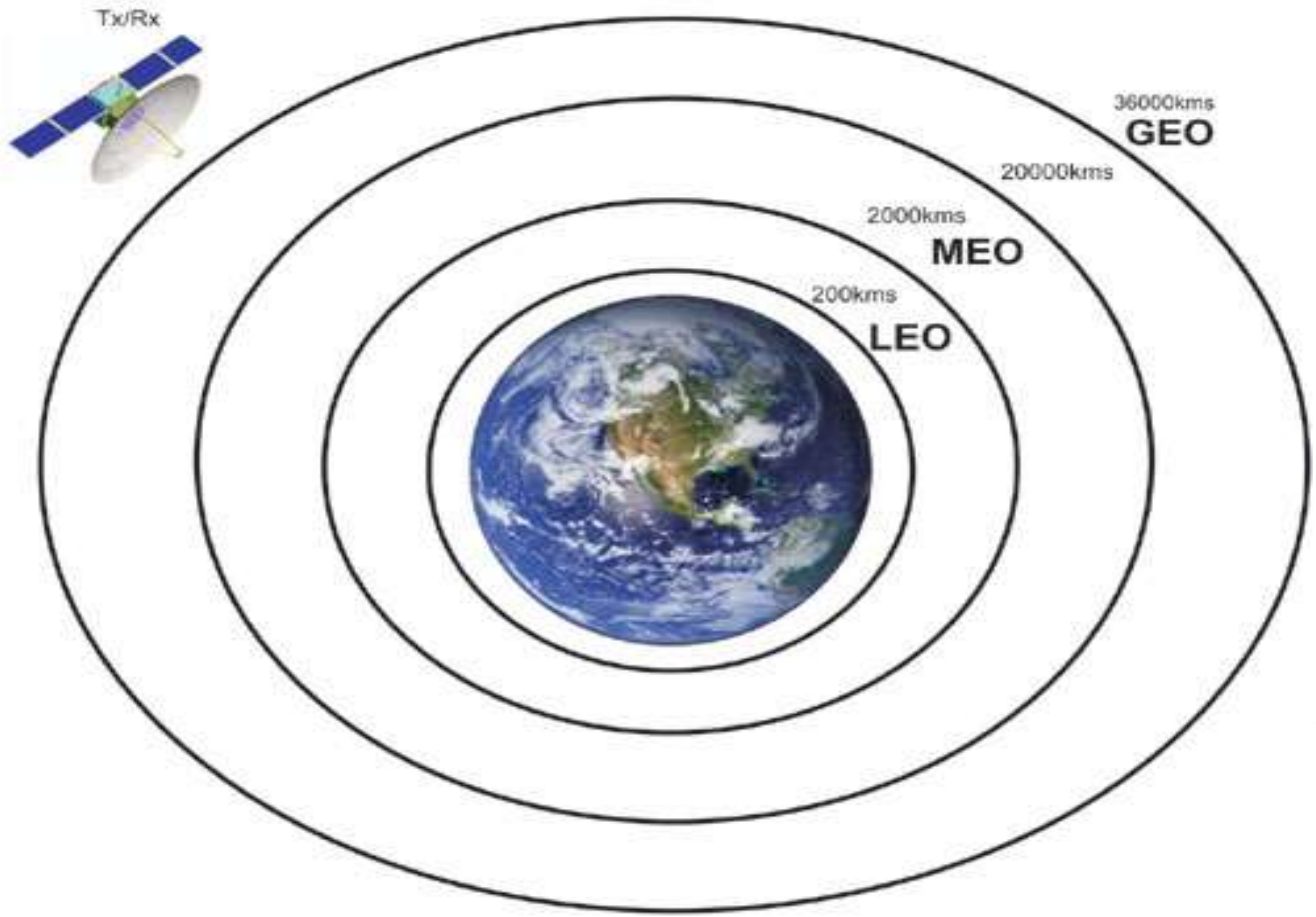


1. LEO

- The Low Earth Orbits (LEO) satellites are located approximately between 186 to 900 miles (300-1500km)
- The speed is 5 mph (8 km/s) so one revolution of the Earth 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 destined 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
- Normally LEO satellites are disposed also 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

2. MEO

- MEO satellites operate in the 1.2-GHz to 1.66-GHz frequency band and
- Orbit between 6000 miles and 12,000 miles 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.

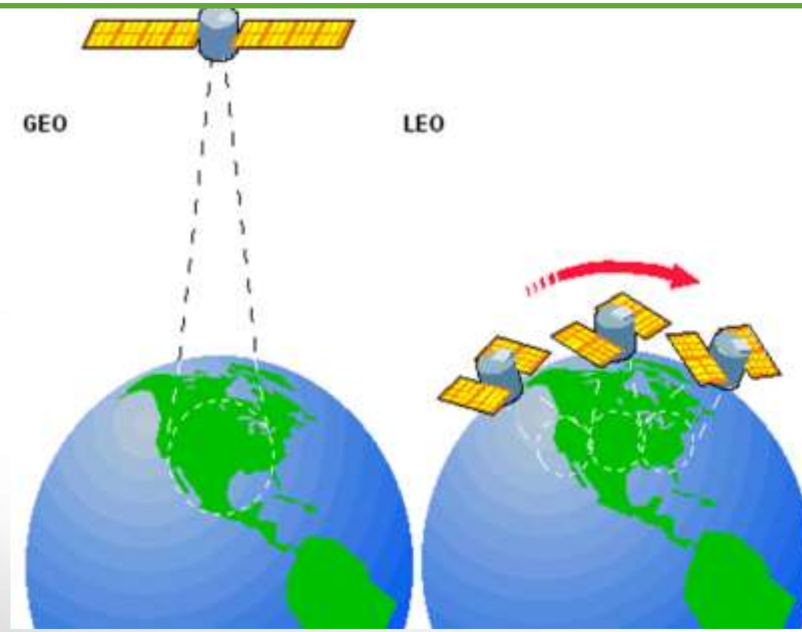
- These orbits are used above all to provide the Goblal Positioning Service (GPS) maintained by the US government, GLONASS or GALILEO, Russian and European version of GPS respectively.

- 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.

2. GEO (Geosynchronous earth orbit)

- The satellite orbits the earth about the equator at a distance of 22,300 mi (or 36,000 km).
- GEO satellite moves at the same speed as the Earth spin on its axis (24 Hours)
- In other words, it appears to be fixed or stationary
- No special earth station tracking antennas are required. The antenna is simply pointed at the satellite and remains in a fixed position.
- GEO satellites must have a 0° angle of inclination (i.e., the satellite must be orbiting directly above Earth's equatorial plane).
- Most communication satellites in use today are of the geosynchronous.

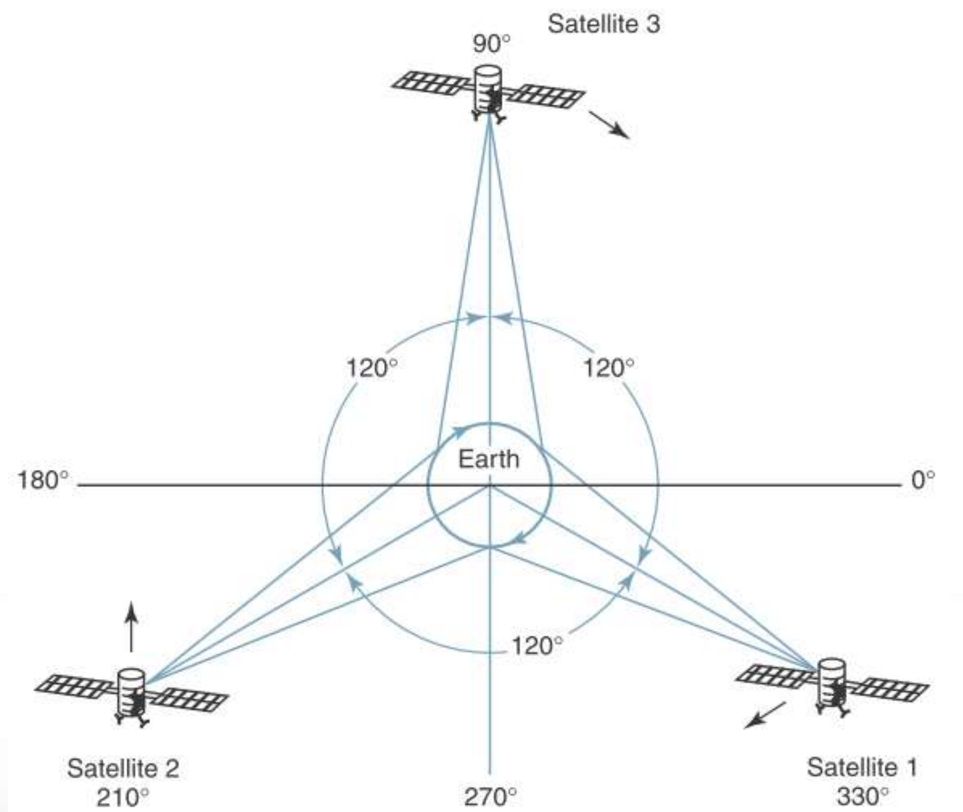
- Higher power is required for such a great distance, and
- The round-trip delay is about 260 ms, which is very noticeable in voice communication (LEO: 10 ms, MEO: 100 ms).



2. GEO (Geosynchronous earth orbit)

- These satellites are placed in the space in such a way that only three satellites are sufficient to provide connection throughout the surface of the Earth (that is; their footprint is covering almost 1/3 rd of the Earth).
- **The orbit of these satellites is circular.**

- 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.
- As shown in Figure, three satellites in Clarke orbits separated by 120° in longitude can provide communications over the entire globe except the polar regions.



2. GEO (Geosynchronous earth orbit)

- The semimajor axis of a geosynchronous earth orbit is the distance from a satellite to the center of Earth
- Using Kepler's third law , with A = 42241.0979 and P = 0.9972, the semimajor axis is given by:

$$\begin{aligned}\alpha &= AP^{2/3}\\ &= (42241.0979)(0.9972)^{2/3}\\ &= 42{,}164\ \text{km}\end{aligned}$$

- The height above mean sea level (h) of a GEO satellite is:

$$\begin{aligned}h &= 42{,}164\ \text{km} - 6378\ \text{km}\\ &= 35{,}786\ \text{km}\end{aligned}$$

2. GEO (Geosynchronous earth orbit)

➢ 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 $$v \approx 6840 \text{ mph}$$

2. GEO (Geosynchronous earth orbit)

- Round-Trip Time Delay of Geosynchronous Satellites

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

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

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

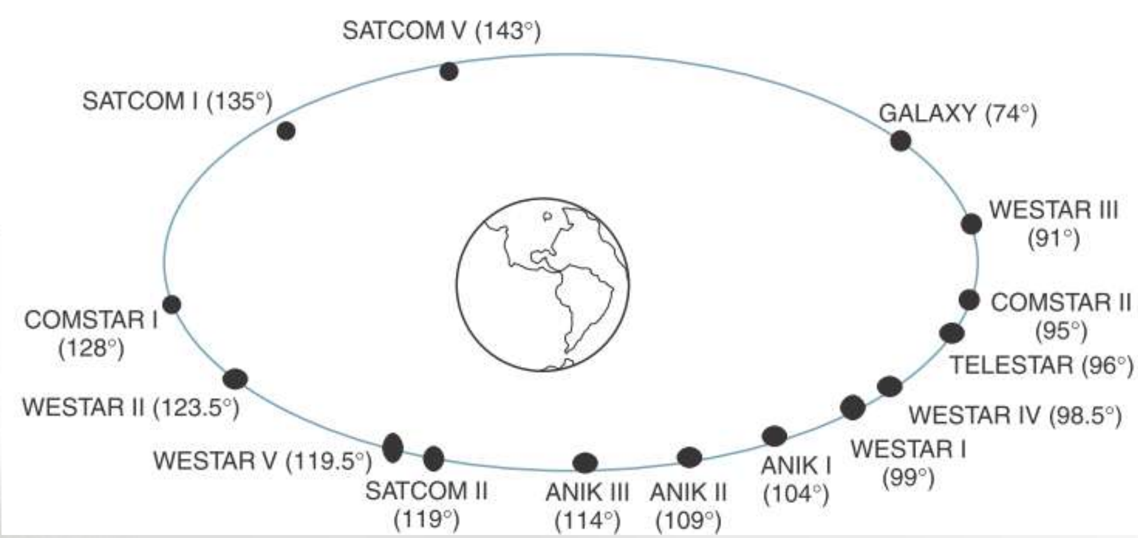
$$= 238 \text{ ms}$$

- 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. GEO (Geosynchronous earth orbit)

- 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 stipulation 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



2. GEO (Geosynchronous earth orbit)

- The disadvantages of GEO satellites :

1. Require sophisticated and heavy propulsion devices on-board to keep them in a fixed orbit.
2. High-altitude orbits introduce much longer propagation delays (can reach 500 ms and 600 ms).
3. Require higher transmit powers and more sensitive receivers because of the longer distances and greater path losses.
4. High-precision spacemanship is required to place a geosynchronous satellite into orbit and to keep it there.

Quiz (1)

- **If you have to choose between GEO system and LEO system, specify which one is better in terms of the following metrics and Why?**

1. **Coverage**
2. **Efficiency**
3. **Complexity**
4. **Cost**
5. **Frequency spectrum**
6. **Time to market**