Satellite Communications

Satellite-Related Terms

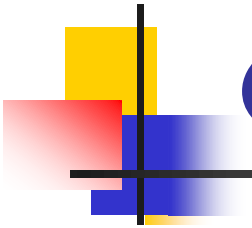
- Earth Stations – antenna systems on or near earth
- Uplink – transmission from an earth station to a satellite
- Downlink – transmission from a satellite to an earth station
- Transponder – electronics in the satellite that convert uplink signals to downlink signals, requires frequency translation

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 (usually classified), 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, usually not symmetrical with respect to earth circumference
- 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
  - Normally will dictate a specific USA launch site
- Altitude of satellites
  - Geostationary orbit (GEO)
  - Medium earth orbit (MEO)
  - Low earth orbit (LEO)



Geometry Terms

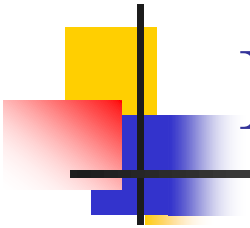
- Elevation angle - the angle from the horizontal to the point on the center of the main beam of the antenna when the antenna is pointed directly at the satellite
- Constraint: Minimum elevation angle
- Coverage angle - the measure of the portion of the earth's surface visible to the satellite

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 (signal passes thru more of the atmosphere)
  - Electrical noise generated by the earth's heat near its surface adversely affects reception

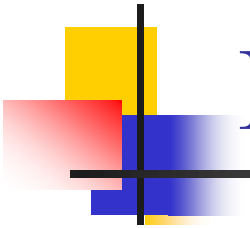
GEO Orbit

- Advantages of the the GEO orbit
  - No problem with Doppler frequency changes
  - Tracking of the satellite is simplified, physics dictates that the orbit be over the earth's equator
  - High coverage area
- Disadvantages of the GEO orbit
  - Weak signal after traveling over 35,000 km
  - Polar regions are poorly served (high latitude)
  - Propagation delay (round-trip transmit & receive) is substantial
  - Launch costs high - expensive to reach, crowded



LEO Satellite Characteristics

- Circular/slightly elliptical 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
- Atmospheric drag results in orbital deterioration
- Orbital debris are a factor



MEO Satellite Characteristics

- Circular orbit at an altitude in the range of 5000 to 12,000 km
- Orbital 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
- Examples: GPS constellation, Globalstar (satellite telephone)
- MEO term not used much if at all

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, $L_{db} \propto d$ and f)
- For downlink, terrestrial distance between earth station antenna and "aim point" of satellite
  - Displayed as a satellite footprint (next slide)
- Atmospheric attenuation
  - Affected by oxygen, water, angle of elevation and higher frequencies
  - Types of loss dependent on frequency
    C Band Attenuation (fog, rain)

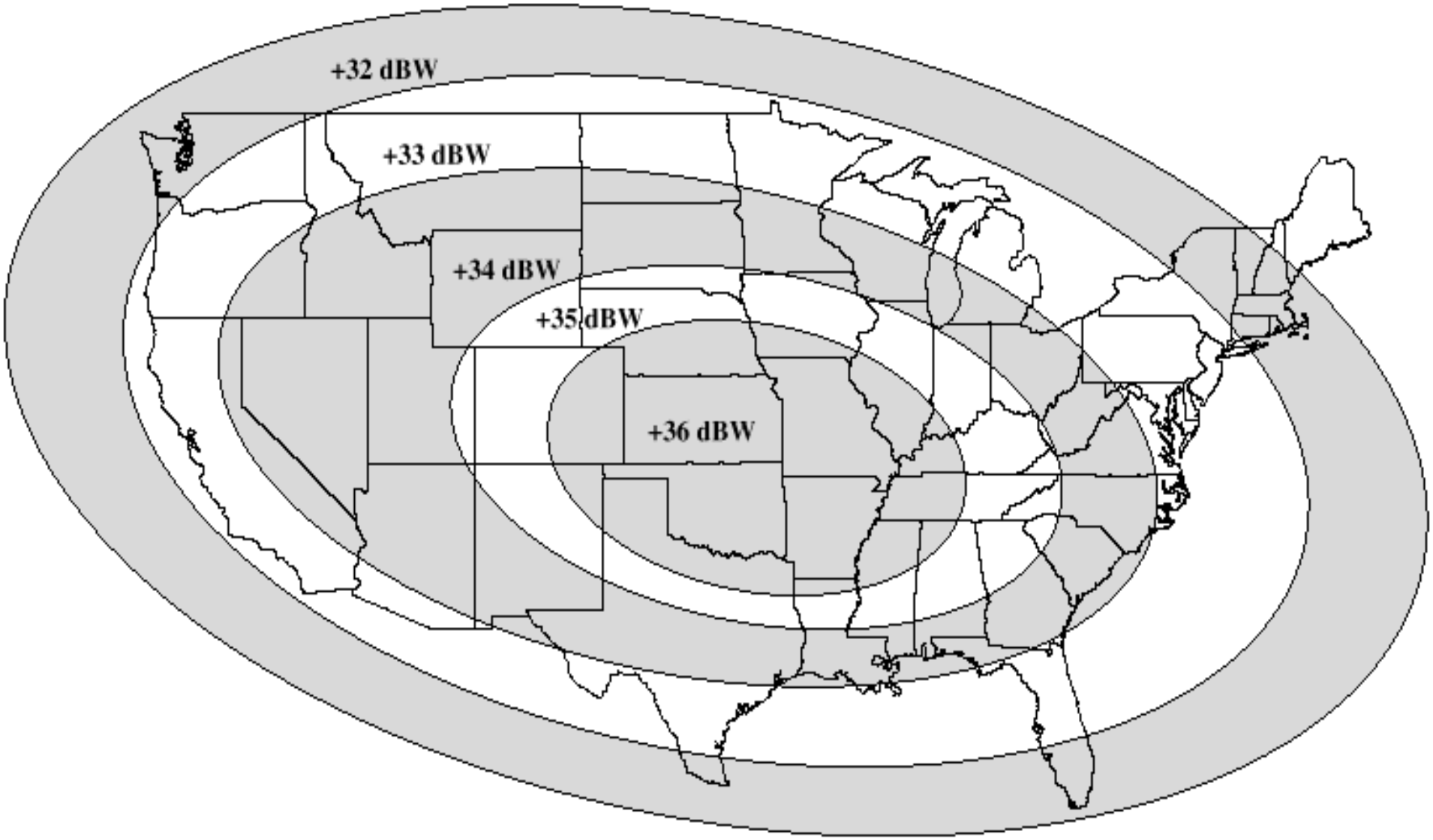
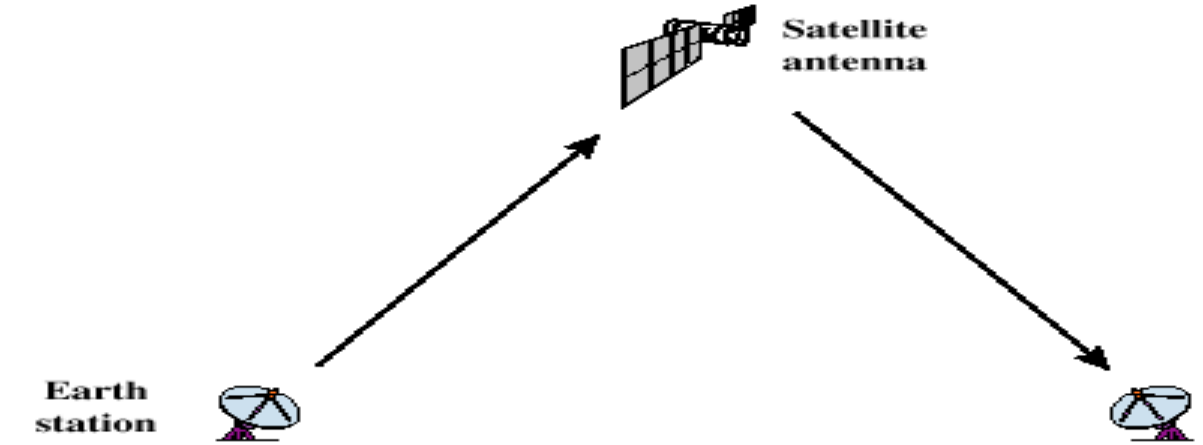
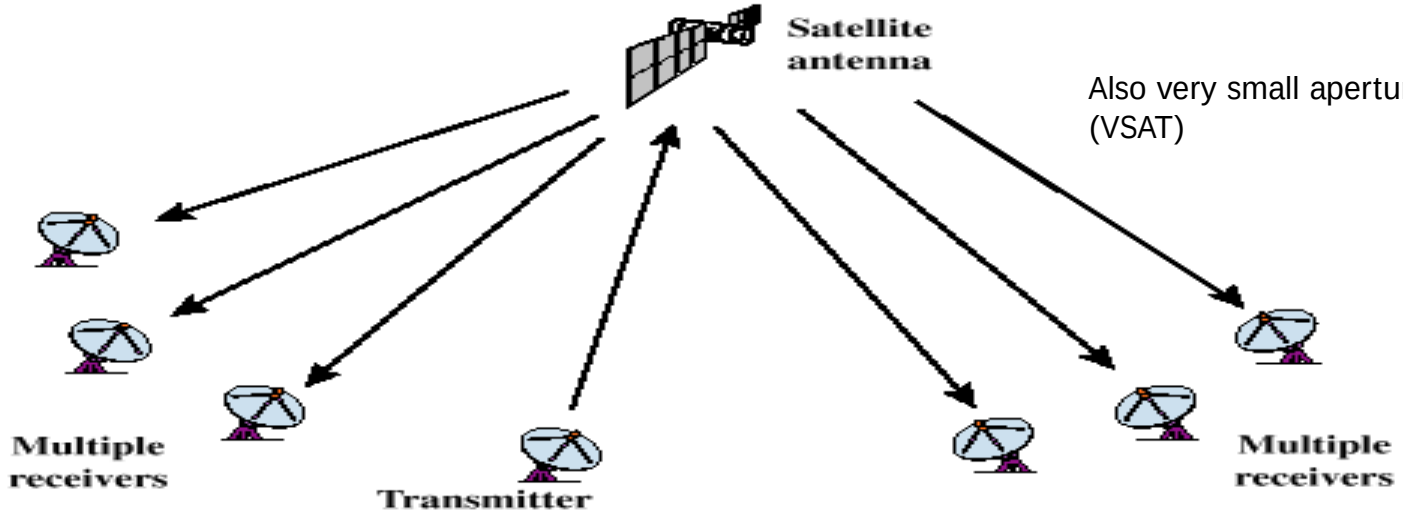


Figure 9.6 Typical Satellite Footprint



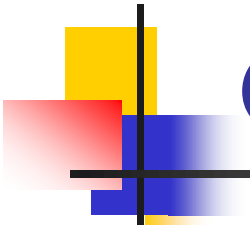
(a) Point-to-point link



Also very small aperture systems (VSAT)

(b) Broadcast link

Figure 9.8 Satellite Communication Configurations



Capacity Allocation Strategies

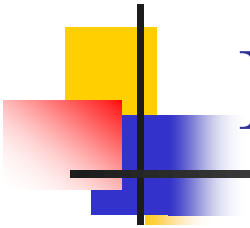
- Satellites an expensive resource; the more paying customers the better
- Frequency division multiple access (FDMA)
- Time division multiple access (TDMA)
- Code division multiple access (CDMA)
- Schemes used with FDMA and TDMA: FAMA-FDMA, DAMA-FDMA, FAMA-TDMA, SS-TDMA

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 Reuse – overlapping channels use orthogonal polarization (vertical/horizontal) to add channel separation. Although the large path distance at these frequencies tends to circularize the signal's polarization.

Frequency-Division Multiple Access

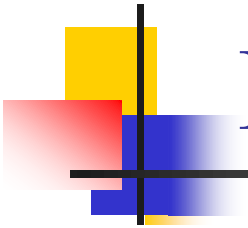
- Factors which limit the number of subchannels provided within a satellite channel via FDMA
  - Thermal noise (a low power problem/mother nature)
  - Intermodulation noise (a high power problem/non-linear)
  - Crosstalk (caused by frequency reuse and high power levels)



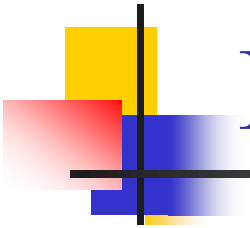
Forms of FDMA

- 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-FDMA



- FAMA (fixed assignment multiple access) – logical links between stations are preassigned
- FAMA – multiple stations access the satellite by using different frequency bands
- Uses considerable bandwidth
- No switching on-board satellite, just translation as a repeater (high to low/vice versa)
- Not an optimal solution for changing traffic loads



DAMA-FDMA

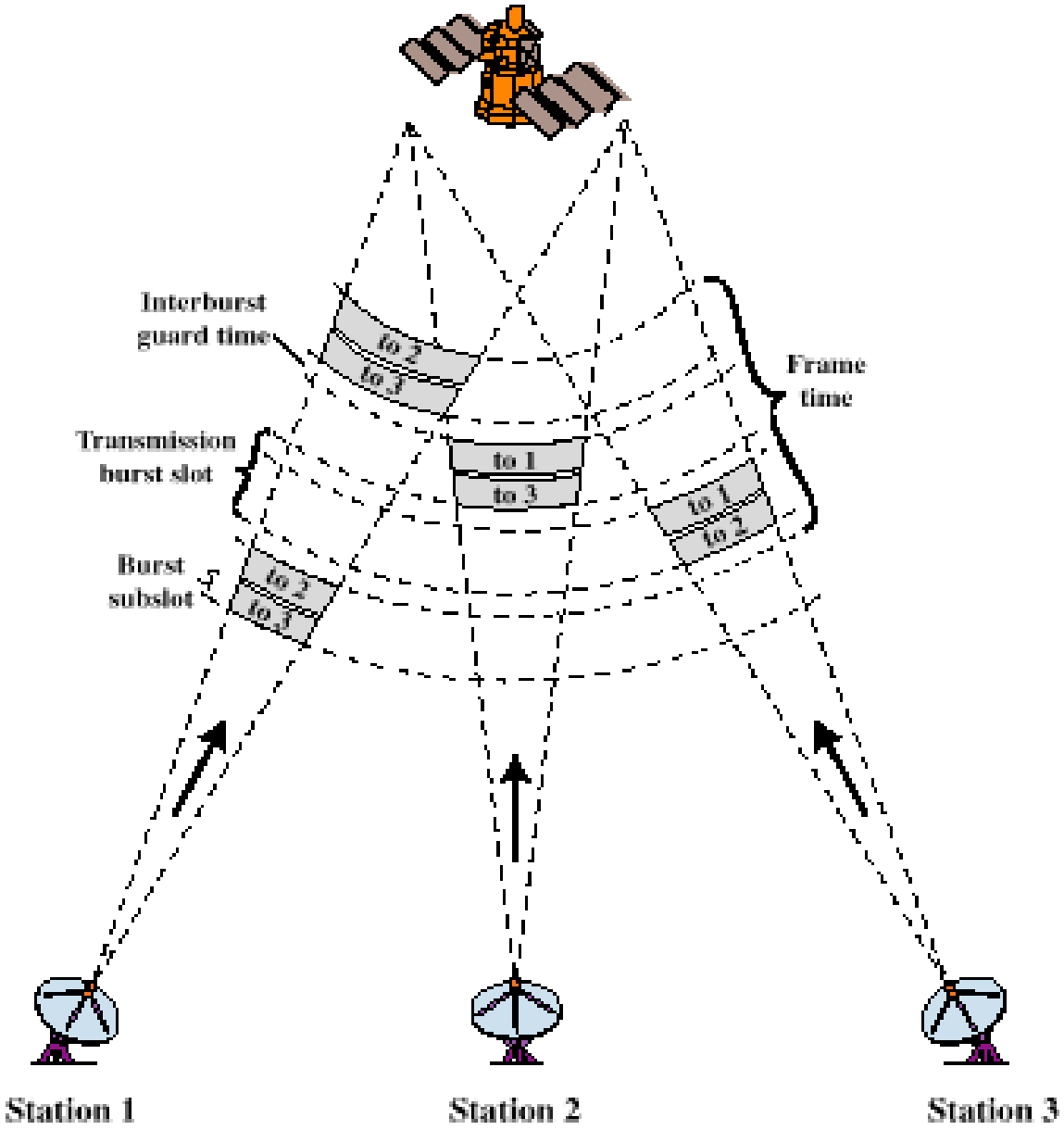
- Single channel per carrier (SCPC) – bandwidth divided into individual Voice Freq (VF) channels versus groups of VF
  - Attractive for remote areas with few user stations near each site
  - Suffers from inefficiency of fixed assignment
- DAMA – set of subchannels in a channel is treated as a pool of 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 station using CSC (common-signaling channel)

Reasons for Increasing Use of TDM (Time Division) Techniques

- Cost of digital components continues to drop while computer processing capability increases
- Advantages of digital components
  - Use of error correction
- Increased efficiency of TDM
  - Lack of intermodulation noise

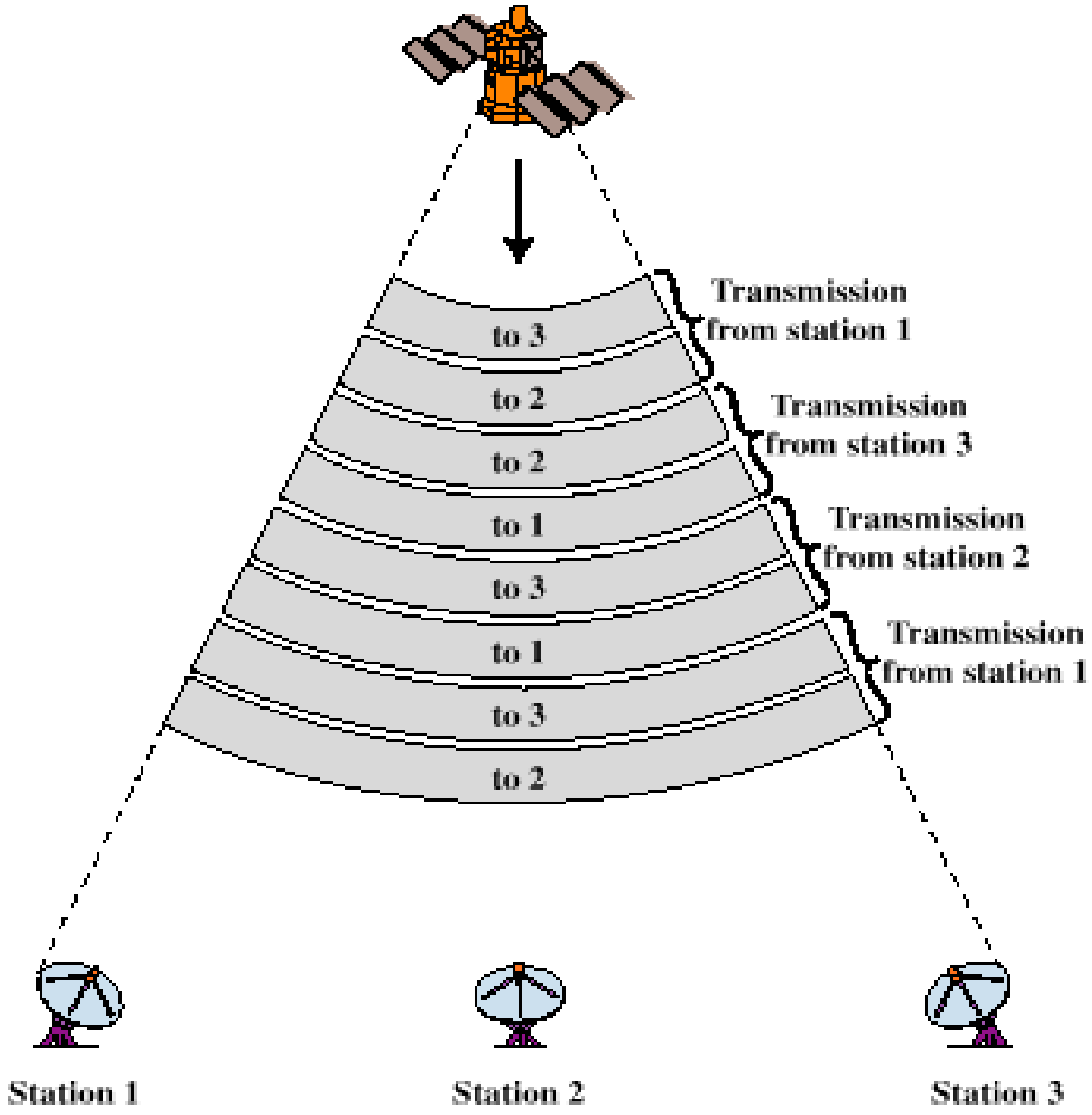
FAMA-TDMA Operation

- 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 (large footprint)
- Stations must know which slot to use for transmission and which to use for reception
- Variations possible with higher frequencies, allowing focused beams → Satellite Switched (SS/TDMA)



(a) Uplink

Figure 9.14 FAMA-TDMA Operation



(b) Downlink

Figure 9.14 FAMA-TDMA Operation

SS/TDMA Operation

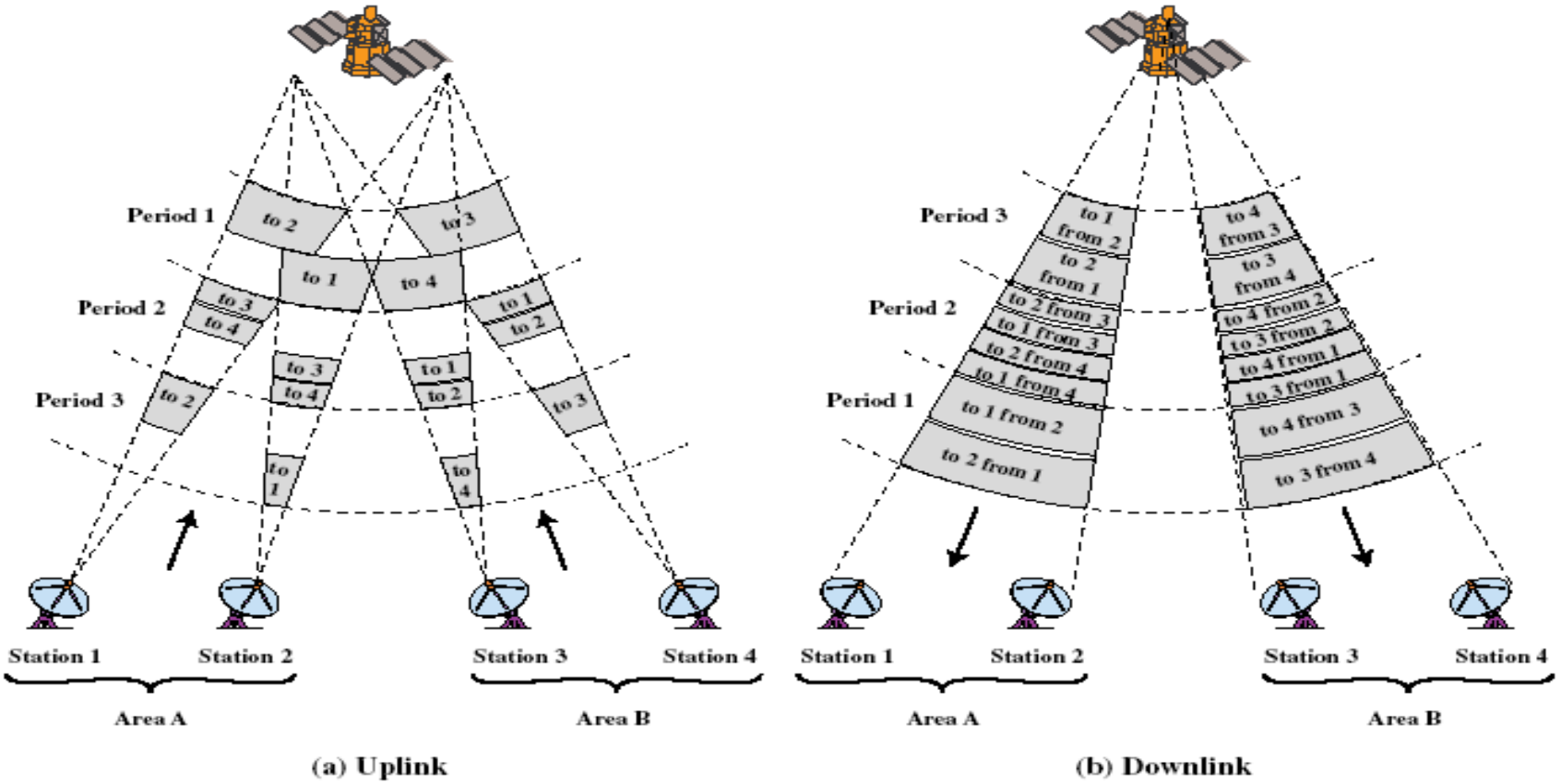


Figure 9.16 SS/TDMA Operation