# Advanced Electronic Communication Systems
# Fourth Year, ECE

## Lecture 5

## Orbital Effects on Satellite's Performance

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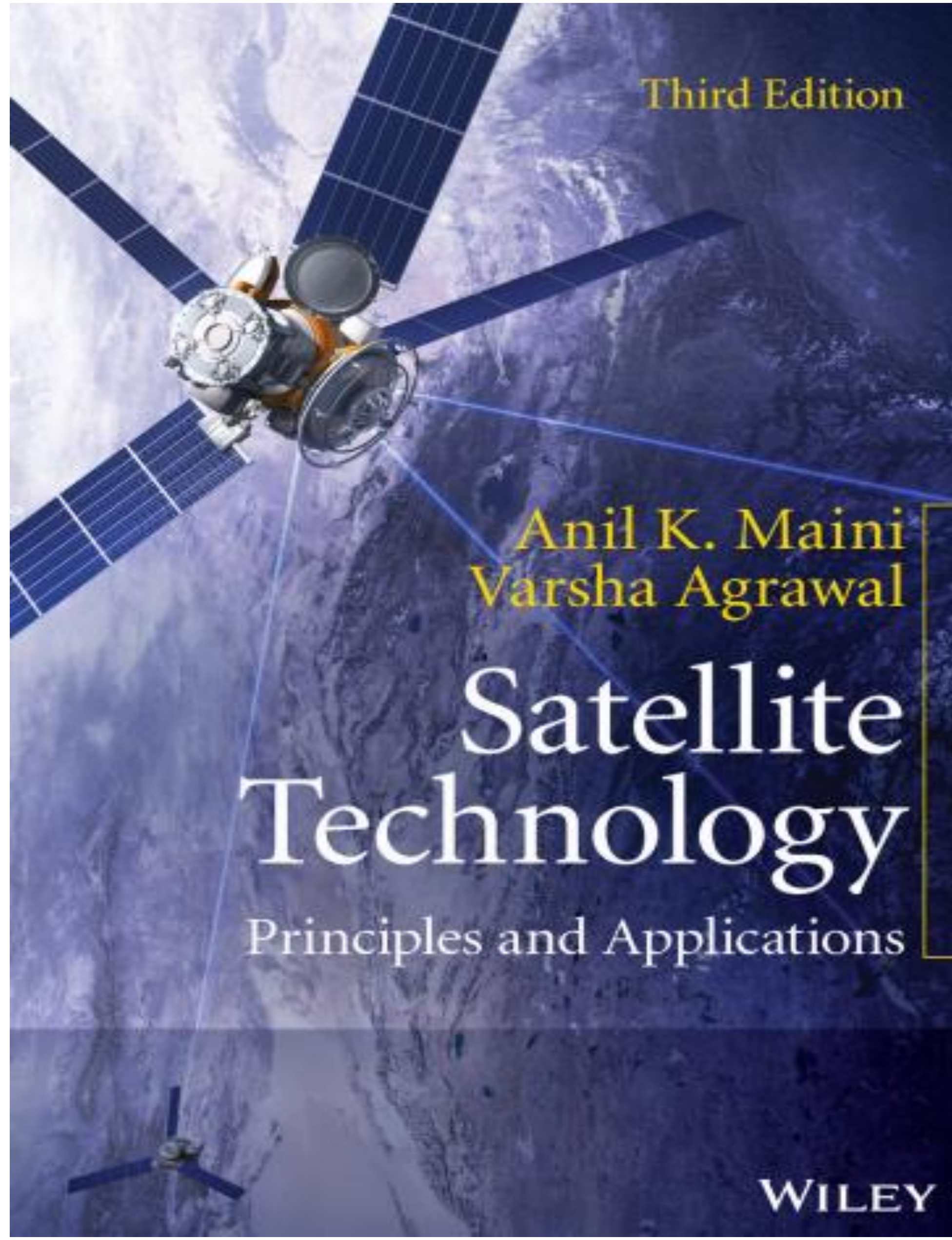
# 3.7 Orbital Effects on Satellite's Performance



Chapter (3)



# 3.7 Orbital Effects on Satellite's Performance

- 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 outrage 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 velocity of light in free space ($3 \times 10^8$ m /s)

# 3.7 Orbital Effects on Satellite's Performance

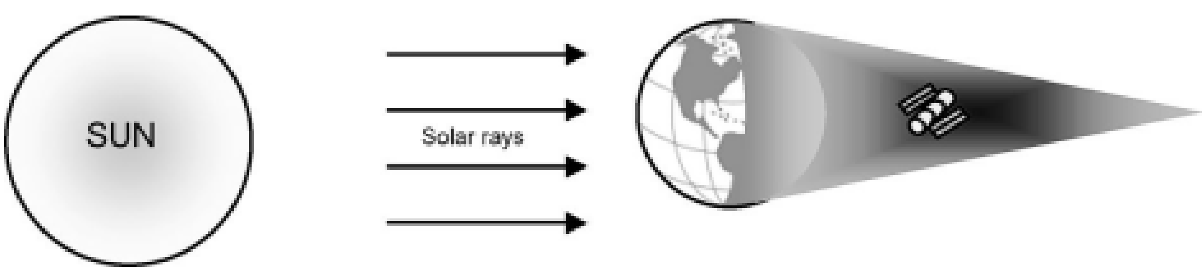


## 3.7.2 Variation in the Orbital Distance

- 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:

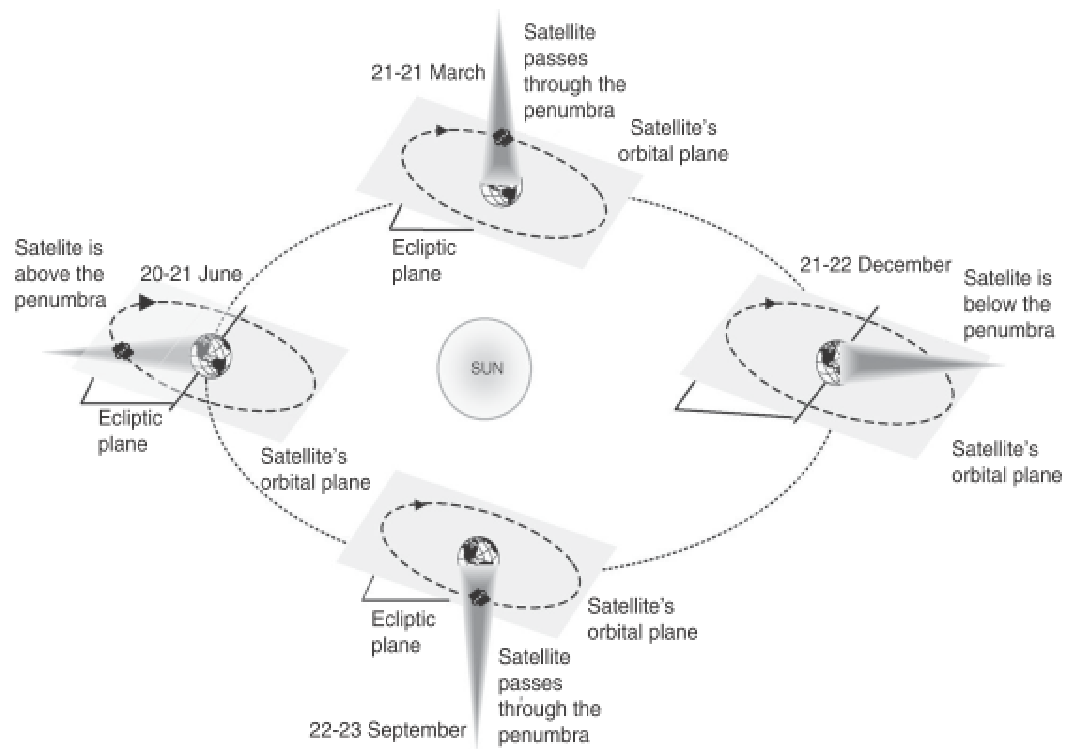
- Umbra: is the dark central region of the shadow, where a total eclipse occurs when the satellite fails to receive any light
- Penumbra: is the less dark region surrounding the umbra , where the satellite receives very little light

# 3.7 Orbital Effects on Satellite's Performance



## 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.

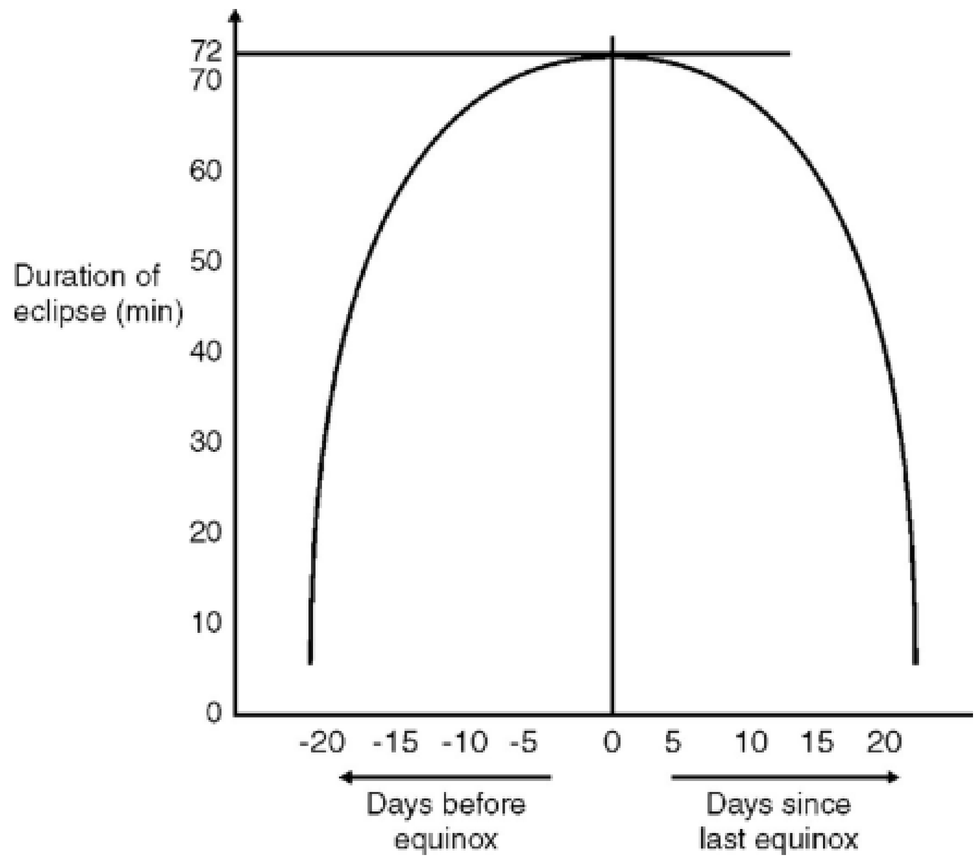



# 3.7 Orbital Effects on Satellite's Performance



## Eclipse:

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

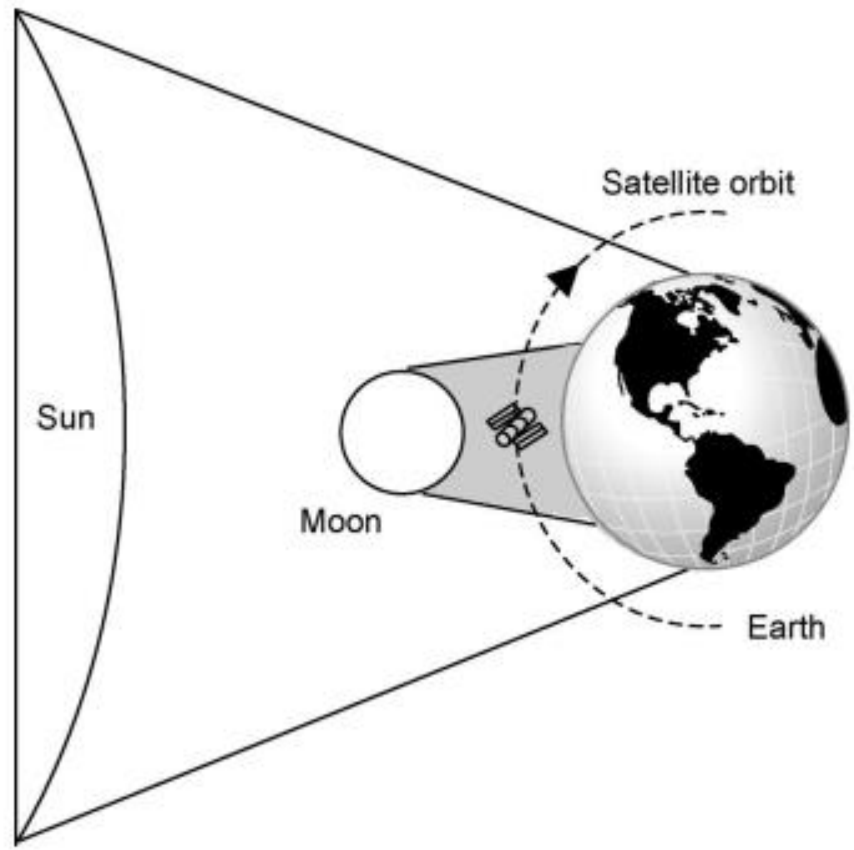


# 3.7 Orbital Effects on Satellite's Performance



## 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.



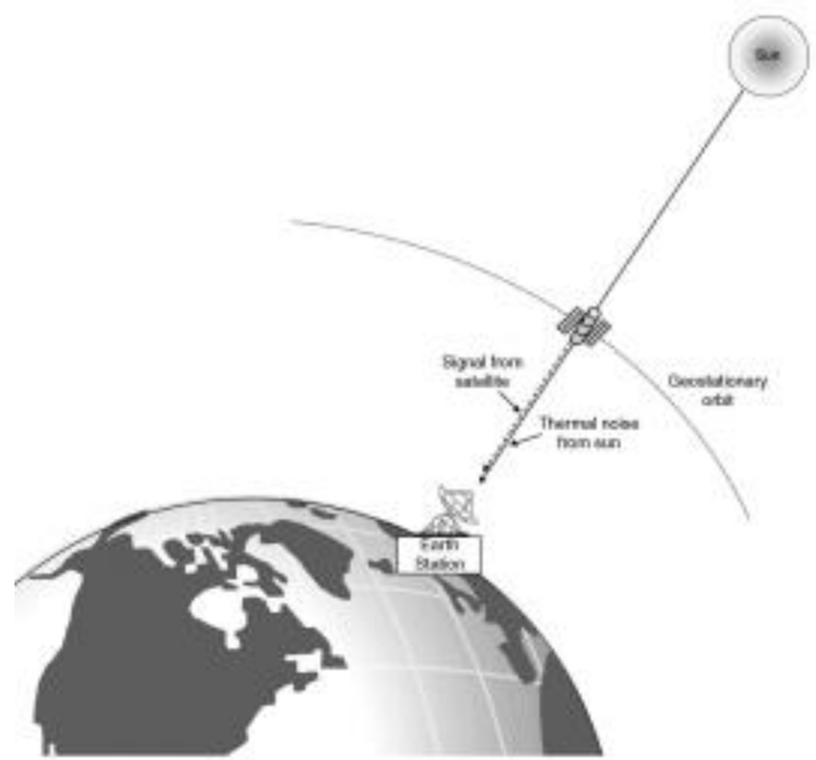
# 3.7 Orbital Effects on Satellite's Performance



## 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.



# Advanced Electronic Communication Systems
# Fourth Year, ECE

## Lecture 5 – Part (2)
## 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

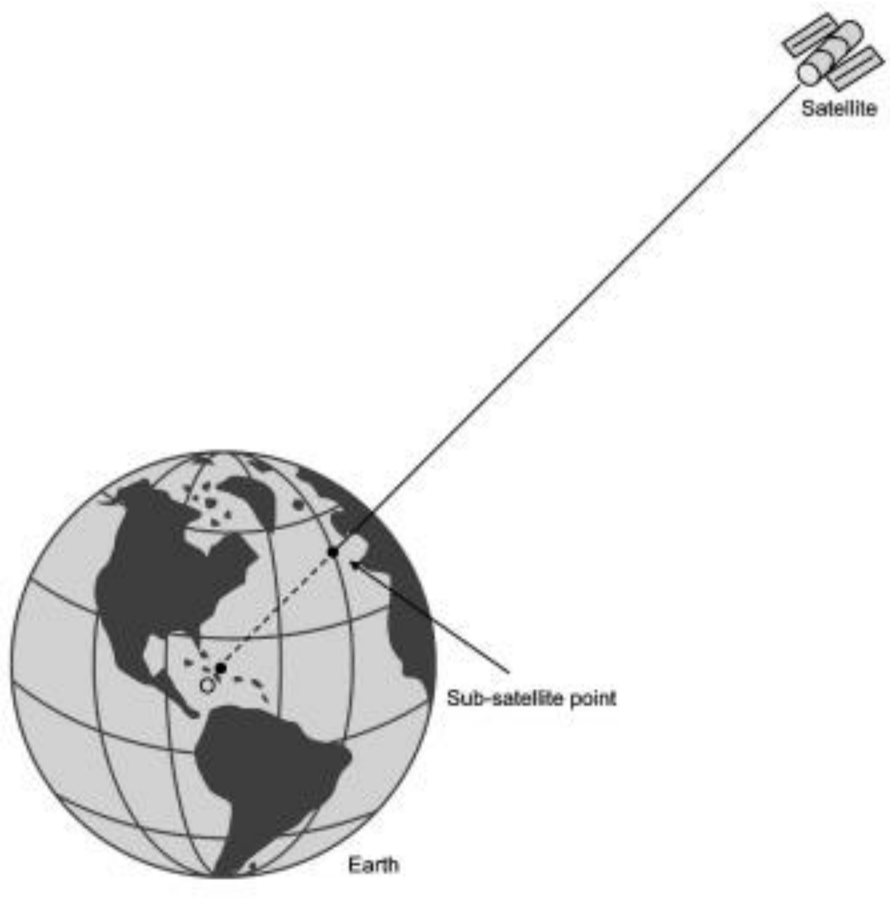
✓ However, because a satellite is orbiting many miles above the Earth's surface, it has no latitude or longitude itself

# Position Coordinates in Latitude and Longitude.



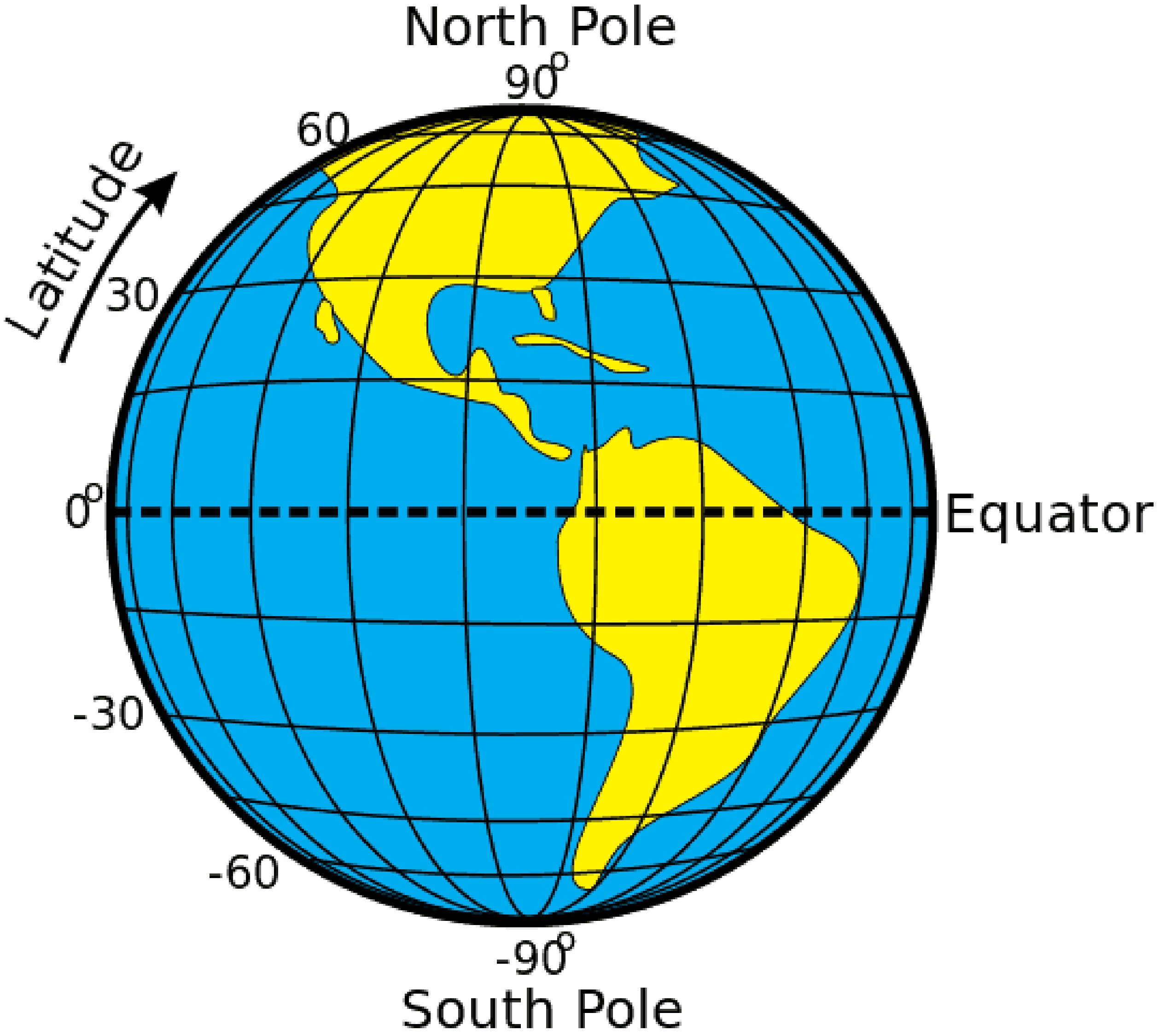
- The satellite location is specified by a point on the surface of the earth directly below the satellite (known as the **subsatellite** point "SSP" ).
- The sub-satellite point is the location on the surface of the Earth that lies directly between the satellite and the centre of the Earth.
- The subsatellite 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.

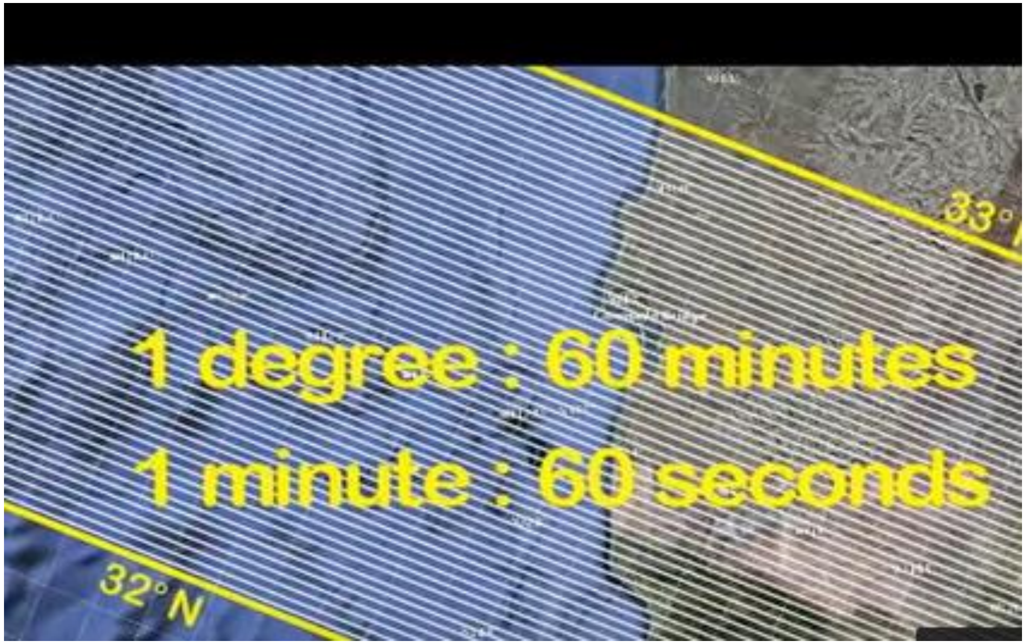



# Standard latitude and longitude coordinates

## latitudes

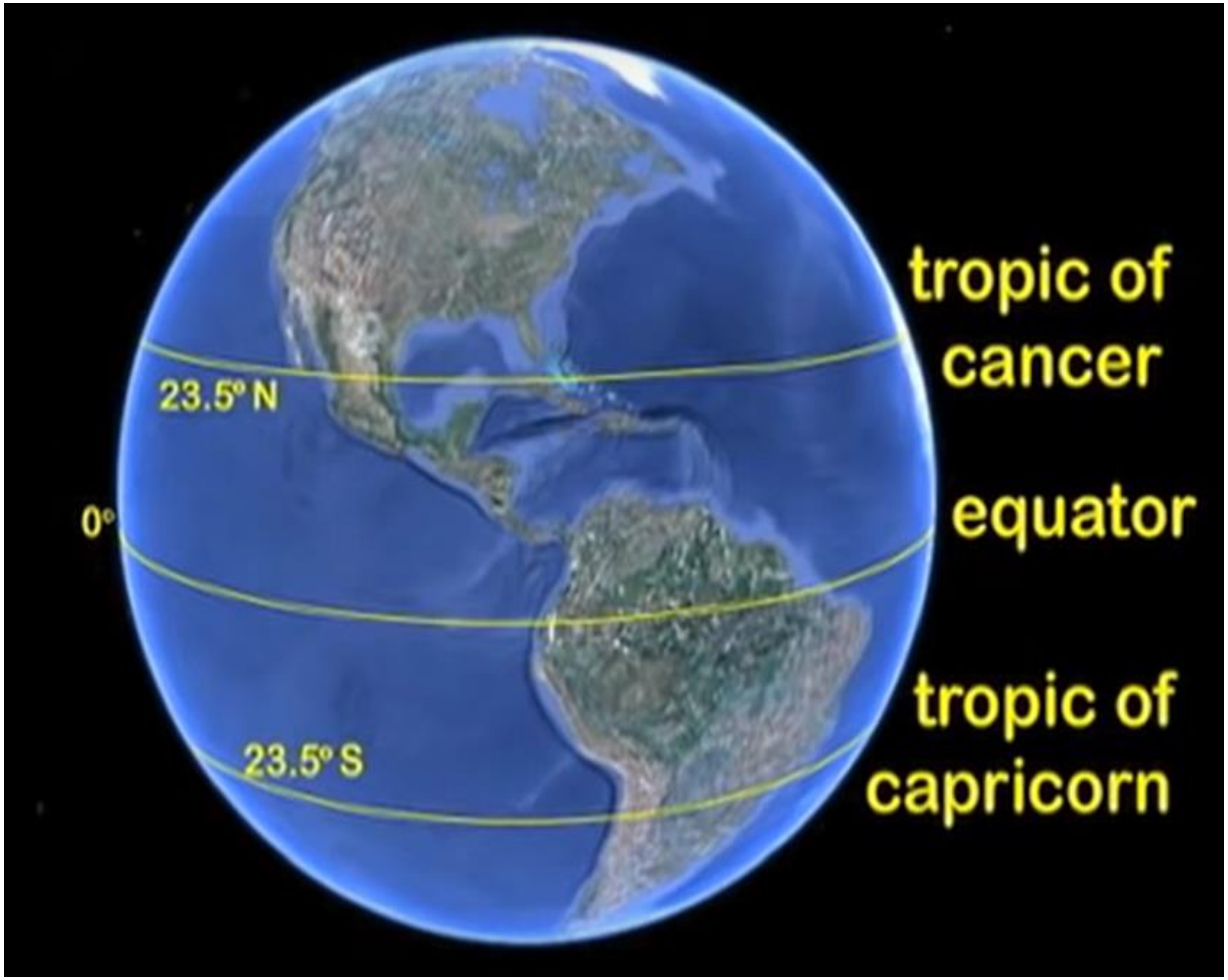
**The same distance apart**

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

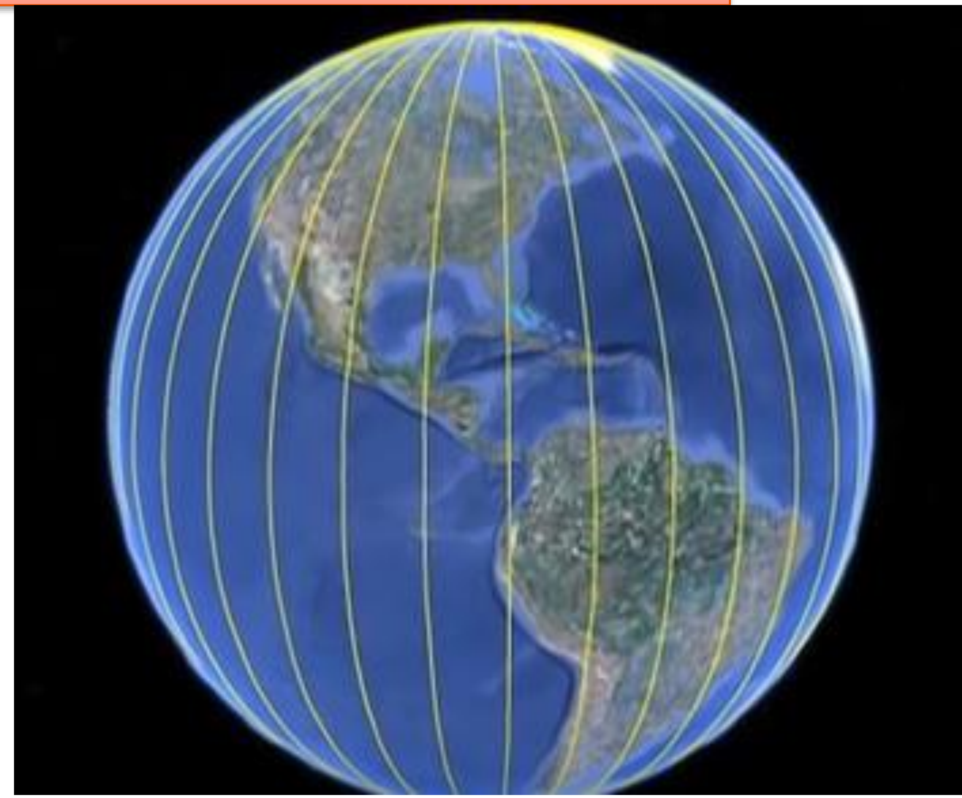

# Standard latitude and longitude coordinates

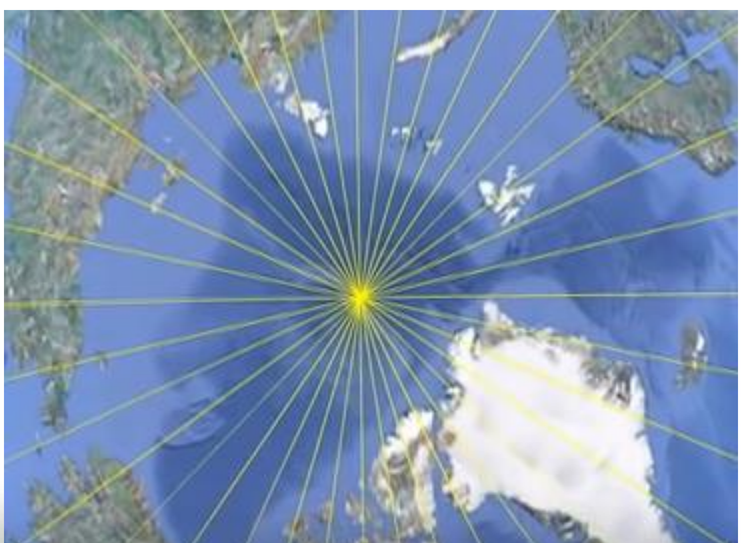
**Unique latitudes**



# 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.

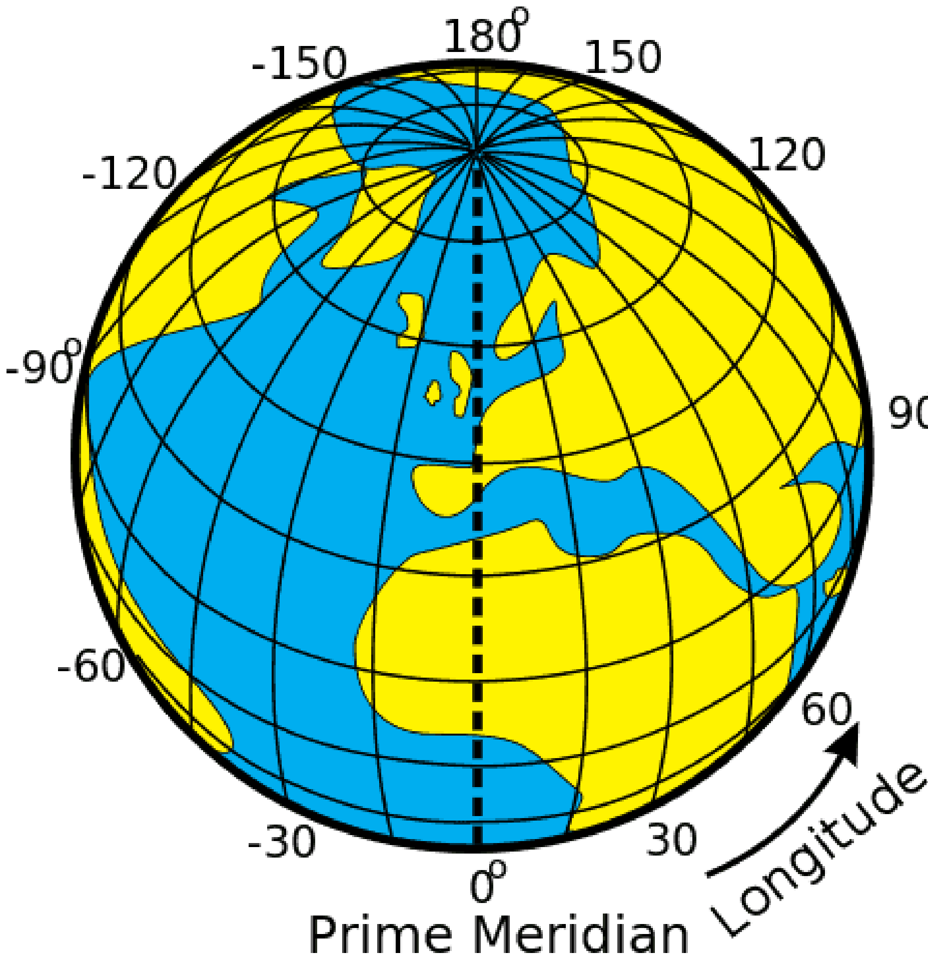




- **Longitudes are not equi-distant from each others like latitude**
- **They intersect at both north and south poles**

# Standard latitude and longitude coordinates





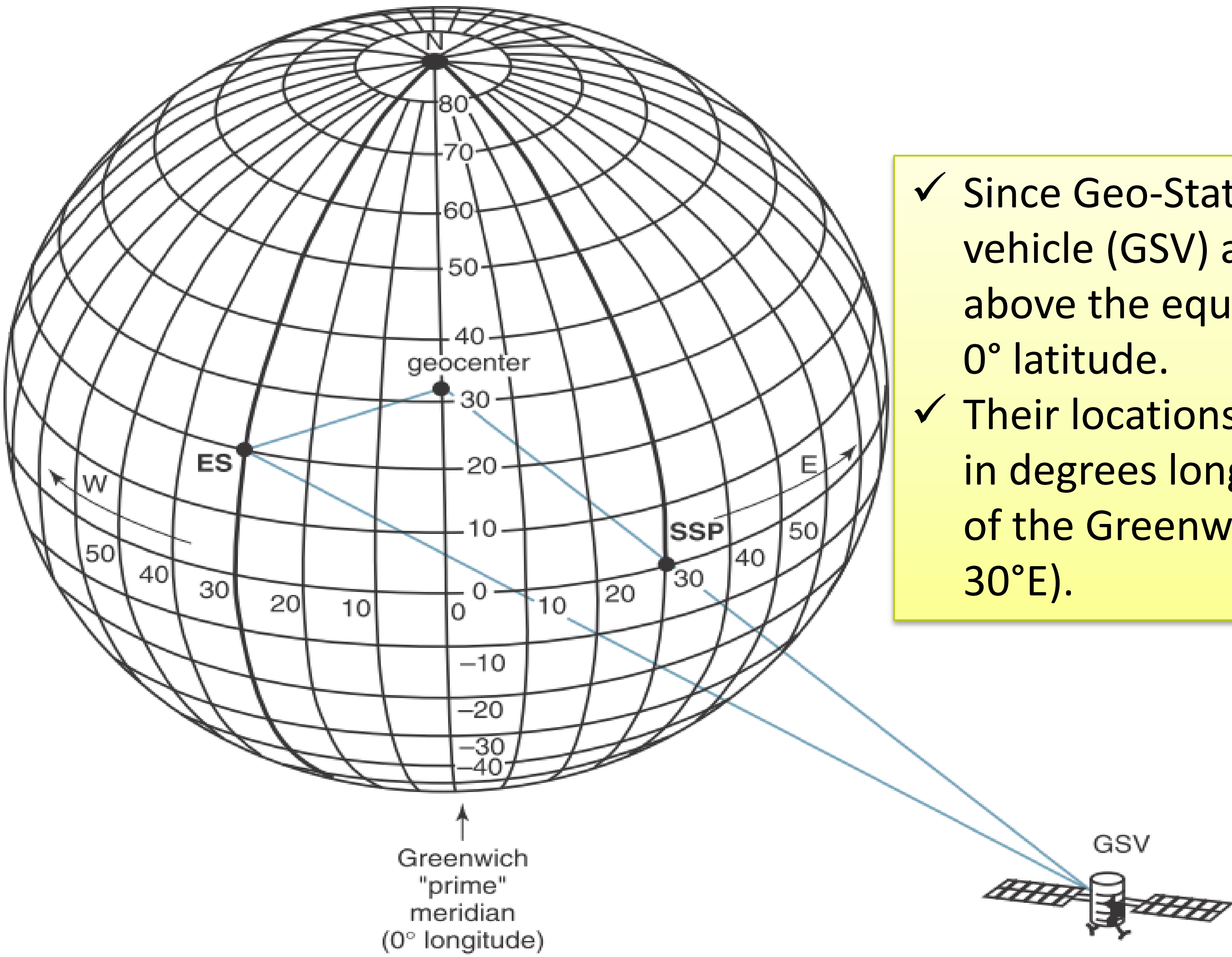

- **Prime Meridian lies on Royal observatory at Greenwich**

# 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.



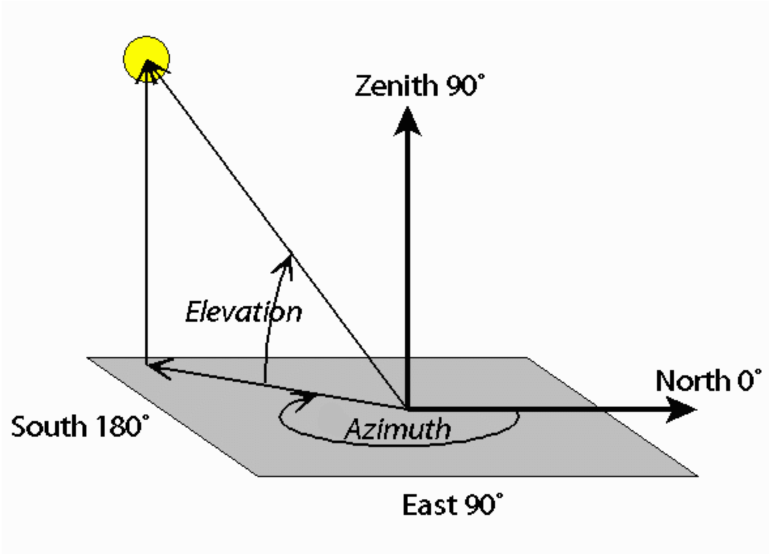

✓ Since Geo-Stationary satellites vehicle (GSV) are located directly above the equator, they all have a 0° latitude.

✓ 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 needs 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°).




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

# Azimuth Angle



✓ 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:**

$A = 180° - A'$. when the Earth station is to the west of the satellite

$A = 180° + A'$. when the Earth station is to the east of the satellite

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

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

$A = 360° - A' \ldots$ when the Earth station is to the east of the satellite

where $A'$ can be computed from

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

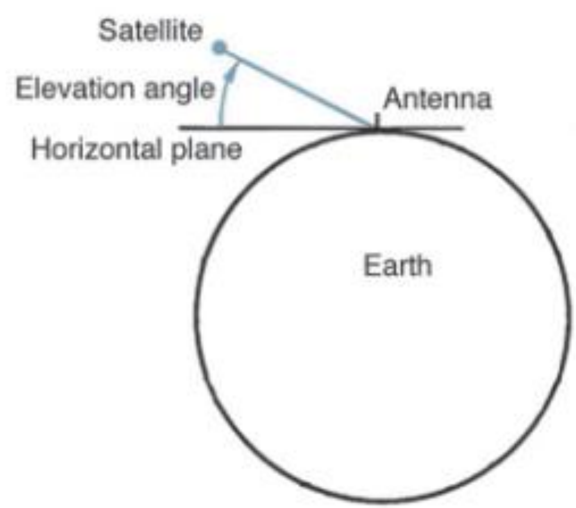
$\theta_s$ = satellite longitude
$\theta_L$ = Earth station longitude
$\theta_1$ = Earth station latitude

# Elevation Angle

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

$r$ = orbital radius, $R$ = Earth's radius

$\theta_s$ = Satellite longitude, $\theta_L$ = Earth station longitude, $\theta_l$ = Earth station latitude



# Relation between Elevation angle, slant range and coverage angle

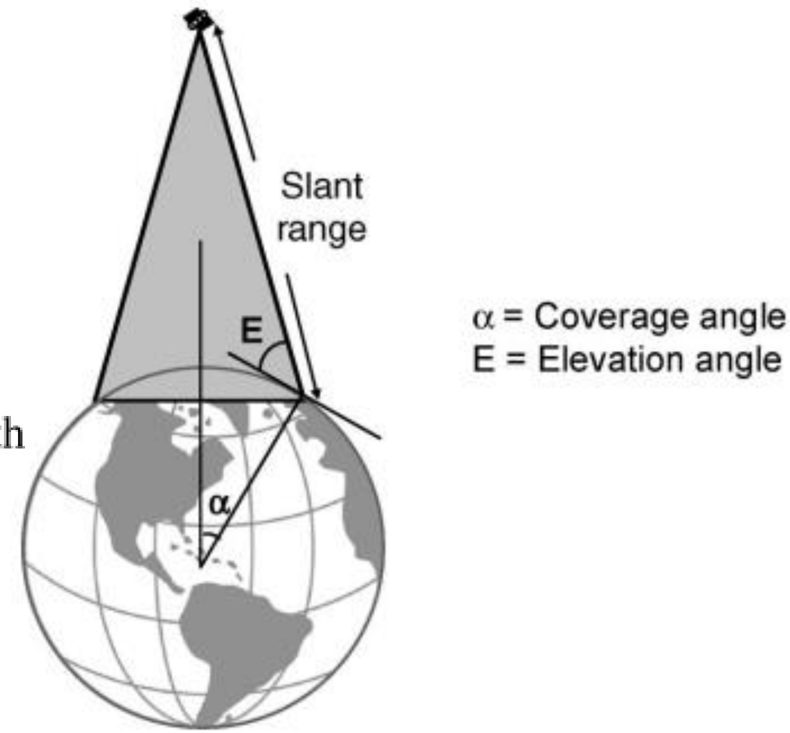


- **The slant range** is line of sight distance between the Earth station and the satellite.
- The smaller the elevation angle of the Earth station, the larger is the slant range and the coverage angle.

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

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

$R$ = radius of the Earth
$E$ = angle of elevation
$H$ = height of the satellite above the surface of the Earth



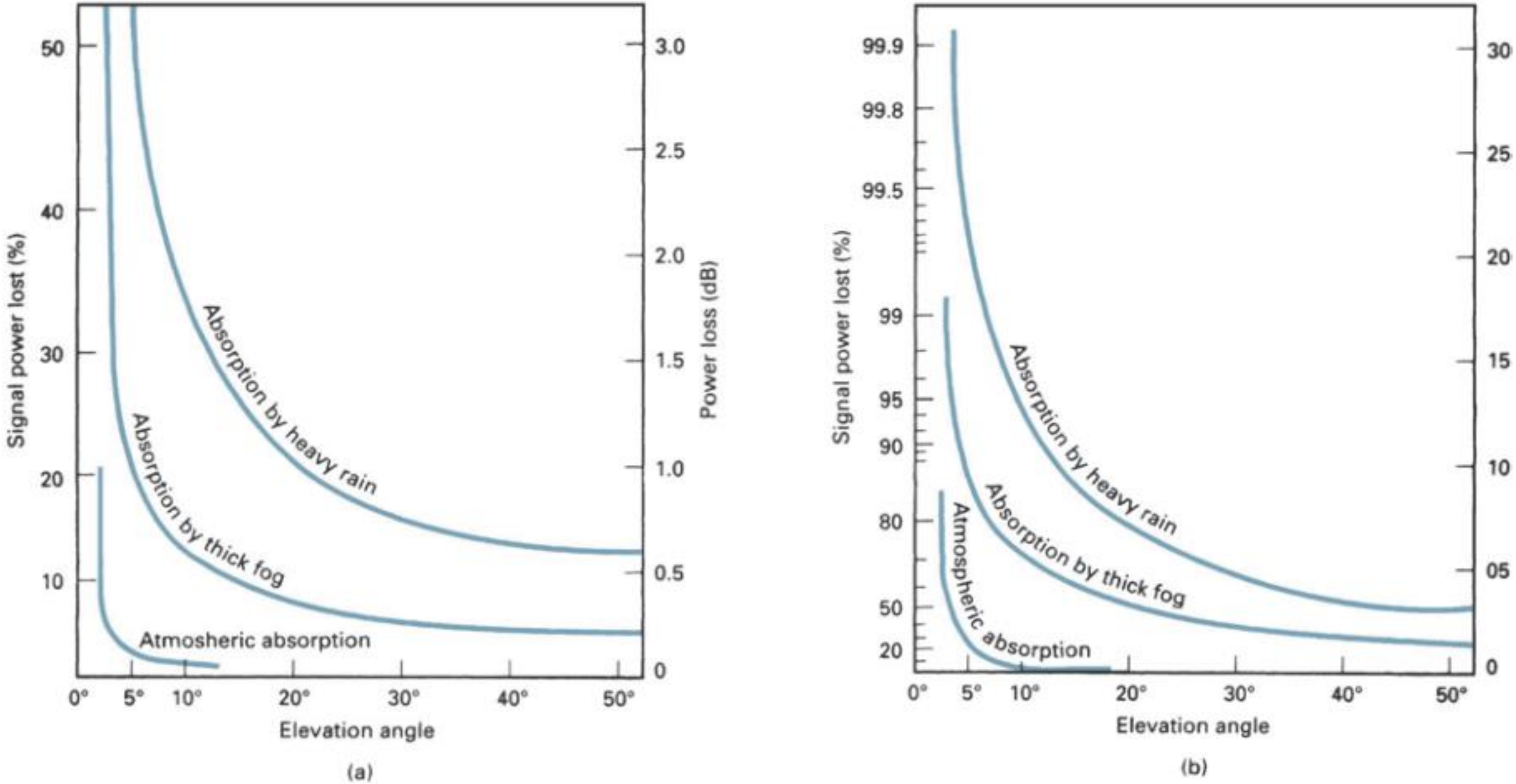
# Signal attenuation with Elevation Angle



- 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 must 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

# Signal attenuation with Elevation Angle






[a] 6/4-GHz band; [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

# References

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