Advanced Electronic Communication Systems

Lecture 5

- Satellite Coordinates and Look Angles
- System Model

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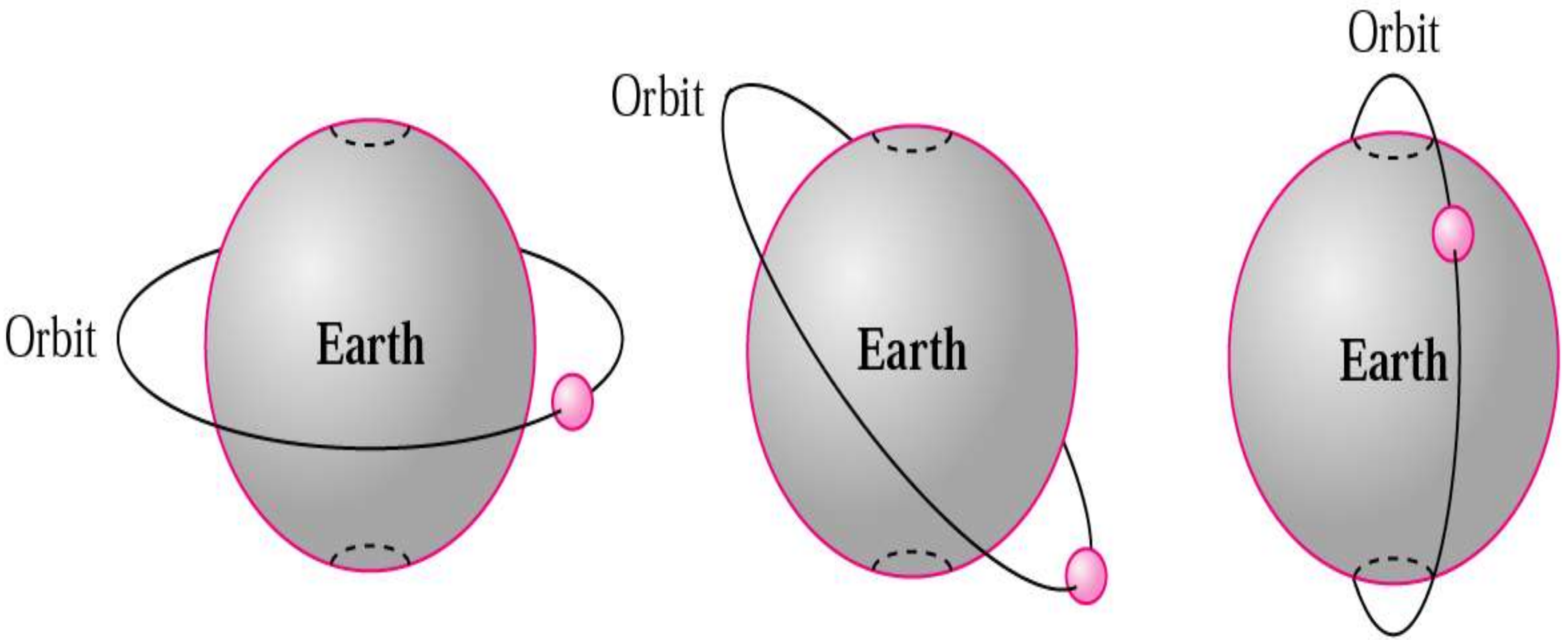
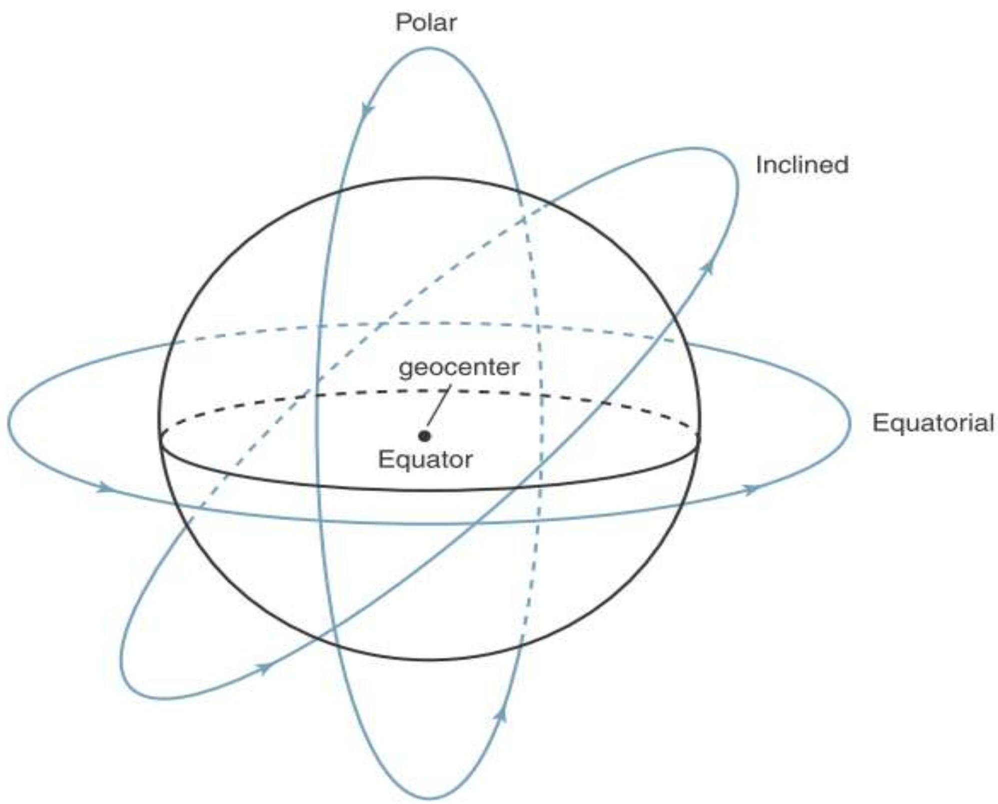
Satellite Orbital Patterns

- Three paths that a satellite can follow as it rotates around Earth: inclined, equatorial, or polar.



a. Equatorial-orbit satellite   b. Inclined-orbit satellite   c. Polar-orbit satellite

Satellite Orbital Patterns



- **Equatorial Orbit:** When the satellite rotates in an orbit above the equator, it is called an equatorial orbit.
- **Polar Orbit:** When the satellite rotates in an orbit that takes it over the north and south poles, it is called a polar orbit.
- **Inclined Orbit:** Any other orbital path is called an inclined orbit.

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.)

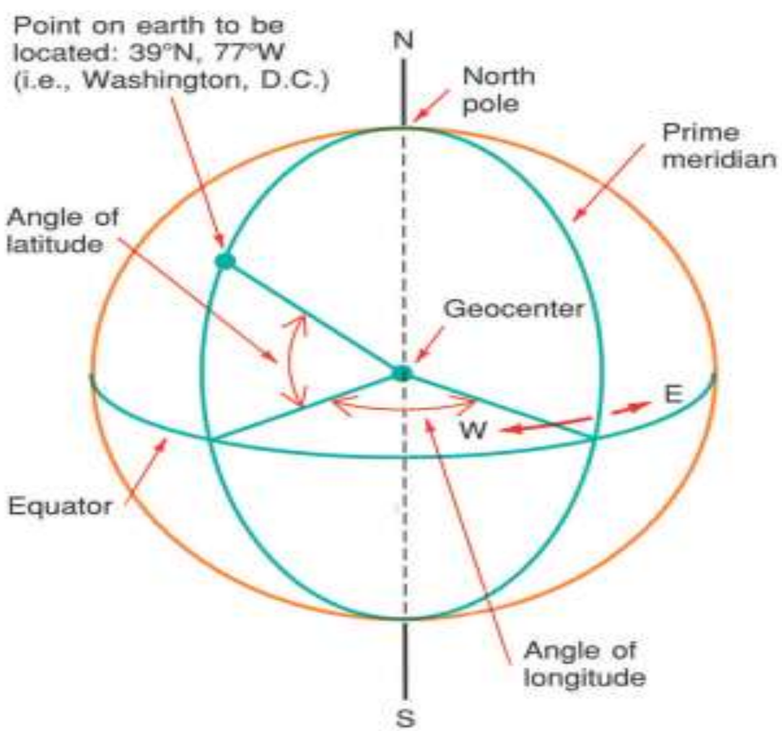
- ✓ The location of a satellite is generally specified in terms of latitude and longitude similar to other points on Earth
- ✓ However, because a satellite is orbiting many miles above the Earth’s surface, it has no latitude or longitude itself

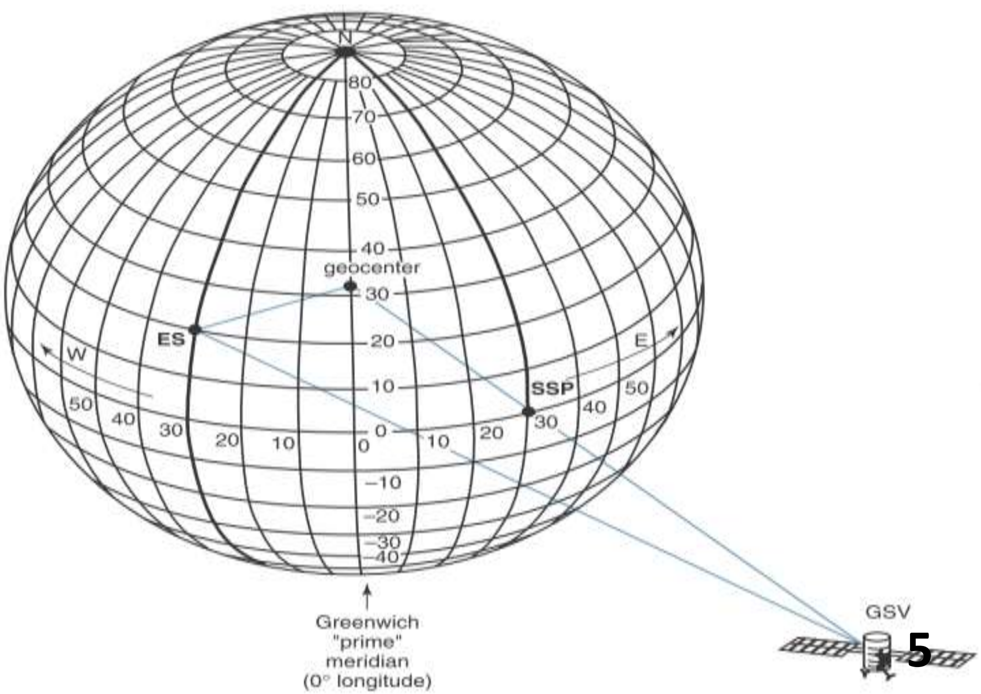
- The satellite location is specified by a point on the surface of the earth directly below the satellite (known as the subsatellite point “SSP”).
- The subsatellite point is then located by using conventional latitude and longitude designations.

Standard latitude and longitude coordinates

- **Latitude** of a given point is defined as the angle **between** (the line drawn from the point on the surface of the earth to the geocenter) and (the line between the geocenter and the equator)

✓ **The 0° latitude is at the equator, and 90° latitude is at either the north or south pole (90N, 90S).**

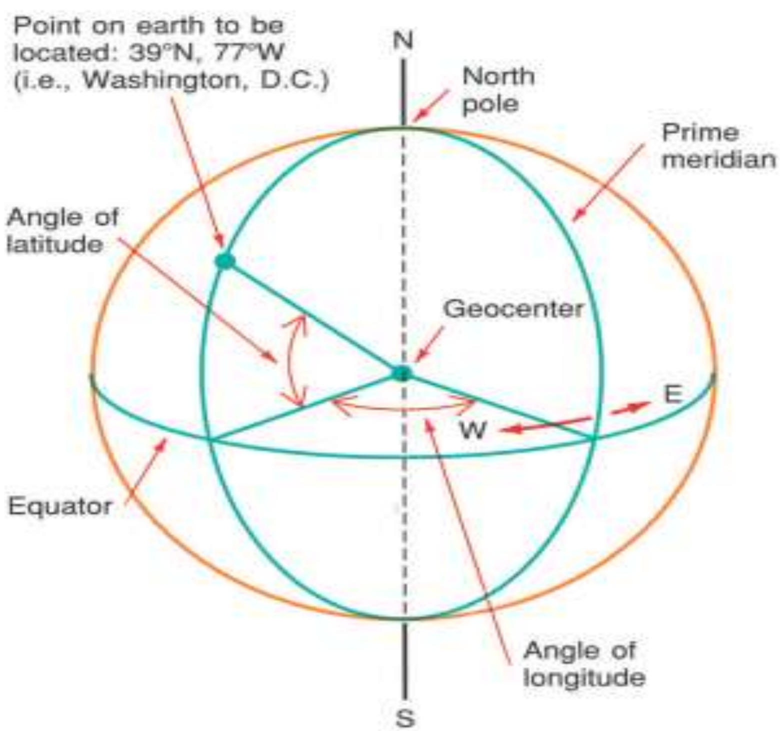


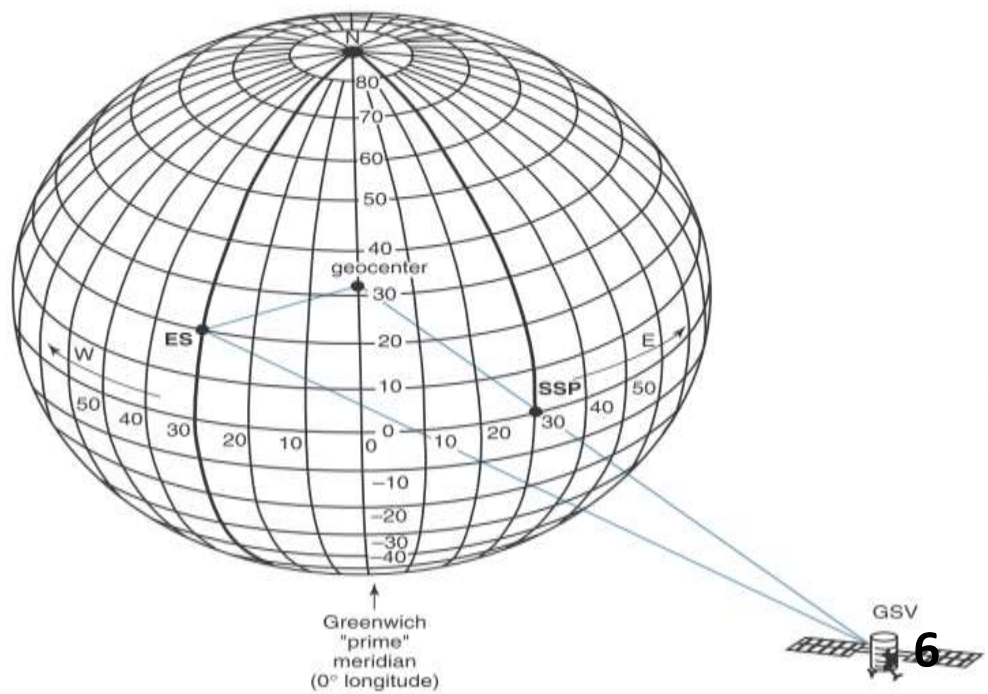


Standard latitude and longitude coordinates

- **The Longitude (or Meridian)** of a given point is the angle between (the line connecting the geocenter of the earth to the point where the prime meridian and equator intersect) and the meridian containing the given point of interest intersect.

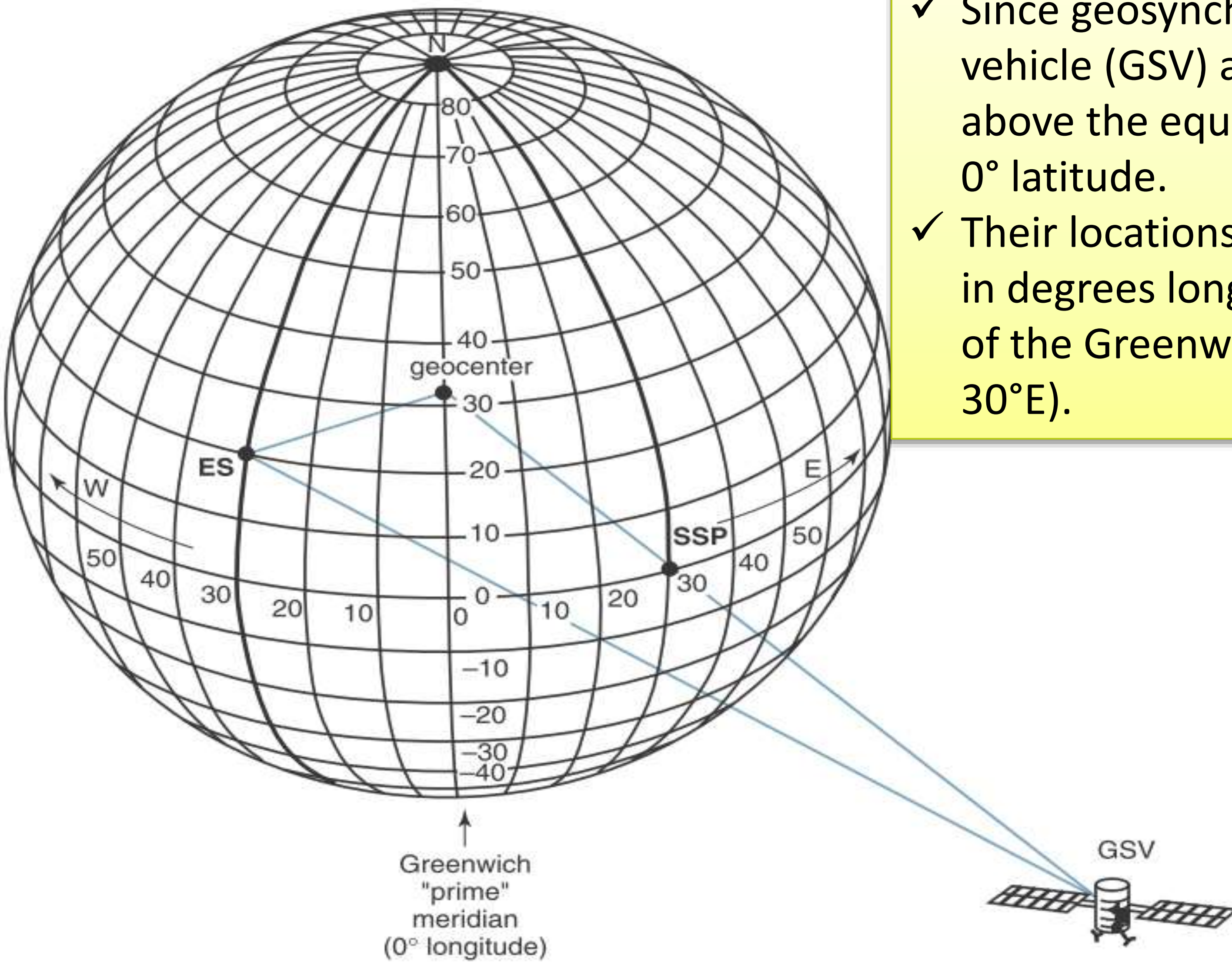
- The 0 longitude is called **the prime meridian** (passing by Greenwich, England).
- The designation east or west is usually added to the longitude angle (10W, 20E)





Satellite and earth station coordinates

- ✓ The earth station has a location of 30°W longitude and 20°N latitude.



- ✓ Since geosynchronous 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).

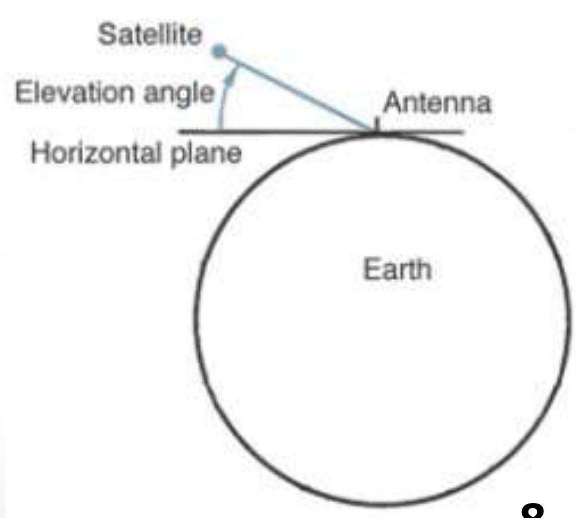
Look Angles (Elevation and Azimuth Angle)

- Knowing the location of the satellite is insufficient information for most earth stations that must communicate with the satellite.
- The earth station need to know the azimuth and elevation settings of its antenna to intercept the satellite.

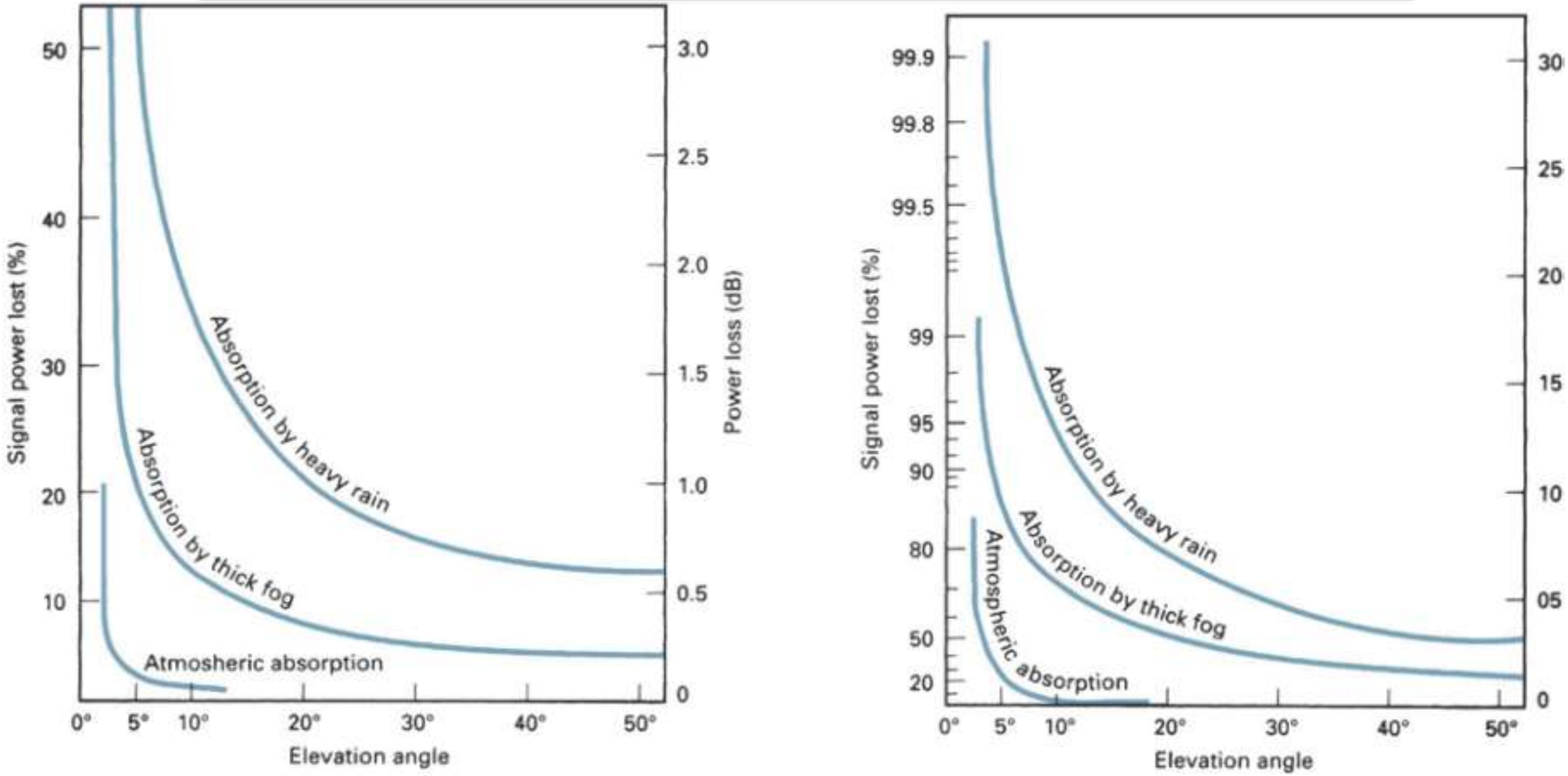
Elevation Angle

Elevation angle is the vertical angle formed between the direction of travel of an electromagnetic wave radiated from an earth station antenna pointing directly toward a satellite and the horizontal plane.

- ✓ The smaller the angle of elevation, the greater the distance a propagated wave must pass through Earth's atmosphere.
- ✓ As distance increases, the signal quality deteriorates
- ✓ Generally, 5° is considered as the minimum acceptable angle of elevation.



Signal attenuation with Elevation Angle



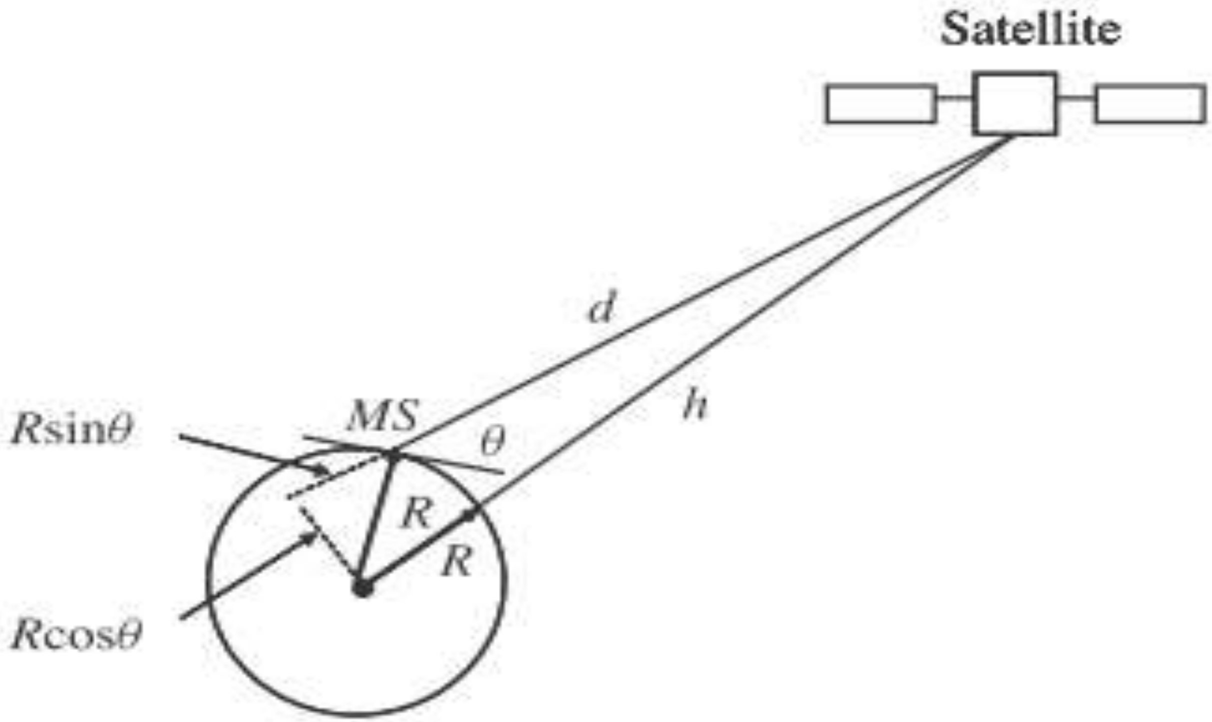
[a] 6/4-GHz band; [b] 14/12-GHz band

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.

Delay and Elevation Angle

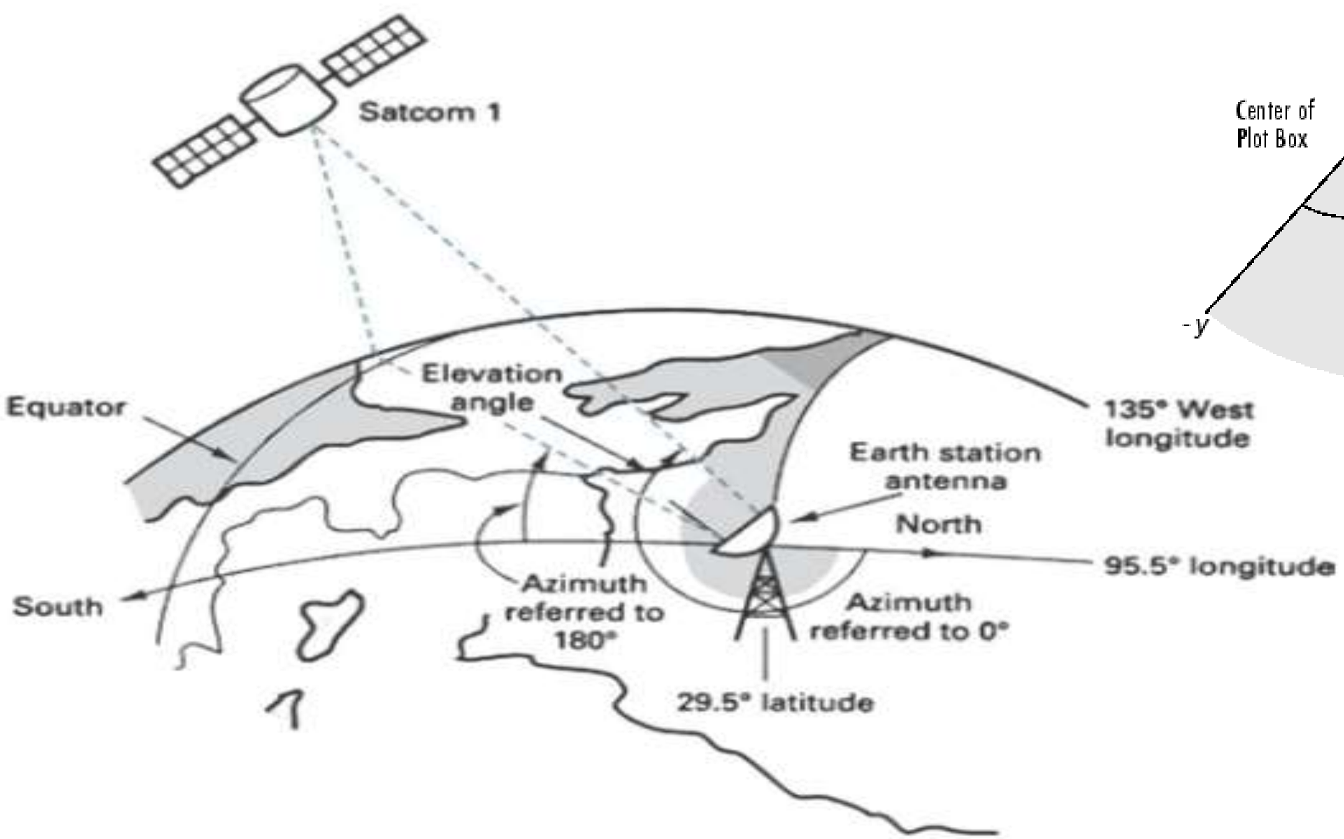
➢ The time delay for the signal to travel from the satellite to a MS is a function of various parameters (including the elevation angle) :

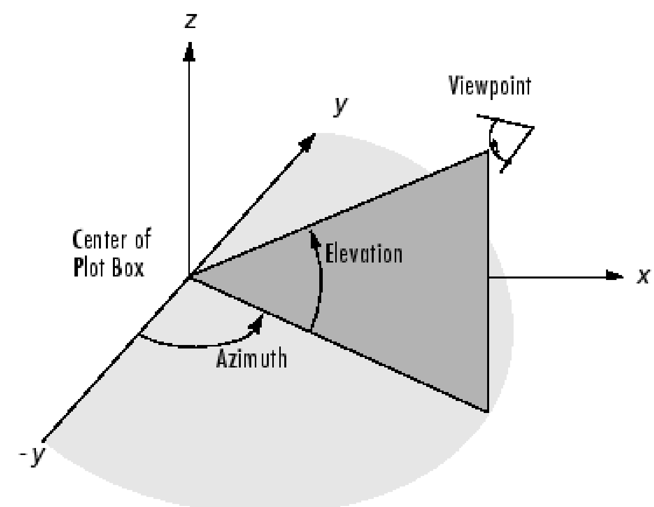


$$\text{Delay} = \frac{d}{c} = \frac{1}{c}\left[\sqrt{(R+h)^2 - R^2\cos^2\theta} - R\sin\theta\right]$$

Azimuth Angle

- Azimuth angle is defined as the horizontal pointing angle of an earth station antenna.
- Azimuth angle is generally referenced north (0°) or to south (180°) in clockwise





Geosynchronous Satellite Look Angles Tables

- For geostationary orbit, the look angles angels values does not change as the satellites are stationary with respect to earth.
- Angle of elevation and azimuth angle both depend on the latitude of the earth station and the longitude of both the earth station and the orbiting satellite.

- The procedure for determining angle of elevation and azimuth for geostationary satellites is as follows:

1. From a good map, determine the longitude and latitude of the earth station.
2. From Table 1, determine the longitude of the satellite of interest.
3. Calculate the difference, in degrees (ΔL), between the longitude of the satellite and the longitude of the earth station.
4. Then from Figure 12 determine the azimuth angle, and from Figure 13 determine the elevation angle.

Table 1 Longitudinal Position of Several Curre
Synchronous Satellites Parked in an Equatorial Arc[a]

Satellite	Longitude (°W
Satcom I	135
Satcom II	119
Satcom V	143
Satcom C1	137
Satcom C3	131
Anik 1	104
Anik 2	109
Anik 3	114
Anik C1	109.25
Anik C2	109.15
Anik C3	114.9
Anik E1	111.1
Anik E2	107.3
Westar I	99
Westar II	123.5
Westar III	91
Westar IV	98.5
Westar V	119.5
Mexico	116.5
Galaxy III	93.5
Galaxy IV	99
Galaxy V	125
Galaxy VI	74
Telstar	96
Comstar I	128
Comstar II	95
Comstar D2	76.6
Comstar D4	75.4
Intelsat 501	268.5
Intelsat 601	27.5
Intelsat 701	186

[a] 0° latitude.

Geosynchronous Satellite Look Angles Tables

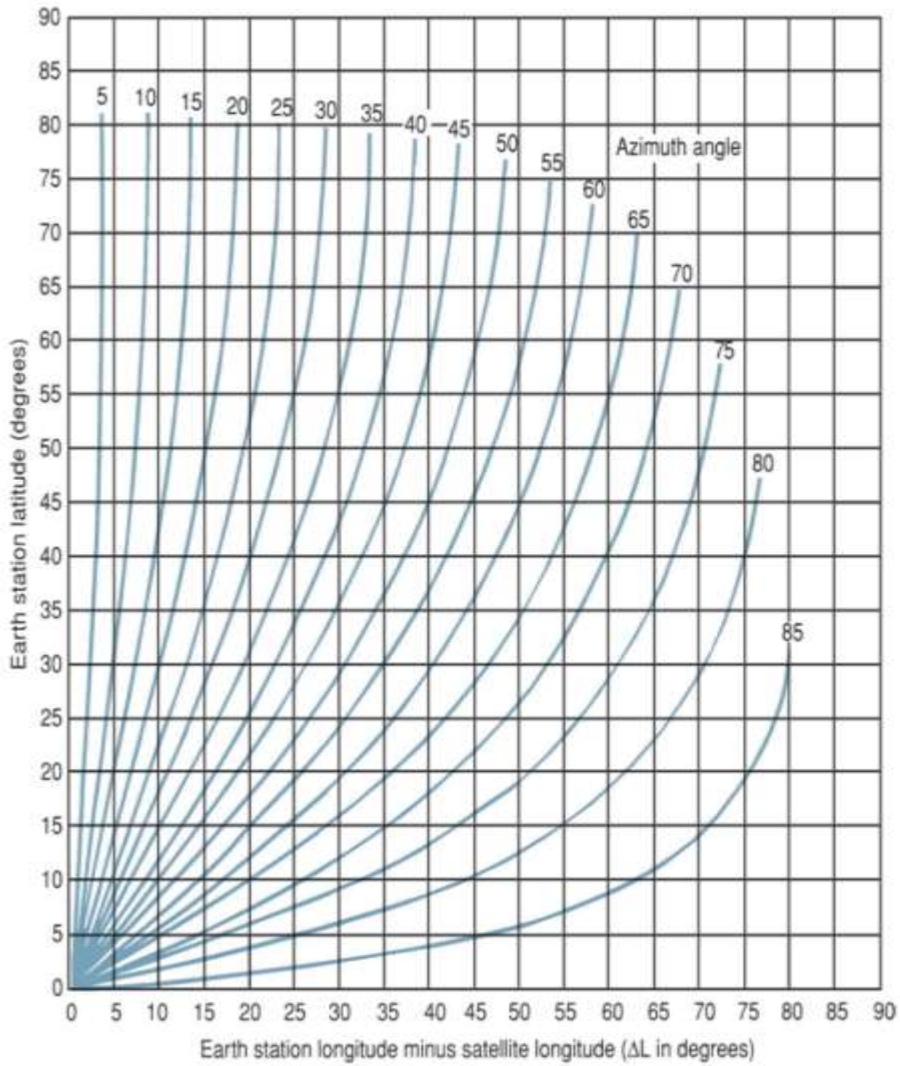


FIGURE 12 Azimuth angles for earth stations located in the northern hemisphere referenced to 180 degrees

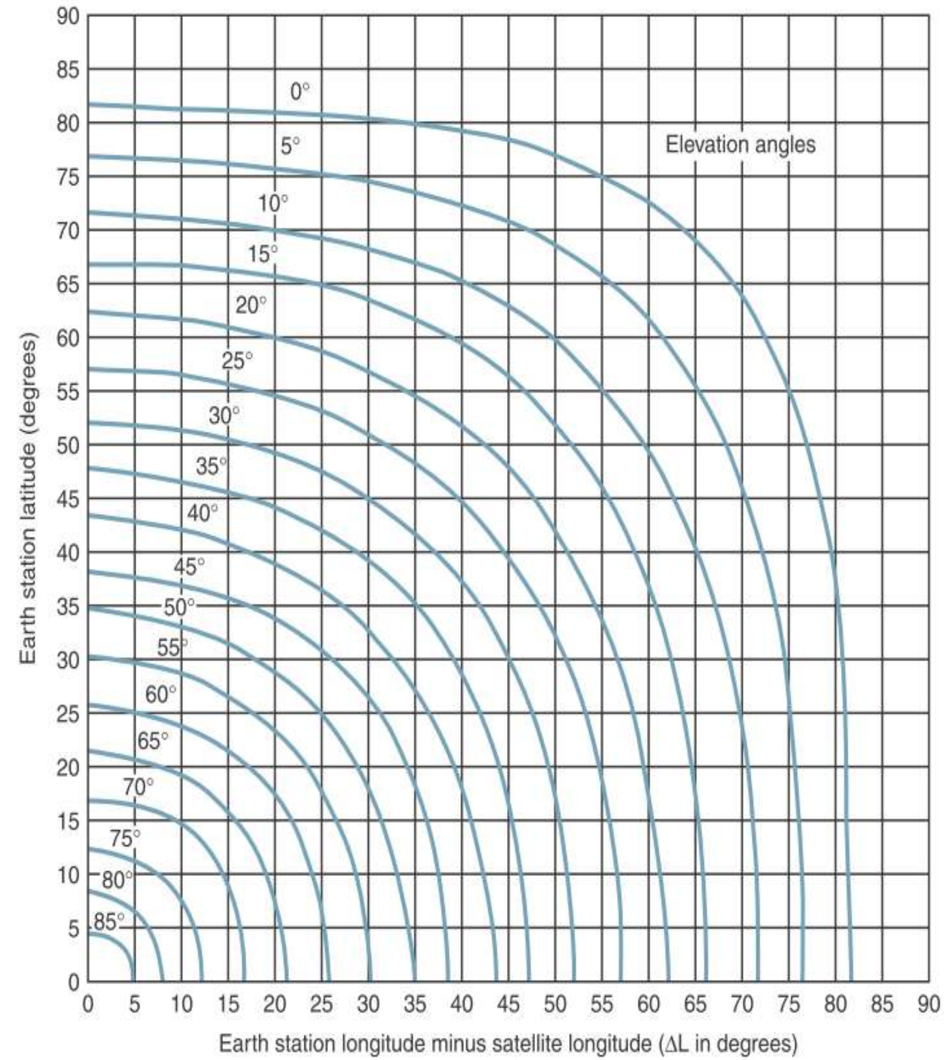


FIGURE 13 Elevation angles for earth stations located in the Northern Hemisphere

Geosynchronous Satellite Look Angles Tables

Example 1

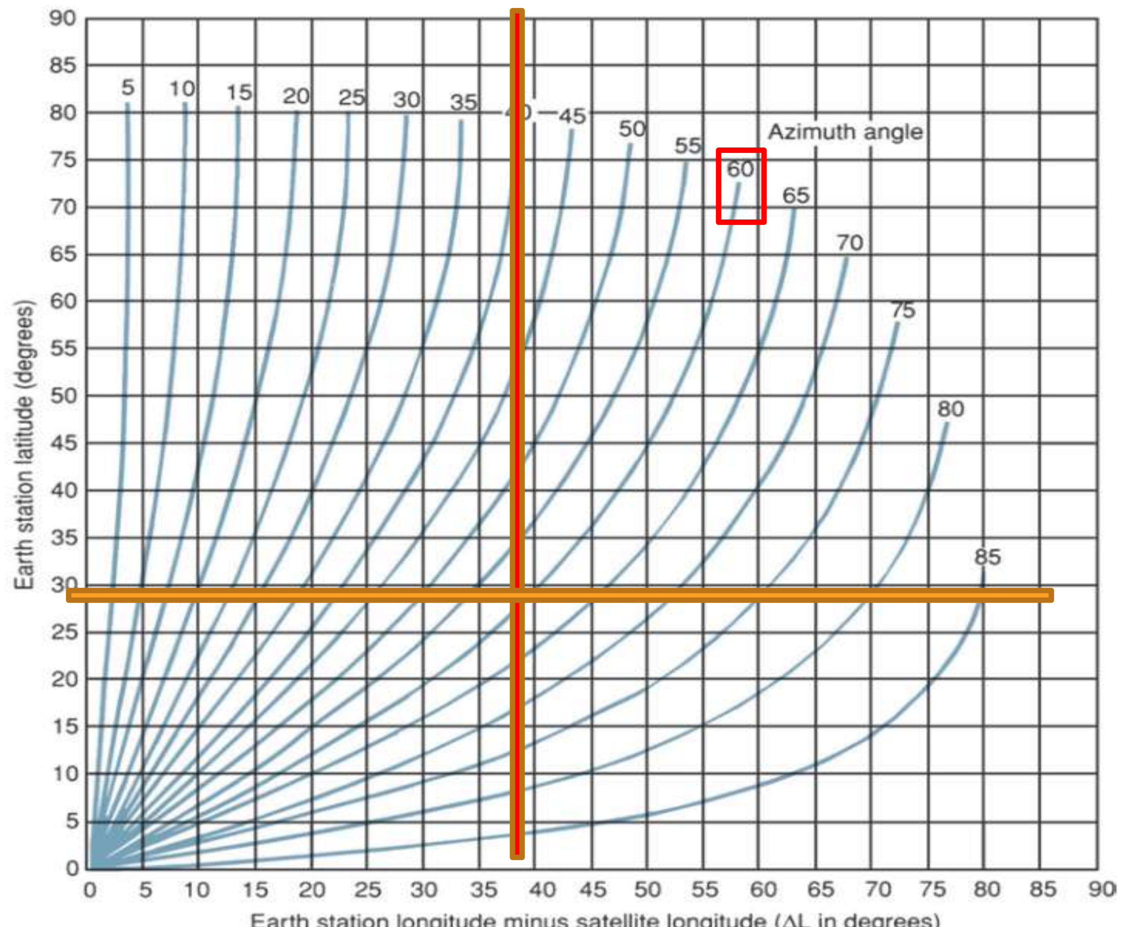
An earth station is located in Houston, Texas, which has a longitude of 95.5°W and a latitude of 29.5°N. The satellite of interest is RCA's *Satcom 1*, which has a longitude of 135°W. Determine the azimuth angle and elevation angle for the earth station.

Solution First determine the difference between the longitude of the earth station and the satellite

$$\Delta L = 135° - 95.5°$$
$$= 39.5°$$

- Locate the intersection of ΔL and the earth station's latitude on Figure 12.

From the figure, the azimuth angle is approximately 59° west of south (i.e., west of 180°).



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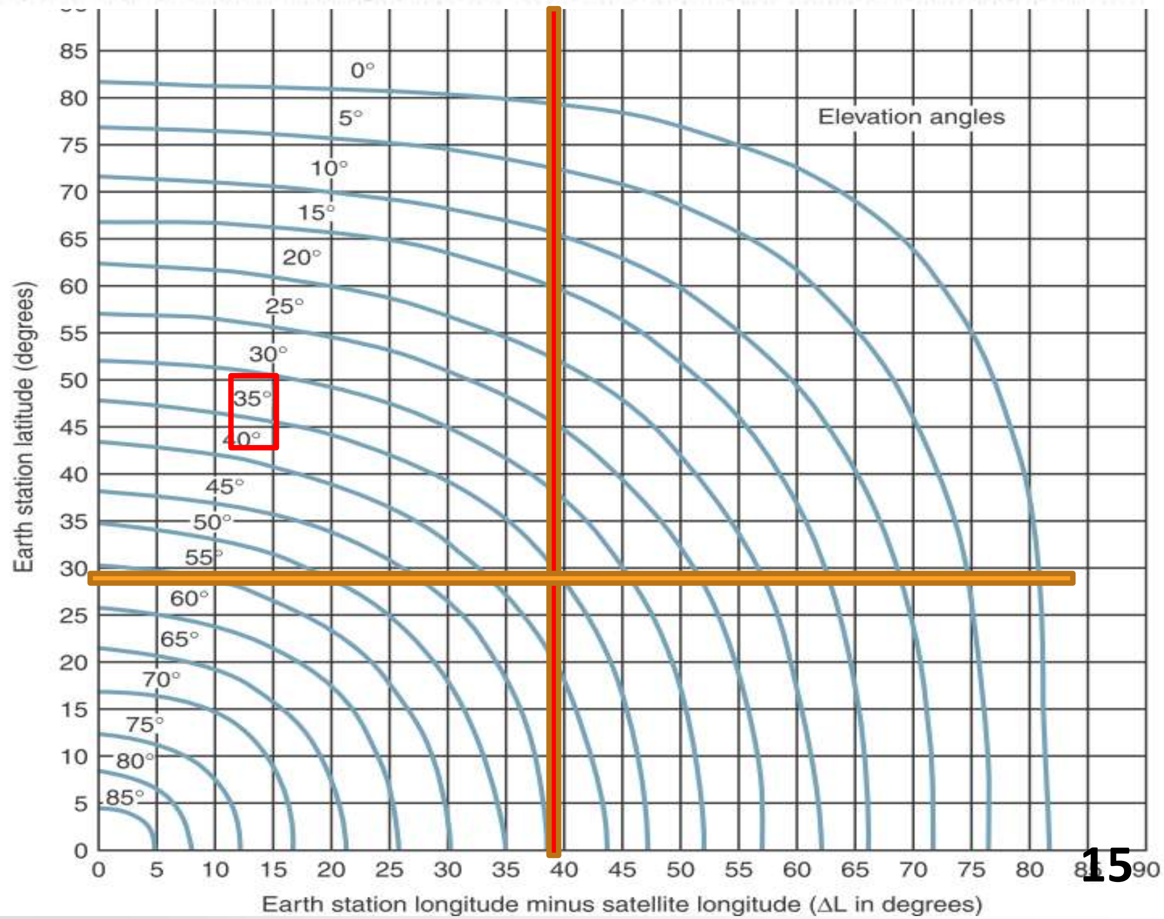
$$= 39.5°$$

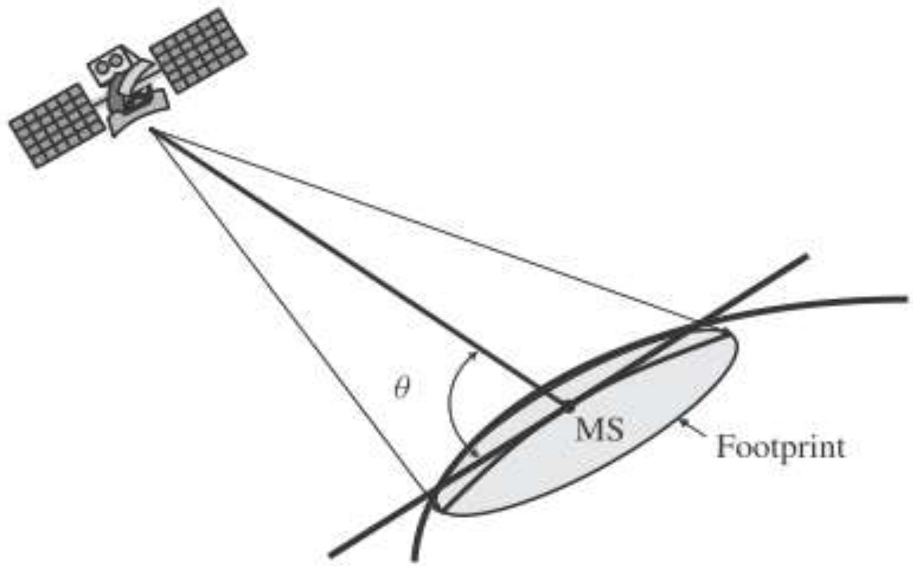
From the figure, the azimuth angle is approximately 59° west of south (i.e., west of 180°).

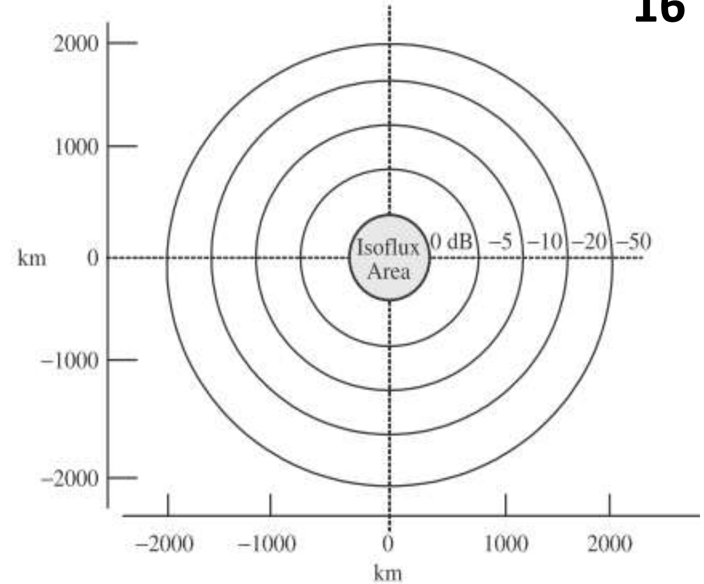
- Locate the intersection of ΔL and the earth station's latitude on Figure 13.

From the figure, the elevation angle is approximately 35°

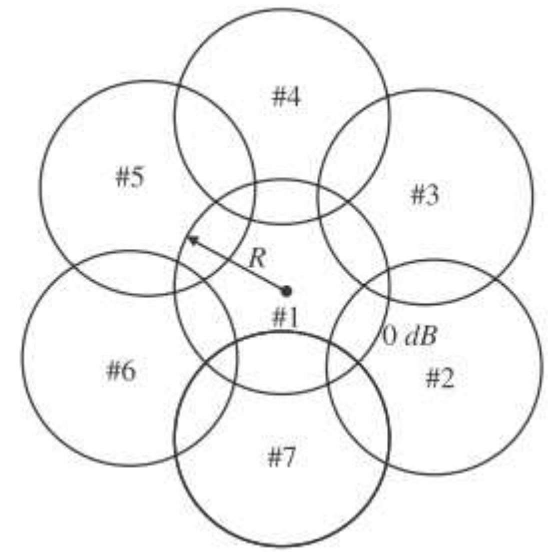


Footprint with Elevation Angle





- The elevation angle between the satellite beam and the surface of the earth has an impact on the illuminated area (known as the footprint)
- The elevation angle θ of the satellite beam governs the distance of the satellite with respect to the MS.



- The satellite beam footprint (highlighted circle with 0 dB intensity) is considered to be an isoflux region

Satellite with several beam geometry like mobile cells

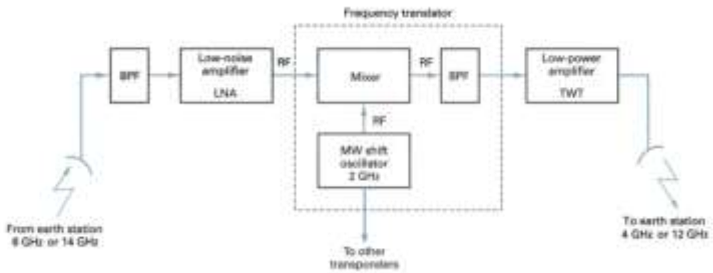
Footprint Categories

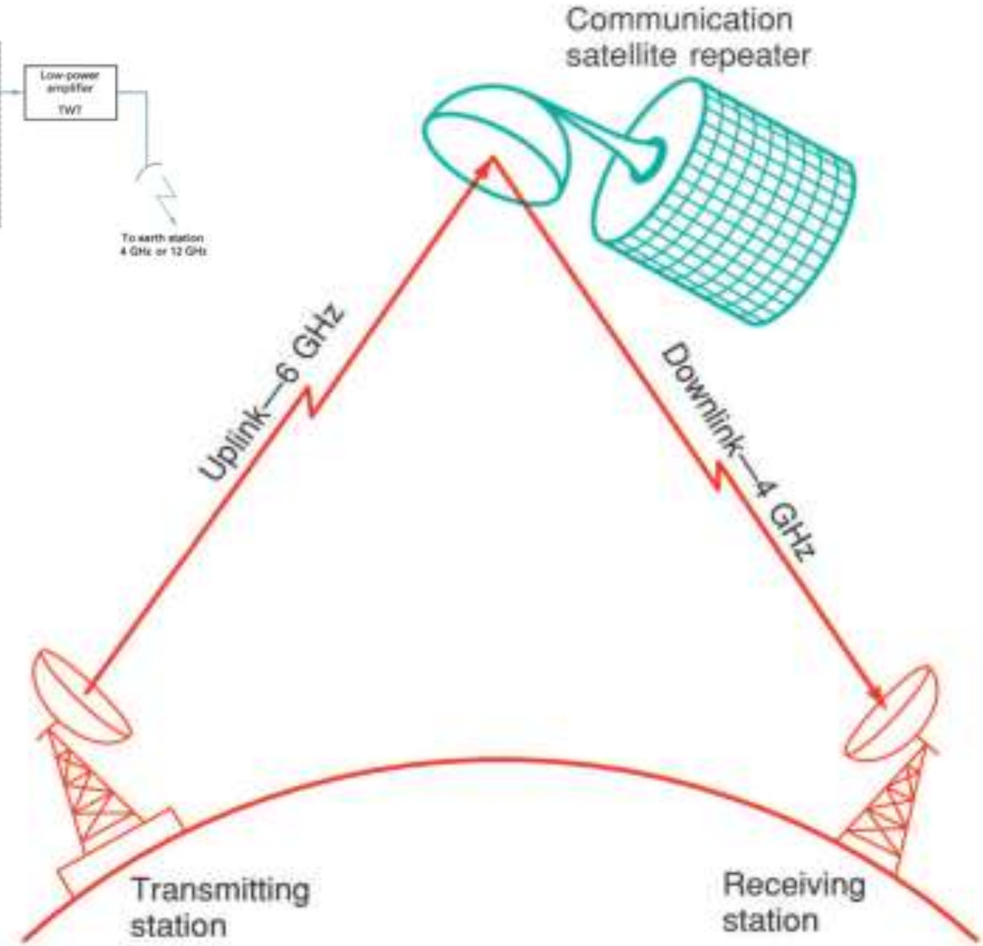
- The area of Earth covered by a satellite depends on:
  1. The location of the satellite in its geosynchronous orbit,
  2. The carrier frequency and
  3. The gain of its antennas.

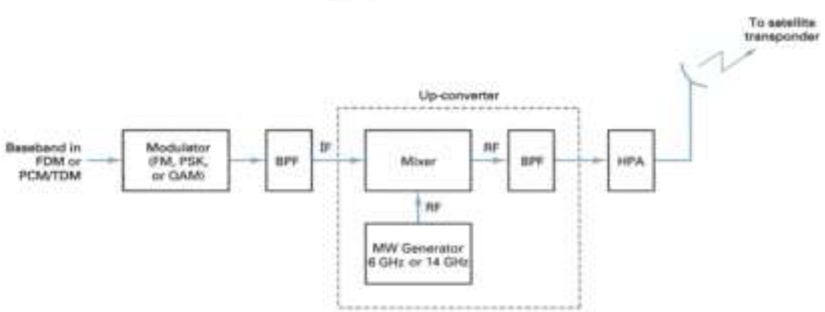
- The radiation pattern from a satellite antenna may be categorized as either spot, zonal or earth.

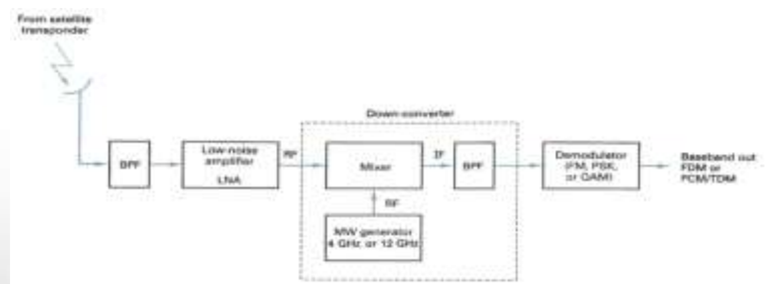
1. Earth Coverage: The radiation patterns covers approximately one-third of Earth's surface.
2. Zonal coverage: covers an area less than one-third of Earth's surface.
3. Spot coverage: beams concentrate the radiated power in a very small geographic area.

SATELLITE SYSTEM LINK MODELS

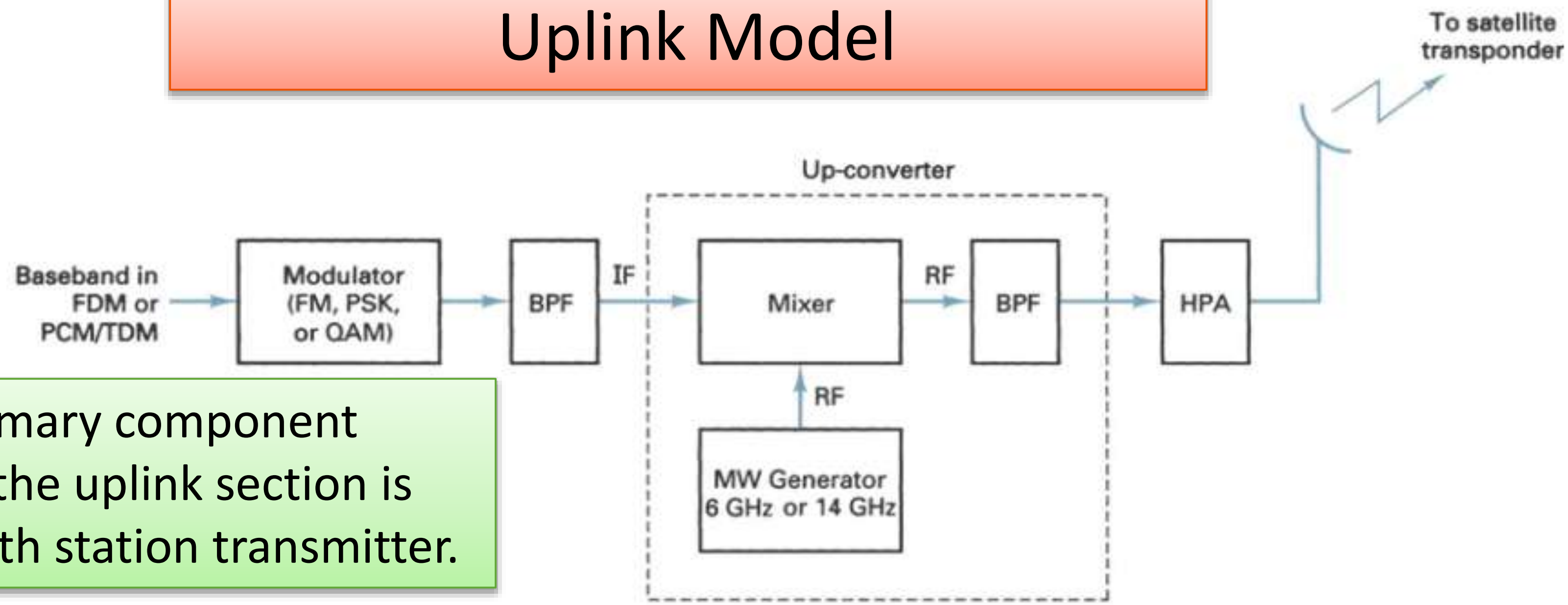








Uplink Model

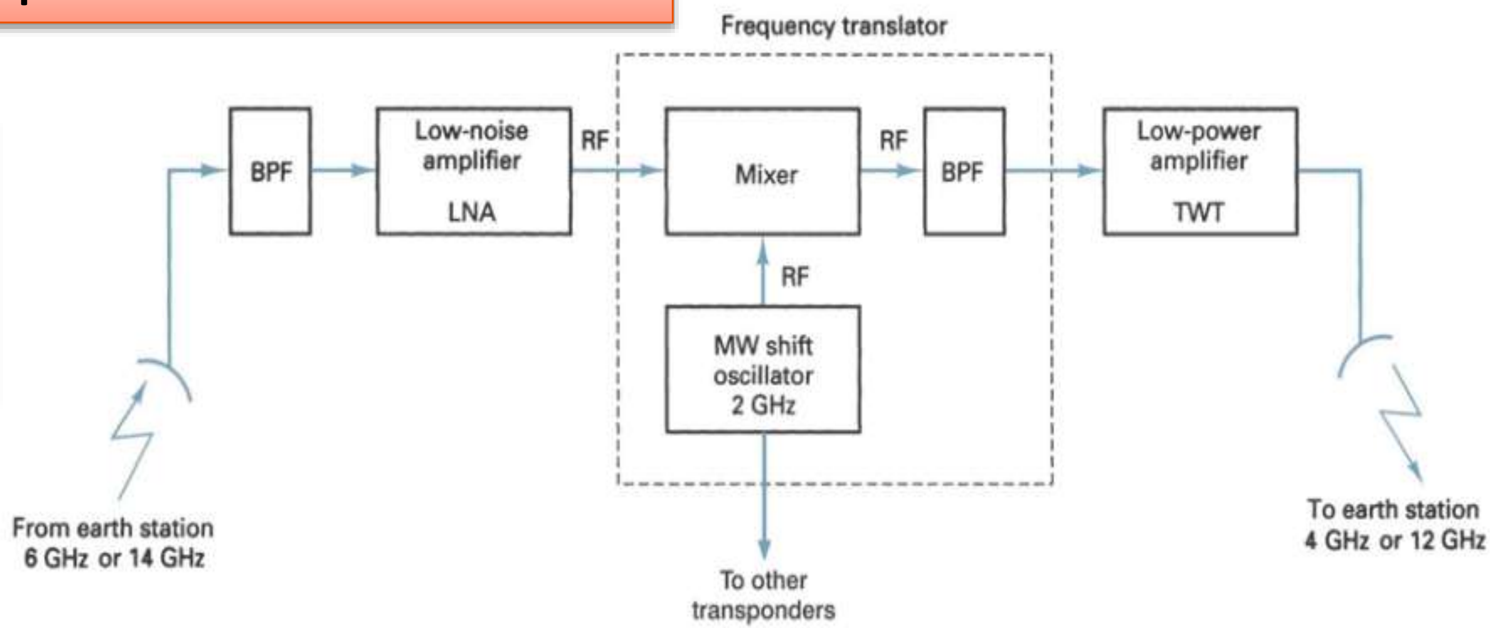


- The primary component within the uplink section is the earth station transmitter.

	Component	function
1	**IF modulator**	converts the input baseband signals to either an FM-, a PSK-, or a QAM-modulated intermediate frequency.
2	**IF-to-RF microwave up-converter**	converts the IF to an appropriate RF carrier frequency.
3	**High-power amplifier (HPA)**	provides adequate gain and output power to propagate the signal to the satellite transponder. HPAs commonly used are klystons and traveling-wave tubes.
4	**Output bandpass filter**	Used for band-limiting of the final output spectrum
5	**Transmitting Antenna**	

Transponder Model

It can be considered as an RF-to-RF repeater.



	Component	function
1	**Input BPF**	limits the total noise applied to the input of the LNA
2	**low-noise amplifier (LNA)**	A common device used as an LNA is a tunnel diode.
3	**Frequency translator**	converts the high-band uplink frequency to the low-band downlink frequency.
4	**Low-level power amplifier**	amplifies the RF signal for transmission through the downlink to earth station receivers (commonly a traveling-wave tube).

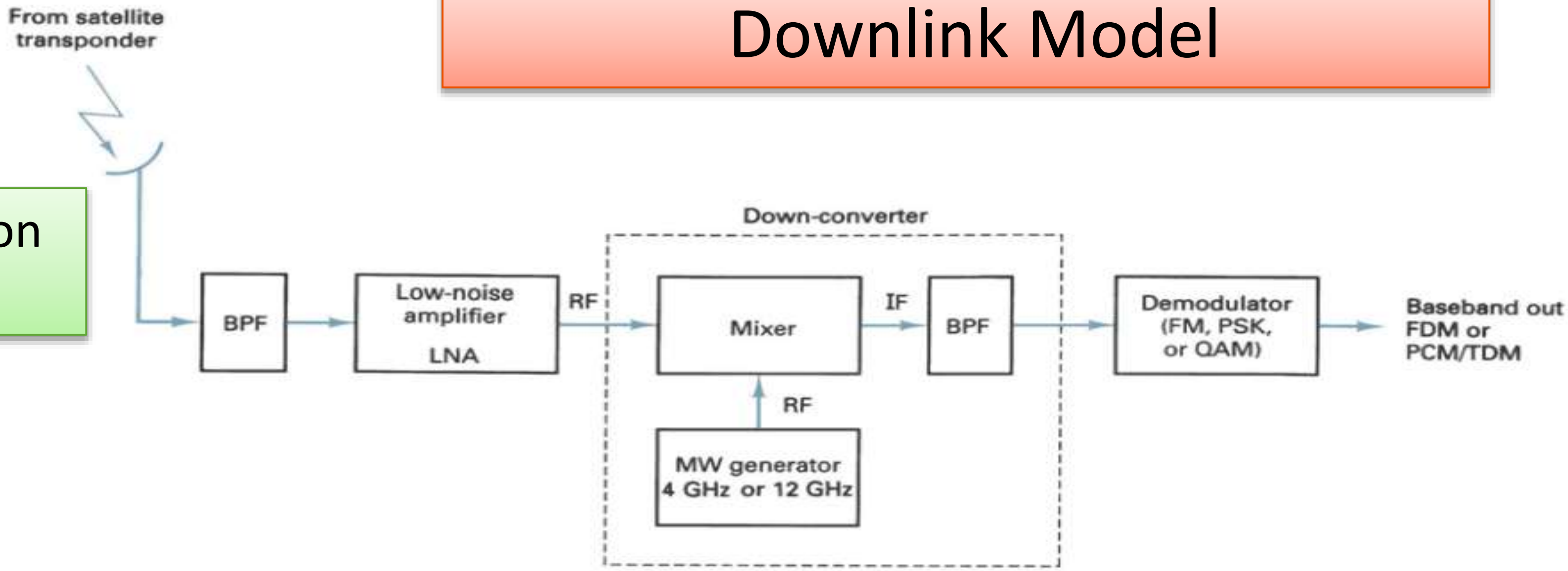
Each RF satellite channel requires a separate transponder.

Transponder Model

- The transmitter-receiver combination in the satellite is known as a transponder.
- The basic functions of a transponder are amplification and frequency translation
- The reason for frequency translation is that the transponder cannot transmit and receive on the same frequency.
- Widely spaced transmit and receive frequencies prevent interference (2 GHz)
- Although the typical transponder has a wide bandwidth, it is used with only one uplink or downlink signal to minimize interference and improve communication reliability.
- Most satellites contain multiple transponders, each operating at a different frequency to be economically feasible (Ex. 24 channels: 12 vertically polarized and 12 horizontally polarized).
- Various multiple-access schemes are used so that each channel can carry multiple information transmissions.

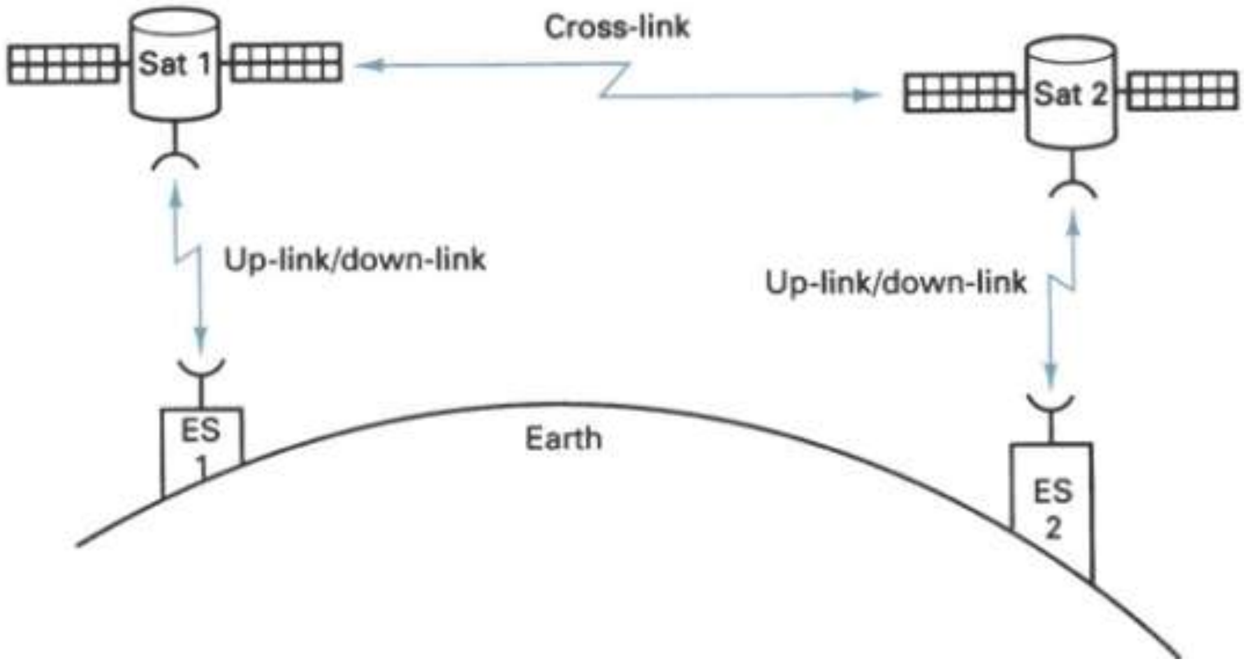
Downlink Model

earth station receiver



	Component	function
1	**Input BPF**	limits the total noise applied to the input of the LNA
2	LNA	is a highly sensitive, low-noise device, such as a tunnel diode amplifier.
3	RF-to-IF down-converter	Is a mixer/bandpass filter combination that converts the received RF signal to an IF frequency.
4	Demodulator	

Cross-Links



- Occasionally, there is an application where it is necessary to communicate between satellites.
- This is done using satellite cross-links or intersatellite links (ISLs)
- A disadvantage of using an ISL is that both the transmitter and the receiver are space bound (i.e. both the transmitter's output power and the receiver's input sensitivity are limited.)

Frequency Allocations

- Most communication satellites operate in the microwave frequency spectrum.
- However, there are some exceptions (For example, many military satellites operate in the 200- to 400-VHF/UHF range).
- VHF, UHF, and microwave signals penetrate the ionosphere with little or no attenuation and are not refracted to earth, as are lower-frequency signals in the 3- to 30-MHz range.

- The microwave spectrum is divided up into frequency bands that have been allocated to satellites as well as other communication services:

- ✓ One of the most widely used satellite communication bands is the C band.
- ✓ Uplink frequencies are 5.925 to 6.425 GHz.
- ✓ The downlink is in the 3.7- to 4.2-GHz range.
- ✓ The C band is referred to by the designation 6/4 GHz, where the uplink frequency is given first.
- ✓ C band is over-crowded now

Frequency bands used in satellite communication.

Band	Frequency
P	225–390 MHz
J	350–530 MHz
L	1530–2700 MHz
S	2500–2700 MHz
C	3400–6425 MHz
X	7250–8400 MHz
Ku	10.95–14.5 GHz
Ka	17.7–31 GHz
Q	36–46 GHz
V	46–56 GHz
W	56–100 GHz

Frequency Allocations

- ✓ Currently, the Ku band is receiving the most attention to avoid interference in the C-band.
- ✓ Ku band designated as 14/12 GHz.

- ➢ Another advantage is that for a given antenna size, the gain is higher in the Ku band than in the C band.
- ➢ This can improve communication reliability while decreasing antenna size and cost.

- ➢ Two other bands of interest are the X and L bands.
- ➢ The military uses the X band for its satellites and radar.
- ➢ The L band is used for navigation as well as marine and aeronautical communication and radar.

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Spectrum Usage

Next Lecture