

Advanced Electronic Communication Systems

Fourth Year, ECE

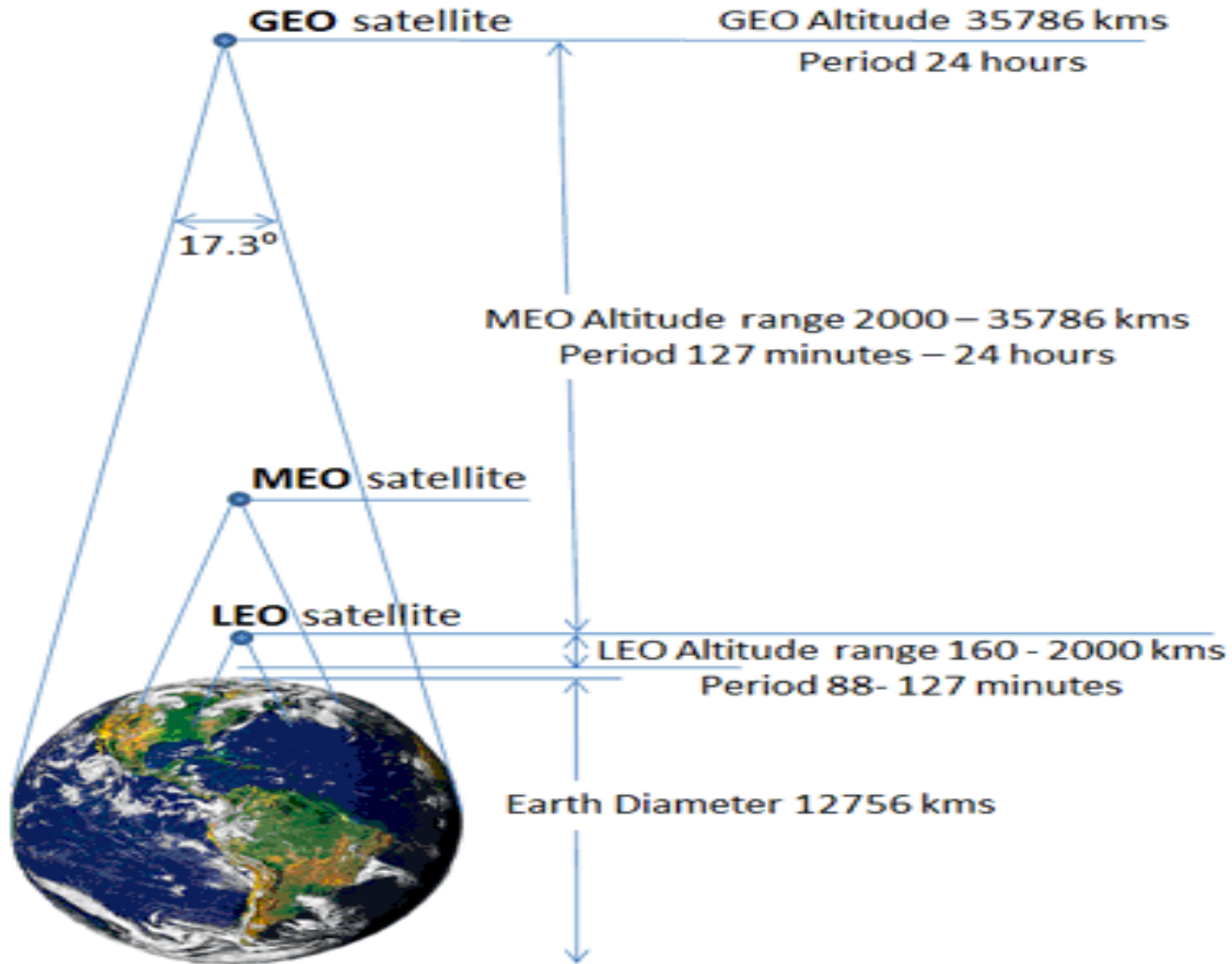


Lecture 5 – Part (1)

Sun-synchronous Orbit

Assoc. Prof. Basem M. ElHalawany

Satellite Orbits, Periods and Footprints



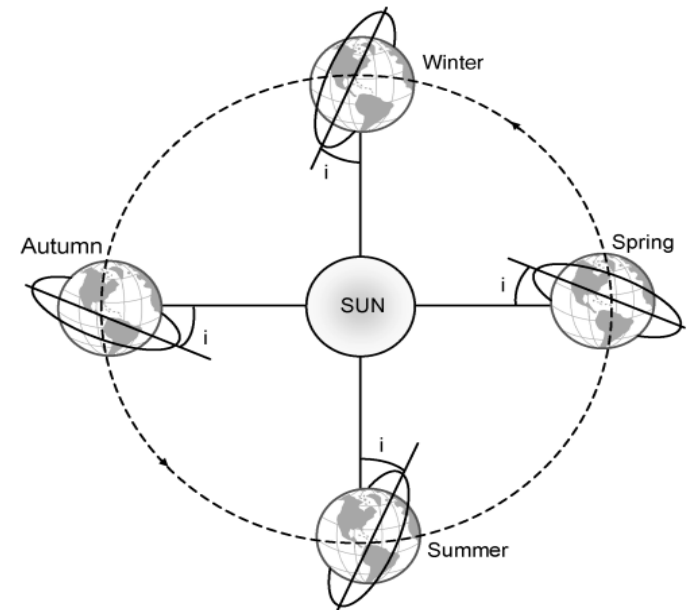
Notice that Some references does not differentiate between Geo-Synchronous and Geo-stationary satellites

2.5.4 Sun-synchronous Orbit (helio-synchronous orbit)

- Sun-synchronous orbit is one that lies in a plane that maintains a fixed angle with respect to the Earth-sun direction throughout the year.
- Satellites in sun-synchronous orbits are used for remote sensing, meteorological, military and atmospheric studies.
- They are LEO satellites with altitudes usually range from 700 to 800 km, with orbital periods of 98 to 102 minutes.

- **Sun-synchronous orbits ensure that:**

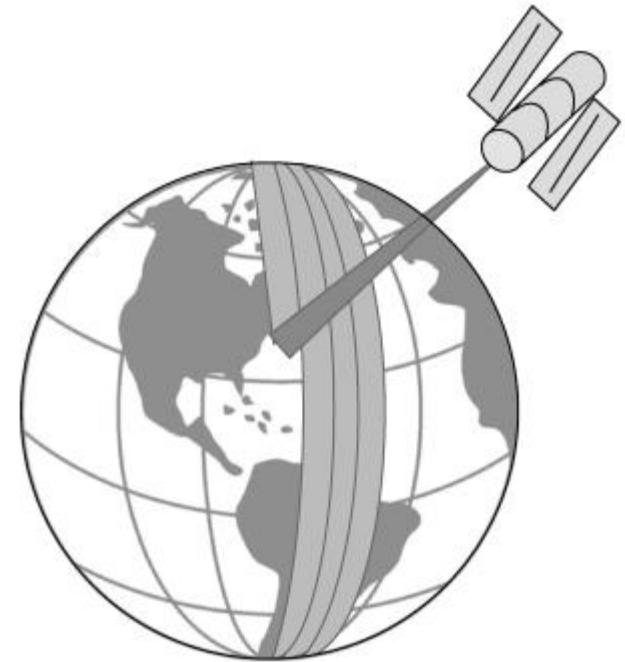
1. The satellite passes over a given location on Earth every time at the same local solar time, i.e. almost the same illumination conditions, which allows changes in surface features to be identified.
2. The satellite covers the whole surface of the Earth since it is a quasi-polar (a nearly polar orbit with inclinations of 98°).



2.5.4 Sun-synchronous Orbit (helio-synchronous orbit)

- Every time a sun-synchronous satellite completes one revolution around Earth, it traverses a **thin strip** on the surface of the Earth.
- During the next revolution it traverses **another strip shifted westward**.
- After a number of revolutions, it comes back close to the first strip.
- It may not exactly overlap the first strip, as the mean distance between the two strips, called the **tracking interval**, may not be an integral multiple of the equatorial perimeter

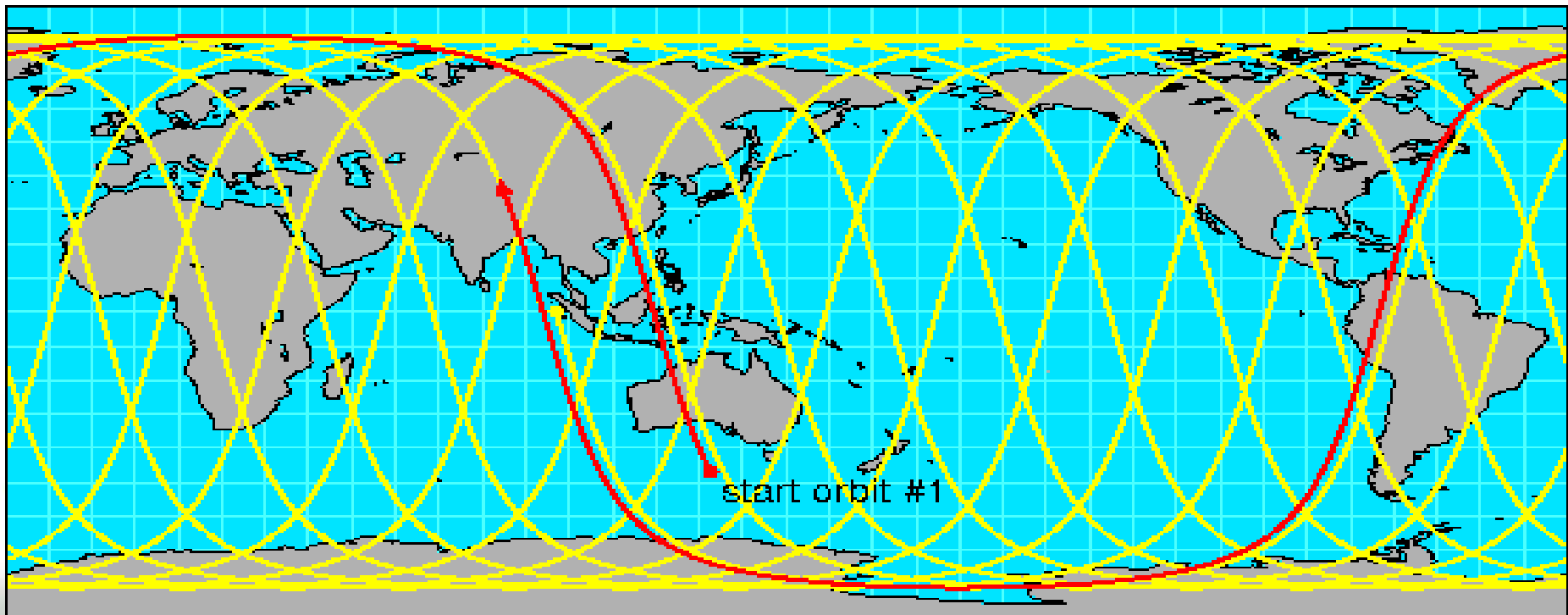
- A number of revolutions required before the satellite repeats the same strip sequence
- **An orbital cycle** means the whole number of orbital revolutions that a satellite must describe in order to be once again flying in the same direction over the same point on the Earth's surface.
- Landsat satellites series have an orbital cycle of 18 days.



2.5.4 Sun-synchronous Orbit (helio-synchronous orbit)

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- This figure duplicated the **orbital ground track** starting from the first red orbit, with 14 additional orbits drawn in yellow.
- This gives a good indication of the daily coverage of a single satellite in sun-synchronous orbit.
- Note that the satellite does not make an integer number of orbits in a single day, so that there is a slight offset in the orbital tracks after 14 orbits



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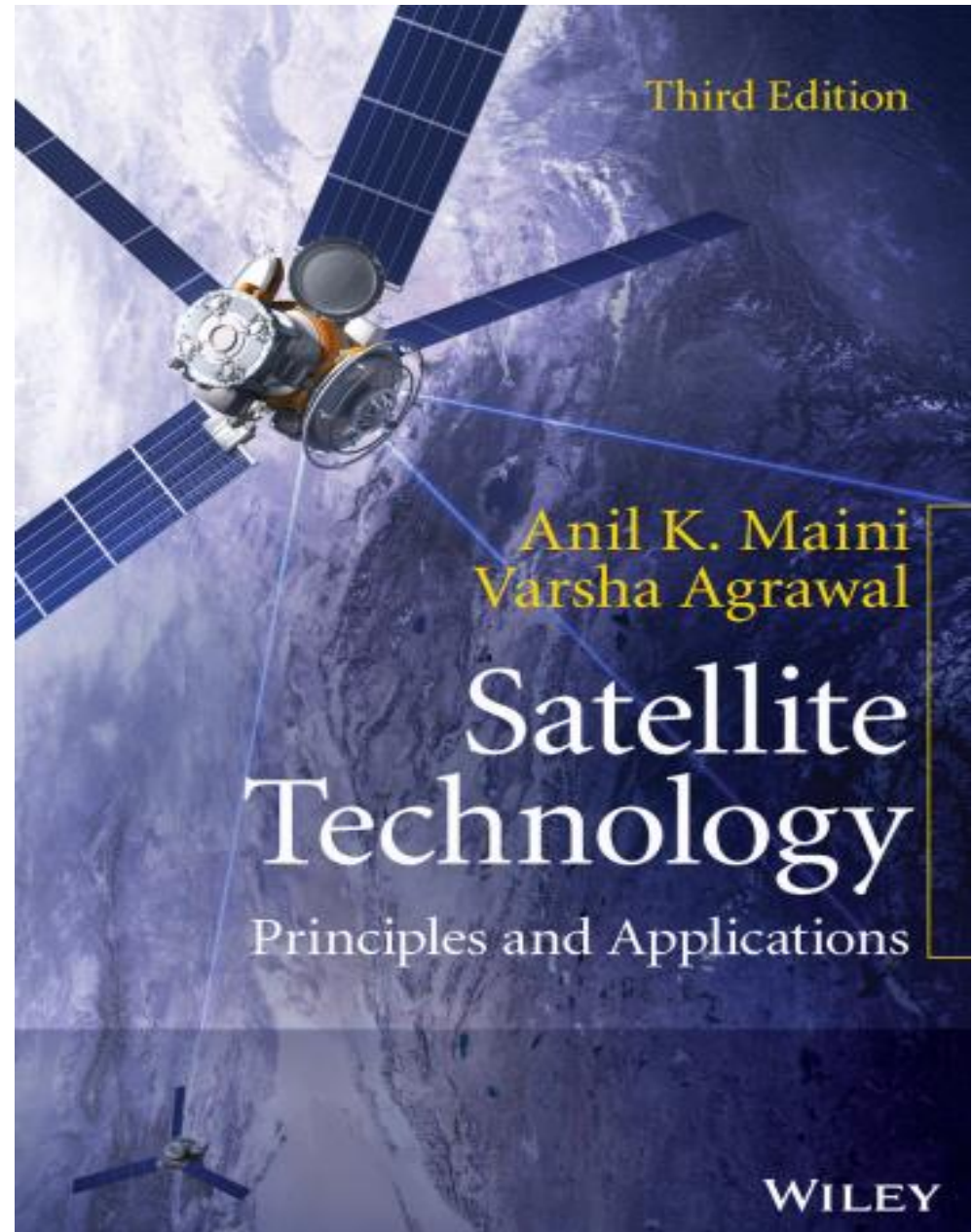


Lecture 5-Part (2)

Orbital Effects on Satellite's Performance

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Chapter (3)



- The motion of the satellite has significant effects on its performance.
- These include:
 1. **The Doppler shift effect**
 2. **The orbital distance variation effect**
 3. **The solar eclipse effect**
 4. **The sun's transit outage effect**

3.7.1 Doppler Shift:

- Usually there is a relative motion between the satellite and the Earth station terminal even for the Geo-Stationary satellites.
- The frequency of the satellite transmitter varies with respect to the receiver on the Earth station terminal.
- If the frequency transmitted by the satellite is f_T , then the received frequency f_R is given by

$$\left(\frac{f_R - f_T}{f_T} \right) = \left(\frac{\Delta f}{f_T} \right) = \left(\frac{v_T}{v_P} \right)$$

- v_T is the component of the satellite transmitter velocity vector directed towards the Earth station receiver
- v_P is the phase velocity of light in free space (3×10^8 m /s)



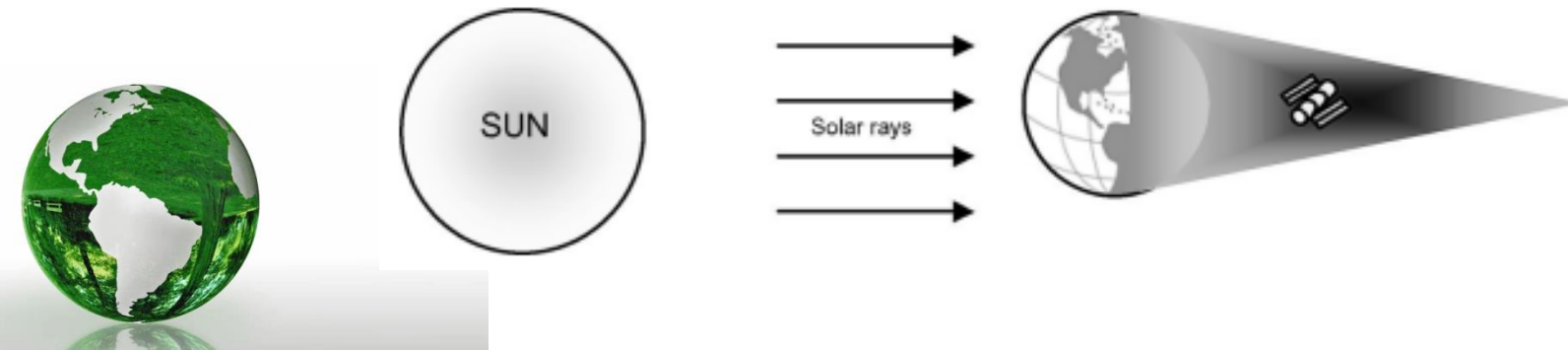
3.7.2 Variation in the Orbital Distance

- Variation in the orbital distance results in variation in the range between the satellite and the Earth station terminal.
- If a Time Division Multiple Access (TDMA) scheme is employed by the satellite, the timing of the frames within the TDMA bursts should be worked out carefully so that the user terminals receive the correct data at the correct time.
- Range variations are more predominant in LEO and MEO satellites compared to GEO satellites.



3.7.3 Solar Eclipse

- Eclipse occurs when the sunlight fails to reach the satellite's solar panel due to an obstruction from a celestial body.
- During these periods the satellites operate using onboard batteries.
- The design of the battery is such so as to provide continuous power during the period of the eclipse.
- It does not significantly affect low power satellites, which can usually continue their operation with back-up power.
- The high power satellites, however, shut down for all but essential services
- The major and most frequent source of an eclipse is due to the satellite coming in the shadow of the Earth (**Solar Eclipse**)



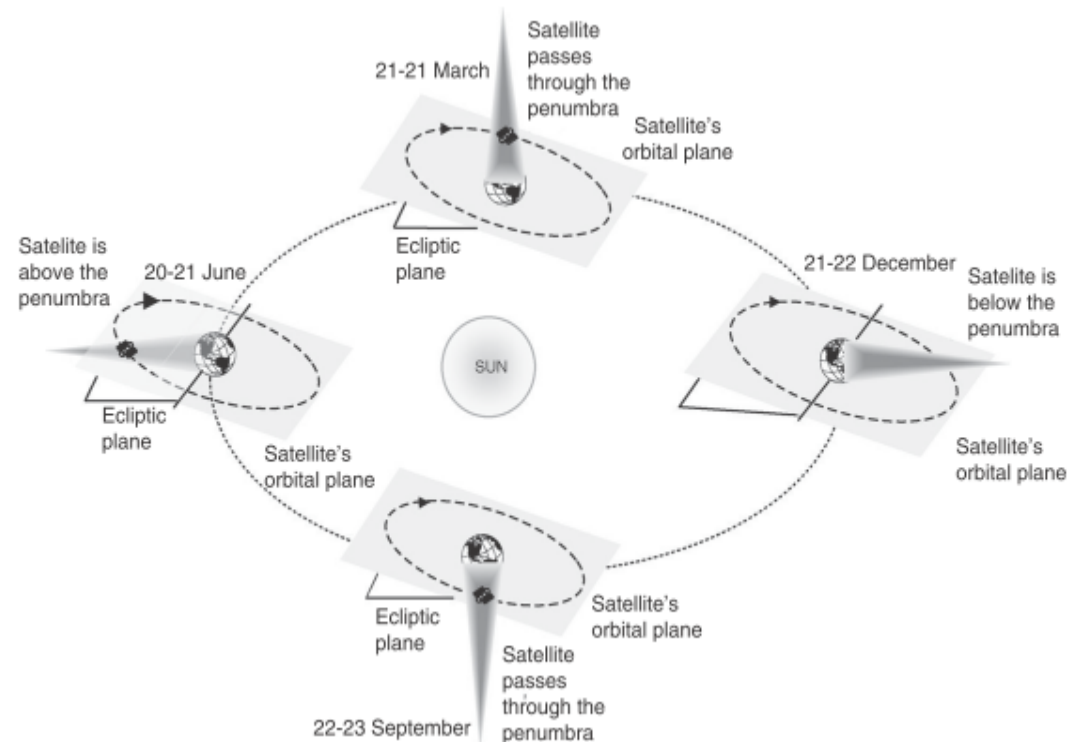
Solar Eclipse:

- Umbra: is the dark central region of the shadow, where a total eclipse occurs when the satellite fails to receive any light
- Penumbra: is the less dark region surrounding the umbra, where the satellite receives very little light



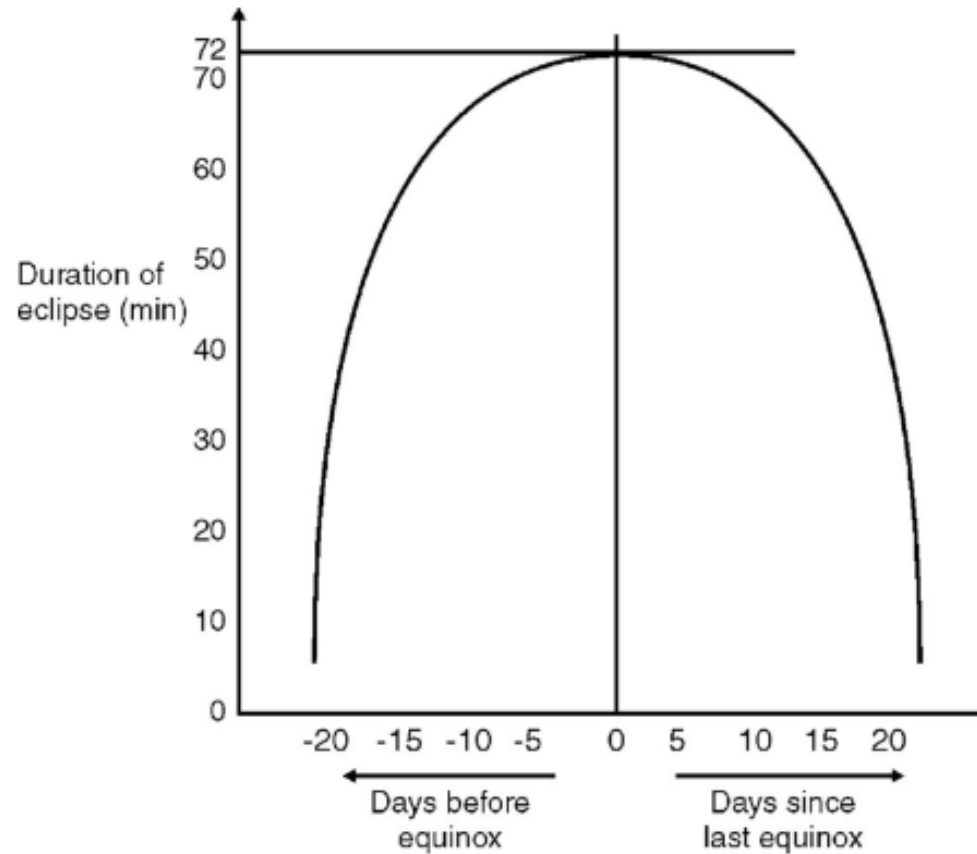
Solar Eclipse:

- The eclipse is seen on 42 nights during the spring and an equal number of nights during the autumn by the geostationary satellite.
- The effect is the worst during the equinoxes (lasts 72 minutes).
- From 21 days before and 21 days after the equinoxes, the satellite crosses the umbral cone each day for some time, thereby receiving only a part of solar light for that time.
- During the rest of the year, the geostationary satellite orbit passes either **above** or **below** the umbral cone, where it is at the maximum distance at the time of the **solstices**.



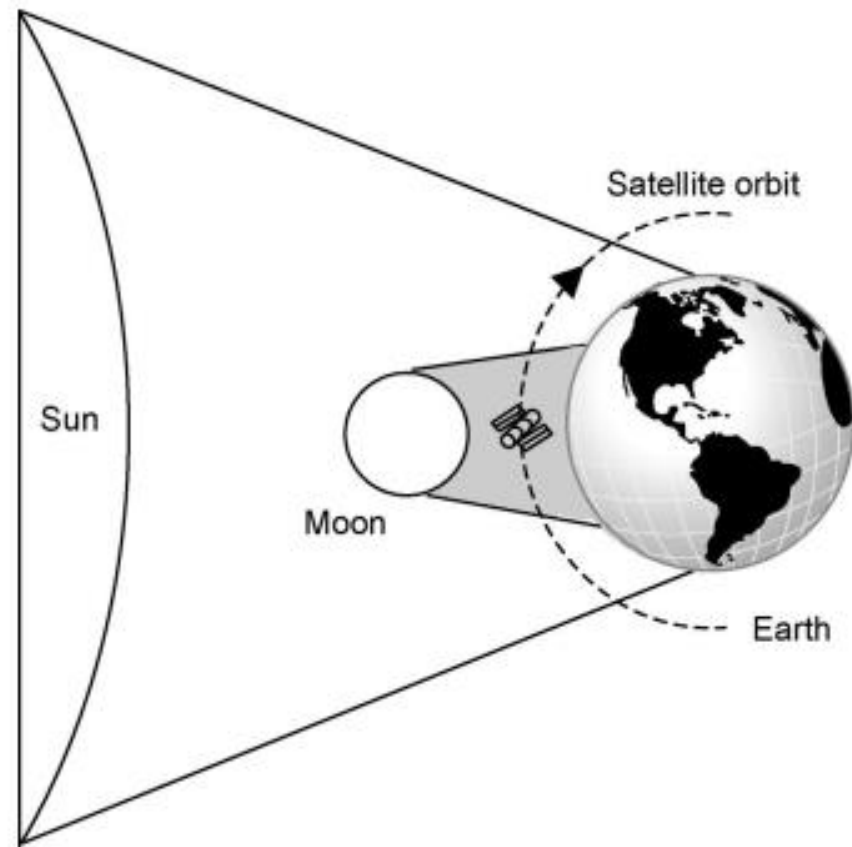
Eclipse:

- The duration of an eclipse on a given day around the equinox can be seen from the graph



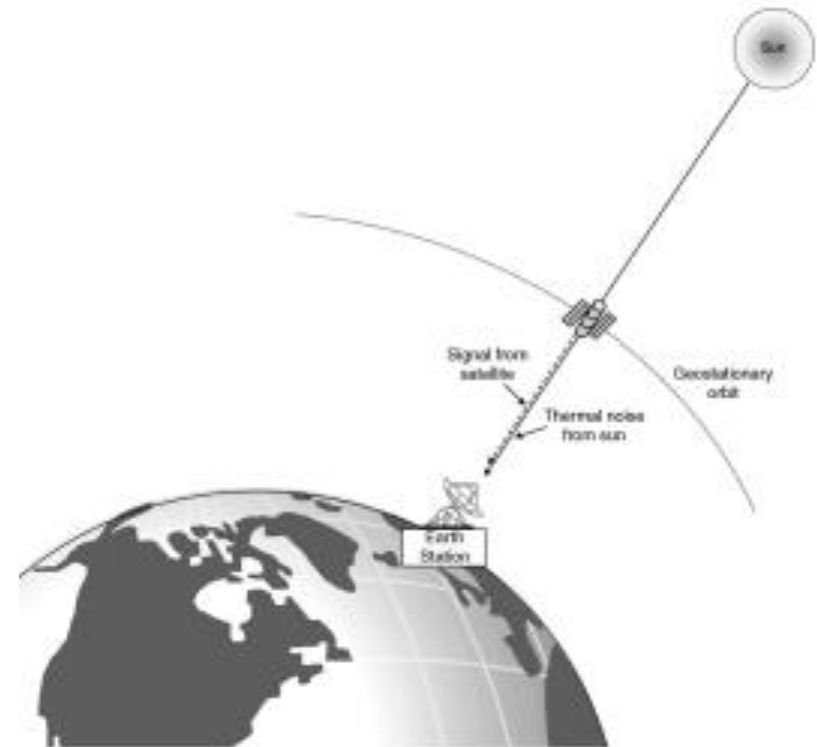
Lunar Eclipse:

- Lunar eclipse occurs when the moon's shadow passes across the satellite
- This is much less common and occurs once in 29 years.



3.7.4 Sun Transit Outrage

- The times when the satellite passes between the sun and the Earth
- The Earth station antenna will receive signals from the satellite as well as the microwave radiation emitted by the sun
- This might cause temporary outage if the magnitude of the solar radiation exceeds the fade margin of the receiver.
- The traffic of the satellite may be shifted to other satellites during such periods.



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Lecture 5 – Part (3)

Satellite Coordinates and Look Angles

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Position Coordinates in Latitude and Longitude.

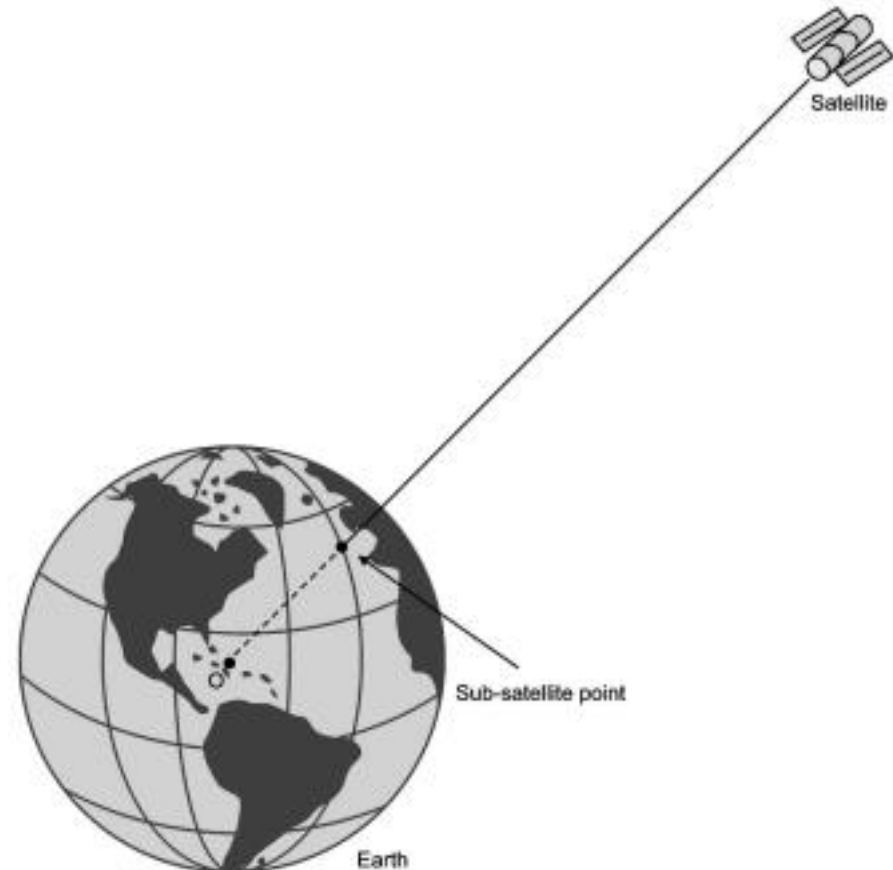
- To use a satellite, you must be able to locate its position in space.
- Once the position is known, the earth station antenna can be pointed at the satellite for optimum transmission and reception.
- A tracking system must be employed (essentially an antenna whose position can be changed to follow the satellite across the sky.)

- ✓ The location of a satellite is generally specified in terms of **latitude** and **longitude similar to other points on Earth**
- ✓ However, because a satellite is orbiting many miles above the Earth's surface, it has no latitude or longitude itself



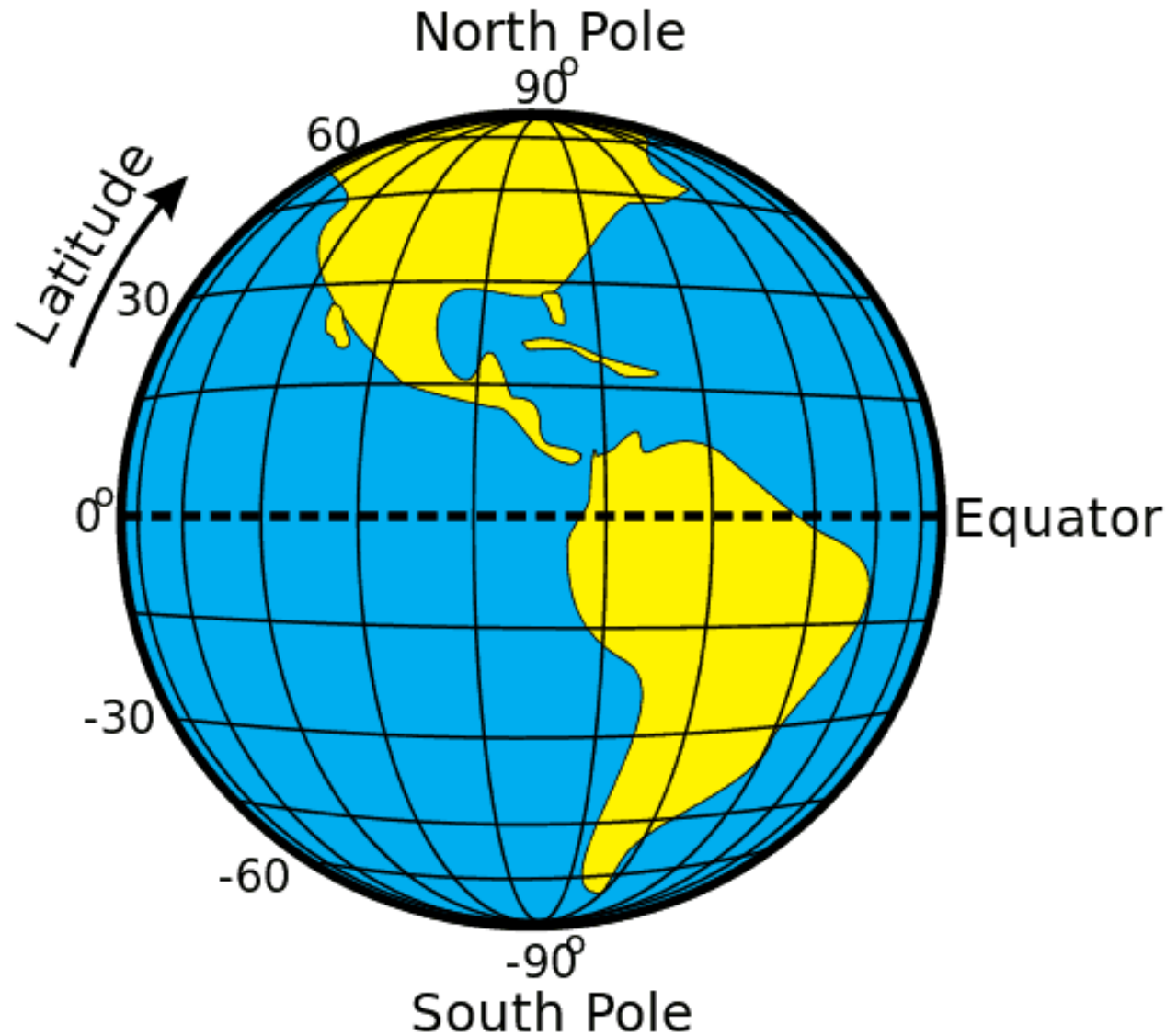
- The satellite location is specified by **a point on the surface** of the earth directly below the satellite (known as the **subsatellite** point “SSP”).
- The sub-satellite point is the location on the surface of the Earth that lies directly between the satellite and the centre of the Earth.
- The subsatellite point is then located by using **standard latitude and longitude** designations.

To an observer on the sub-satellite point, the satellite will appear to be directly overhead.



Standard latitude and longitude coordinates

Latitudes measure how far a point is north or south of the equator.

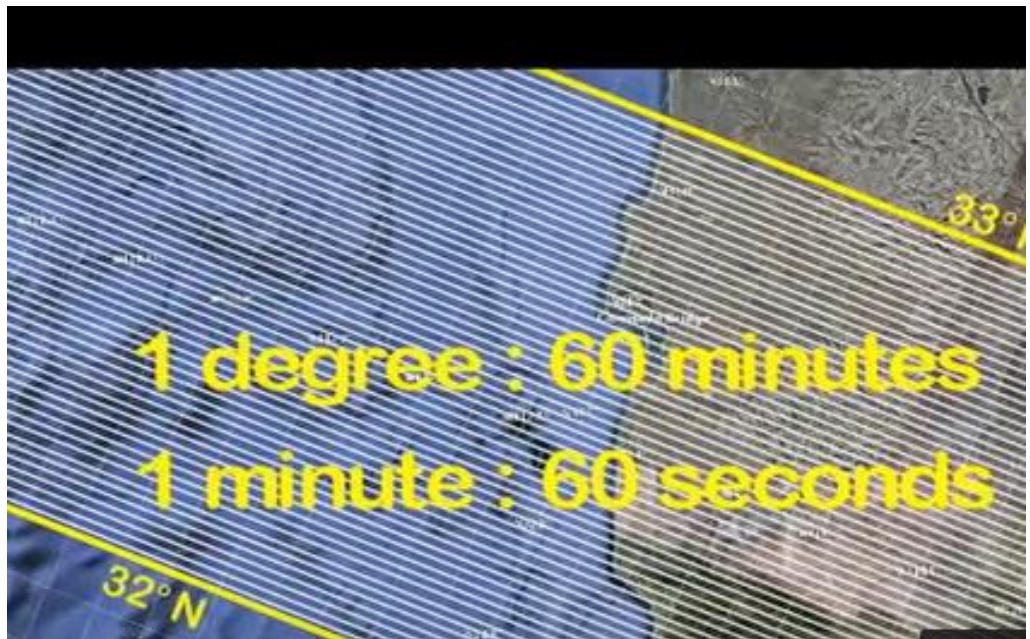


Standard latitude and longitude coordinates

latitudes

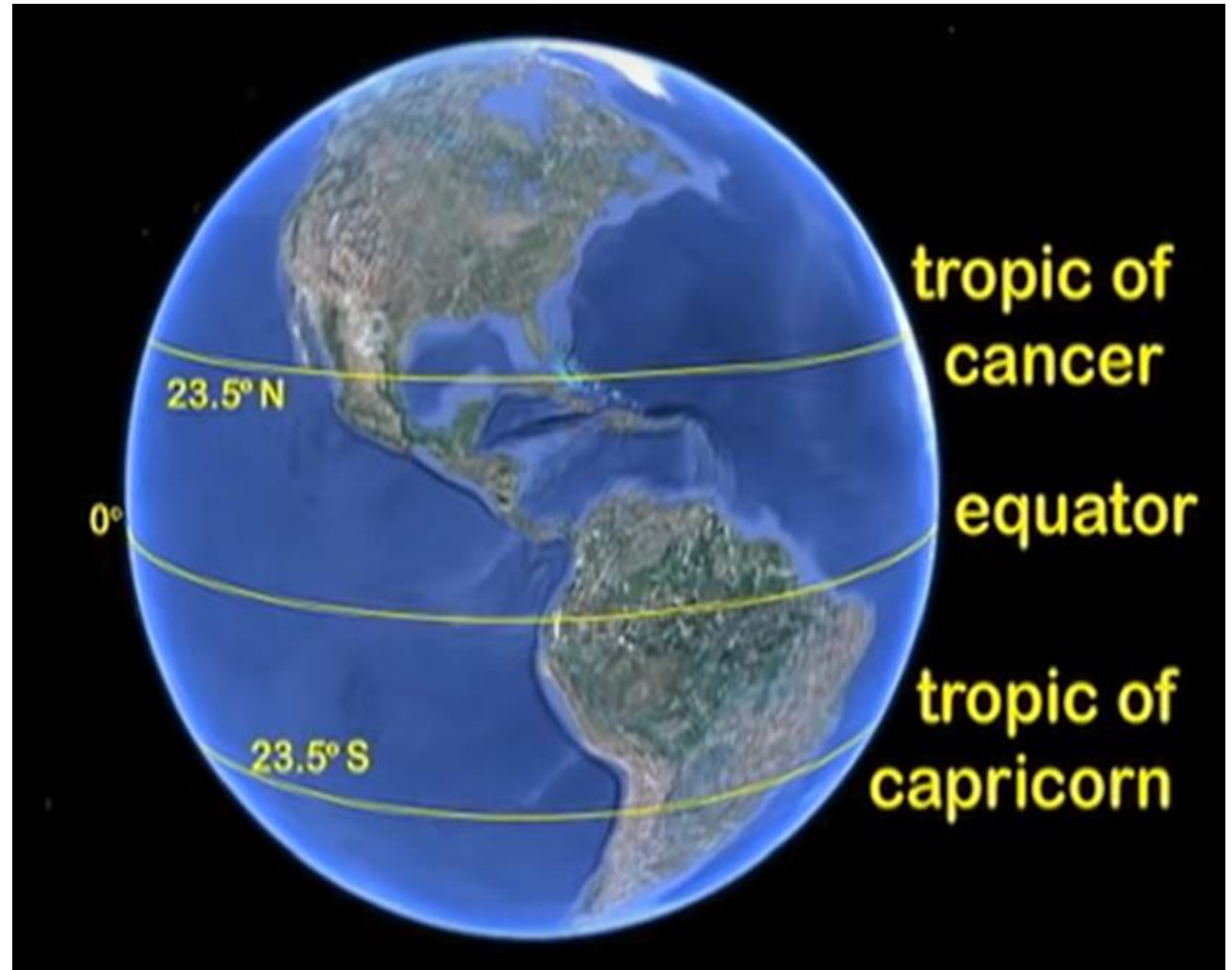
The same distance apart

- Lines of latitude are 180 deg in total
- Distance between each degree of latitude is about 69 miles (110 kilometers).



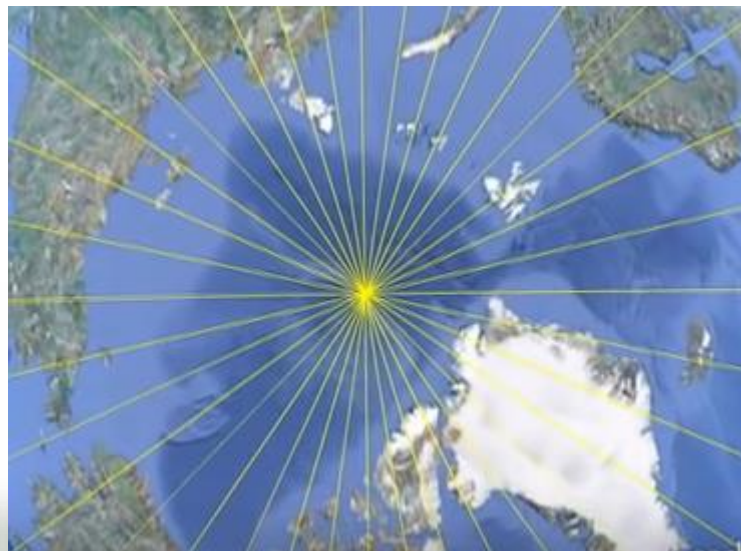
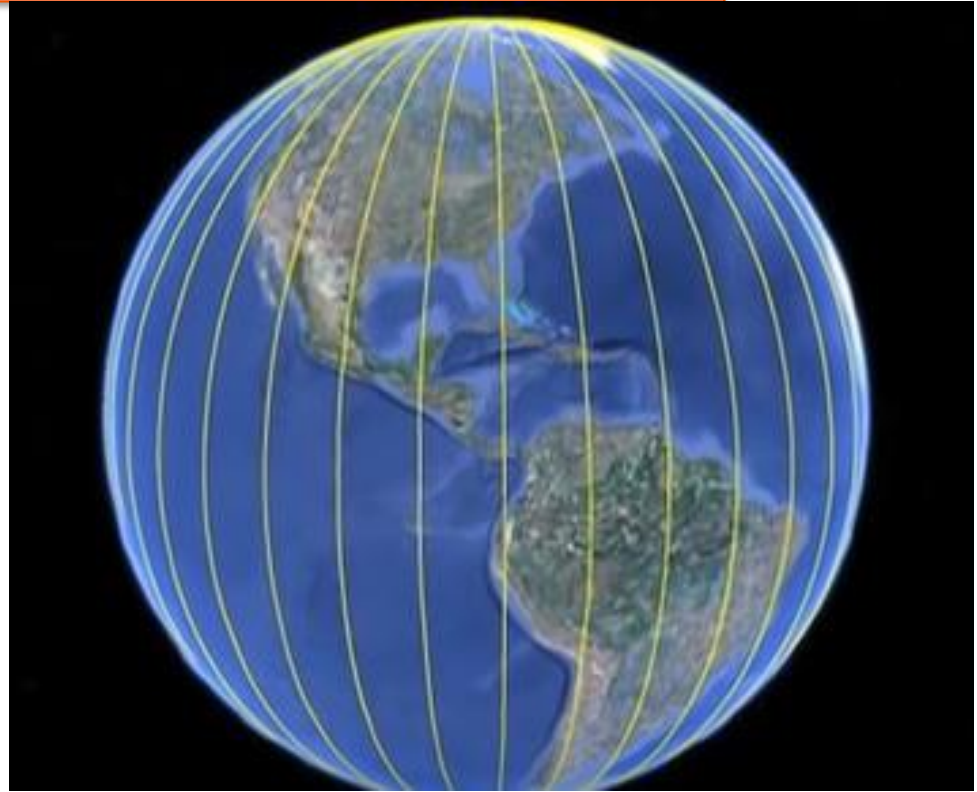
Standard latitude and longitude coordinates

Unique latitudes

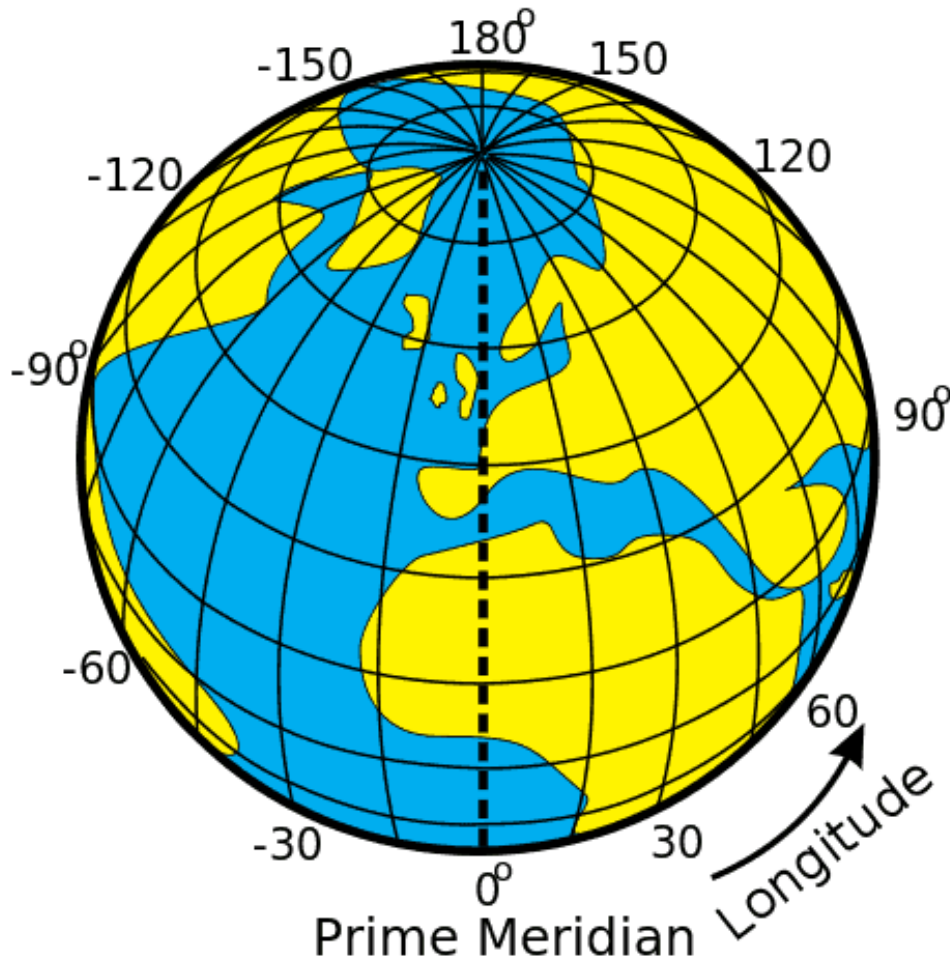


Standard latitude and longitude coordinates

Longitudes (Meridians) measure how far a point is east or west of the prime meridian -- arbitrarily set as Greenwich, England.



- Longitudes are not equi-distant from each others like latitude
- They intersect at both north and south poles



- **Prime Meridian lies on Royal observatory at Greenwich**



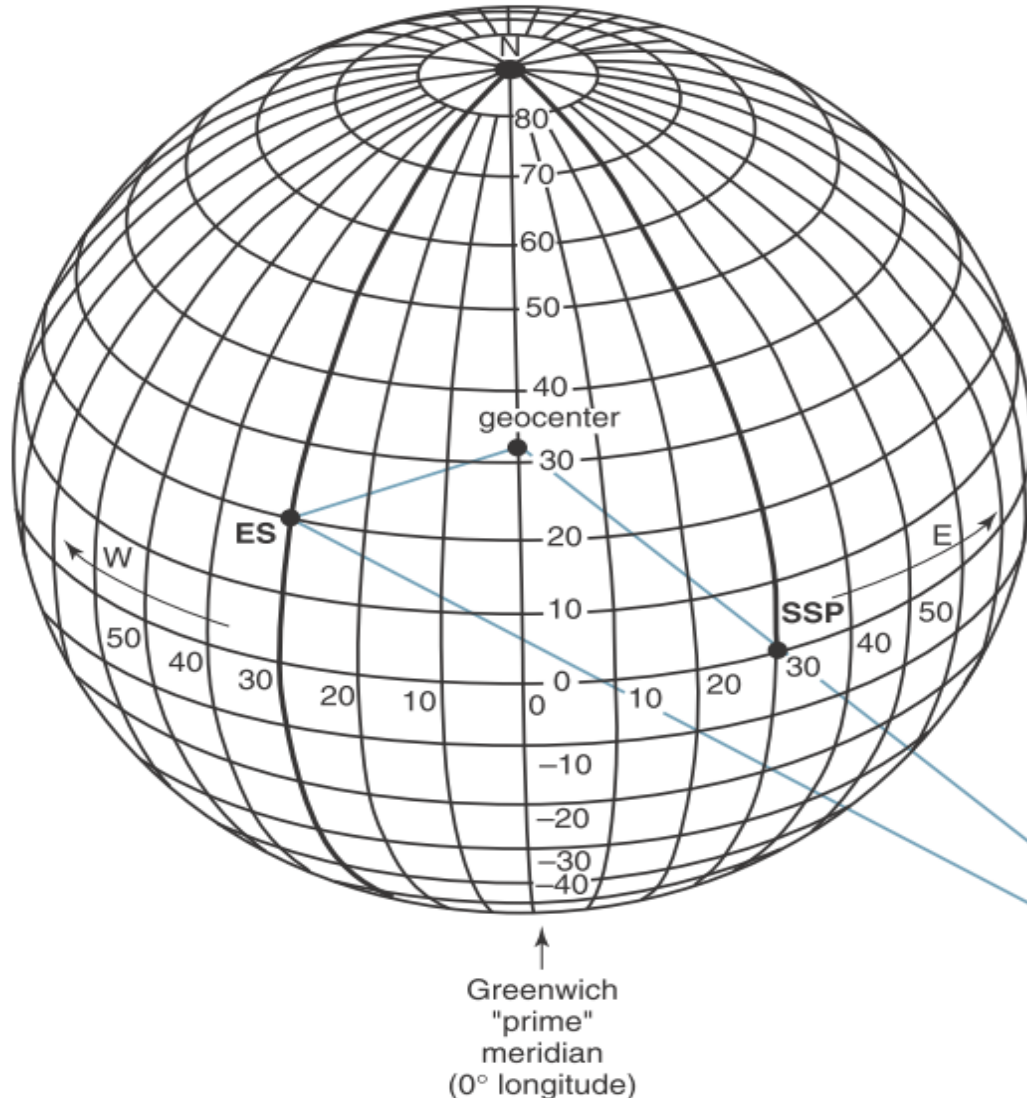
Standard latitude and longitude coordinates

➤ Location coordinates



Satellites and earth stations coordinates

- ✓ An earth station (ES) has a location of 30°W longitude and 20°N latitude.



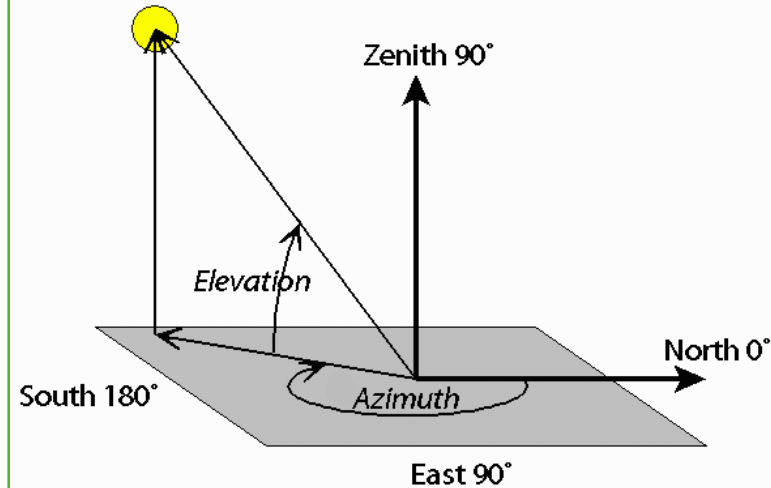
- ✓ Since Geo-Stationary satellites vehicle (GSV) are located directly above the equator, they all have a 0° latitude.
- ✓ Their locations are normally given in degrees longitude east or west of the Greenwich meridian (Ex. 30°E).



Look Angles (Elevation and Azimuth Angle)

- The earth station need to know the **azimuth** and **elevation** settings of its antenna to intercept the satellite.

- ✓ **Azimuth** tells you what direction to face and **Elevation** tells you how high up in the sky to look.
- ✓ Both are measured in degrees.
- ✓ Azimuth refers to the rotation of the whole antenna around a vertical axis
- ✓ Azimuth varies from 0° to 360° .
- ✓ It starts with North at 0° . As you turn to your right (in a clockwise direction) you'll face East (which is 90°), then South (which is 180°), then West (which is 270°), and then return to North (which is 360° and also 0°).

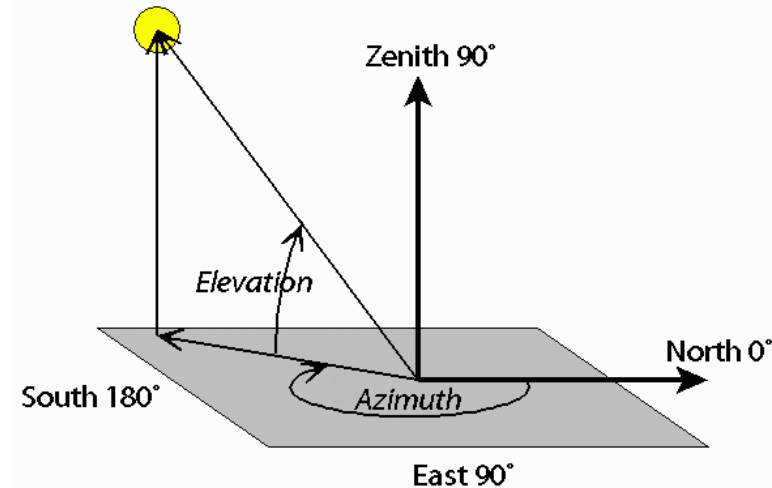


Look Angles (Elevation and Azimuth Angle)

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- Generally, the values of these angles change for non-geostationary orbits. Whereas, the values of these angles don't change for geostationary orbits.

✓ Depending upon the location of the Earth station and the sub-Satellite point, the azimuth angle can be computed as follows:

- **Earth station in the northern hemisphere:**

$A = 180^\circ - A'$ when the Earth station is to the west of the satellite

$A = 180^\circ + A'$ when the Earth station is to the east of the satellite

- **Earth station in the southern hemisphere:**

$A = A' \dots$ when the Earth station is to the west of the satellite

$A = 360^\circ - A' \dots$ when the Earth station is to the east of the satellite

where A' can be computed from

$$A' = \tan^{-1} \left(\frac{\tan |\theta_s - \theta_L|}{\sin \theta_1} \right)$$

θ_s = satellite longitude

θ_L = Earth station longitude

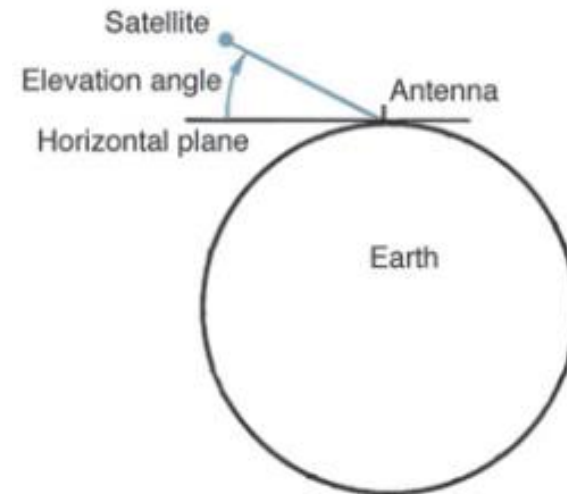
θ_1 = Earth station latitude



$$E = \tan^{-1} \left[\frac{r - R \cos \theta_1 \cos |\theta_s - \theta_L|}{R \sin \{ \cos^{-1}(\cos \theta_1 \cos |\theta_s - \theta_L|) \}} \right] - \cos^{-1}(\cos \theta_1 \cos |\theta_s - \theta_L|)$$

r = orbital radius, R = Earth's radius

θ_s = Satellite longitude, θ_L = Earth station longitude, θ_1 = Earth station latitude



- **The slant range:** is line of sight distance between the Earth station and the satellite.
- The smaller the elevation angle of the Earth station, the larger is the slant range and the coverage angle.

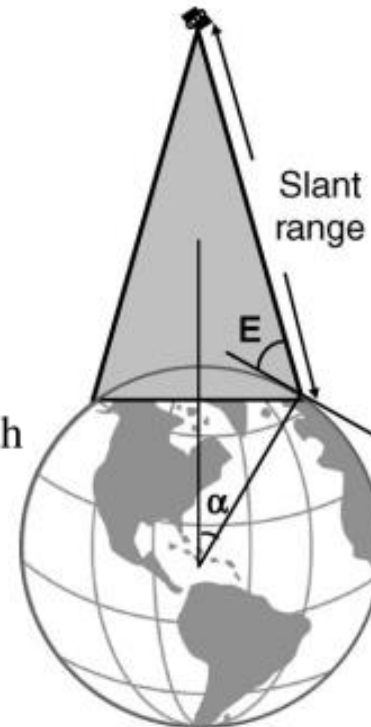
$$\text{Slant range } D = \sqrt{R^2 + (R + H)^2 - 2R(R + H) \sin \left[E + \sin^{-1} \left\{ \left(\frac{R}{R + H} \right) \cos E \right\} \right]}$$

$$\text{Coverage angle } \alpha = \sin^{-1} \left\{ \left(\frac{R}{R + H} \right) \cos E \right\}$$

R = radius of the Earth

E = angle of elevation

H = height of the satellite above the surface of the Earth



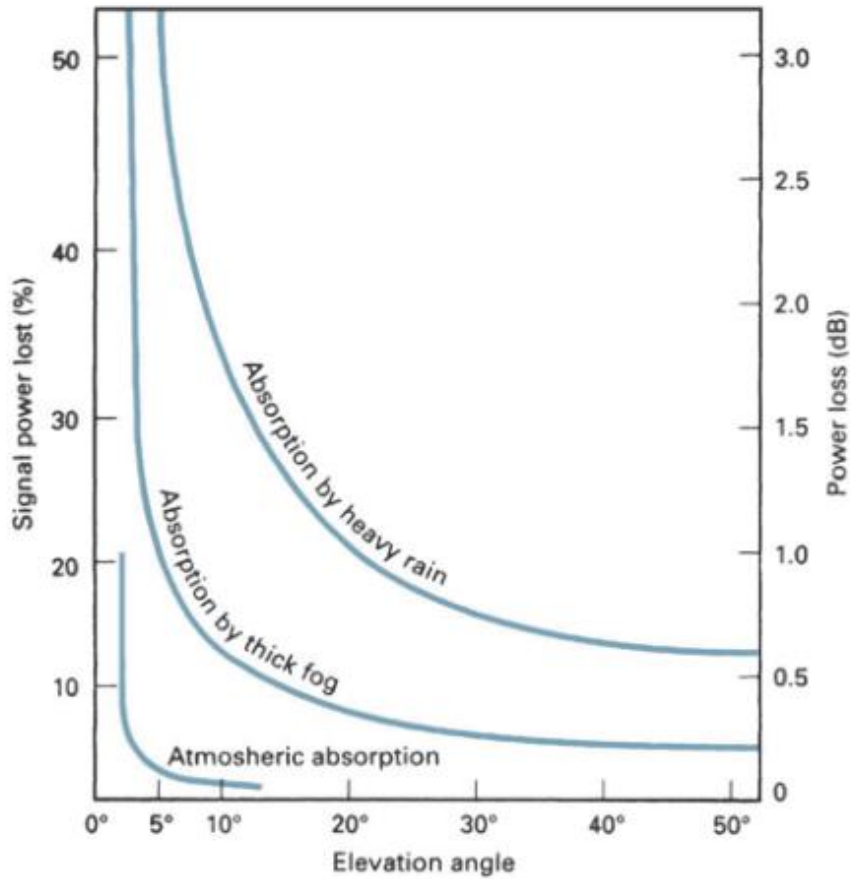
α = Coverage angle

E = Elevation angle



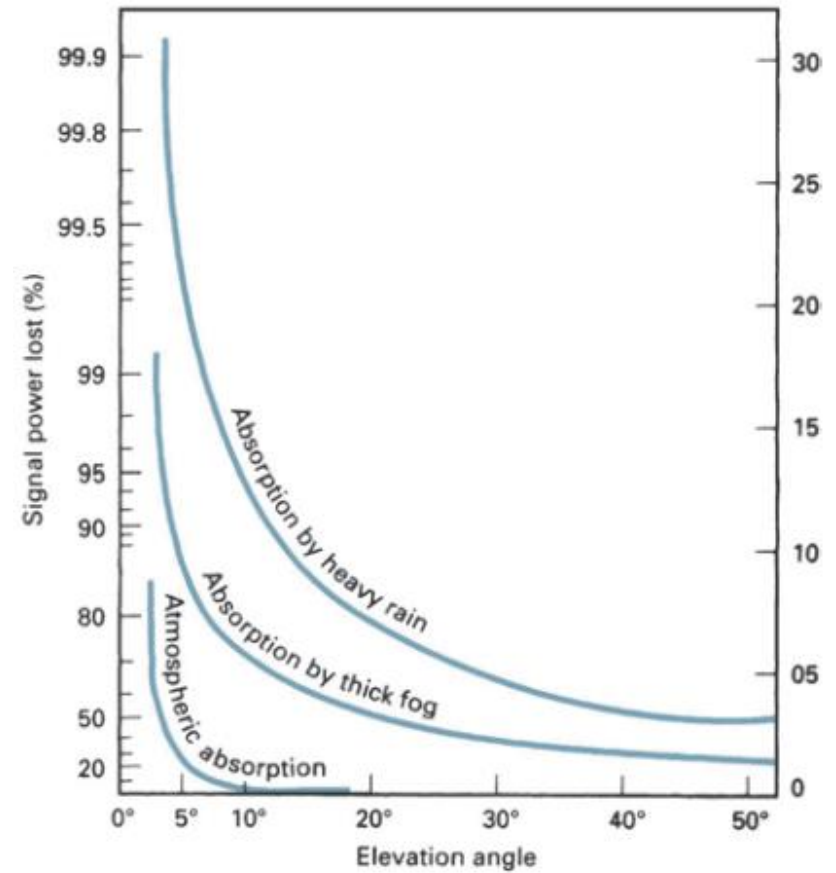
- The **smaller the angle** of elevation, the larger slant range means a longer propagation delay time and a greater impairment of signal quality, as the signal has to travel a greater distance through the Earth's atmosphere.
- Generally, 5° is considered as the minimum acceptable angle of elevation.
- Delay is defined as the slant angle divided by the speed of Electromagnetic wave





(a)

[a] 6/4-GHz band;



(b)

[b] 14/12-GHz band

FIGURE 10 Attenuation due to atmospheric absorption:

- The 14/12-GHz band is more severely affected than the 6/4-GHz band
- At elevation angles less than 5°, the amount of signal power lost increases significantly.

Thank you



<https://www.youtube.com/watch?v=tX3Y5bzNDiU>

<https://ral.ucar.edu/~djohnson/satellite/coverage.htm>

|

Sun-Synchronous ground tracks:

<https://ral.ucar.edu/~djohnson/satellite/coverage.html>

