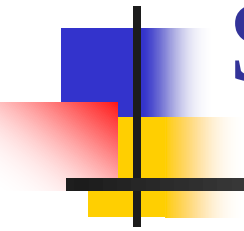


# Satellite Communications

Chapter 9

# Satellite-Related Terms

- Earth Stations – antenna systems on or near earth
- Uplink – transmission from an earth station to a satellite
- Downlink – transmission from a satellite to an earth station
- Uplink frequency is greater than downlink cause Earth station has more power to compensate free space loss.
- Transponder – electronics in the satellite that convert uplink signals to downlink signals

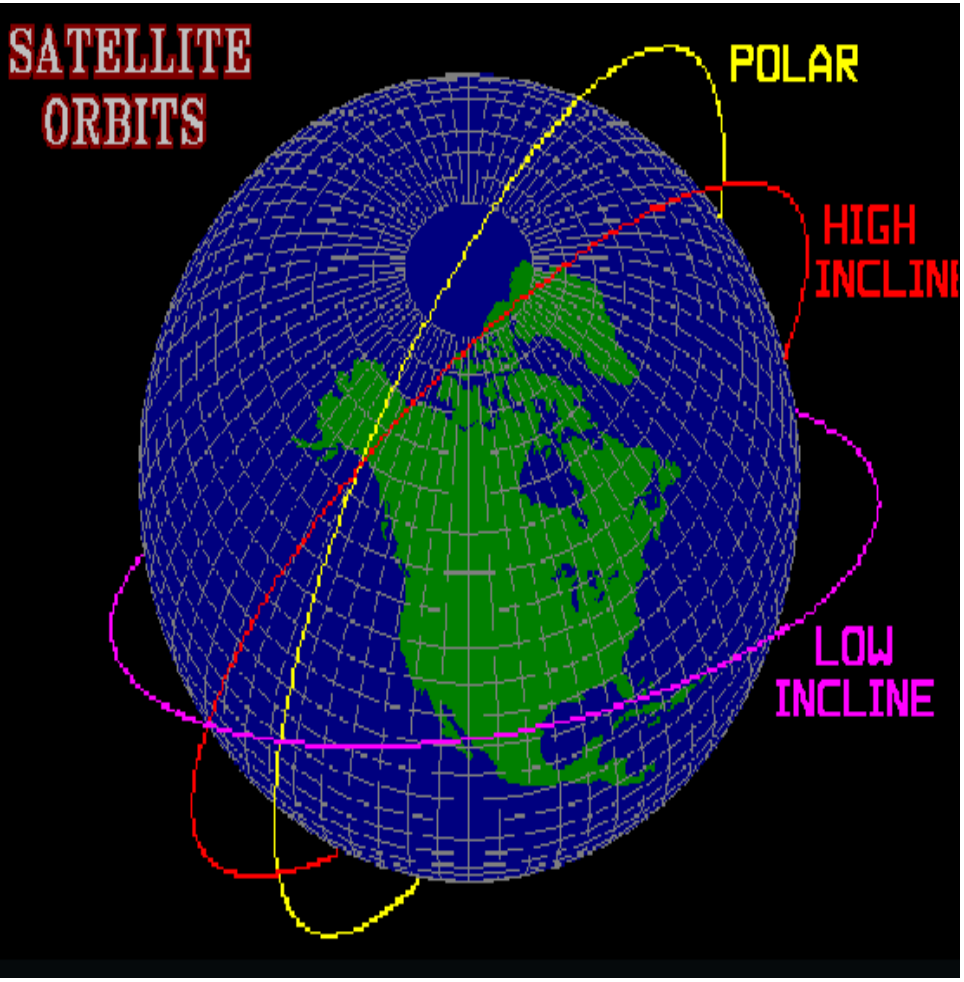
# Ways to Categorize Communications Satellites

- Coverage area
  - Global, regional, national
- Service type
  - Fixed service satellite (FSS)
  - Broadcast service satellite (BSS)
  - Mobile service satellite (MSS)
- General usage
  - Commercial, military, amateur, experimental

# Classification of Satellite Orbits

- Circular or elliptical orbit
  - Circular with center at earth's center
  - Elliptical with one foci at earth's center
- Orbit around earth in different planes
  - Equatorial orbit above earth's equator
  - Polar orbit passes over both poles
  - Other orbits referred to as inclined orbits
- Altitude of satellites
  - Geostationary orbit (GEO)
  - Medium earth orbit (MEO)
  - Low earth orbit (LEO)

# Satellite Orbits



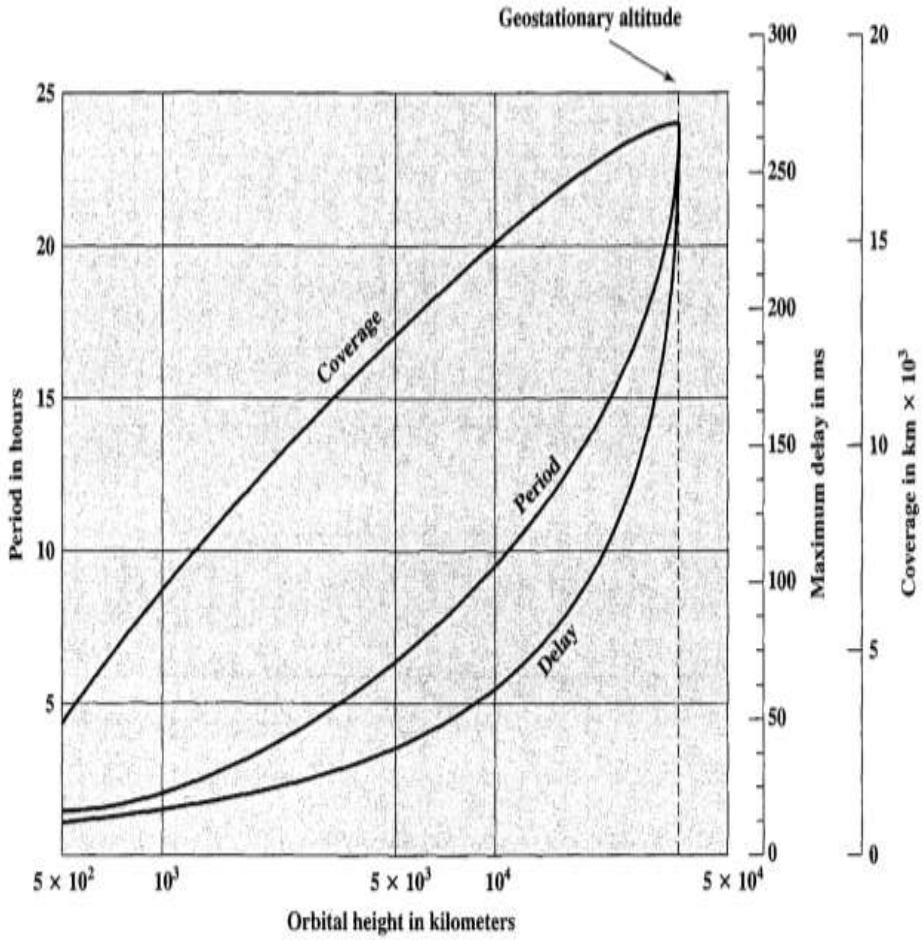




Figure 9.2 Satellite Parameters as a Function of Orbital Height

# Geometry Terms

- Elevation angle (θ): the angle from the horizontal to the point on the center of the main beam of the antenna when the antenna is pointed directly at the satellite
- Minimum elevation angle is preferred
- Coverage angle (β): the measure of the portion of the earth's surface visible to the satellite
- Distance from satellite and farthest point:

$$d = \frac{(R + h)\sin\beta}{\cos\theta} = \frac{R\sin\beta}{\sin\alpha}$$

- Round-trip transmission delay:

$$\frac{2h}{c} \le t \le \frac{2(R + h)\sin\beta}{c(\cos\theta)}$$

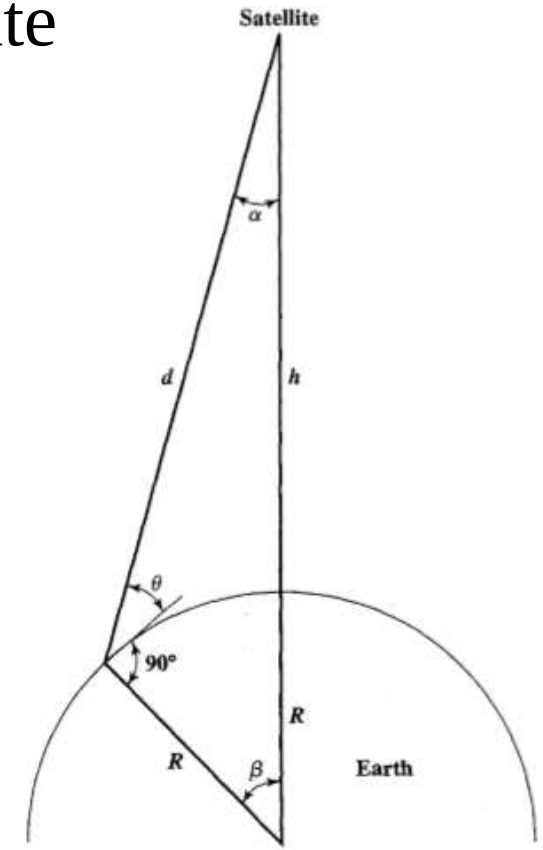


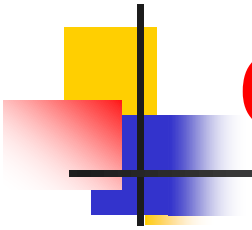

Figure 9.1 Coverage and Elevation Angles

# Minimum Elevation Angle

- Reasons affecting minimum elevation angle of earth station's antenna (>0$^{o}$)
  - Buildings, trees, and other terrestrial objects block the line of sight
  - Atmospheric attenuation is greater at low elevation angles
  - Electrical noise generated by the earth's heat near its surface adversely affects reception

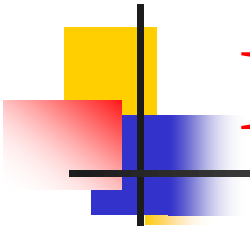
# GEO Satellite Characteristics

- The most common type of satellite communication
- Usually, the satellite is in a circular orbit 35,863 km above the earth's surface
- Diameter of coverage is about 16,000 km
- Rotate at exactly the same angular speed as the earth
- So, they remain above the same spot on the equator as the earth rotates.



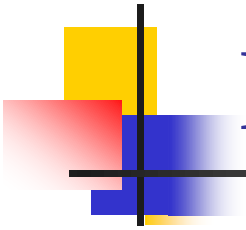
# GEO Orbit

- Advantages:
  - No problem with frequency changes
  - Tracking of the satellite is simplified
  - Large coverage area
- Disadvantages:
  - Weak signal after traveling over 35,000 km
  - Polar regions are poorly served
  - Signal sending delay is substantial (round trip delay 500 ms)



# LEO Satellite Characteristics

- Often in polar orbit under 2000 km
- Orbit period ranges from 1.5 to 2 hours
- Diameter of coverage is about 8000 km
- Round-trip signal propagation delay less than 20 ms
- Maximum satellite visible time up to 20 min
- System must cope with large Doppler shifts



# LEO Categories

- Little LEOs
  - Frequencies below 1 GHz
  - 5MHz of bandwidth
  - Data rates up to 10 kbps
  - Aimed at paging, tracking, and low-rate messaging
- Big LEOs
  - Frequencies above 1 GHz
  - Support data rates up to a few megabits per sec
  - Offer same services as little LEOs in addition to voice and positioning services

# LEO Orbit

- Advantages:
  - Reduced propagation delay
  - Strong received LEO signal compared with GEO
  - Localized small coverage so that the spectrum can be conserved (reused)
- Disadvantages:
  - Many satellites are needed for broad coverage over 24 hours
  - Problem with frequency changes

# MEO Satellite Characteristics

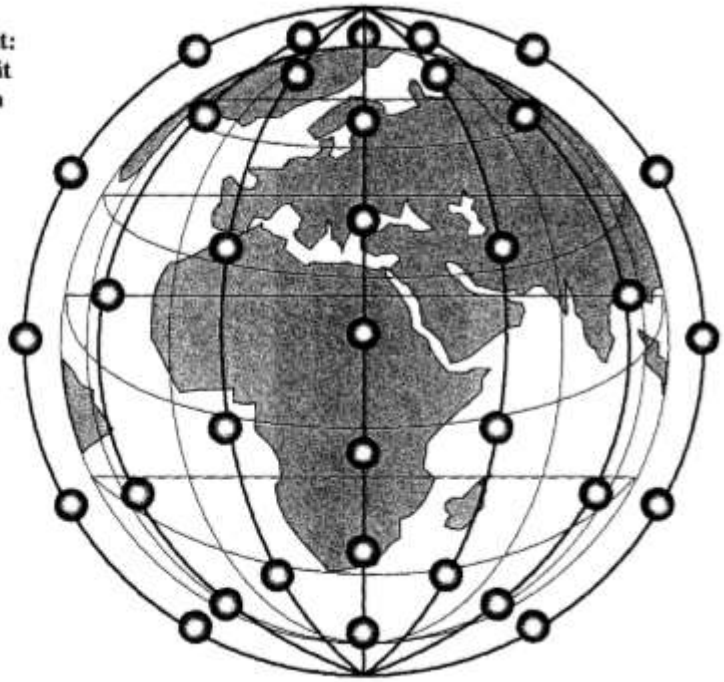
- Inclined orbit at an altitude in the range of 5000 to 12,000 km
- Orbit period of 6 hours
- Diameter of coverage is 10,000 to 15,000 km
- Round trip signal propagation delay less than 50 ms
- Maximum satellite visible time is a few hours

**Table 9.1** Orbital Comparison for Satellite Communications Applications

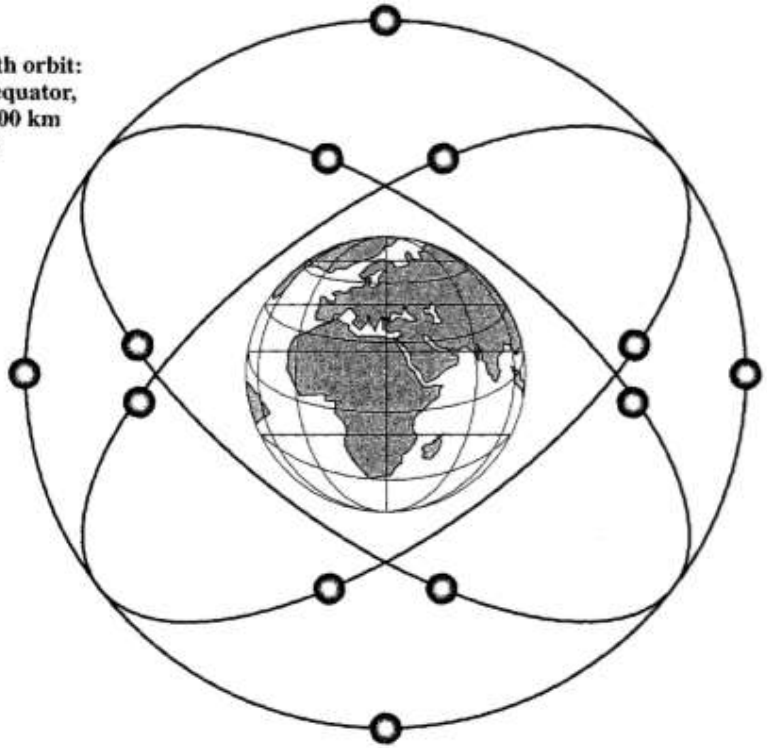
| Orbits | LEO | MEO | GEO |
|---|---|---|---|
| Orbital period | 1.5 to 2 h | 5 to 10 h | 24 h |
| Altitude range | 500 to 1500 km | 8000 to 18,000 km | 35,863 km |
| Visibility duration | 15 to 20 min/pass | 2 to 8 hr/pass | Permanent |
| Elevation | Rapid variations; high and low angles | Slow variations; high angles | No variation; low angles at high latitudes |
| Round-trip propagation delay | Several millliseconds | Tens of milliseconds | ≈250ms |
| Instantaneous ground coverage (diameter at 10° elevation) | ≈6000 km | ≈12,000 to 15,000 km | 16,000 km |
| Examples of systems | Iridium<br>Globalstar<br>Teledesic<br>Skybridge, Orbcomm | Odyssey<br>Inmarsat | Intelstat<br>Interspoutnik<br>Inmarsat |

# LEO and MEO Satellite

(a) Low earth orbit: often in polar orbit at 500 to 1500 km altitude



(b) Medium earth orbit: inclined to the equator, at 5000 to 18,000 km altitude



# Frequency Bands Available for Satellite Communications

| Band | Frequency Range | Total Bandwidth | General Application |
|---|---|---|---|
| L | 1 to 2 GHz | 1 GHz | Mobile satellite service (MSS) |
| S | 2 to 4 GHz | 2 GHz | MSS, NASA, deep space research |
| C | 4 to 8 GHz | 4 GHz | Fixed satellite service (FSS) |
| X | 8 to 12.5 GHz | 4.5 GHz | FSS military, terrestrial earth exploration, and meteorological satellites |
| Ku | 12.5 to 18 GHz | 5.5 GHz | FSS, broadcast satellite service (BSS) |
| K | 18 to 26.5 GHz | 8.5 GHz | BSS, FSS |
| Ka | 26.5 to 40 GHz | 13.5 GHz | FSS |

# Satellite Link Performance Factors

- Distance between earth station antenna and satellite antenna
  - Free space loss propagation model
- For downlink, terrestrial distance between earth station antenna and "aim point" of satellite
  - Displayed as a satellite footprint (Figure 9.6)
- Atmospheric attenuation
  - Affected by oxygen, water, angle of elevation, and higher frequencies

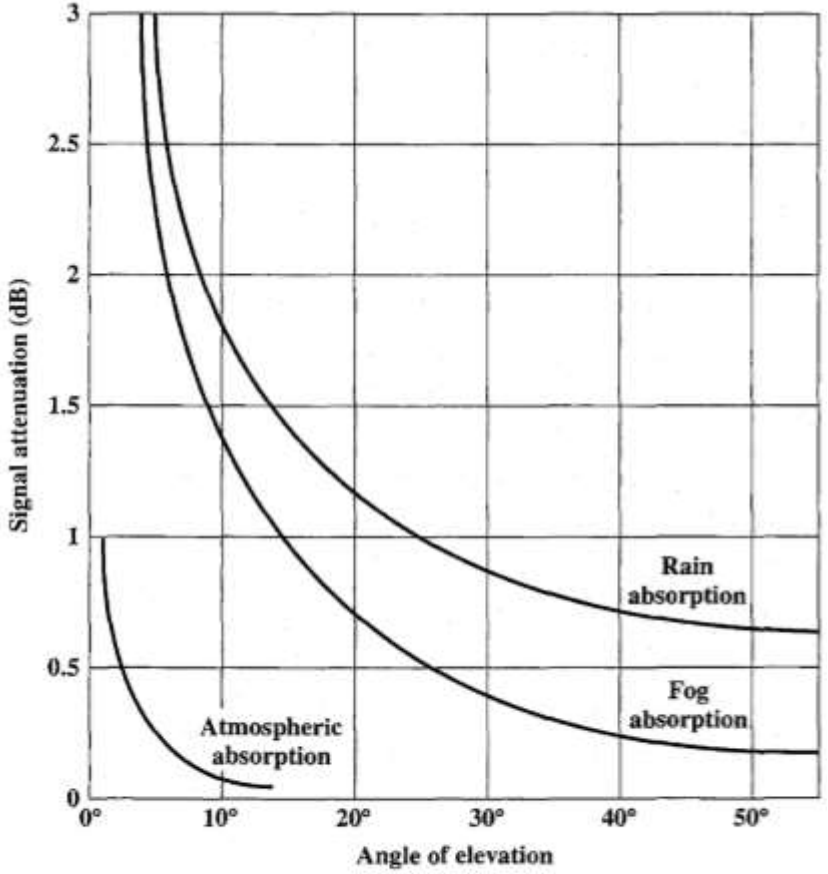



Figure 9.7 Signal Attenuation Due to Atmospheric Absorption (C Band)

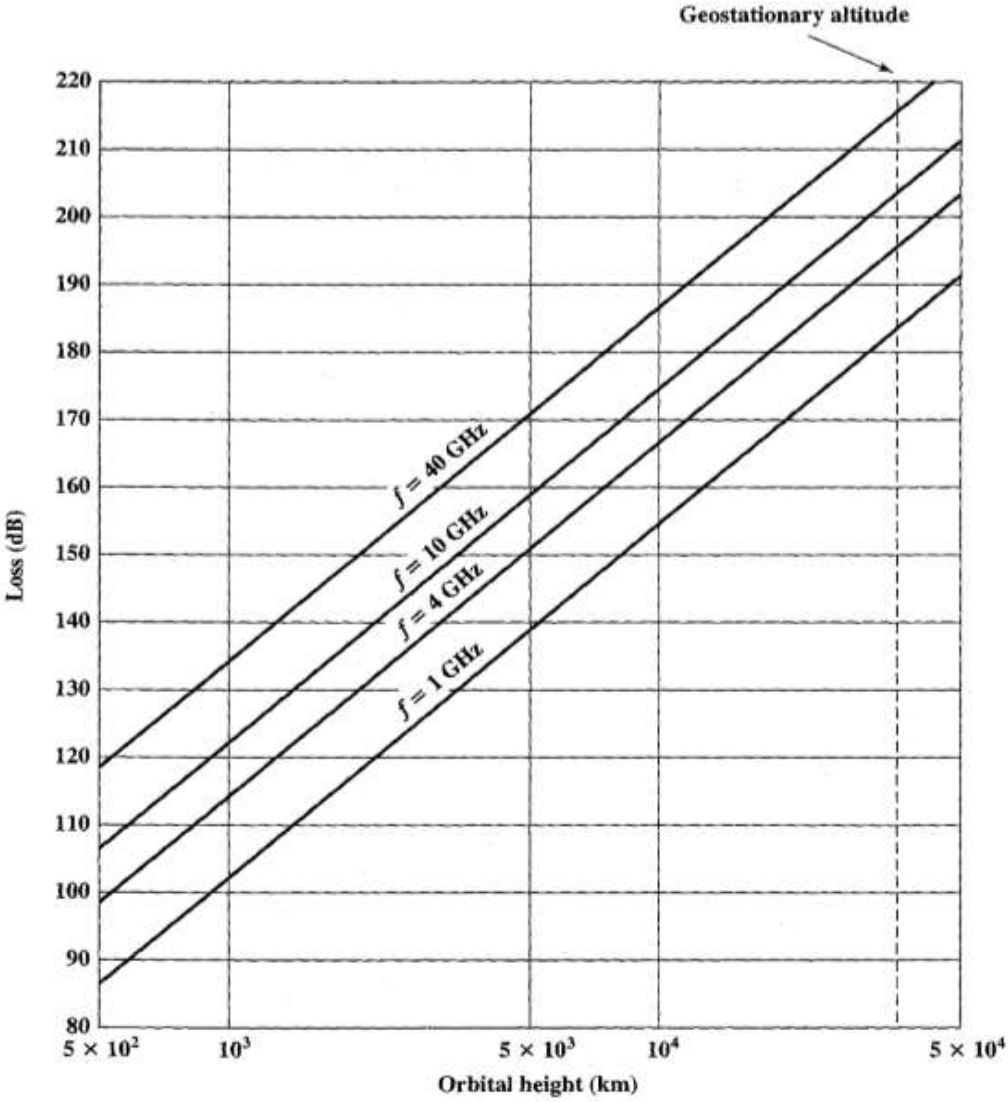



Figure 9.5 Minimum Free Space Loss as a Function of Orbital Height

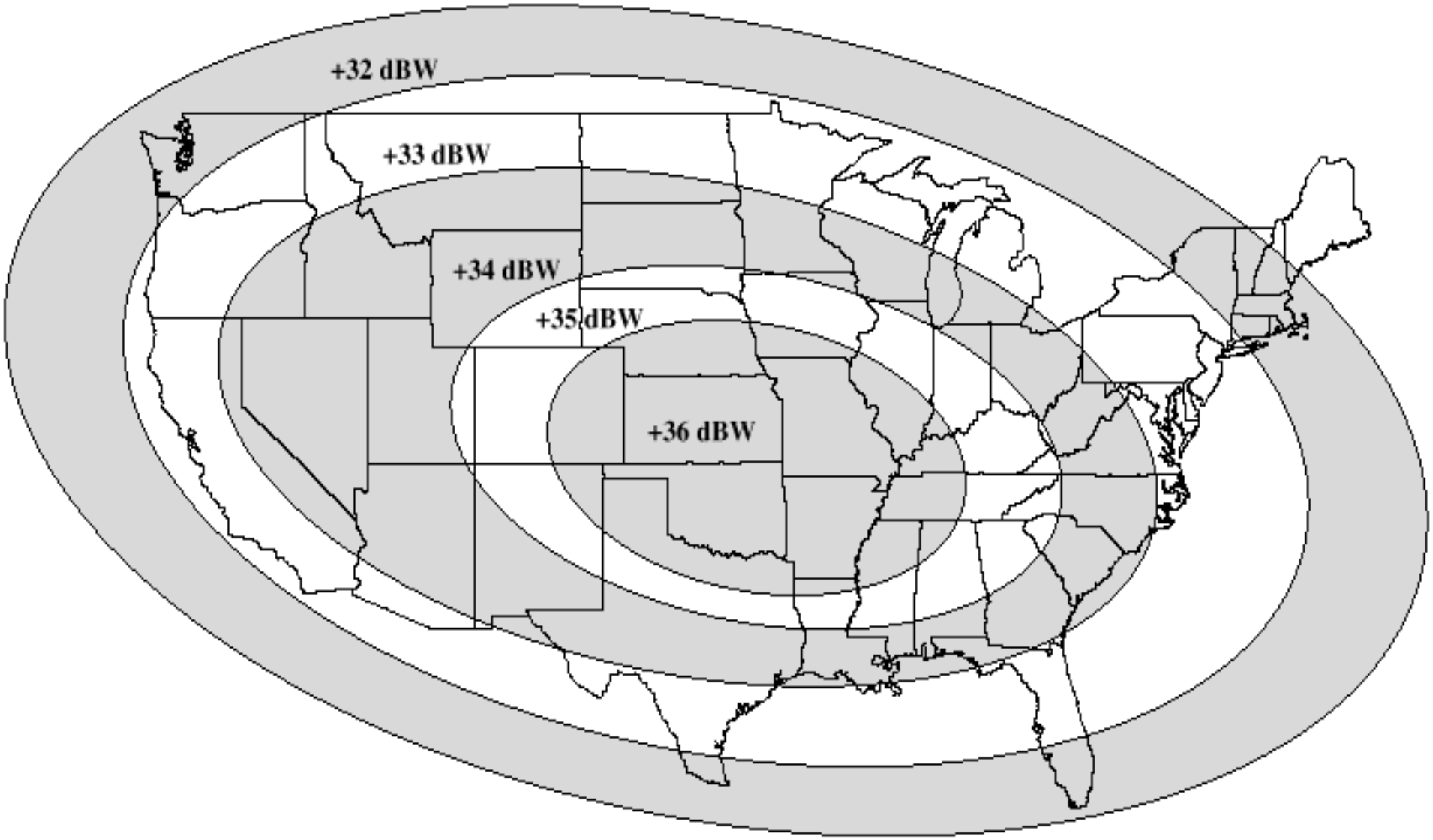
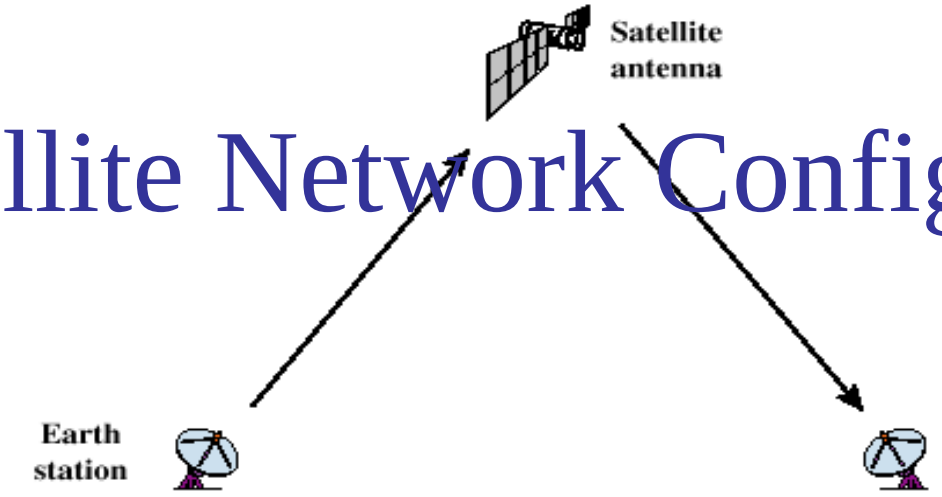
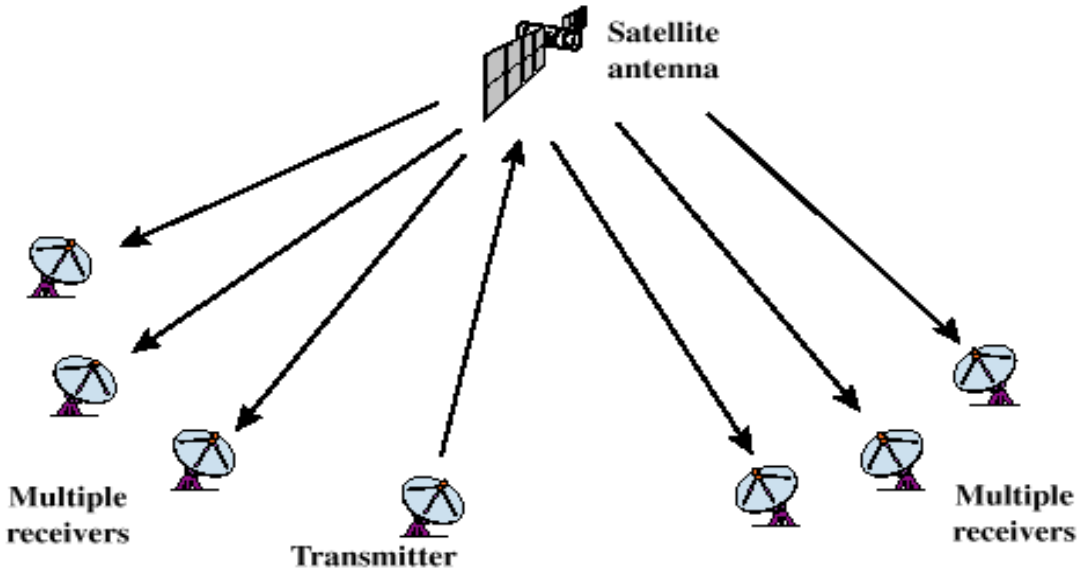



**Figure 9.6 Typical Satellite Footprint**

# Satellite Network Configurations




(a) Point-to-point link




(b) Broadcast link

**Figure 9.8 Satellite Communication Configurations**

# Capacity Allocation Strategies

- Frequency division multiple access (FDMA)
- Time division multiple access (TDMA)
- Code division multiple access (CDMA)

# Frequency-Division Multiplexing

- Alternative uses of channels in point-to-point configuration:
  - 1200 voice-frequency (VF) voice channels
  - One 50-Mbps data stream
  - 16 channels of 1.544 Mbps each
  - 400 channels of 64 kbps each
  - 600 channels of 40 kbps each
  - One analog video signal
  - Six to nine digital video signals

# Frequency-Division Multiple Access

- Factors which limit the number of subchannels provided within a satellite channel via FDMA:
  - Thermal noise
  - Intermodulation noise
  - Crosstalk

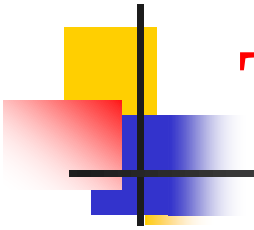
# Forms of FDMA

- Fixed-assignment multiple access (FAMA)
  - The assignment of capacity is distributed in a fixed manner among multiple stations
  - Demand may fluctuate
  - Results in the significant underuse of capacity
- Demand-assignment multiple access (DAMA)
  - Capacity assignment is changed as needed to respond optimally to demand changes among the multiple stations

# FAMA-DAMA

- FAMA – logical links between stations are preassigned
- FAMA – multiple stations access the satellite by using different frequency bands
- Uses considerable bandwidth
- DAMA – set of subchannels in a channel is treated as a pool of available links:
  - For full-duplex between two earth stations, a pair of subchannels is dynamically assigned on demand
  - Demand assignment performed in a distributed fashion by earth stations or satellite

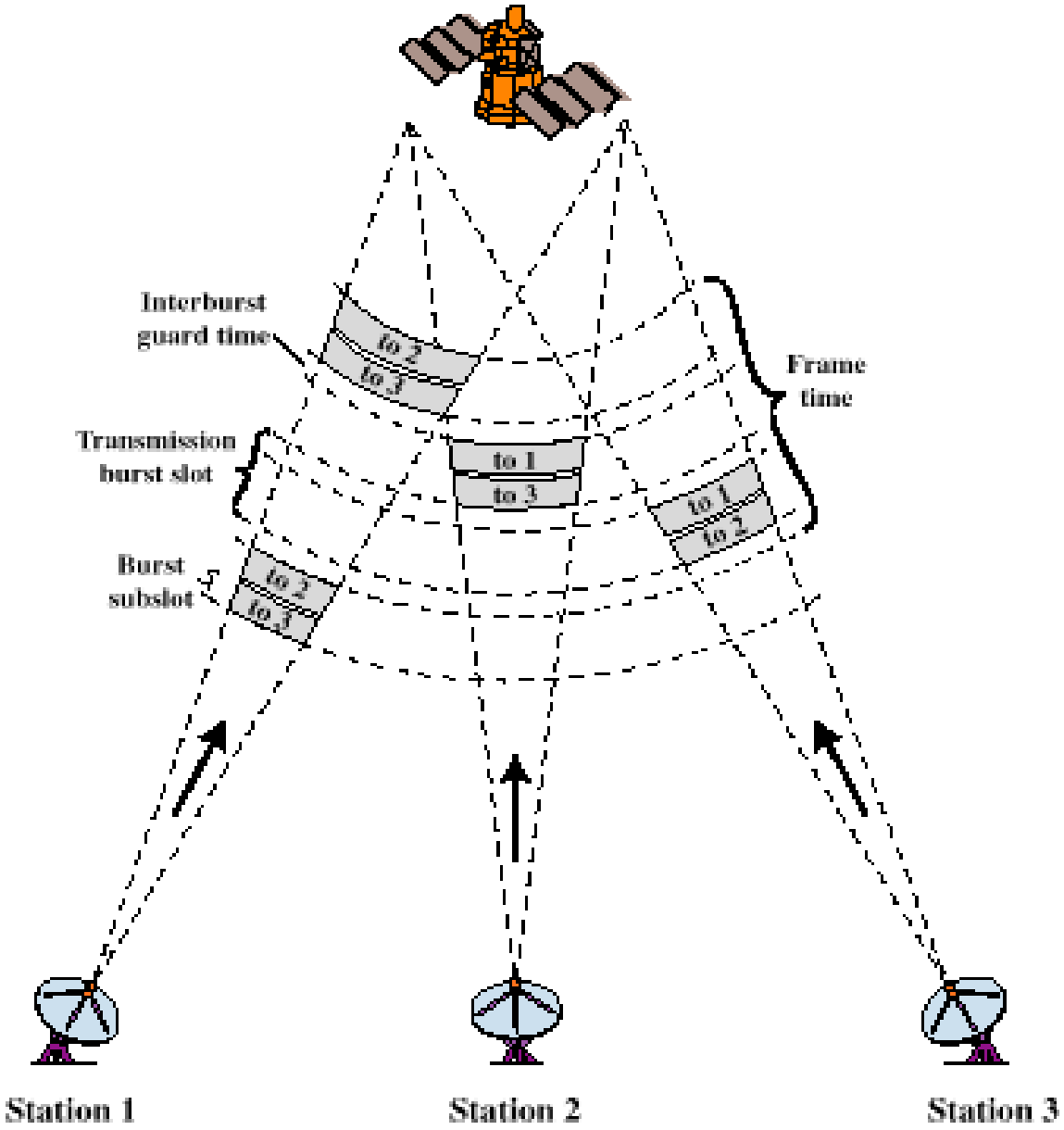
# Reasons for Increasing Use of TDM Techniques



- Cost of digital components continues to drop
- Advantages of digital components:
  - Use of error correction
- Increased efficiency of TDM:
  - Lack of intermodulation noise

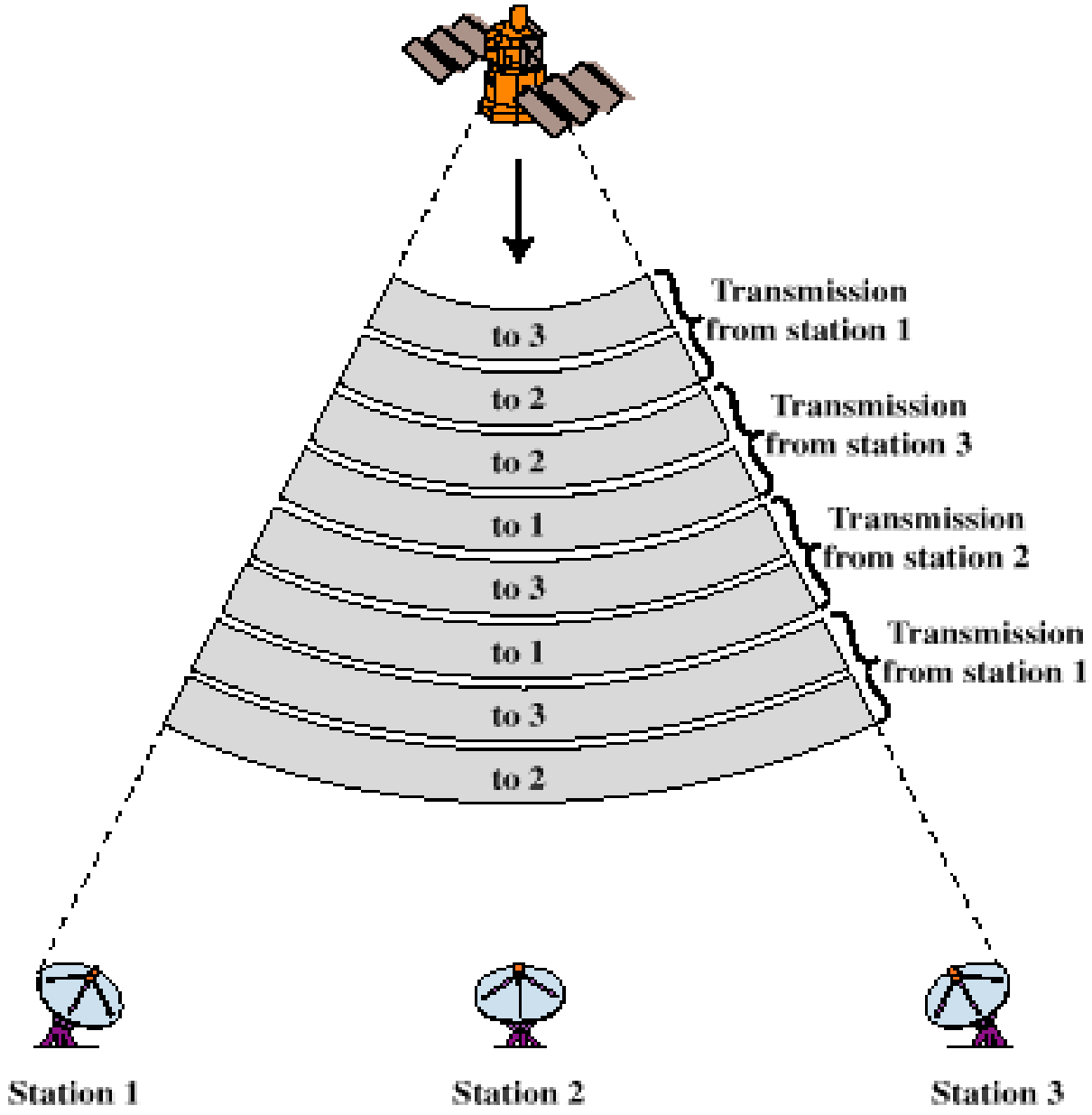
# FAMA-TDMA Operation

- Transmission in the form of repetitive sequence of frames:
  - Each frame is divided into a number of time slots
  - Each slot is dedicated to a particular transmitter
- Earth stations take turns using uplink channel
  - Sends data in assigned time slot
- Satellite repeats incoming transmissions
  - Broadcast to all stations
- Stations must know which slot to use for transmission and which to use for reception




(a) Uplink

**Figure 9.14 FAMA-TDMA Operation**




(b) Downlink

**Figure 9.14 FAMA-TDMA Operation**