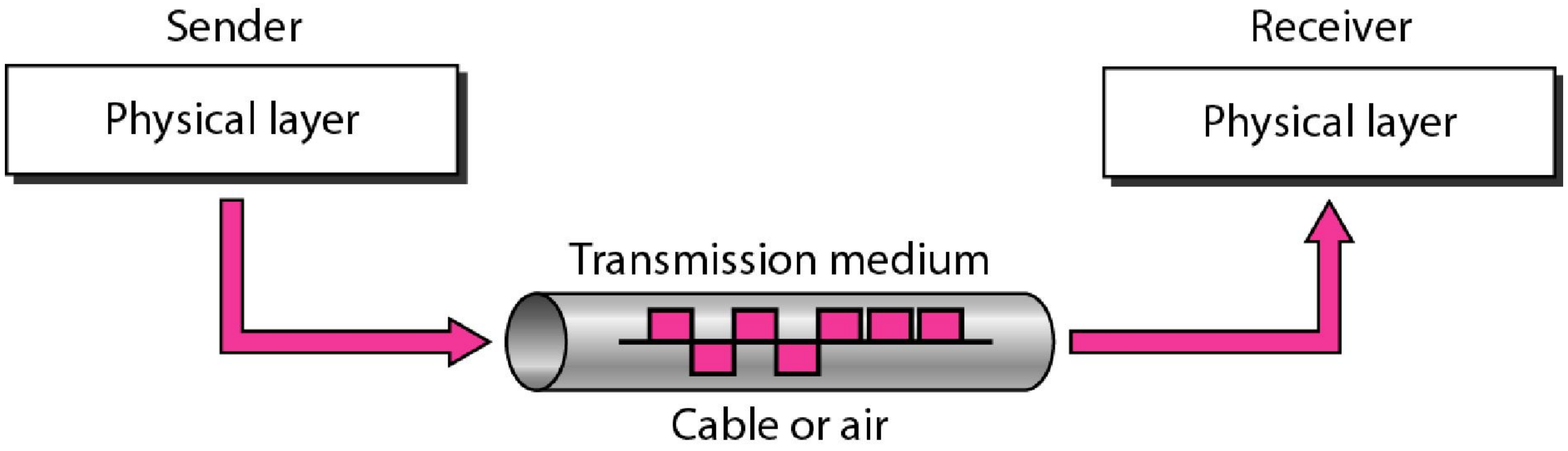
Transmission Media

- The transmission medium is the physical path between transmitter and receiver.
- In One type of transmission medium , transmission occurs through a ***s****olid medium, such as copper twisted pair, copper coaxial cable, and optical fiber*
- For second type of transmission medium , transmission occurs wireless through the atmosphere, outer space, or water.

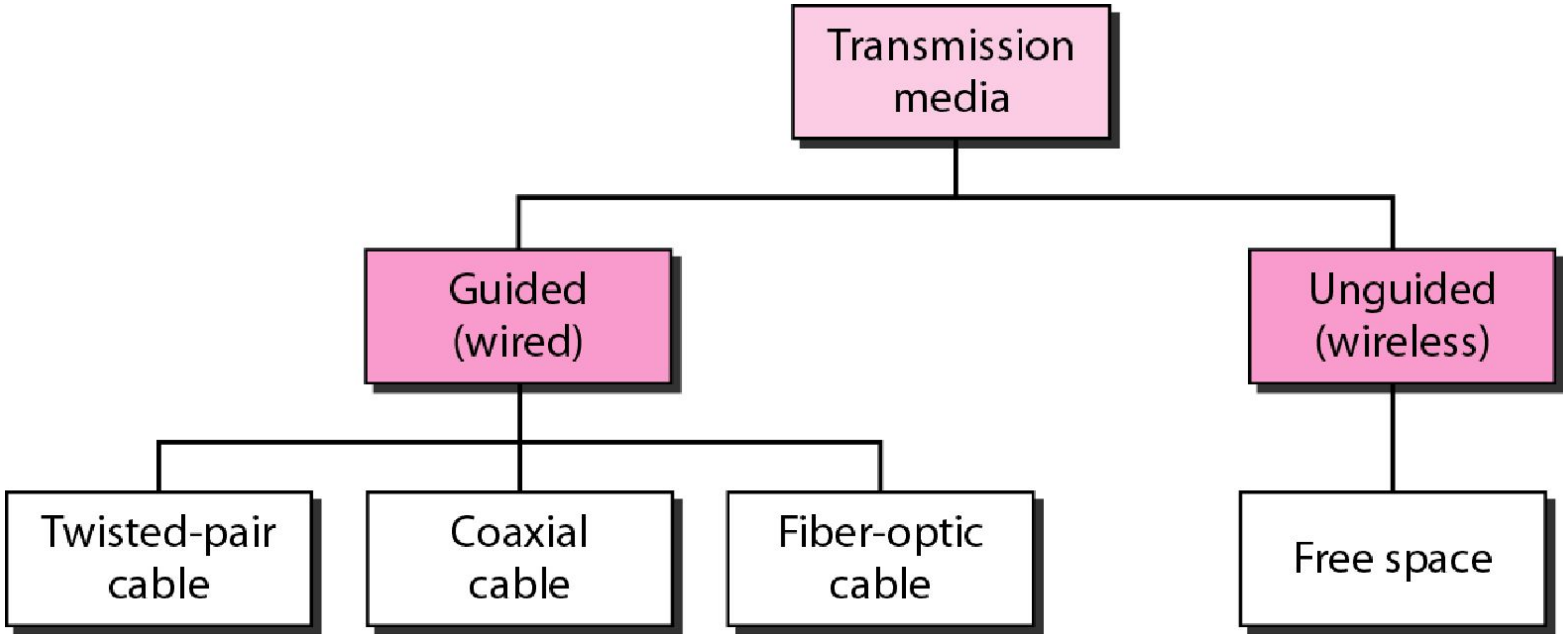
Transmission medium and physical layer



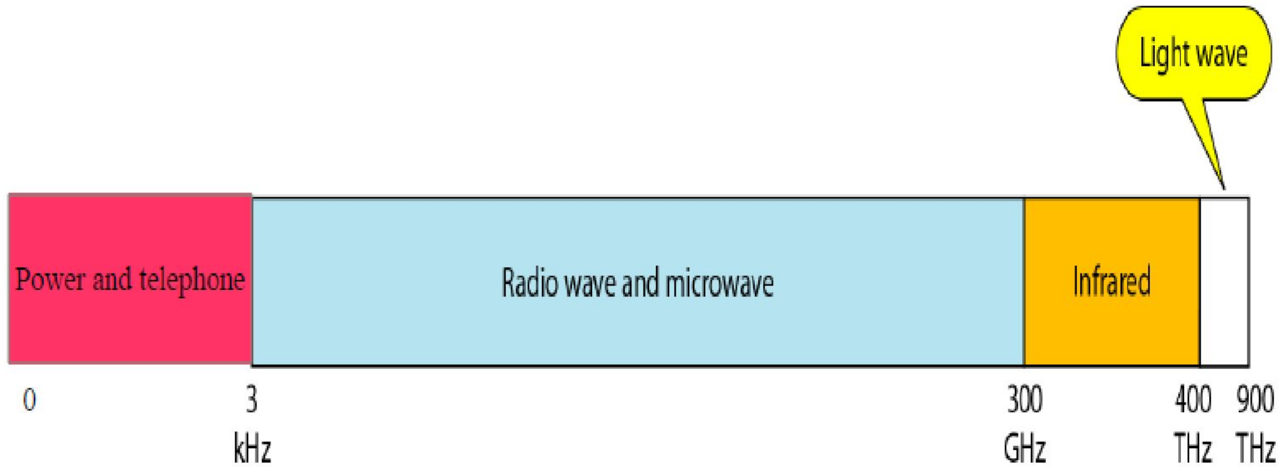
Design factors relating to the transmission medium

- **Bandwidth:** the greater the bandwidth of a signal, the higher the data rate that can be achieved.
- **Transmission impairments:** Impairments, such as Attenuation, Noise and Distortion.
- **Interference:** Interference from competing signals in overlapping frequency bands can distort or wipe out a signal.
- **Number of receivers:** A guided medium can be used to construct a point-to-point link or a shared link with multiple attachments.

Classes of transmission media



Electromagnetic spectrum for Transmission Media



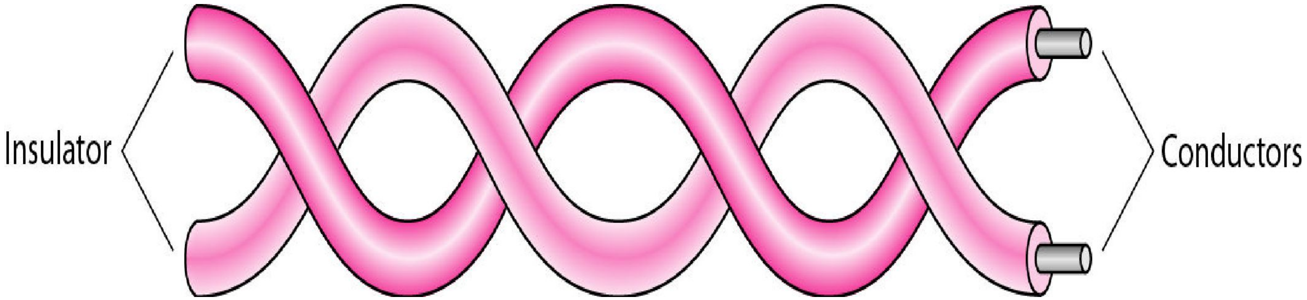
GUIDED MEDIA

- For Guided Media electromagnetic waves are guided along a solid medium, such as
  - **Twisted-Pair Cable**
  - **Coaxial Cable**
  - **Fiber-Optic Cable**

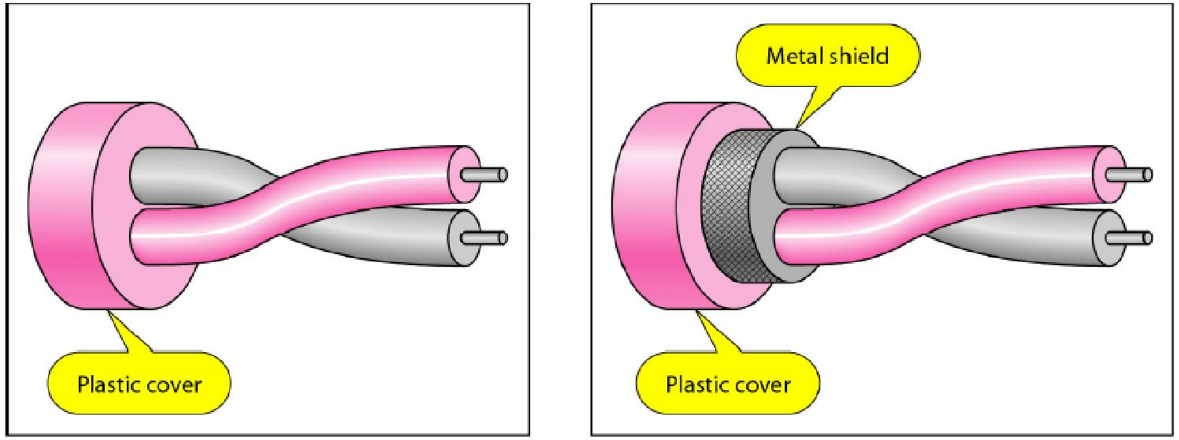
- A twisted pair consists of two insulated copper wires, typically about 1 mm thick. The wires are twisted together in a helical form, just like a DNA molecule.
- Twisting is done because two parallel wires constitute a fine antenna. When the wires are twisted, the waves from different twists cancel out, so the wire radiates less effectively.
- One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference.
- The receiver uses the difference between the two. In addition to the signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals.

- A signal is usually carried as the difference in voltage between the two wires in the pair. This provides better immunity to external noise because the noise tends to affect both wires the same, leaving the differential unchanged.
- Twisting tends to **decrease the crosstalk interference** between adjacent pairs in a cable.
- Neighboring pairs in a bundle typically have different twist lengths to reduce the crosstalk interference

Twisted Pair



UTP and ***STP cables***



a. UTP

b. STP

- Twisted pairs can be used for transmitting either analog or digital information.
- The bandwidth depends on the thickness of the wire and the distance travelled, but several megabits/sec can be achieved for a few kilometres in many cases.
- Due to their adequate performance and low cost, twisted pairs are widely used

Unshielded Versus Shielded Twisted-Pair Cable

- The most common twisted-pair cable used in communications is referred to as unshielded twisted-pair (UTP).
- IBM has also produced a version of twisted-pair cable for its use called shielded twisted-pair (STP). STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors.
- Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive.

Twisted Pair - Transmission Characteristics

- Analog
  - Amplifiers every 5km to 6km
- Digital
  - Use either analog or digital signals
  - repeater every 2km or 3km
- Limited distance
- Limited bandwidth (1MHz)
- Limited data rate (100MHz)
- Susceptible to interference and noise

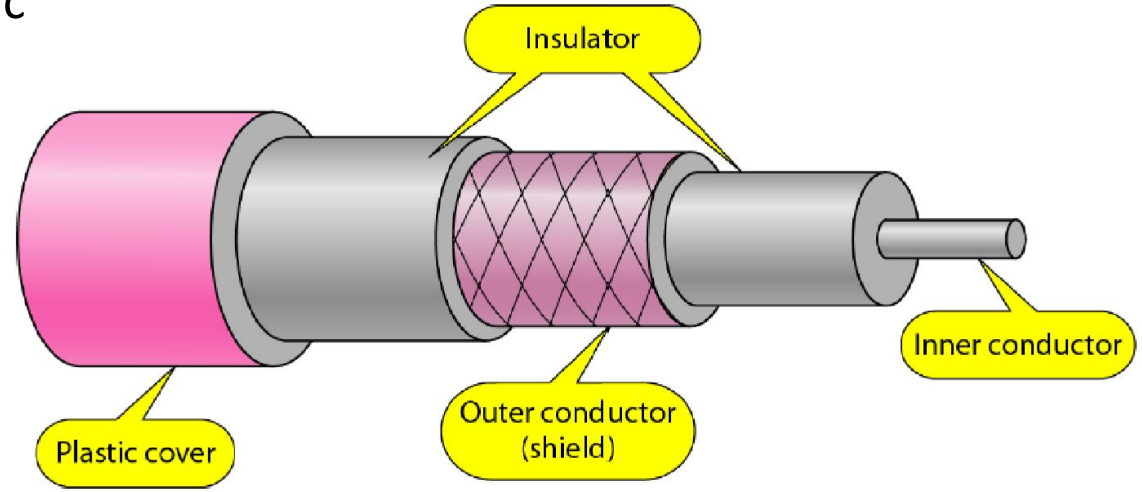
Crosstalk

- Cross talk in UTP cables is caused by capacitive coupling between pairs. Signals on pair A cause noise signals on pair B, and often the cross talk noise proves to be the limiting factor in the link performance.
- Cross talk occurs in two ways. Near- end cross talk (NEXT) happens when a signal from a transmitter at one end of a cable interferes with a receiver at the same end of the cable.
- Far-end cross talk (FEXT) occurs when a signal interferes with a receiver at the opposite end of the cable from the transmitter.
- Coupling of signal from one pair to another
- Coupling takes place when transmit signal entering the link couples back to receiving pair
- i.e. near transmitted signal is picked up by near receiving pair

Coaxial Cable

- Another common transmission medium is the coaxial cable or“coax”
- It has better shielding and greater bandwidth than unshielded twisted pairs, so it can span longer distances at higher speeds.
- Two kinds of coaxial cable are widely used.
- One kind, 50-ohm cable, is commonly used when it is intended for digital transmission from the start.
- The other kind, 75-ohm cable, is commonly used for analog transmission and cable television.

A coaxial cable consists of a stiff copper wire as the core, surrounded by an insulating material.
The insulator is encased by a cylindrical conductor, often as a closely woven braided mesh.
The outer conductor is covered in a protective plastic sheath.
The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit.

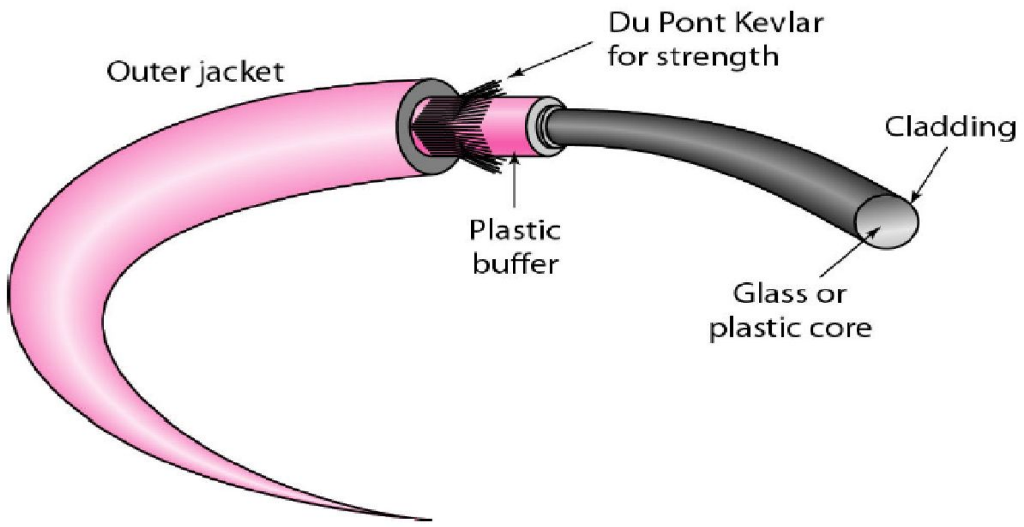


Coaxial Cable - Transmission Characteristics

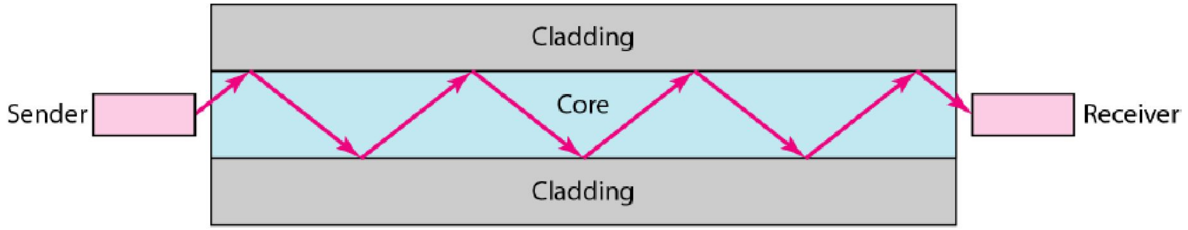
- Analog
  - Amplifiers every few km
  - closer spacing required if higher frequencies are used.
  - Up to 500MHz
- Digital
  - Repeater every 1km
  - closer spacing needed for higher data rates.

Fiber-Optic Cable

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.



- Optical fibers use reflection to guide light through a channel.
- A glass or plastic core is surrounded by a cladding of less dense glass or plastic.
- The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it.

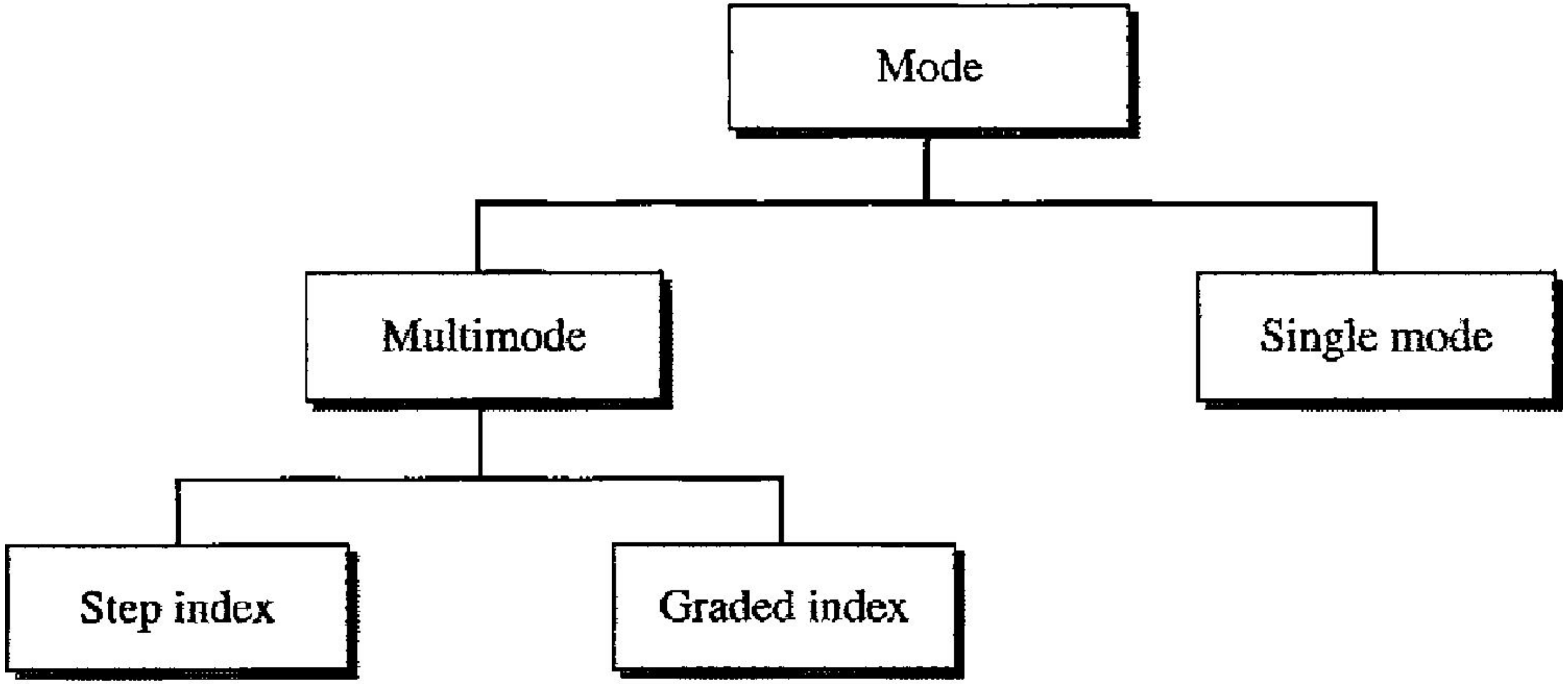


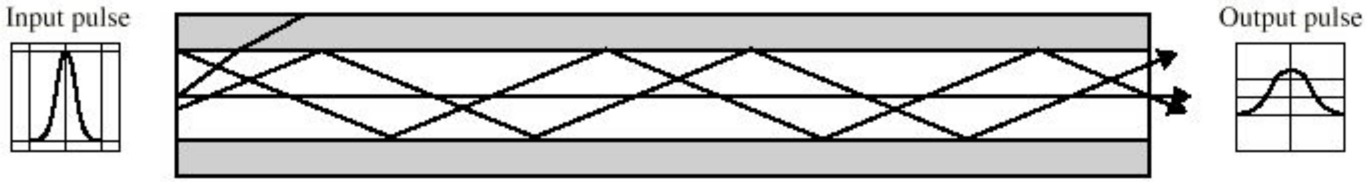
Optical Fiber - Benefits

- Greater capacity
  - Data rates of hundreds of Gbps
- Smaller size & weight
- Lower attenuation
- Electromagnetic isolation
- Greater repeater spacing
  - 10s of km at least

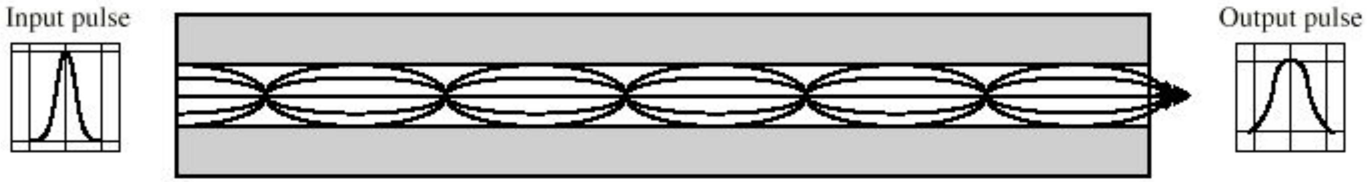
Propagation Modes

Two modes (multimode and single mode) for propagating light along optical channels, each requiring fiber with different physical characteristics.





(a) Step-index multimode



(b) Graded-index multimode

(c) Single mode

- Multimode is so named because multiple beams from a light source move through the core in different paths.
- In multimode step-index fiber, the density of the core remains constant from the center to the edges.
- A beam of light moves through this constant density in a straight line until it reaches the interface of the core and the cladding.
- At the interface, there is an abrupt change due to a lower density; this alters the angle of the beam's motion.
- The term *step index* refers to the suddenness of this change, which contributes to the distortion of the signal as it passes through the fiber.

- A second type of fiber, called multimode graded-index fiber, decreases this distortion of the signal through the cable.
- The word *index* here refers to the index of refraction. The index of refraction is related to density.
- A graded-index fiber, therefore, is one with varying densities.
- Density is highest at the center of the core and decreases gradually to its lowest at the edge.

- Single-Mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal.
- The single mode fiber itself is manufactured with a much smaller diameter than that of multimode fiber, and with substantially lower density (index of refraction).
- The decrease in density results in a critical angle that is close enough to 90° to make the propagation of beams almost horizontal. In this case, propagation of different beams is almost identical, and delays are negligible.
- All the beams arrive at the destination "together" and can be recombined with little distortion to the signal

Optical Fiber - Transmission Characteristics

- Act as wave guide for 10^{14} to 10^{15} Hz
  - Portions of infrared and visible spectrum
- Light Emitting Diode (LED)
  - Cheaper
  - Wider operating temp range
  - Last longer
- Injection Laser Diode (ILD)
  - More efficient
  - Greater data rate
- Wavelength Division Multiplexing

UNGUIDED MEDIA: WIRELESS

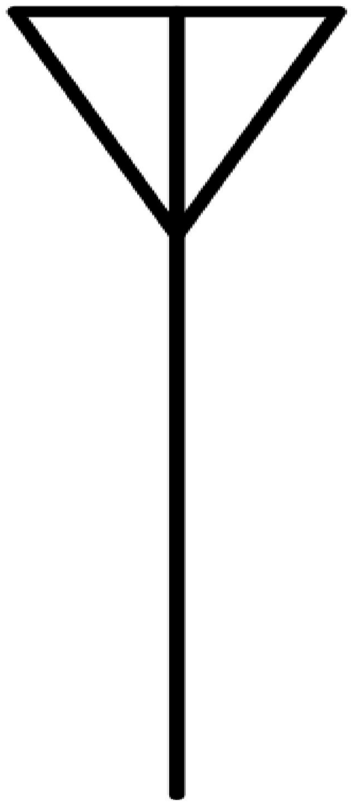
- Unguided media transport electromagnetic waves without using a physical conductor.
- The Signals are transmitted through the air (in some cases water). These are available to anyone who can receive them.
    - Radio Waves
    - Microwaves
    - Infrared

Electromagnetic spectrum for Wireless Transmission

- **30MHz to 1GHz (Radio Frequency)**
  - Omnidirectional, Broadcast radio
- **2GHz to 40GHz (Microwave Frequency)**
  - Highly directional
  - Point to point devices
- Microwave communications
  - **3×10^{11} to 2×10^{14} (Local Frequency)**
- For Local applications, local point-to-point and multipoint applications within confined areas, such as a single room

Antennas

- electrical conductor used to radiate or collect electromagnetic energy
  1)transmission antenna
  2)reception antenna



Radiation Pattern

- Antenna might radiate power in all direction
- Not same performance in all directions
- How can we determine the performance of an antenna?
- Solution is “Radiation Pattern”

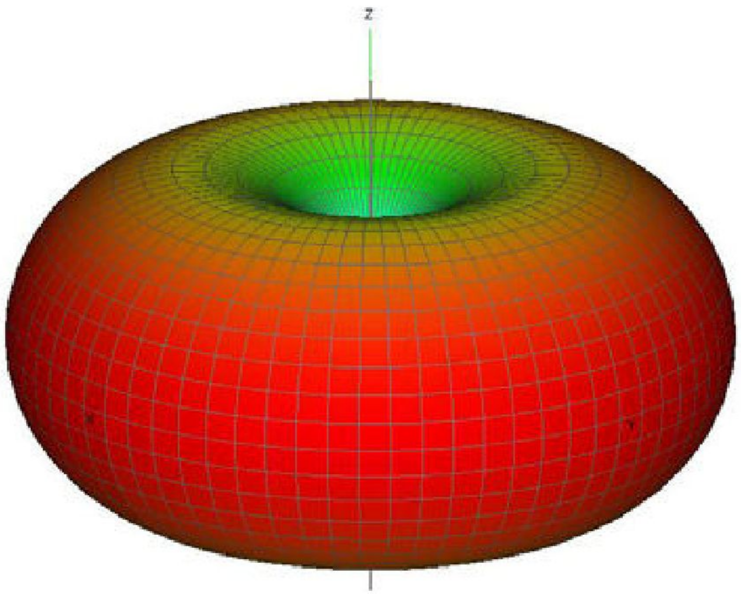
  Graphical representation of the radiated power
- Isotropic antenna is an ideal antenna
- Radiates Equal Energy in all directions.
- Use as a reference to characterize the power

Isotropic antenna

- The radiation pattern of a simple omnidirectional antenna , a vertical half-wave dipole antenna.
- In this graph the antenna is at the

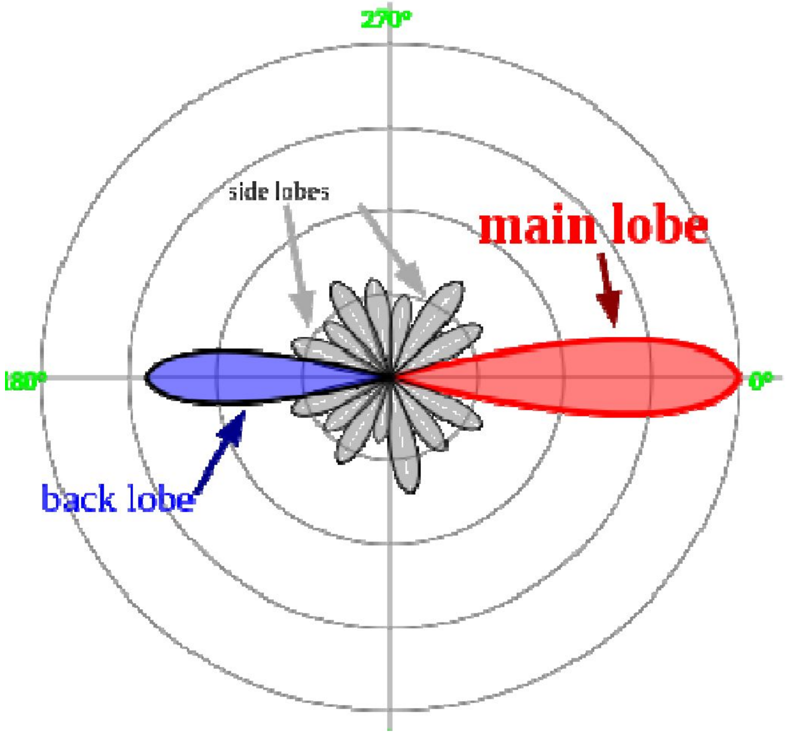
center of the "donut," or torus.

Isotropic Radiation Pattern



- In a directive antenna, the largest lobe, in the desired direction of propagation, is called the "main lobe".

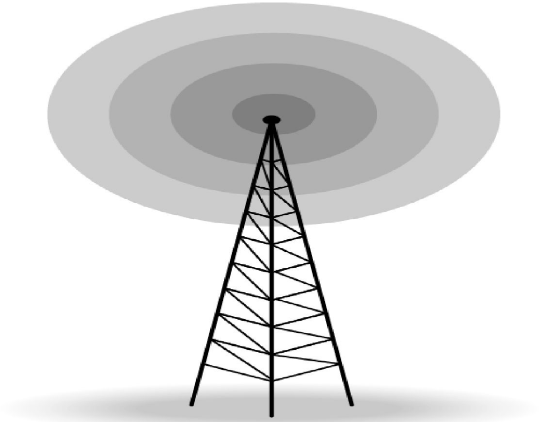
The other lobes are called "side lobes" and usually represent radiation in unwanted directions



- Antenna Gain
- Measure of directionality of antenna
- Power output in particular direction compared with that produced by isotropic antenna
- Measured in decibels (dB)

- Antennas Types

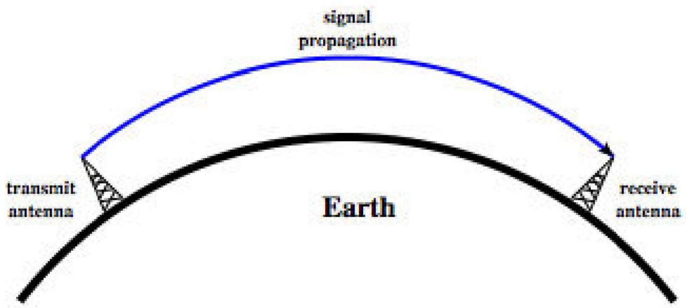
1)Omnidirectional Antenna



2)Unidirectional Antenna or Directional Antenna or Parabolic antenna

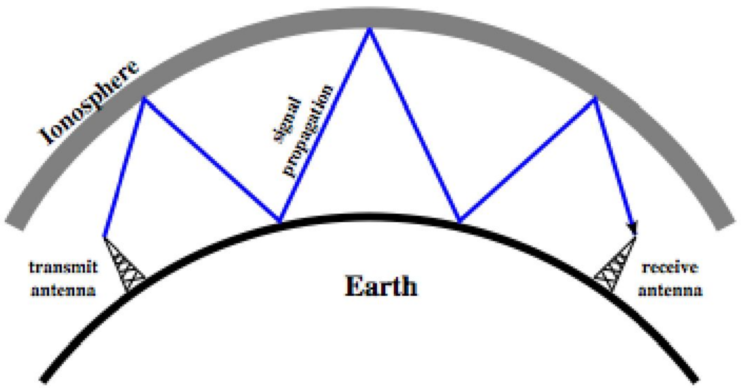
Wireless Propagation

- Ground Wave



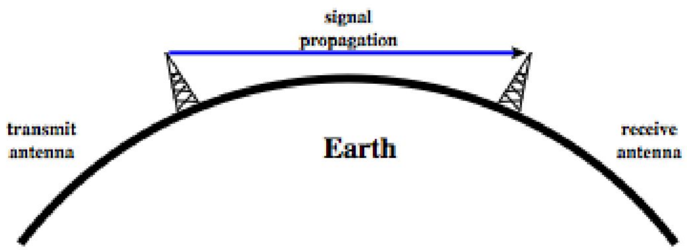
(a) Ground-wave propagation (below 2 !

- Sky Wave

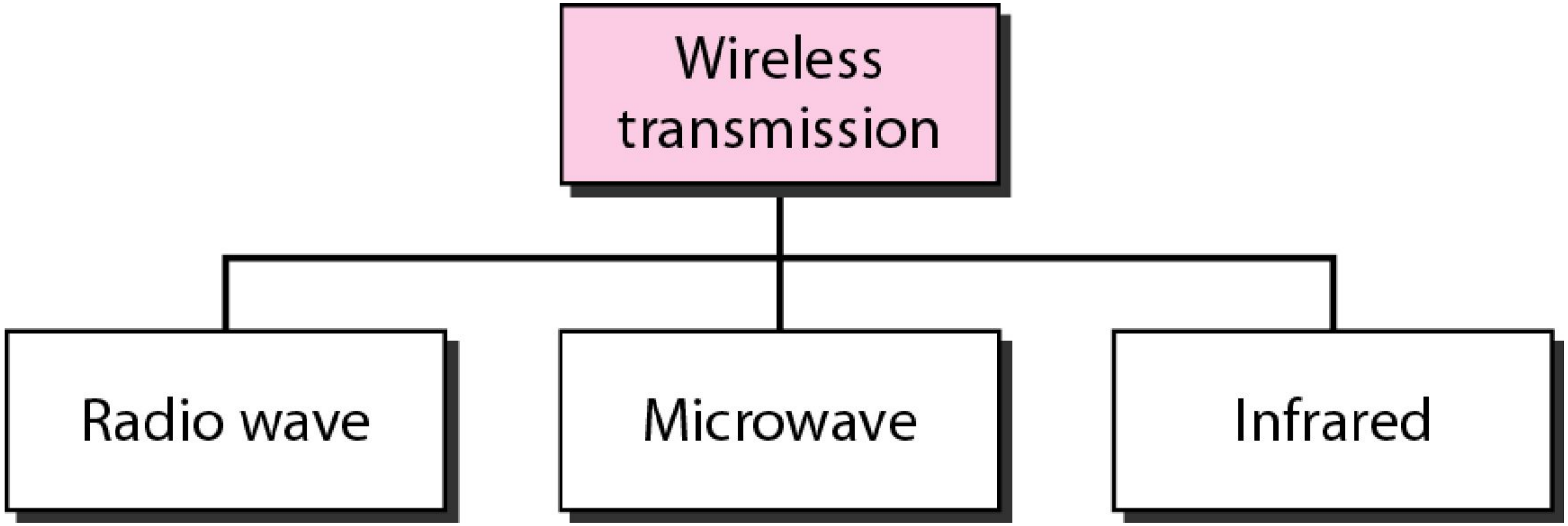


(b) Sky-wave propagation (2 to 30 MHz)

- Line of Sight



(c) Line-of-sight (LOS) propagation (above 30 MHz)



Wireless transmission
Radio wave
Microwave
Infrared

Radio Waves

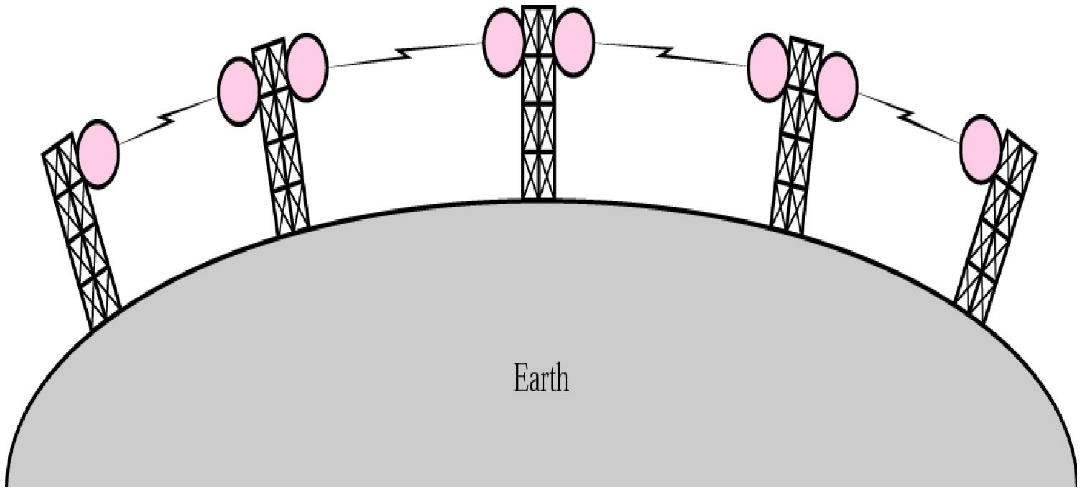
- radio is 3kHz to 300GHz
- use broadcast radio, 30MHz - 1GHz, for:
  - FM radio
  - UHF and VHF television
- is omnidirectional, Sky wave propagation
- They can penetrate through walls but line of sight can give better results.
- suffers from multipath interference reflections from land, water, other objects

MICROWAVE

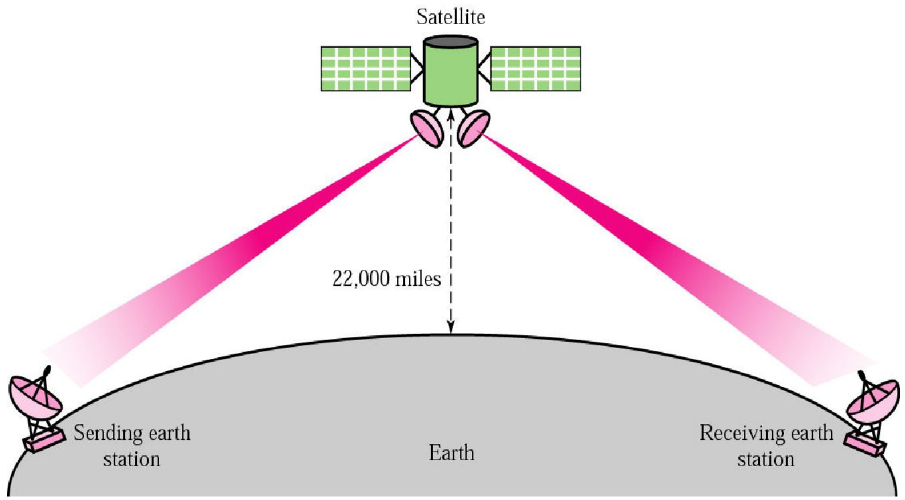
- 2GHz to 40GHz
- Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.
- Higher frequency ranges cannot penetrate walls.

- TERRESTRIAL MICROWAVE
- SATELLITE MICROWAVE

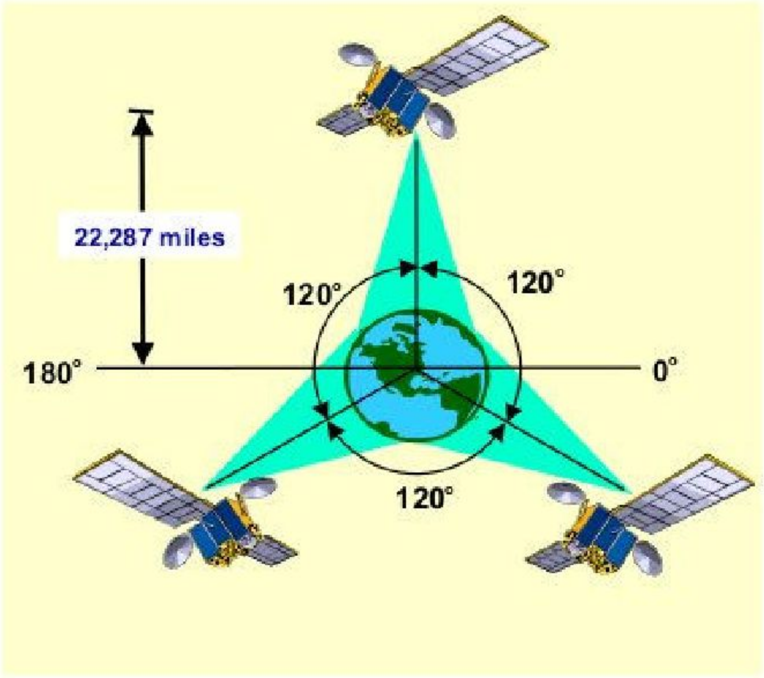
- Terrestrial Microwave
- used for long distance telecommunications and short point-to-point links,
- use a parabolic dish to focus a narrow beam onto a receiver antenna



- satellite is relay station
- receives on one frequency,
- repeats signal and transmits on another frequency
- Separate frequencies are assigned for
- upward transmission (uplink)
- downward transmission(downlink)
- eg. uplink 5.925-6.425 GHz & downlink 3.7-4.2 GHz

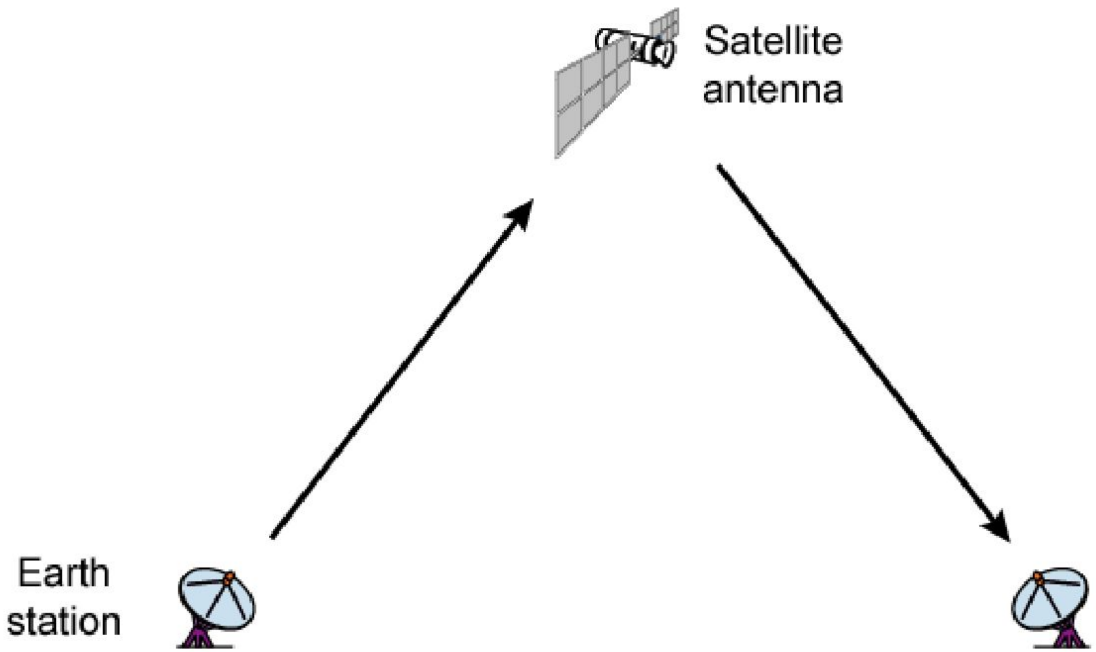


Geostationary Satellite



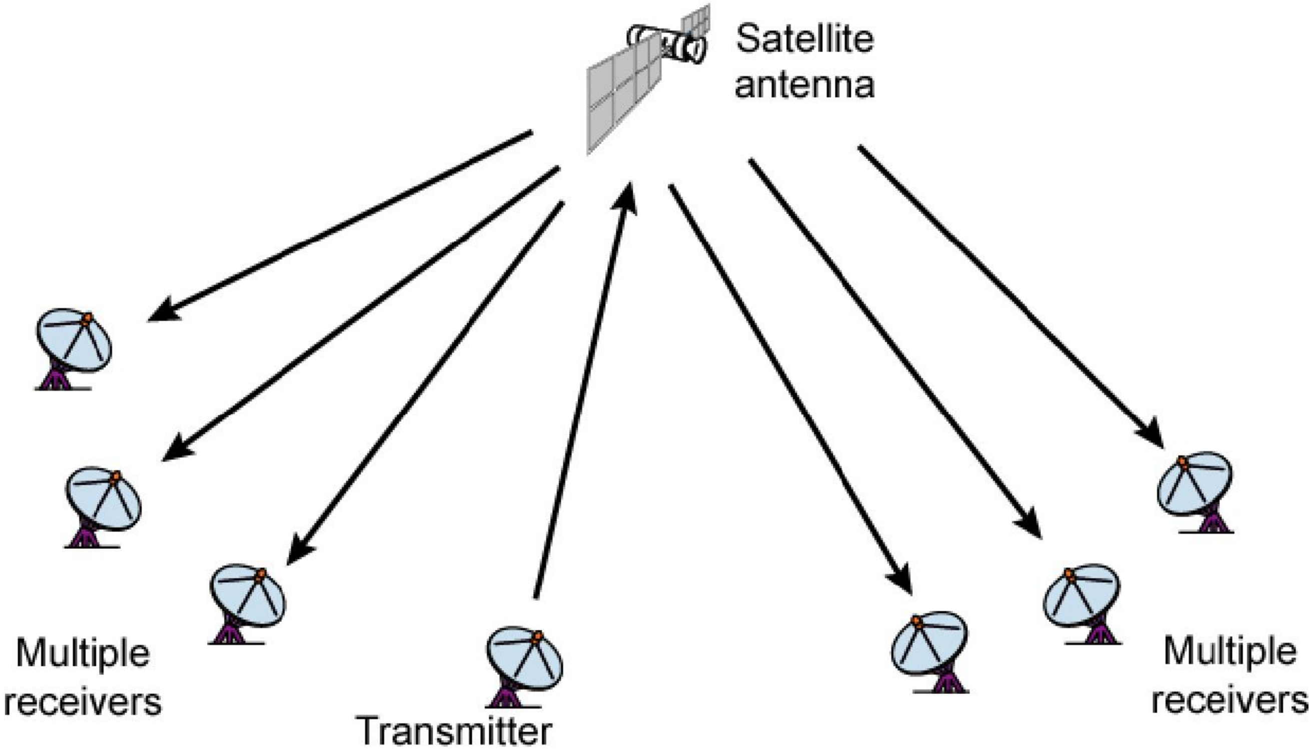
- Remains in a fixed position relative to ground station.
- Used for communication purposed.
- Used 3 satellites to cover all over the earth except the polar extreme (latitudes > 81° north or south).

Satellite Point to Point Link



(a) Point-to-point link

Satellite Broadcast Link



(b) Broadcast link

Infrared

- Infrared communications is achieved using transmitters/receivers (transceivers) that modulate infrared light.
- Transceivers must be within the line of sight of each other either directly or via reflection from a light-colored surface such as the ceiling of a room.
- infrared does not penetrate walls.