Satellite Communications Systems

Class Contents

- Satellite Parameters and Configurations
  - Satellite Orbits
  - Frequency Bands
  - Transmission Impairments
  - Satellite Network Configurations
- Capacity Allocation – Frequency Division
  - FDM (Frequency Division Multiplexing)
  - FDMA (Frequency Division Multiple Access)
- Capacity Allocation – Time Division

Satellite Parameter and Configurations

- Parts of a Satellite System
  - Earth Station
  - Uplink
  - Downlink
  - Transponder

Categorization

- Coverage Area
  - Global
  - Regional
  - National
- Service Provided
  - Fixed Service Satellite (FSS)
  - Broadcast Service Satellite (BSS)
  - Mobile Service Satellite
- Usage
  - Commercial, Military, Amateur, Experimental

Differences with Terrestrial Wireless Communications. Design Parameters

- The area of coverage of a satellite system far exceeds that of a terrestrial system.
- Spacecraft power and allocated bandwidth are limited resources that call for careful tradeoffs in earth station/satellite design parameters
- Conditions between communicating satellites are more time invariant than those between satellite and earth station, or between 2 terrestrial wireless antennas.
- Within the satellite's area of coverage, transmission cost is independent of distance.

Differences with Terrestrial Wireless Communications. Design Parameters

- Broadcast, multicast and point-to-point applications are readily accommodated.
- Availability of very high bandwidths and data rates.
- The quality of transmission is extremely high in satellite links, even though they are subject to short-term outages or degradations.
- A transmitting earth station can in many cases receive its own transmission

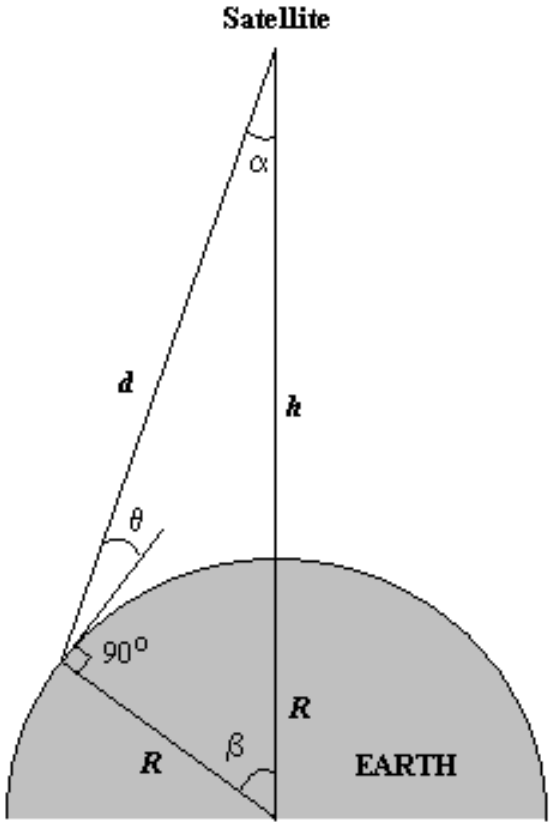
Satellite Orbits

- Type of Orbit
  - Circular
  - Elliptical
- Plane of Orbit
  - Equatorial
  - Polar
  - Inclined

Satellite Orbits

- Altitude of the orbit
  - Geostationary Satellites (GEO)
  - Low Earth Orbit (LEO)
  - Medium Earth Orbit (MEO)

Design Parameters



- Orbit Height
- Coverage Angle
- Elevation Angle

Parameters

- Elevation Angle
  - Problems dictate that should be > 0^0.
    - Objects Blocking the LOS
    - Atmospheric attenuation is greater at low elevation angles
    - Electrical noise generated by earth heat near the surface affects reception.
- Uplink (min 5^0) – Downlink (5^0 – 20^0)

Parameters

- Coverage Angle (β)
  - Defines a circle in the surface of the earth.
  - Area of coverage can be calculated.
  - Area of coverage expressed as the diameter of the area covered:

$$2 \cdot \beta \cdot R$$

Radius of the Earth
6370 Km

Expressed in Radians

Parameters

- Distance from Satellite to Earth

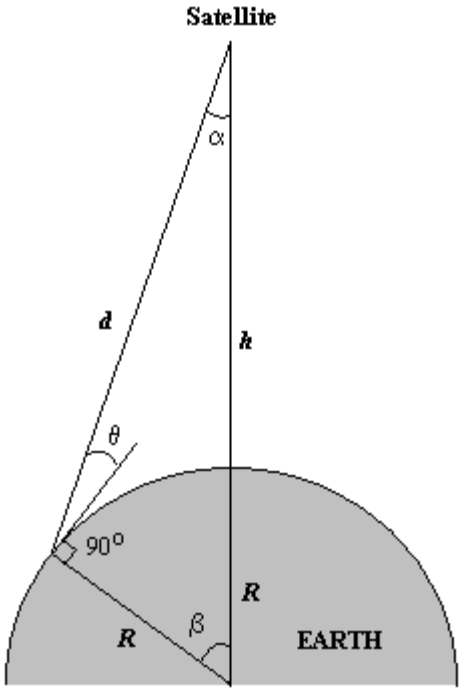
$$d = \frac{(R+h)\sin(\beta)}{\cos(\theta)}$$

- Round Trip Delay Time

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

Trigonometric Identities:

- Sine Theorem
- Cosine Theorem
- $\sin(x) = \cos(x - \pi/2)$
- $\sin(x + \pi/2) = \cos(x)$



Geostationary Satellites (GEO)

- Orbit Height 35863 Km
- No problems due to Doppler effect
- Satellite tracking is simplified
- Satellite can communicate with roughly $1/4^{th}$ of the earth
- 3 satellites separated 120^0 needed to cover most inhabited areas of the earth. (except both poles)

Geostationary Satellites (GEO)

Problems:

- Signal weak after travelling 35000+ Km.
- Polar regions on both hemispheres are poorly served by GEO
- Minimum delay in sending the signal is 0.24 seconds.

Low Earth Orbit Satellites

- Circular or slightly elliptical orbit at under 2000 Km. Proposed and actual systems are in the range of 500 to 1500 Km.
- The orbit period is in the range off 1.5 to 2 hours.
- The diameter of coverage is about 8000 Km.

Low Earth Orbit Satellites

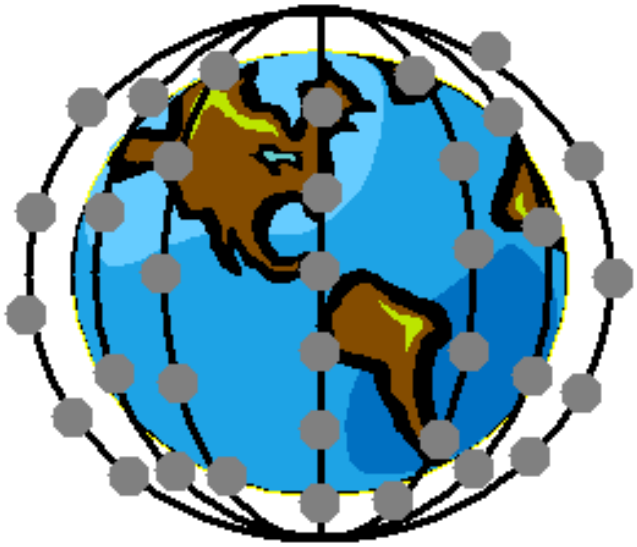
- Roundtrip signal propagation delay is less than 20 ms.
- The maximum time that the satellite is visible from a fixed point on earth (above the radio horizon) is up to 20 minutes.

Low Earth Orbit Satellites

- Because the motion of the satellite relative to a fixed point on earth is high, the system must be able to cope with large Doppler shifts, which change the frequency of the signal.
- The atmospheric drag on a LEO satellite is significant, resulting in gradual orbital deterioration.

LEOs – Advantages over GEOs

- Reduced propagation delay
- Received signal is much stronger than that of a GEO for the same transmission power
- Coverage can be better localized, so that spectrum can be better conserved.



LEO commercial proposals

- Little LEOs
  - Frequency below 1 GHz
  - Bandwidth below 5 MHz
  - Data Rates of up to 10 kbps
  - Aimed at paging, tracking and low rate messaging
- Big LEOs
  - Frequecy Above 1 GHz
  - Datarates up to a few Gbps
  - Same service as little LEO plus voice and positioning services

Medium Earth Orbit (MEO)

- Circular orbit at an altitude in the range 5000 to 12000 Km.
- The orbit period is about 6 hours
- The diameter of coverage is from 10000 to 15000 Km.
- Round trip signal propagation delay is less than 50 ms.
- The maximum time that the satellite is visible from a fixed point on earth (above the radio horizon) is a few hours

Frequency Bands

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, 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

General Applications

- **Mobile Satellite Service (MSS)**: Is a satellite system which uses portable terrestrial terminals. MSS terminals may be mounted on a ship, an airplane, an automobile or may even be carried by an individual. The most promising application of Mobile Satellite Service is portable satellite telephones which will enable phone service anywhere on the globe. Another application is global positioning systems (GPS)

- **Fixed Satellite Services (FSS)**: Broadcast feed used between TV networks. Main application is on National Cable Channels supplied to the TV head station

- **Broadcast Satellite Service(BSS)**: This is also known as Direct Broadcast Satellite. communications satellite that transmits to small DBS satellite dishes (usually 18" to 24" in diameter). DBS technology is used for DTH-oriented (Direct-To-Home) satellite tv services, such as DirecTV, Dish Network, and Sky Angel in the United States, ExpressVu in Canada, and Sky Digital in the UK.

Sources of Impairment

- Distance between earth and satellite
- Atmospheric Attenuation
- Terrestrial Distance between the receiving antenna and the aim point of the satellite (Satellite Footprint)

Distances and Free Space Loss

$$L_{dB} = -20\log(\lambda) + 20\log(d) + 21.98\ \text{dB}$$

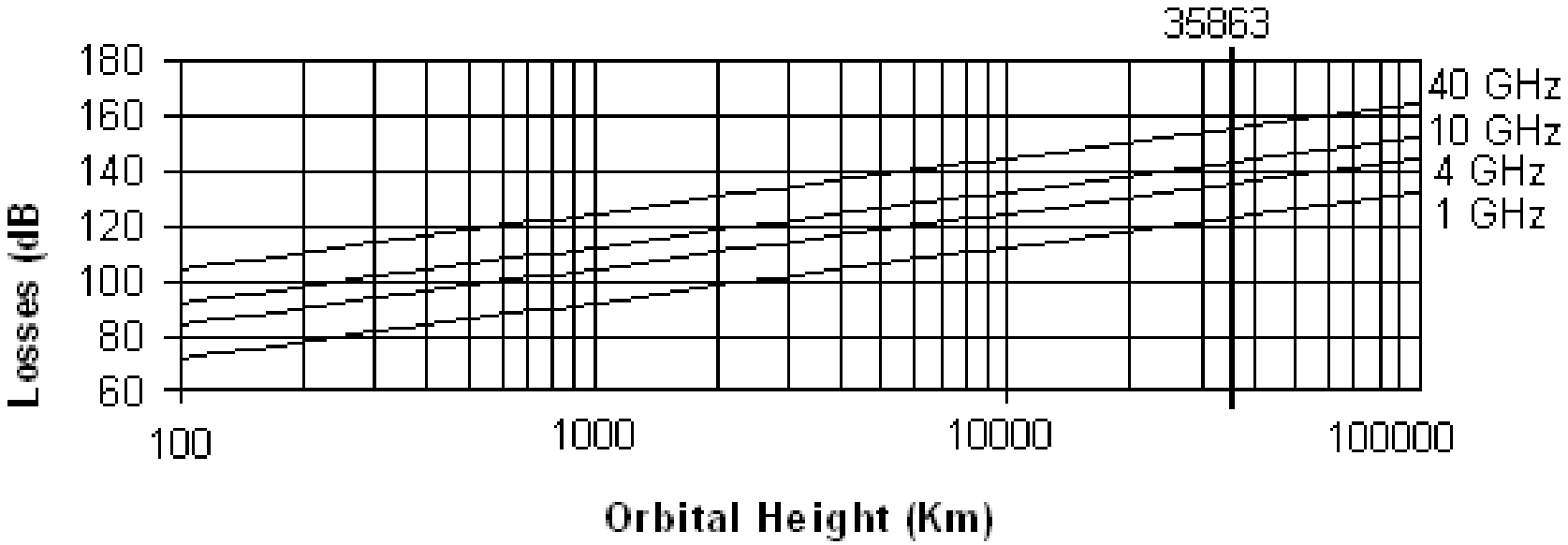
GEO: Losses at the equator

$$L_{dB} = -20\log(\lambda) + 173.07\ \text{dB}$$

GEO: Losses at maximum distance (horizon) d=42711 Km)

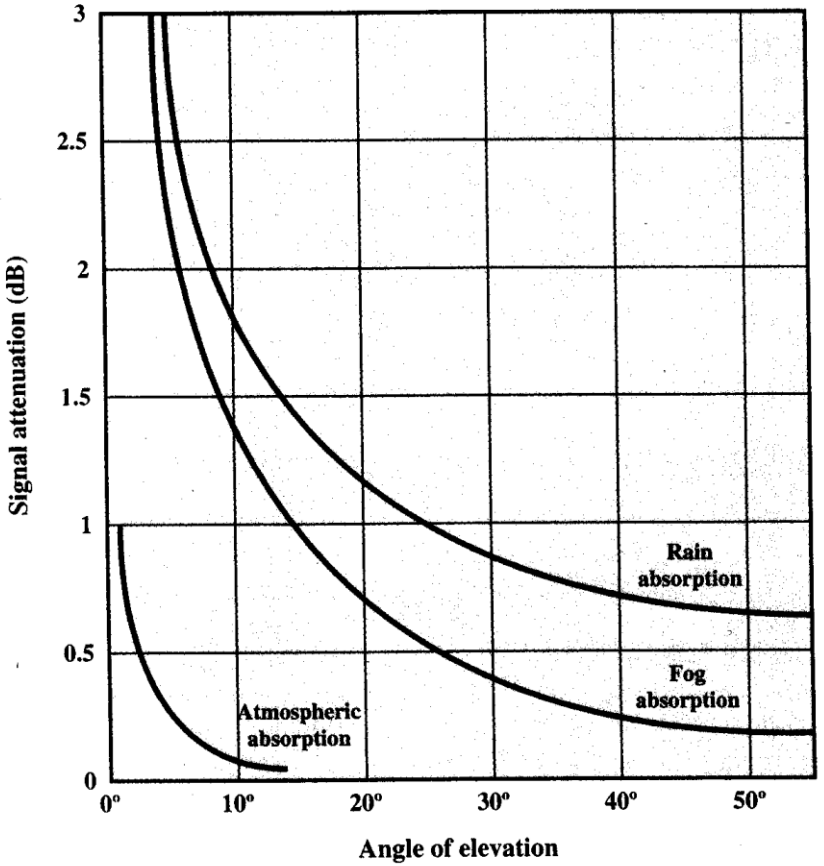
$$L_{dB} = -20\log(\lambda) + 174.59\ \text{dB}$$

Distances and Free Space Loss

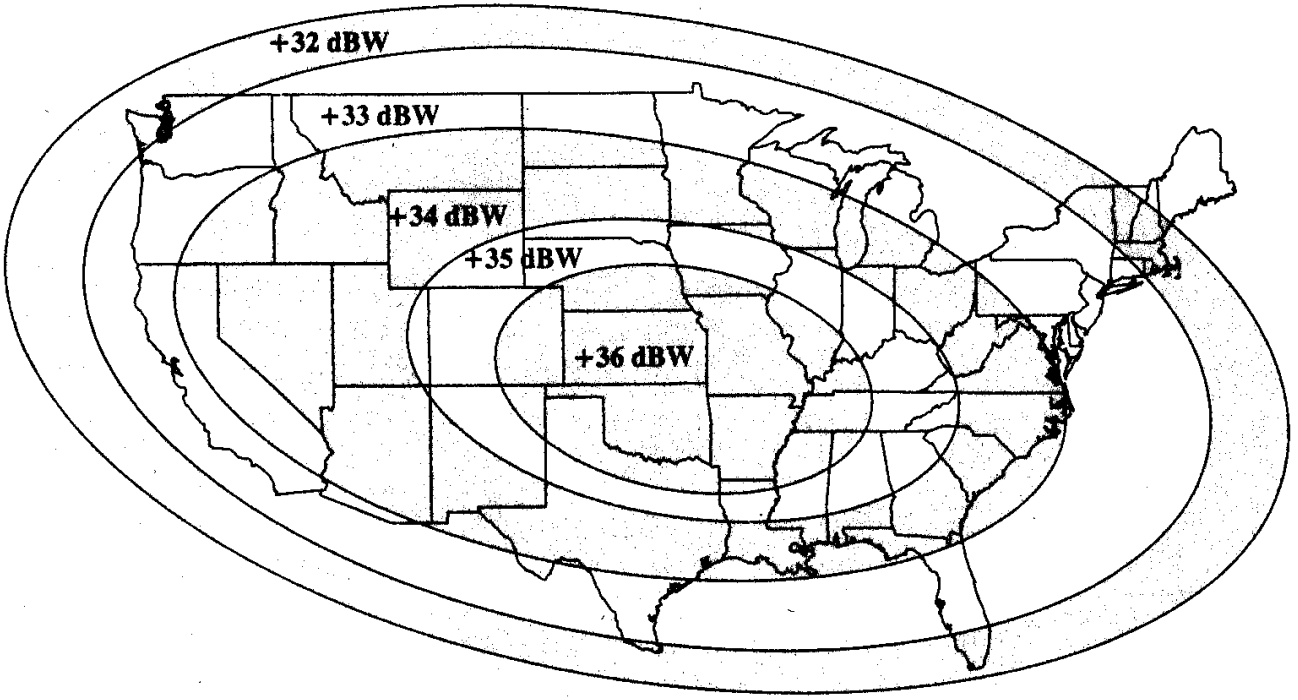


Atmospheric Attenuation

- Oxygen and Water – primary causes
- Angle of Elevation

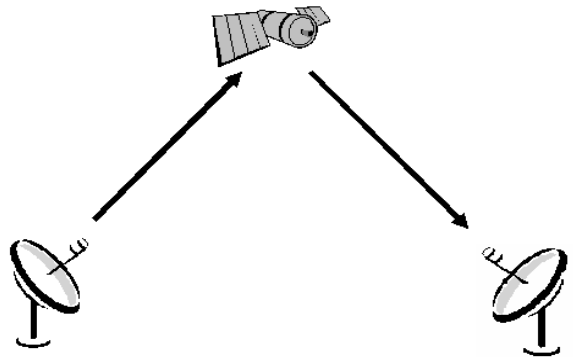


Satellite Footprint

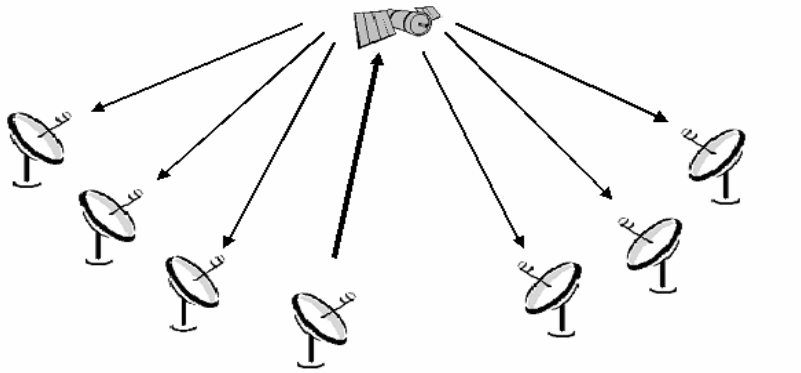


Satellite Network Configurations

- Point to Point

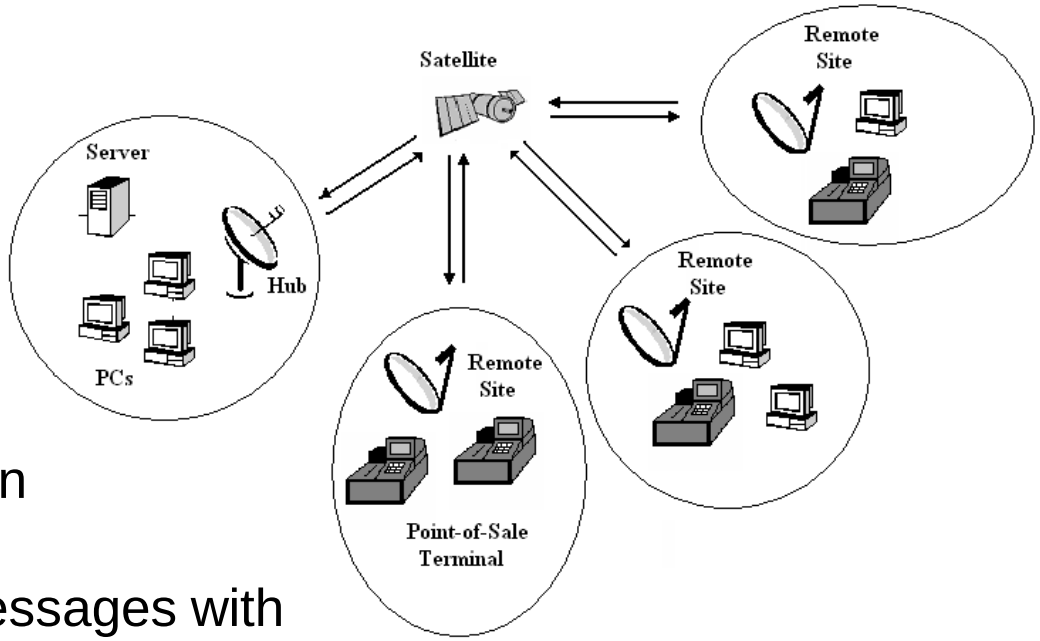


- Broadcast



Satellite Network Configurations

- Sub-Type of Broadcast : VSAT (very small aperture terminal)



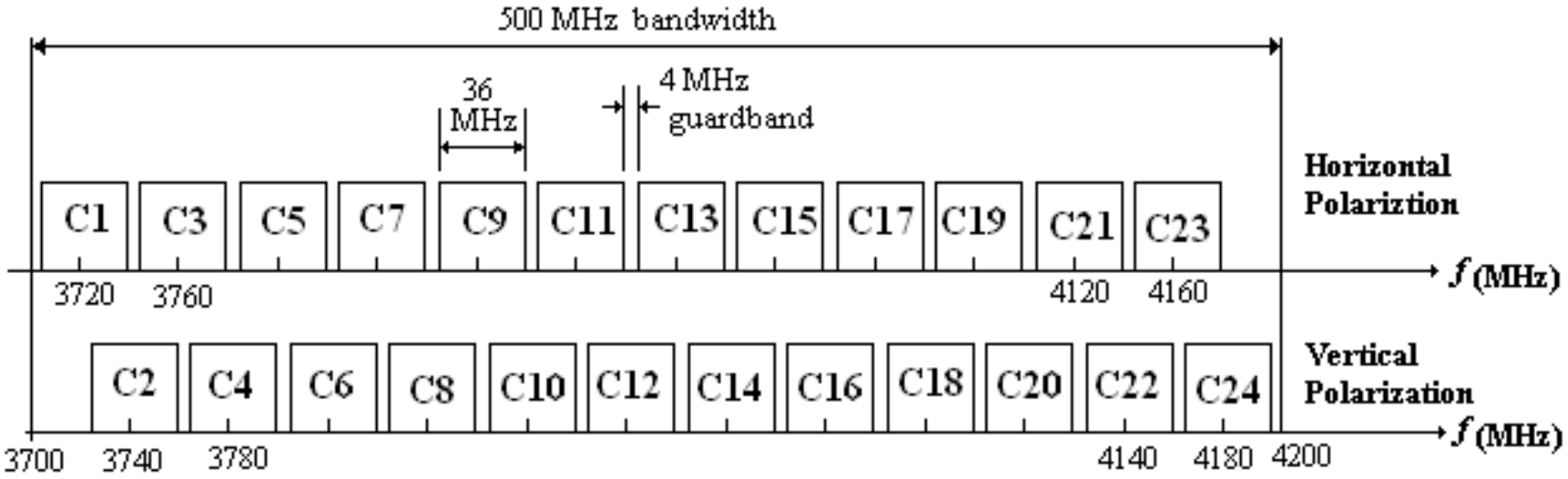
- Subscribers use low cost VSAT antenna.
- Stations share a satellite transmission capacity for transmission to a hub station
- Hub can exchange messages with the subscribers and relay messages between the subscribers

Capacity Allocation – Frequency Division

Allocation Strategies:

- FDMA (Frequency Division Multiple Access)
- TDMA (Time Division Multiple Access)
- CDMA (Code Division Multiple Access)

Frequency Division Multiplexing



- Satellite squeezes 24 channels in 500 MHz using frequency reuse

Frequency Division Multiplexing

- Examples of channel use 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 analogue video signal.
  - Six to nine digital video signals

FDMA

- In Satellite Comms - Is the ability of multiple earth station to access the same channel.
- Limitation in the number of sub-channels:
  - Thermal Noise
  - Intermodulation Noise
  - Crosstalk

Types of FDMA

- Fixed-assignment multiple access (FAMA)
  - Fixed frequency assignment
  - Underuse of capacity due to fluctuations in demand
- Demand-assignment multiple access (DAMA)
  - Capacity allocated to cope with demand fluctuations among multiple stations.

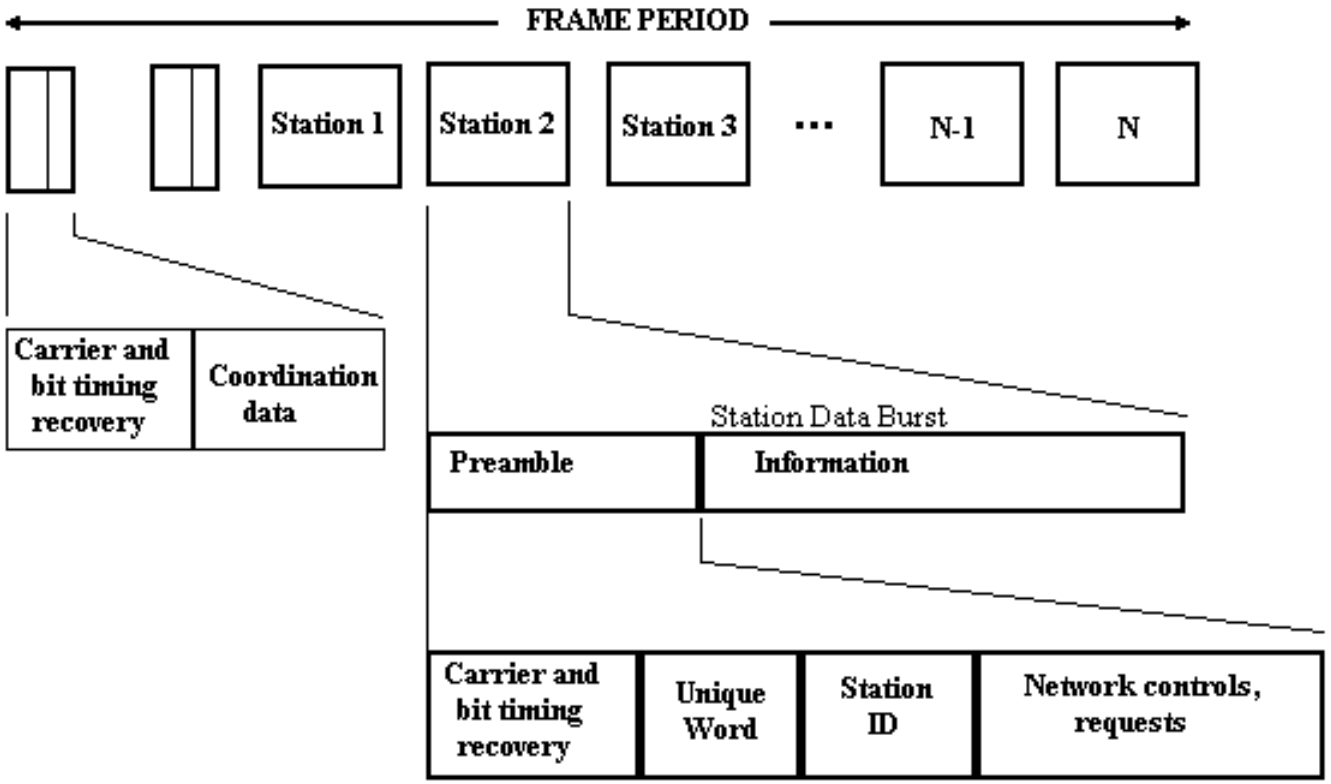
Capacity Allocation – Time Division

- Transmission is in the form of a repetitive sequence of frames.
- Each frame is divided into a number of time slots.

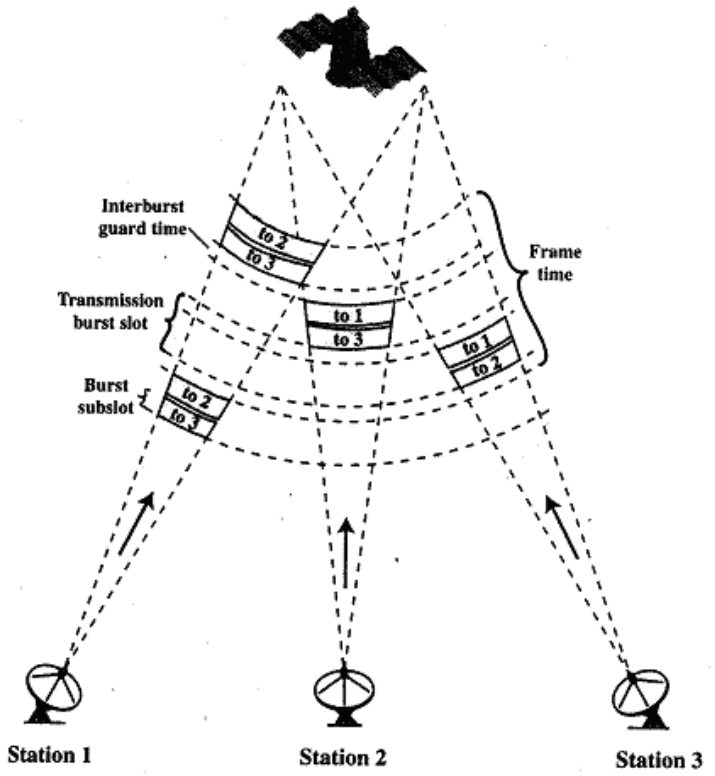
Capacity Allocation – Time Division

- Each slots position across the sequence of frames is dictated to a particular transmitter.
- Frame periods range from 100 μs to over 2 ms and consist of from 3 to over 100 slots. Data rates range from 10 Mbps to over 100 Mbps

Capacity Allocation – Time Division

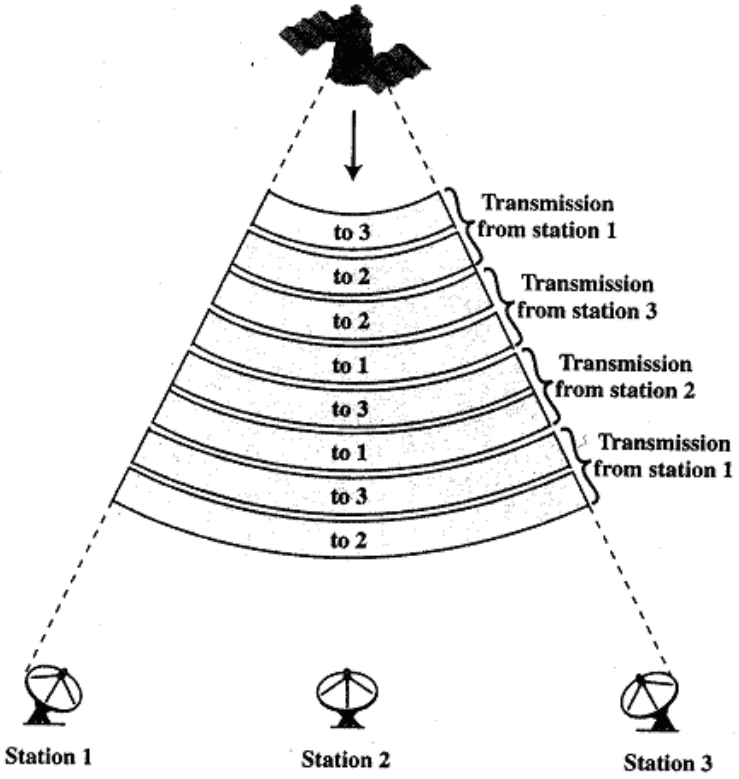


FAMA-TDMA operation



UPLINK

FAMA-TDMA operation



DOWNLINK