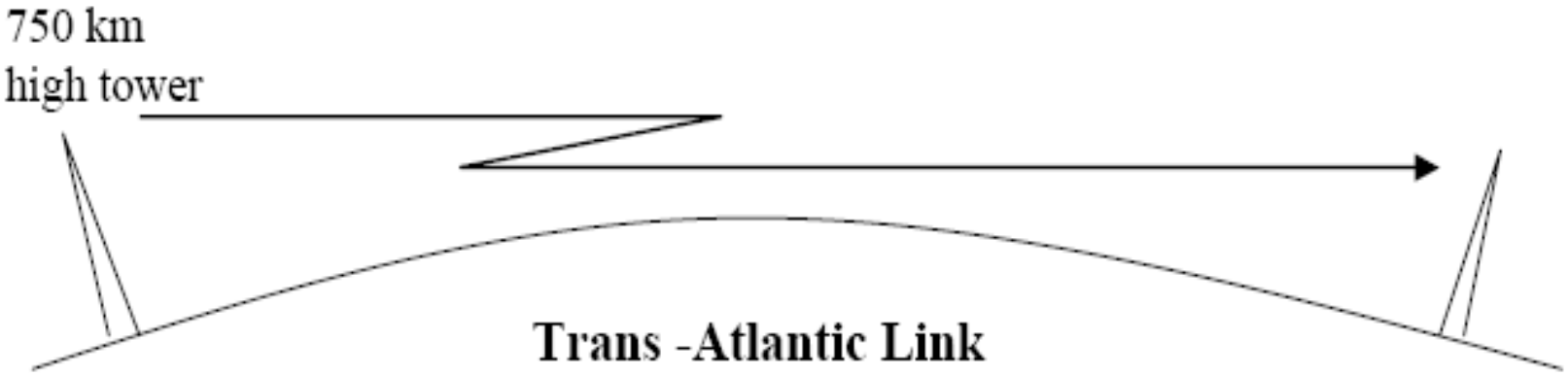
Satellite Systems

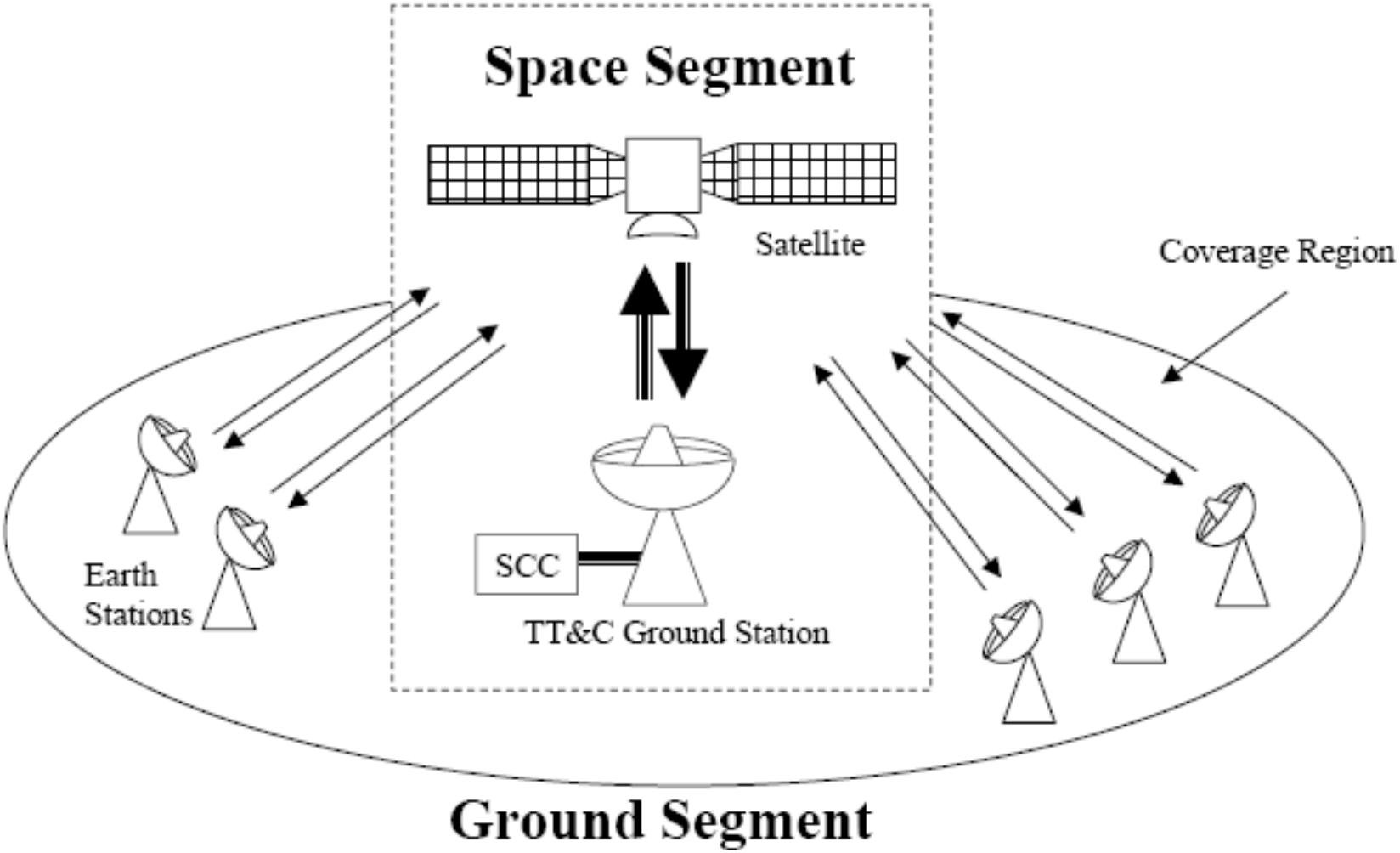
Overview

- Satellite is a microwave repeater in the space
- They are:
  - Wide area coverage of the earth's surface
  - Transmission delay is about 0.3 second
- It contains several transponders which listens to some portion of spectrum, amplifies the incoming signal and broadcasts it in another frequency to avoid interference with incoming signals

Motivation to use Satellites



Satellite System Elements



Space Segment

- Satellite Launching Phase
- Transfer Orbit Phase
- Deployment
- Operation
  - TT&C - Tracking Telemetry and Command Station
  - SSC - Satellite Control Center, a.k.a.:
    - OCC - Operations Control Center
    - SCF - Satellite Control Facility
- Retirement Phase

Advantages of Satellites

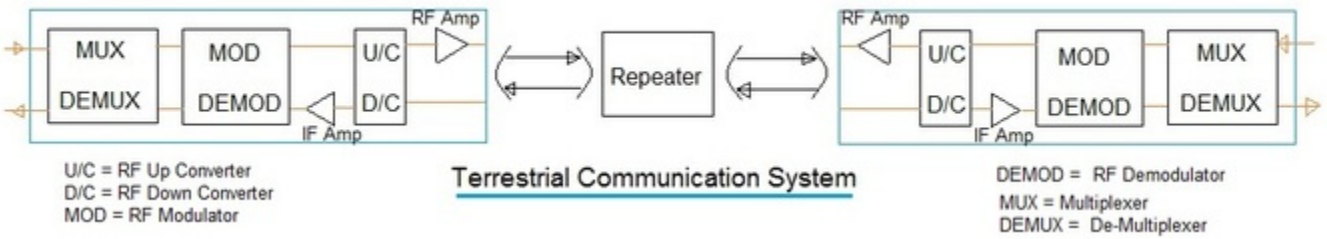
- The advantages of satellite communication over terrestrial communications are:
  - The coverage area of a satellite greatly exceeds that of a terrestrial system.
  - Transmission cost of a satellite is independent of the distance from the center of the coverage area.
  - Satellite to Satellite communication is very precise.
  - Higher Bandwidths are available for use.

Disadvantages of Satellites

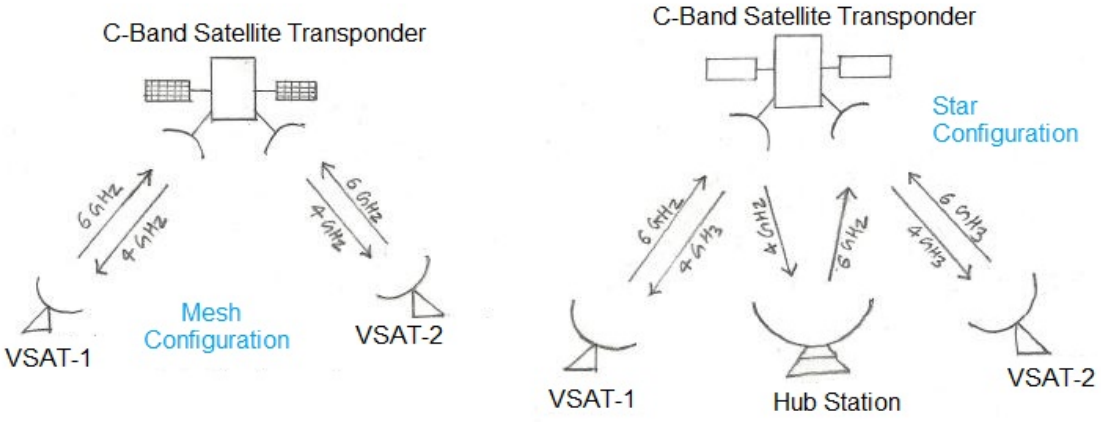
- The disadvantages of satellite communication:
  - Launching satellites into orbit is costly.
  - Satellite bandwidth is gradually becoming used up.
  - There is a larger propagation delay in satellite communication than in terrestrial communication.

Terrestrial vs Satellite Communication System

- Terrestrial Communication System



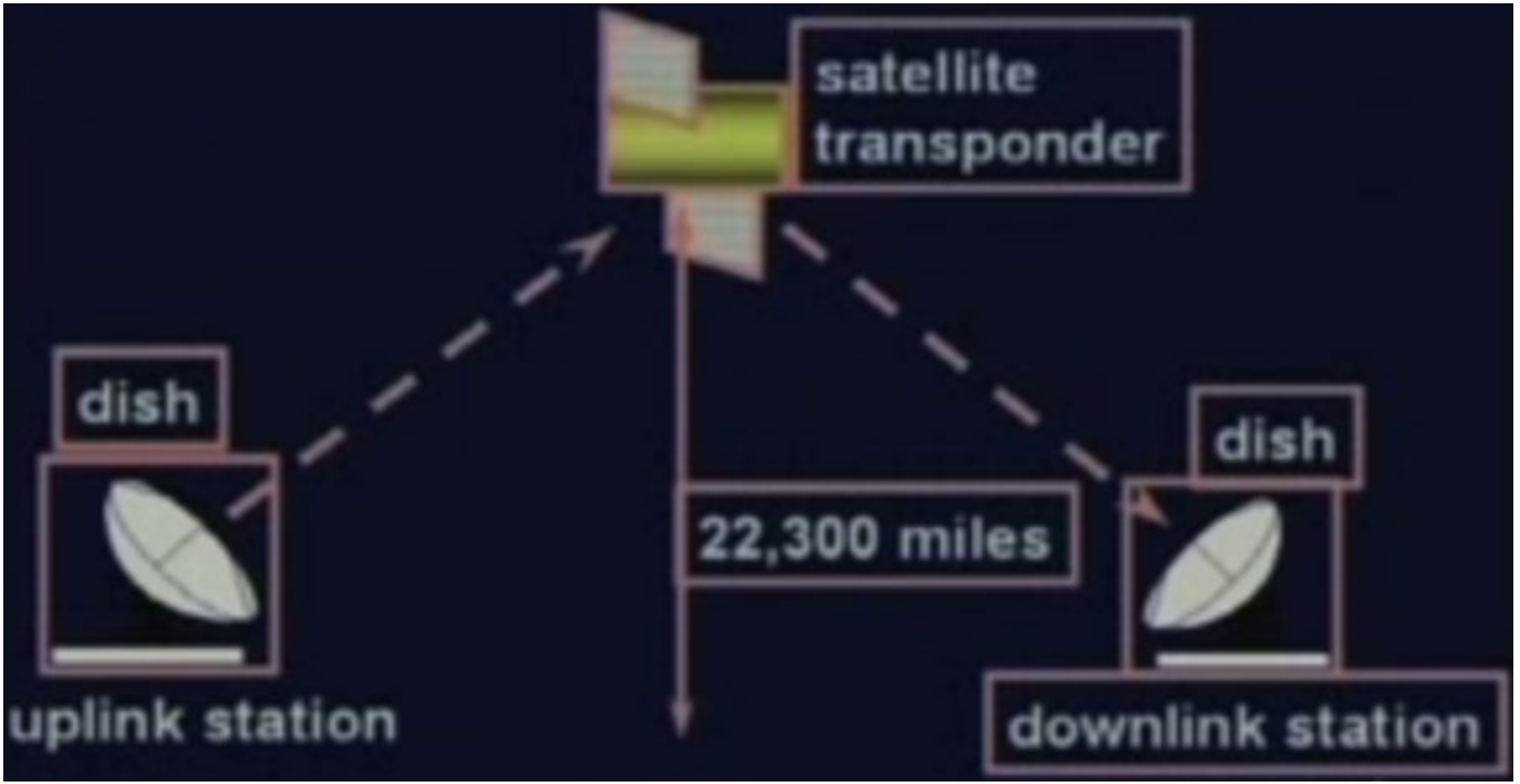
- Satellite Communication System



Satellite Uplink and Downlink

- Downlink
  - The link from a satellite down to one or more ground stations or receivers
- Uplink
  - The link from a ground station up to a satellite.
- Some companies sell uplink and downlink services to
  - television stations, corporations, and to other telecommunication carriers.
  - A company can specialize in providing uplinks, downlinks, or both.

Satellite Uplink and Downlink



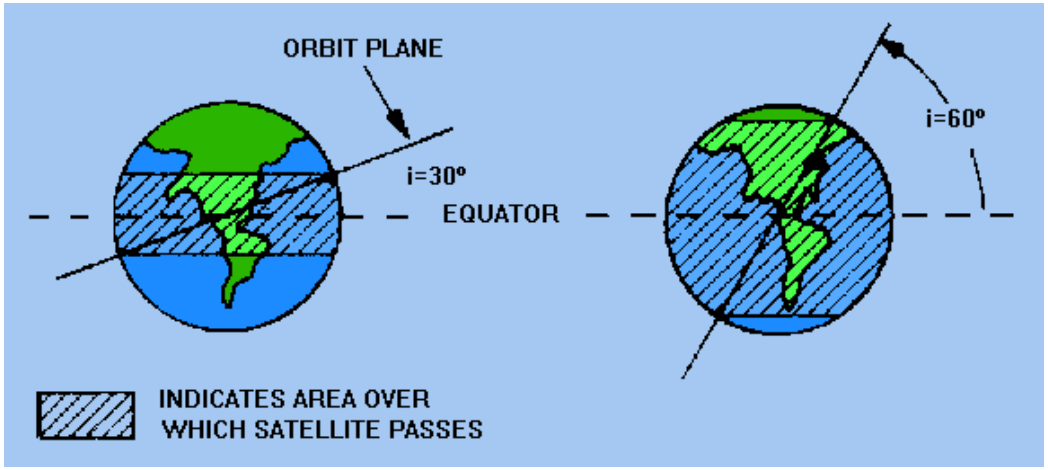
Satellite Transmission Bands

Frequency Band	Downlink	Uplink
C	3,700-4,200 MHz	5,925-6,425 MHz
Ku	11.7-12.2 GHz	14.0-14.5 GHz
Ka	17.7-21.2 GHz	27.5-31.0 GHz

The C band is the most frequently used. The Ka and Ku bands are reserved exclusively for satellite communication but are subject to rain attenuation

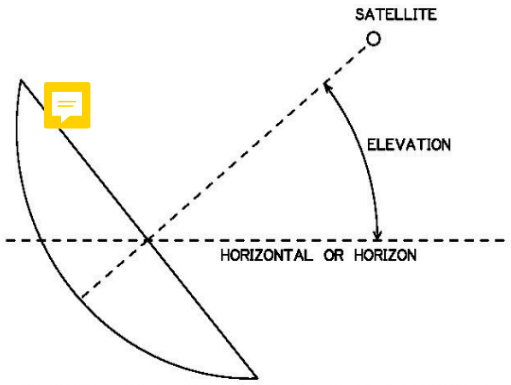
Factors in Satellite Communication

- Inclination angle
  - The angle between the equatorial plane and the plane described by the satellite orbit
  - An inclination angle of zero degrees means that the satellite is exactly above the equator



Factors in Satellite Communication

- Elevation angle
  - The angle of the horizontal of the earth surface to the center line of the satellite transmission beam
  - This effects the satellites coverage area. Ideally, you want a elevation angle of o degrees, so the transmission beam reaches the horizon visible to the satellite in all directions.



angle of horizontal of the earth surface to the centerline of satellite transmission beam

Factors in Satellite Communication

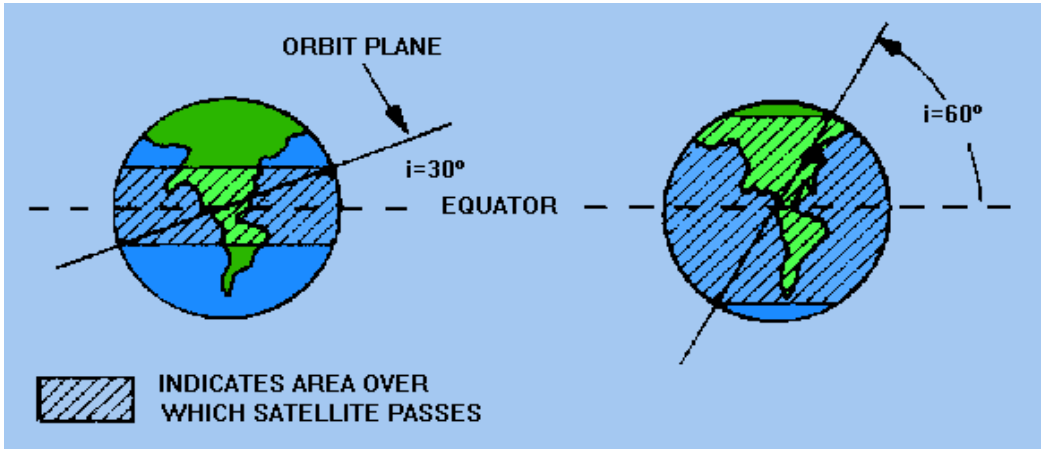
- Impairments to satellite communication:
  - The distance between an earth station and a satellite (free space loss).
  - Satellite Footprint: The satellite transmission's strength is strongest in the center of the transmission, and decreases farther from the center as free space loss increases. Angle of elevation of the satellite form the earth station. The smaller the angle, the more of the atmosphere that the signal must travel through. Frequency: higher frequency attenuates easily

Factors in Satellite Communication

- Impairments to satellite communication:
  - Atmospheric Attenuation caused by air and water can impair the transmission. It is particularly bad during rain and fog.

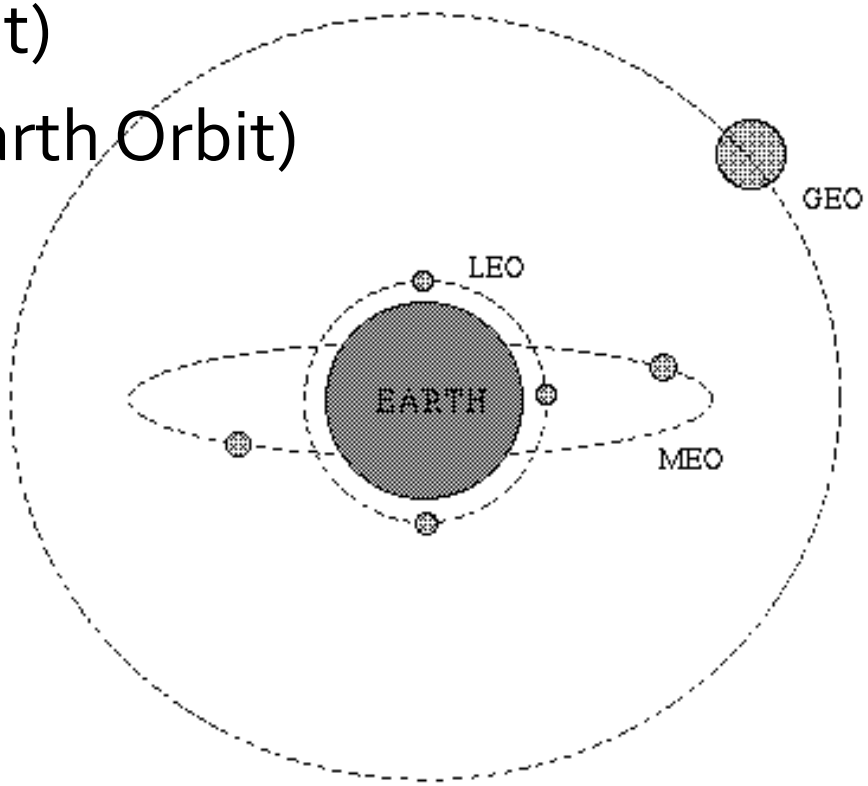
Pop Quiz

- A satellite has been set the angle between the equator and the orbit is to 30 degree. However, the user wanted to have the bigger coverage area. What should you do?
  - Define the scenario.
  - What should you do?
  - Positive effect of the action?
  - Negative effect of the action?



Satellite Orbits

- Satellite orbits
  - LEO (Low Earth Orbit)
  - MEO (Medium Earth Orbit)
  - GEO (Geosynchronous Earth Orbit)



Low Earth Orbit (LEO)

- LEO satellites are much closer to the earth than GEO satellites, ranging from 500 to 1,500 km above the surface.
- LEO satellites don't stay in fixed position relative to the surface, and are only visible for 15 to 20 minutes each pass.
- A network of LEO satellites is necessary for LEO satellites to be useful

LEO (cont.)

- Advantages
  - A LEO satellite's proximity to earth compared to a GEO satellite gives it a better signal strength and less of a time delay, which makes it better for point to point communication.
  - A LEO satellite's smaller area of coverage is less of a waste of bandwidth.

LEO (cont.)

- Disadvantages
  - A network of LEO satellites is needed, which can be costly
  - LEO satellites have to compensate for Doppler shifts cause by their relative movement. (http://astro.unl.edu/classaction/animations/light/dopplershift.html)
  - Atmospheric drag effects LEO satellites, causing gradual orbital deterioration.

Medium Earth Orbit (MEO)

- A MEO satellite is in orbit somewhere between 8,000 km and 18,000 km above the earth's surface.
- MEO satellites are similar to LEO satellites in functionality.
- MEO satellites are visible for much longer periods of time than LEO satellites, usually between 2 to 8 hours.
- MEO satellites have a larger coverage area than LEO satellites.

MEO (cont.)

- Advantage
  - A MEO satellite's longer duration of visibility and wider footprint means fewer satellites are needed in a MEO network than a LEO network.
- Disadvantage
  - A MEO satellite's distance gives it a longer time delay and weaker signal than a LEO satellite, though not as bad as a GEO satellite.

Geostationary Earth Orbit (GEO)

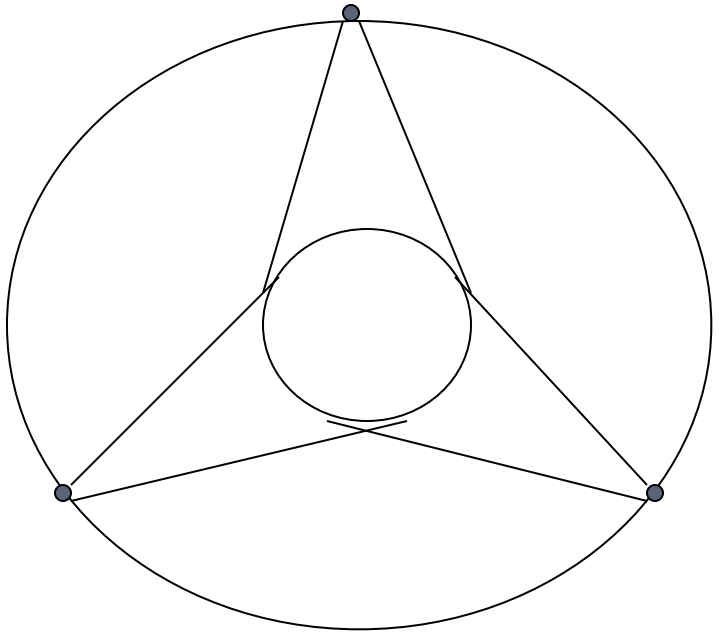
- These satellites are in orbit 35,863 km above the earth's surface along the equator.
- Objects in Geostationary orbit revolve around the earth at the same speed as the earth rotates. This means GEO satellites remain in the same position relative to the surface of earth.

GEO (cont.)

- Advantages
  - A GEO satellite's distance from earth gives it a large coverage area, almost a fourth of the earth's surface.
  - GEO satellites have a 24 hour view of a particular area.
  - These factors make it ideal for satellite broadcast and other multipoint applications.

GEO (cont.)

- At the Geostationary orbit the satellite covers 42.2% of the earth's surface.
- Theoretically 3 geostationary satellites provides 100% earth coverage



GEO (cont.)

- Disadvantages
  - A GEO satellite's distance also cause it to have both a comparatively weak signal and a time delay in the signal, which is bad for point to point communication.
  - GEO satellites, centered above the equator, have difficulty broadcasting signals to near polar regions

Limited Space for GEO Satellite

- Due to the constant o° latitude and circularity of geostationary orbits, satellites in GEO differ in location by longitude only.
- Satellites in geostationary orbit must all occupy a single ring above the equator.
- The requirement to space these satellites apart to avoid harmful radio-frequency interference during operations means that there are a limited number of orbital "slots" available, thus only a limited number of satellites can be operated in geostationary orbit.

Capacity Allocation

- FDMA
  - FAMA-FDMA
  - DAMA-FDMA
- TDMA
  - Advantages over FDMA

FDMA

- Satellite frequency is already broken into bands, and is broken in to smaller channels in Frequency Division Multiple Access (FDMA).
- Overall bandwidth within a frequency band is increased due to frequency reuse (a frequency is used by two carriers with orthogonal polarization).

FDMA (cont.)

- The number of sub-channels is limited by three factors:
  - Thermal noise (too weak a signal will be effected by background noise).
  - Intermodulation noise (too strong a signal will cause noise).
  - Crosstalk (cause by excessive frequency reusing).

FDMA (cont.)

- FDMA can be performed in two ways:
  - Fixed-assignment multiple access (FAMA): The sub-channel assignments are of a fixed allotment. Ideal for broadcast satellite communication.
  - Demand-assignment multiple access (DAMA): The sub-channel allotment changes based on demand. Ideal for point to point communication.

TDMA

- TDMA (Time Division Multiple Access) breaks a transmission into multiple time slots, each one dedicated to a different transmitter.
- TDMA is increasingly becoming more widespread in satellite communication.
- TDMA uses the same techniques (FAMA and DAMA) as FDMA does.

TDMA (cont.)

- Advantages of TDMA over FDMA.
  - Digital equipment used in time division multiplexing is increasingly becoming cheaper.
  - There are advantages in digital transmission techniques. Ex: error correction.
  - Lack of intermodulation noise means increased efficiency.