Advanced Electronic Communication Systems
Fourth Year, ECE

Lecture 6

Satellite Look Angles (Part 2)

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Geostationary Satellite Look Angles Tables

- For geostationary orbit, the look angles 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. 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.

Geostationary Satellite Look Angles Tables

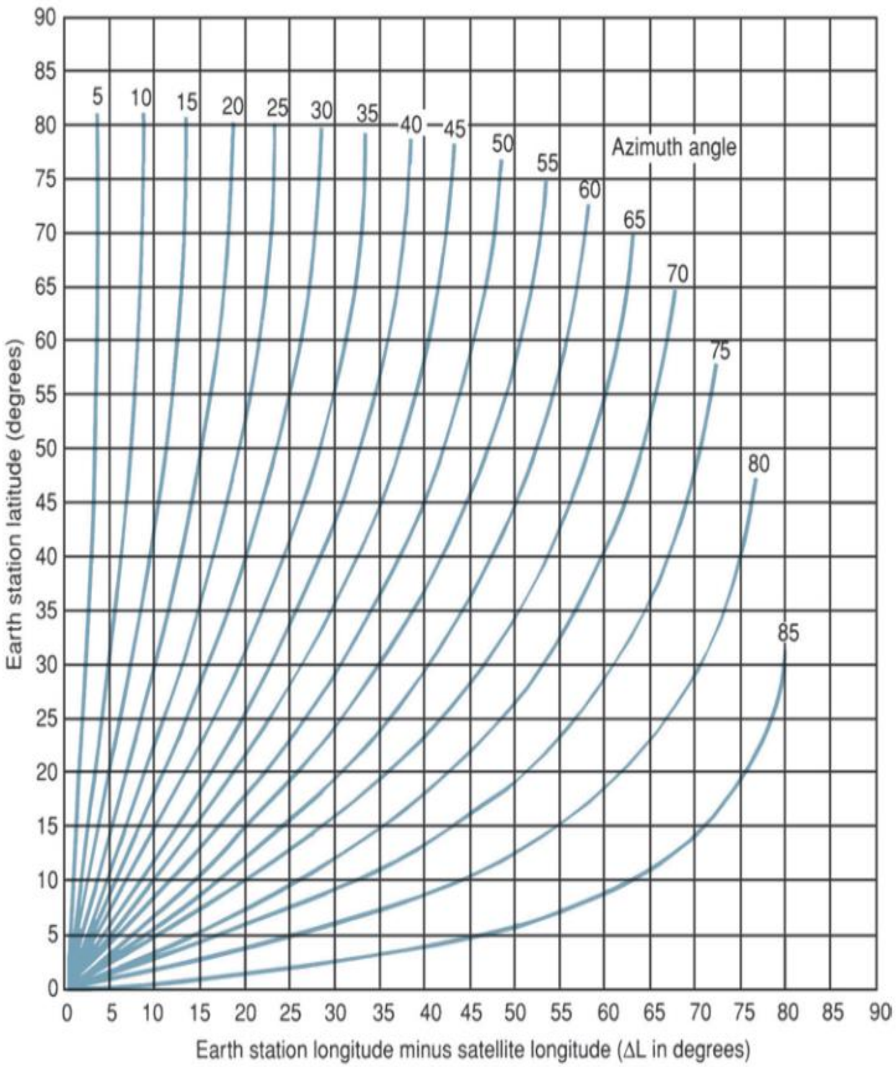


FIGURE 12 Azimuth angles for earth stations located in the northern hemisphere referenced to 180 degrees

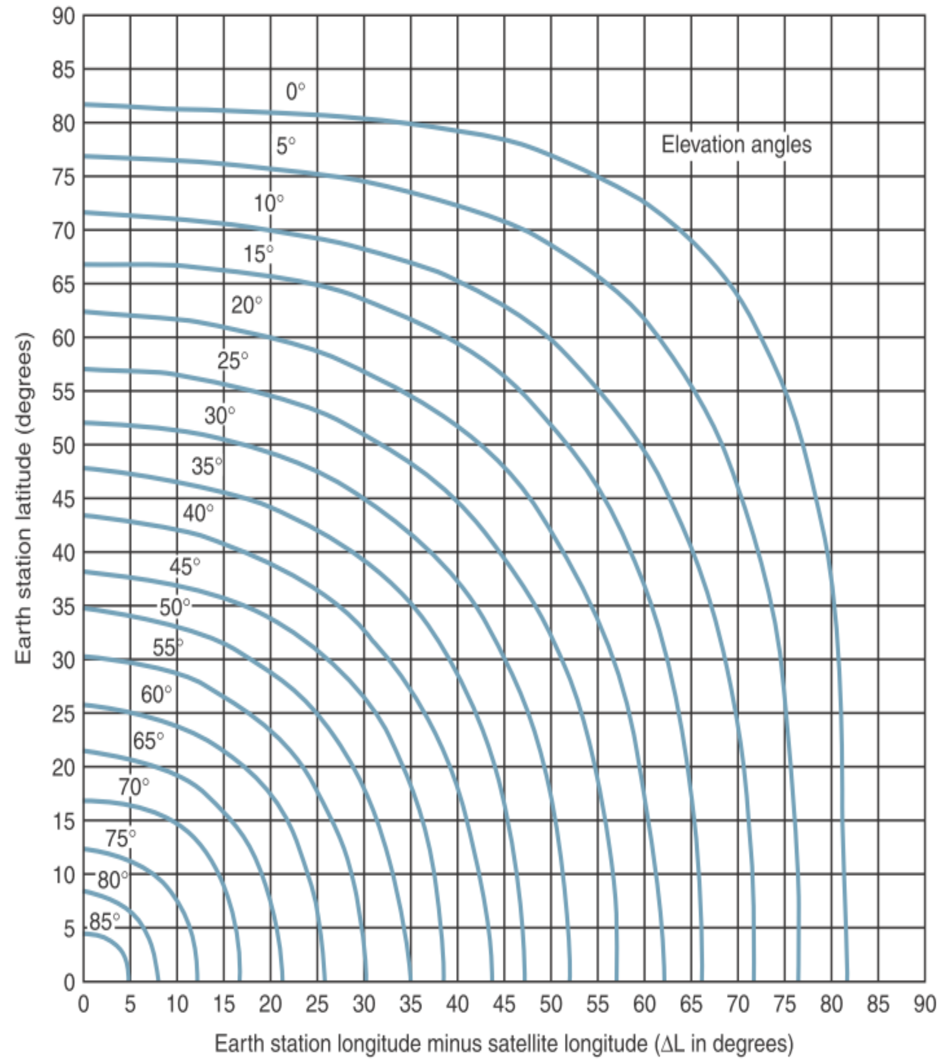


FIGURE 13 Elevation angles for earth stations located in the Northern Hemisphere

Geostationary Satellite Look Angles Tables

Example 1

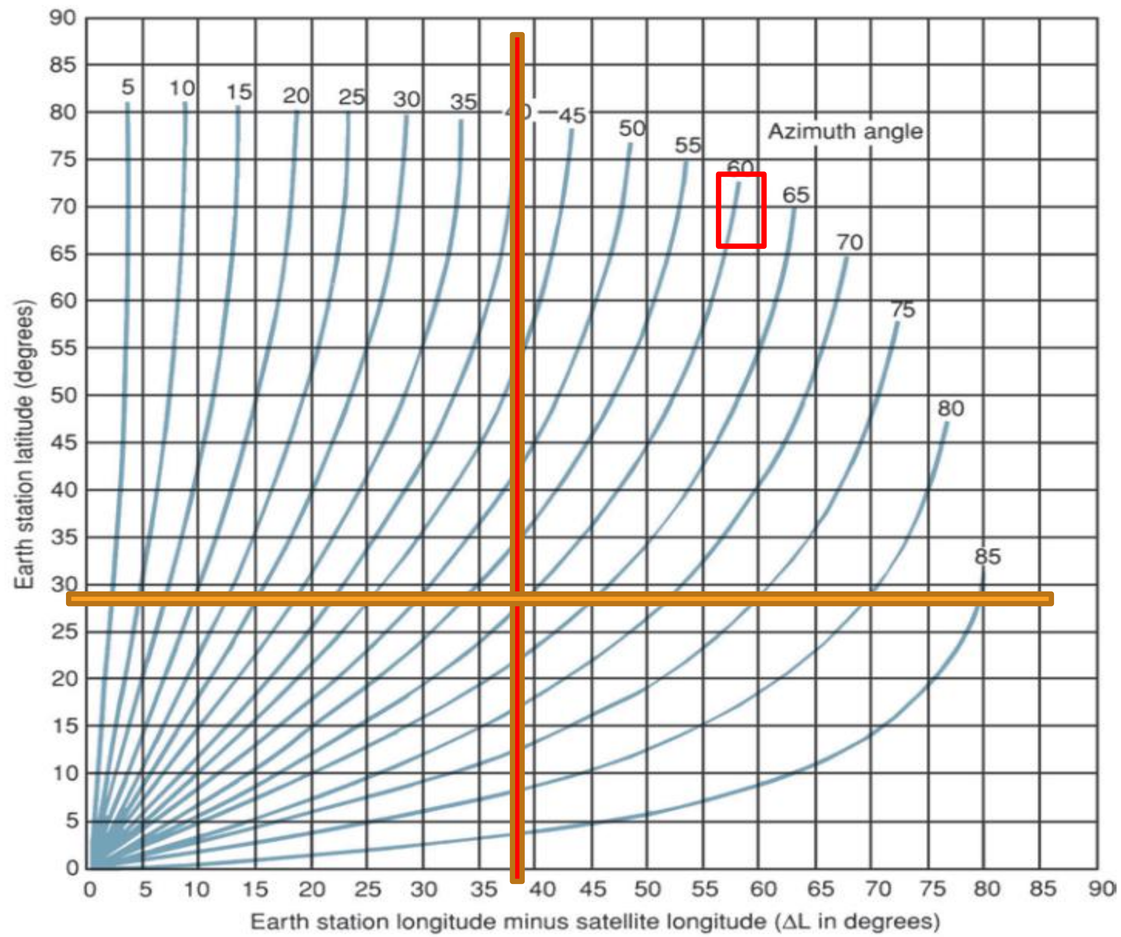
An earth station is located in Houston, Texas, which has a longitude of 95.5°W and a latitude of 29.5°N. The satellite of interest is RCA's *Satcom 1*, which has a longitude of 135°W. Determine the azimuth angle and elevation angle for the earth station.

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°



Geostationary Satellite Look Angles Tables

Example 1

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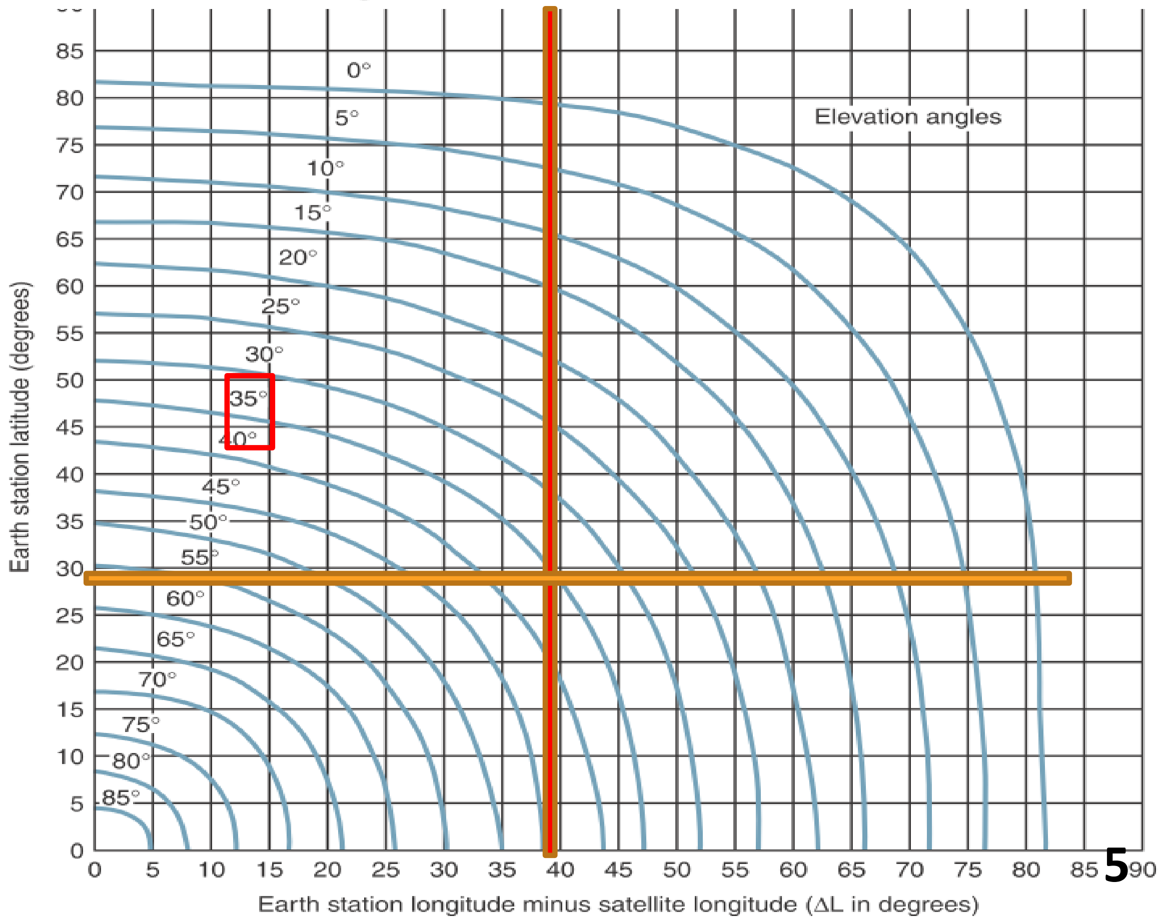
Solution First determine the difference between the longitude of the earth station and the satellite

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

From the figure, the azimuth angle is approximately 59°

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

From the figure, the elevation angle is approximately 35°



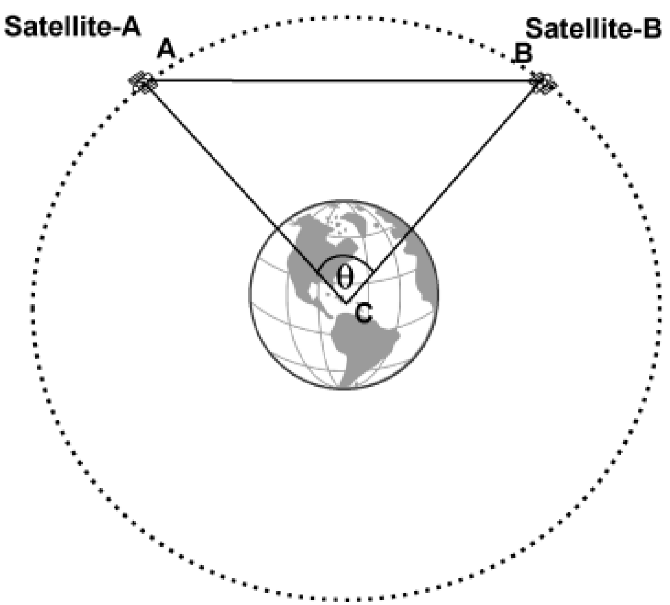
3.9.4 Computing the Line-of-Sight Distance between Two Satellites

- The line-of-sight distance between two satellites placed in the same circular orbit can be computed from triangle ABC

$$AB = \sqrt{(AC^2 + BC^2 - 2\,AC\,BC\ \cos\theta)}$$

where AC = BC = orbit radius for a geo-stationary orbit

- The angle θ will be the angular separation of the longitudes of the two satellites.
  - ✓ If the two satellites are located at 30° E and 60° E, then $\theta = 30°$.
  - ✓ If the two locations are 30° W and 60° E, then $\theta = 90°$.



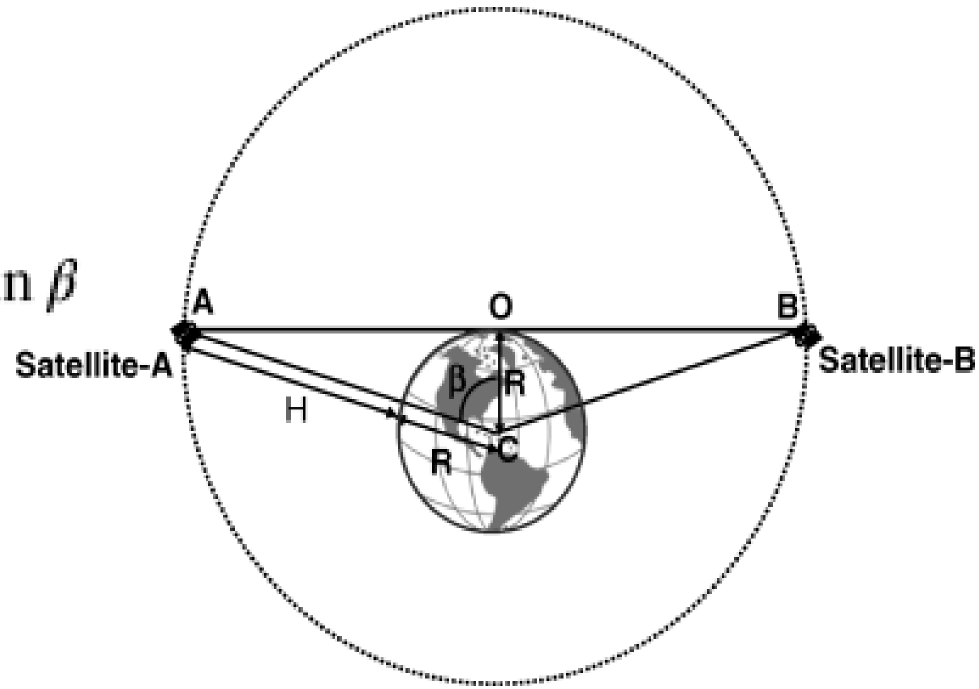
- The **maximum line-of-sight** distance between these two satellites occurs when the satellites are placed so that the line joining the two becomes tangent to the Earth's surface,

$$AB = OA + OB$$

$$OA = OB$$

$$OA = AC \sin\beta = (R + H) \sin\beta$$

$$\beta = \cos^{-1}\left(\frac{R}{R+H}\right)$$



$$\text{Maximum line-of-sight distance} = 2(R + H) \sin\left[\cos^{-1}\left(\frac{R}{R+H}\right)\right]$$

3.10 Earth Coverage and Ground Tracks

- **Earth coverage**, also known as the ‘footprint’, is the surface area of the Earth that can possibly be covered by a given satellite.

- The area of Earth covered by a satellite depends on:
  1. The location of the satellite in its geostationary 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.

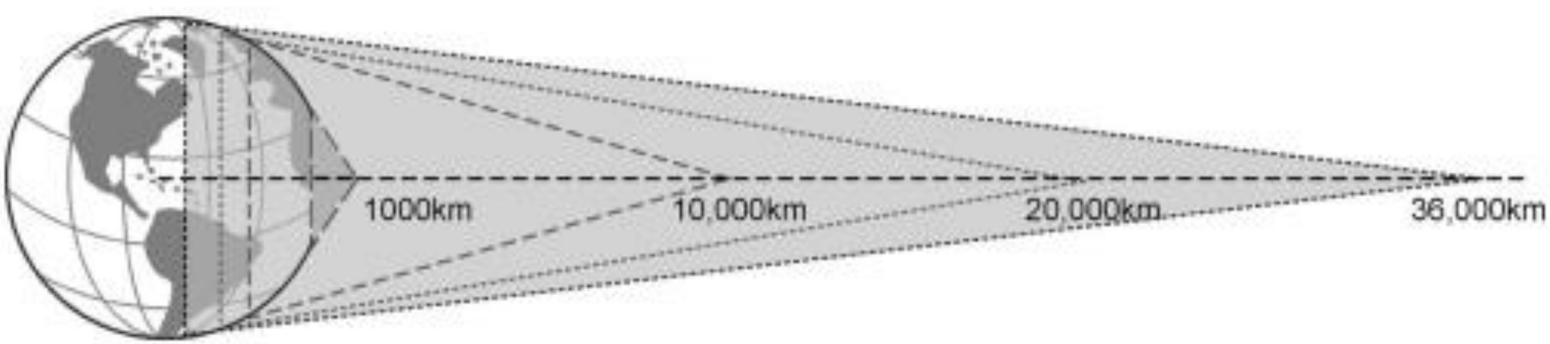
1. Earth Coverage: The radiation patterns covers approximately one-third of Earth’s surface.
2. Zonal coverage: covers an area less than one-third of Earth’s surface.
3. Spot coverage: beams concentrate the radiated power in a very small geographic area.

3.10 Earth Coverage and Ground Tracks

3.10.1 Satellite Altitude and the Earth Coverage Area

- The coverage area increases with the height of the satellite above the surface of the Earth.
- It varies from something like 1.5 % of the Earth's surface area for a LEO at 200 km to about 43 % for a GEO at 36 000 km.
- The coverage angle, from Equation (3.26), can be computed :

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



3.10 Earth Coverage and Ground Tracks

3.10.1 Satellite Altitude and the Earth Coverage Area

Table 3.7 Variation of the coverage area as a function of the satellite altitude

Satellite altitude (km)	Coverage area (% of Earth's surface area)
200	1.5
300	2.0
400	2.5
500	3.0
600	3.5
700	4.5
800	5.5
900	6.0
1 000	7.0
2 000	12.0
4 000	18.5
5 000	21.5
6 000	24.0
7 000	26.0
8 000	27.5
9 000	29.0
10 000	30.0
15 000	35.0
20 000	37.5
25 000	40.0
30 000	41.5
36 000	43.0

It can be seen from the table that the increase in coverage area with an increase in altitude is steeper in the beginning than it is as the altitude increases beyond 10 000 km.

3.10 Earth Coverage and Ground Tracks

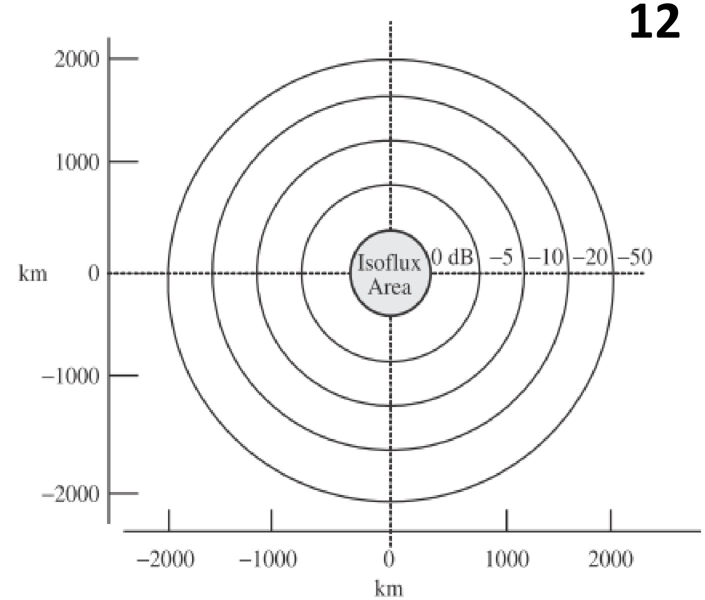
3.10.1 Satellite Altitude and the Earth Coverage Area

Table 3.8 Variation of the full coverage angle as a function of the satellite altitude

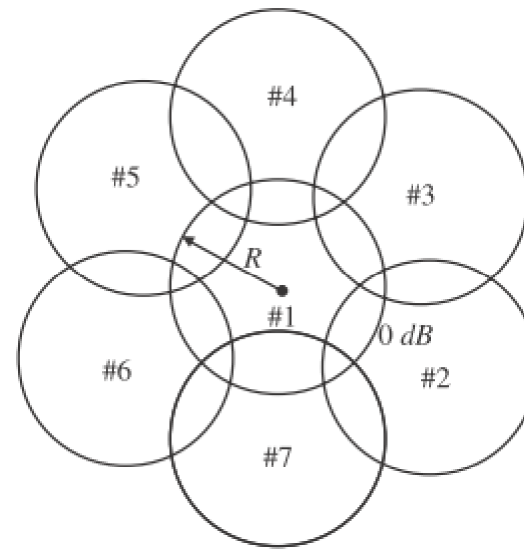
Satellite altitude (km)	Full Coverage angle (deg)
200	150
300	144
400	138
500	134
600	130
700	126
800	124
900	120
1 000	118
2 000	100
4 000	76
5 000	68
6 000	60
7 000	56
8 000	52
9 000	48
10 000	44
15 000	32
20 000	26
25 000	22
30 000	18
36 000	17

Footprints isoflux

- 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



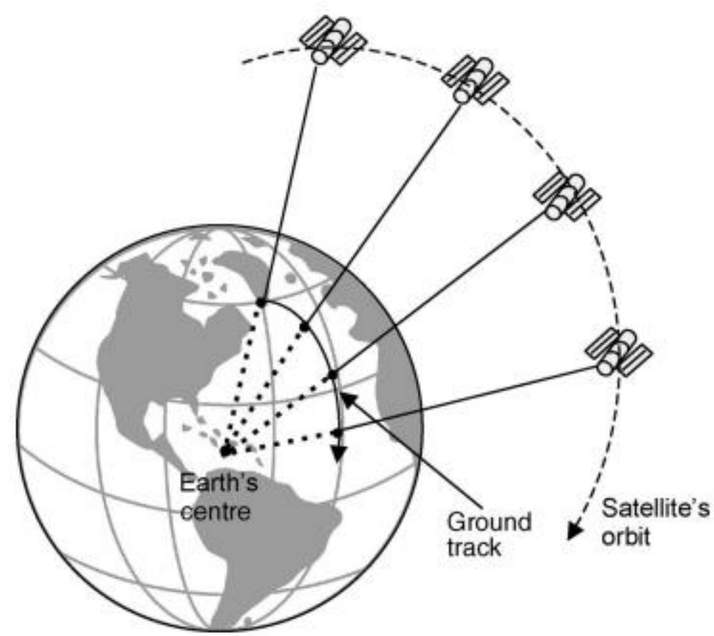
3.10 Earth Coverage and Ground Tracks

- **Ground track** is the path followed by the sub-satellite point while the satellites rotates in its orbit.

3.10.2 Satellite Ground Tracks

- If the Earth were not rotating, the ground track would simply be the circumference of the great circle formed by the bisection of the Earth with the orbital plane of the satellite.
- Two factors that influence the ground track due to Earth’s rotation:

1. The altitude of the satellite
2. The latitude at which the satellite is located

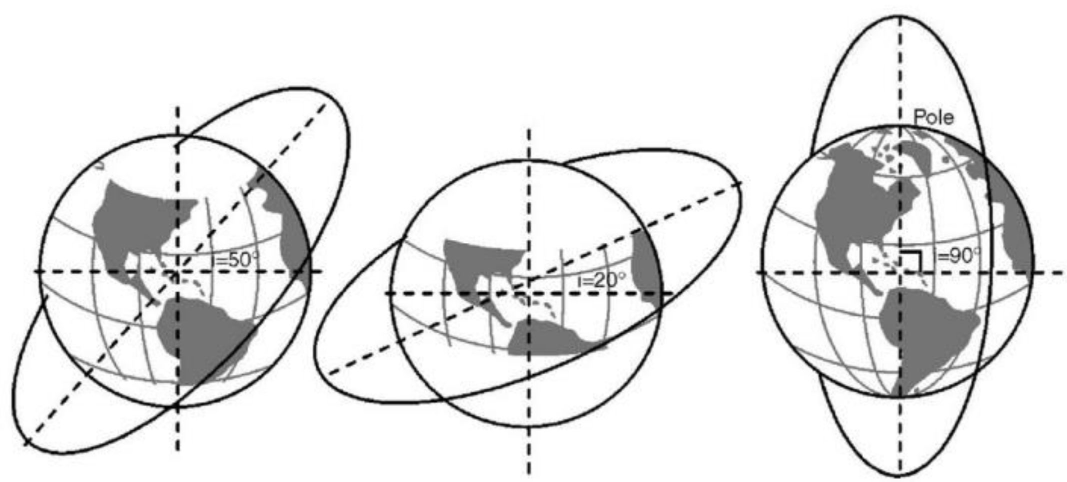


Satellite Ground Track

Molniya Satellite Ground Track
(HEO Track)

3.10.3 Orbit Inclination and Latitude Coverage

- The northern and southern latitudes of the terrestrial segment covered by the satellite's ground track depend upon the satellite orbit inclination
- The **covered zone** from the extreme northern latitude to the extreme southern latitude, which is symmetrical about the equator, is called the **latitude coverage**
- The latitude coverage is 100 % only in the case of polar orbits.
- The higher the orbit inclination, the greater is the latitude coverage.
- This also explains why an equatorial orbit is not useful for higher latitude regions and also why a highly inclined Molniya orbit is more suitable for the territories of Russia



Advanced Electronic Communication Systems
Fourth Year, ECE

Lecture 7

Intro to Satellite System Hardware

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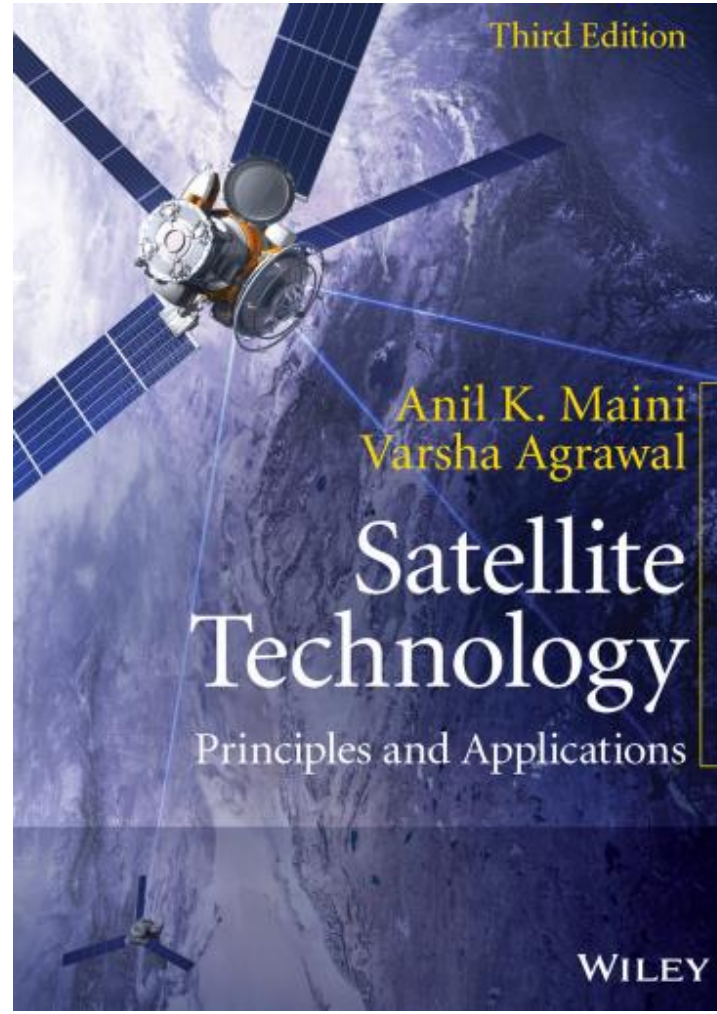
4

Satellite Hardware

- This chapter presents a closer look at what a typical satellite comprises, irrespective of its intended application.
- Different subsystems and their major functions are also presented



4.1 Satellite Subsystems

- A typical satellite (communications, weather forecasting ,or remote sensing satellite) consists of the following subsystems:

1. Mechanical structure
2. Propulsion subsystem
3. Thermal control subsystem
4. Power supply subsystem
5. Telemetry, tracking and command (TT&C) subsystem
6. Attitude and orbit control subsystem
7. Payload subsystem
8. Antenna subsystem

4.1 Satellite Subsystems

1. The mechanical structural subsystem

- Provides the framework for mounting other subsystems of the satellite
- Provides an interface between the satellite and the launch vehicle.

2. The propulsion subsystem

- is used to provide the thrusts required to impart the necessary velocity changes to execute all the maneuvers during the satellite lifetime
- This would include major maneuvers required to move the satellite from its transfer orbit to the final orbit or moving it to the **graveyard** orbit for decommission at the end of its life-span and also the smaller maneuvers needed throughout the lifespan of the satellite, such as those required for station keeping or avoiding debris.

4.1 Satellite Subsystems

3. The thermal control subsystem

- It is essential to maintain the satellite platform within its operating temperature limits for the type of equipment on board the satellite.
- It also ensures the desirable temperature distribution throughout the satellite structure, which is essential to retain dimensional stability and maintain the alignment of certain critical equipment.

4. The power supply subsystem

- It is used to collect the solar energy, transform it to electrical power with the help of arrays of solar cells
- It distributes electrical power to other components and
- It contains batteries, which provide standby power during eclipse periods, other emergency situations, and during the launch phase of the satellite when the solar arrays are not yet functional

4.1 Satellite Subsystems

5. The telemetry, tracking and command (TT&C) subsystem

- It monitors and controls the satellite from the lift-off stage to the end of its operational life in space.
- The tracking part determines the position of the spacecraft and follows its travel using angle, range and velocity information.
- The telemetry part gathers information on the health of various subsystems of the satellite, encodes this information and then transmits the same.
- The command element receives and executes remote control commands to effect changes to the platform functions, configuration, position and velocity.

4.1 Satellite Subsystems

6. The attitude and orbit control (AOC) subsystem

- It performs two primary functions.
- It controls the orbital path, which is required to ensure that the satellite is in the correct location in space to provide the intended services.
- It also provides attitude control, which is essential to prevent the satellite from tumbling in space and also to ensure that the antennas remain pointed at a fixed point on the Earth’s surface.

4.1 Satellite Subsystems

7. The payload subsystem

- It is that part of the satellite that carries the desired instrumentation required for performing its intended function and is therefore the most important subsystem of any satellite.
- **The nature of the payload on any satellite depends upon its mission.**
- The basic payload in the case of a **communication** satellite is the transponder, which acts as a receiver, an amplifier and a transmitter.
- For a **weather forecasting** satellite, a radiometer is the most important payload.
- For **a remote sensing** satellite, High resolution cameras, multispectral scanners and thematic mappers are the main payloads
- **Scientific** satellites have a variety of payloads depending upon the mission. These include telescopes, spectrographs, plasma detectors, magnetometers, spectrometers and so on.

4.1 Satellite Subsystems

8. The Antennas subsystem

- Antennas are used for both receiving signals from ground stations as well as for transmitting signals towards them.
- There are a variety of antennas available for use on board a satellite.
- The final choice depends mainly upon the frequency of operation and required gain.
- **Typical antenna types used on satellites include** horn antennas, centre-fed and offset-fed parabolic reflectors and lens antennas.

Thank you