Transmission Media

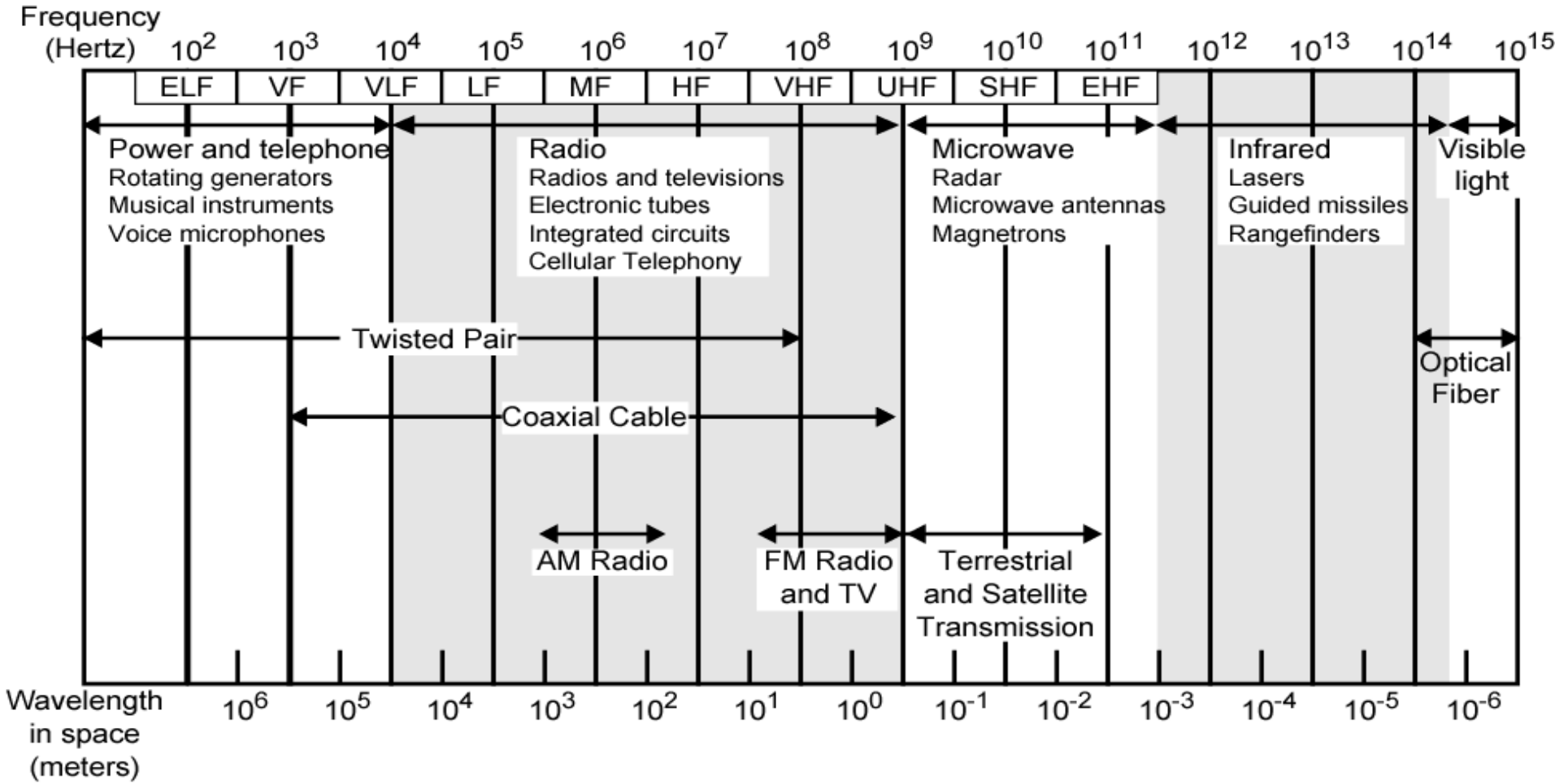
Overview

- Guided - wire
- Unguided - wireless
- Characteristics and quality determined by medium and signal
- For guided, the medium is more important
- For unguided, the bandwidth produced by the antenna is more important
- Key concerns are data rate and distance

Design Factors

- Bandwidth
  - —Higher bandwidth gives higher data rate
- Transmission impairments
  - —Attenuation
- Interference
- Number of receivers
  - —In guided media
  - —More receivers (multi-point) introduce more attenuation

Electromagnetic Spectrum



ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

Guided Transmission Media

- Twisted Pair
- Coaxial cable
- Optical fiber

Transmission Characteristics of Guided Media

	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μs/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 μs/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μs/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/km	5 μs/km	40 km

Twisted Pair

—Separately insulated
—Twisted together
—Often "bundled" into cables
—Usually installed in building during construction

(a) Twisted pair

- Consists of two insulated copper wires arranged in a regular spiral pattern to minimize the electromagnetic interference between adjacent pairs
- Often used at customer facilities and also over distances to carry voice as well as data communications
- Low frequency transmission medium

Twisted Pair

Issues:

(1) Interference due to unwanted electrical coupling of two copper

(2) Interference due to unwanted electrical coupling between the neighboring twisted pairs

Twisted Pair - Applications

- Most common medium
- Telephone network
  - —Between house and local exchange (subscriber loop)
- Within buildings
  - —To private branch exchange (PBX)
- For local area networks (LAN)
  - —10Mbps or 100Mbps

Twisted Pair - Pros and Cons

- Cheap
- Easy to work with
- Low data rate
- Short range

Twisted Pair - Transmission Characteristics

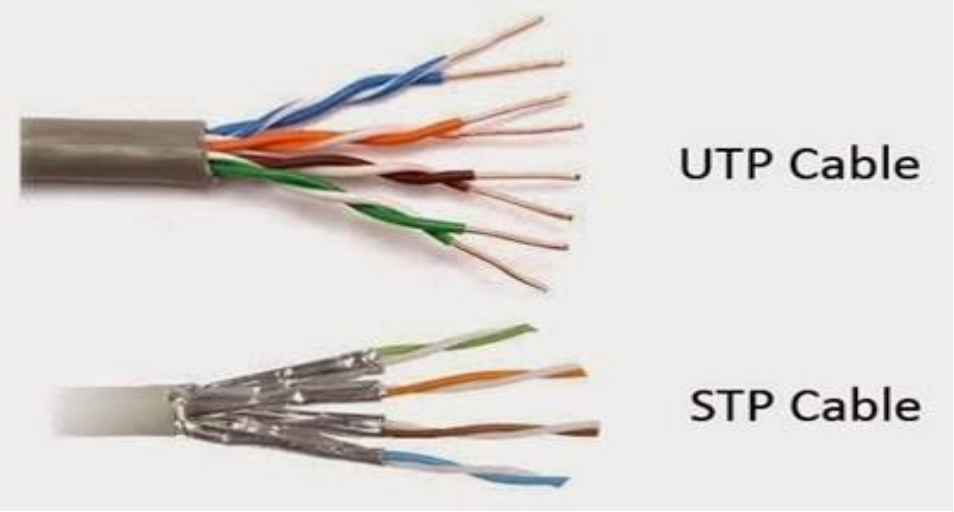
- Analog
  - —Amplifiers every 5km to 6km
- Digital
  - —Use either analog or digital signals
  - —repeater every 2km or 3km
- Limited distance
- Limited bandwidth (1MHz)
- Limited data rate (100MHz)
- Susceptible to interference and noise

Near End Crosstalk

- 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

Types of Twisted Pair

- STP (shielded twisted pair)
  - —the pair is wrapped with metallic foil or braid to insulate the pair from electromagnetic interference
- UTP (unshielded twisted pair)
  - —each wire is insulated with plastic wrap, but the pair is encased in an outer covering



Unshielded and Shielded TP

- Unshielded Twisted Pair (UTP)
  - —Ordinary telephone wire
  - —Cheapest
  - —Easiest to install
  - —Suffers from external EM interference
- Shielded Twisted Pair (STP)
  - —Metal braid or sheathing that reduces interference
  - —More expensive
  - —Harder to handle (thick, heavy)

UTP Categories

- Cat 3
  - up to 16MHz
  - Voice grade found in most offices
  - Twist length of 7.5 cm to 10 cm
- Cat 4
  - up to 20 MHz
- Cat 5
  - up to 100MHz
  - Commonly pre-installed in new office buildings
  - Twist length 0.6 cm to 0.85 cm
- Cat 5E (Enhanced) –see tables
- Cat 6
- Cat 7

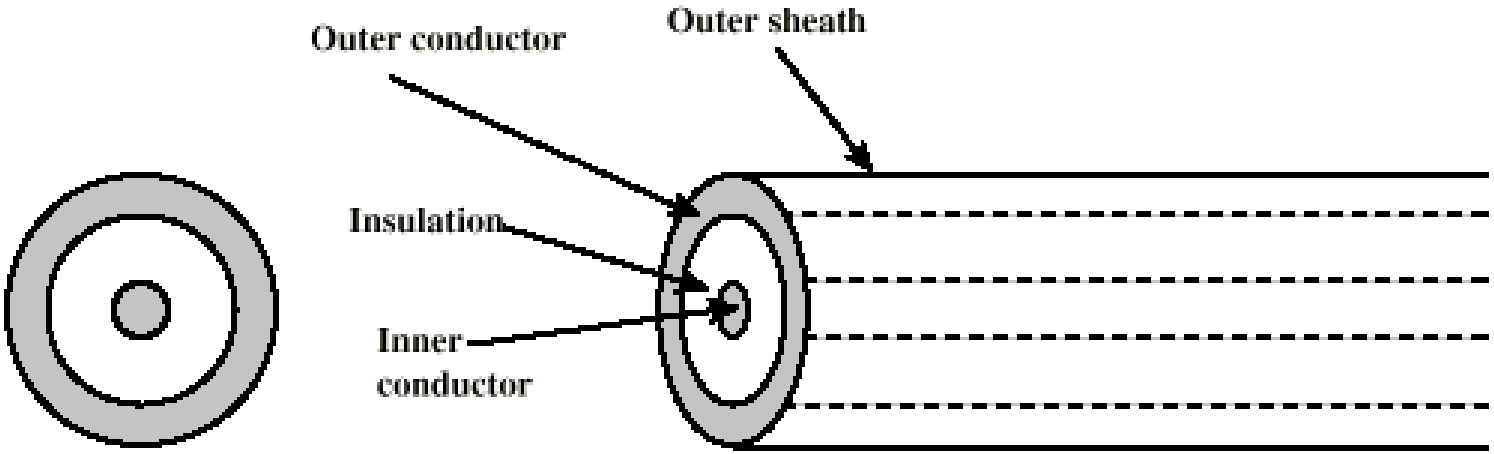
Comparison of Shielded and Unshielded Twisted Pair

	Attenuation (dB per 100 m)			Near-end Crosstalk (dB)		
Frequency (MHz)	**Category 3 UTP**	**Category 5 UTP**	**150-ohm STP**	**Category 3 UTP**	**Category 5 UTP**	**150-ohm STP**
1	2.6	2.0	1.1	41	62	58
4	5.6	4.1	2.2	32	53	58
16	13.1	8.2	4.4	23	44	50.4
25	—	10.4	6.2	—	41	47.5
100	—	22.0	12.3	—	32	38.5
300	—	—	21.4	—	—	31.3

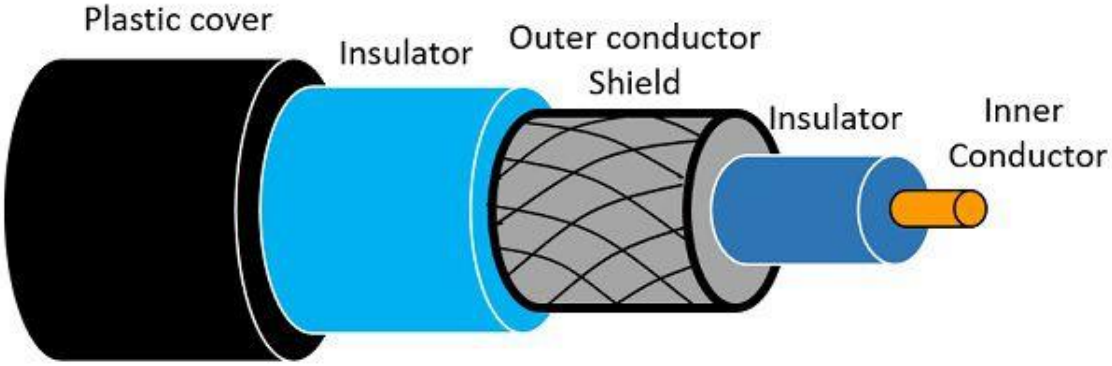
Twisted Pair Categories and Classes

	Category 3 Class C	Category 5 Class D	Category 5E	Category 6 Class E	Category 7 Class F
Bandwidth	16 MHz	100 MHz	100 MHz	200 MHz	600 MHz
Cable Type	UTP	UTP/FTP	UTP/FTP	UTP/FTP	SSTP
Link Cost (Cat 5 =1)	0.7	1	1.2	1.5	2.2

Coaxial Cable



—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding



Coaxial Cable Construction

Coaxial Cable

- Used for cable television, LANs, telephony
- Has an inner conductor surrounded by a braided mesh
- Both conductors share a common center axial, hence the term “co-axial”

Coaxial Cable Applications

- Most versatile medium
- Television distribution
  - —Ariel to TV
  - —Cable TV
- Long distance telephone transmission
  - —Can carry 10,000 voice calls simultaneously
  - —Being replaced by fiber optic
- Short distance computer systems links
- Local area networks

Coaxial Cable - Transmission Characteristics

- Analog
  - —Amplifiers every few km
  - —Closer if higher frequency
  - —Up to 500MHz
- Digital
  - —Repeater every 1km
  - —Closer for higher data rates

Coax Advantages

- Higher bandwidth
  - —400 to 600Mhz
  - —up to 10,800 voice conversations
- Can be tapped easily (pros and cons)
- Much less susceptible to interference than twisted pair

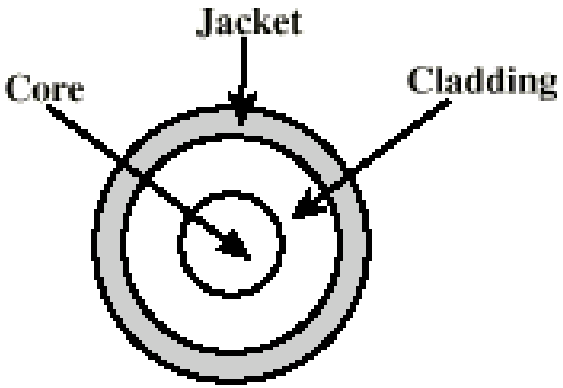
Coax Disadvantages

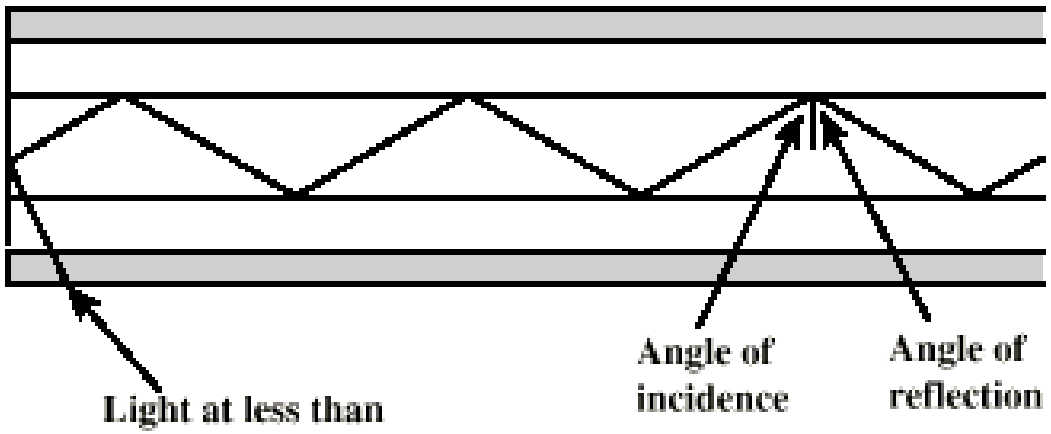
- High attenuation rate makes it expensive over long distance
- Bulky

Optical Fiber

- Relatively new transmission medium used by telephone companies in place of long-distance trunk lines
- Also used by private companies in implementing local data communications networks
- Require a light source with injection laser diode (ILD) or light-emitting diodes (LED)

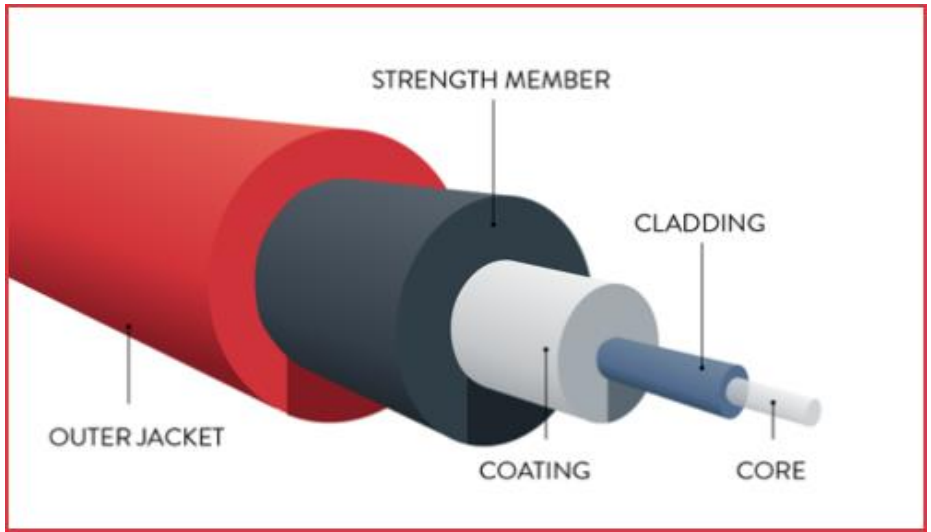
Optical Fiber





—Glass or plastic core
—Laser or light emitting diode
—Specially designed jacket
—Small size and weight

Light at less than ciritical angle is absorbed in jacket



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

Optical Fiber - Disadvantages

- expensive over short distance
- requires highly skilled installers
- adding additional nodes is difficult

Optical Fiber - Applications

- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- LANs

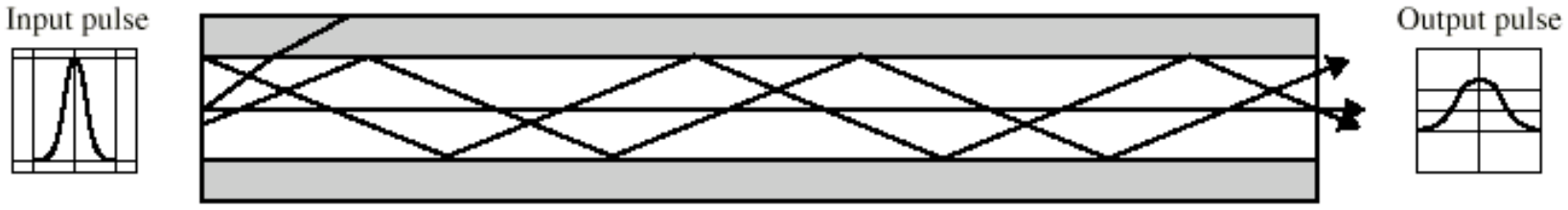
Optical Fiber - Transmission Characteristics

- 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

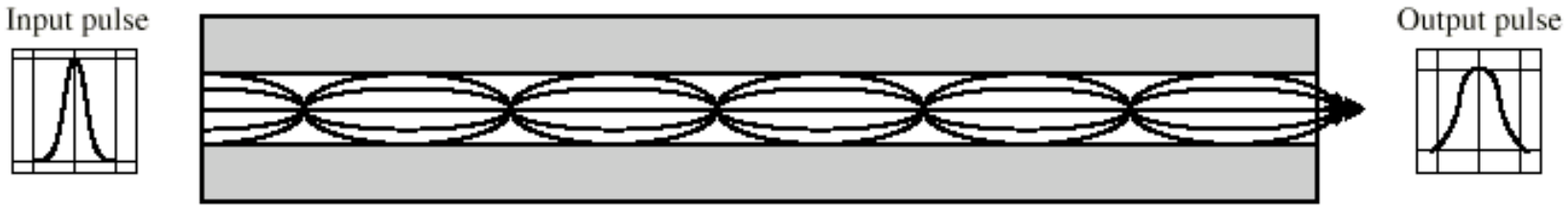
Optical Fiber Transmission Modes

- multimode step-index fiber
  - —the reflective walls of the fiber move the light pulses to the receiver
- multimode graded-index fiber
  - —acts to refract the light toward the center of the fiber by variations in the density
- single mode fiber
  - —the light is guided down the center of an extremely narrow core

Optical Fiber Transmission Modes



(a) Step-index multimode



(b) Graded-index multimode

(c) Single mode

Frequency Utilization for Fiber Applications

Wavelength (in vacuum) range (nm)	Frequency range (THz)	Band label	Fiber type	Application
820 to 900	366 to 333		Multimode	LAN
1280 to 1350	234 to 222	S	Single mode	Various
1528 to 1561	196 to 192	C	Single mode	WDM
1561 to 1620	185 to 192	L	Single mode	WDM

Twisted pair cable	Co-axial cable	Optical fiber
1. Transmission of signals takes place in the electrical form over the metallic conducting wires.	1. Transmission of signals takes place in the electrical form over the inner conductor of the cable.	1. Signal transmission takes place in an optical forms over a glass fiber.
2. In this medium the noise immunity is low.	2. Coaxial having higher noise immunity than twisted pair cable.	2. Optical fiber has highest noise immunity as the light rays are unaffected by the electrical noise.
3. Twisted pair cable can be affected due to external magnetic field.	3. Coaxial cable is less affected due to external magnetic field.	3. Not affected by the external magnetic field.
4. Cheapest medium.	4. Moderate Expensive.	4. Expensive
5. Low Bandwidth.	5. Moderately high bandwidth.	5. Very high bandwidth
6. Attenuation is very high.	6. Attenuation is low.	6. Attenuation is very low.
7. Installation is easy.	7. Installation is fairly easy.	7. Installation is difficult.

Wireless Transmission Frequencies

- 2GHz to 40GHz
  - —Microwave
  - —Highly directional
  - —Point to point
  - —Satellite
- 30MHz to 1GHz
  - —Omnidirectional
  - —Broadcast radio
- 3×10^{11} to 2×10^{14}
  - —Infrared
  - —Local

Wireless (Unguided Media) Transmission

- transmission and reception are achieved by means of an antenna
- directional
  - —transmitting antenna puts out focused beam
  - —transmitter and receiver must be aligned
- omnidirectional
  - —signal spreads out in all directions
  - —can be received by many antennas

Antennas

- Electrical conductor (or system of..) used to radiate electromagnetic energy or collect electromagnetic energy
- Transmission
  - Radio frequency energy from transmitter
  - Converted to electromagnetic energy
  - By antenna
  - Radiated into surrounding environment
- Reception
  - Electromagnetic energy impinging on antenna
  - Converted to radio frequency electrical energy
  - Fed to receiver
- Same antenna often used for both

Radiation Pattern

- Power radiated in all directions
- Not same performance in all directions
- Isotropic antenna is (theoretical) point in space
  - —Radiates in all directions equally
  - —Gives spherical radiation pattern

Wireless Examples

- terrestrial microwave
- satellite microwave
- broadcast radio
- infrared

Terrestrial Microwave

- used for long-distance telephone service
- uses radio frequency spectrum, from 2 to 40 Ghz
- parabolic dish transmitter, mounted high
- used by common carriers as well as private networks
- requires unobstructed line of sight between source and receiver
- curvature of the earth requires stations (repeaters) ~30 miles apart

Terrestrial Microwave Applications

- Television distribution
- Long-distance telephone transmission
- Private business networks

Microwave Transmission Disadvantages

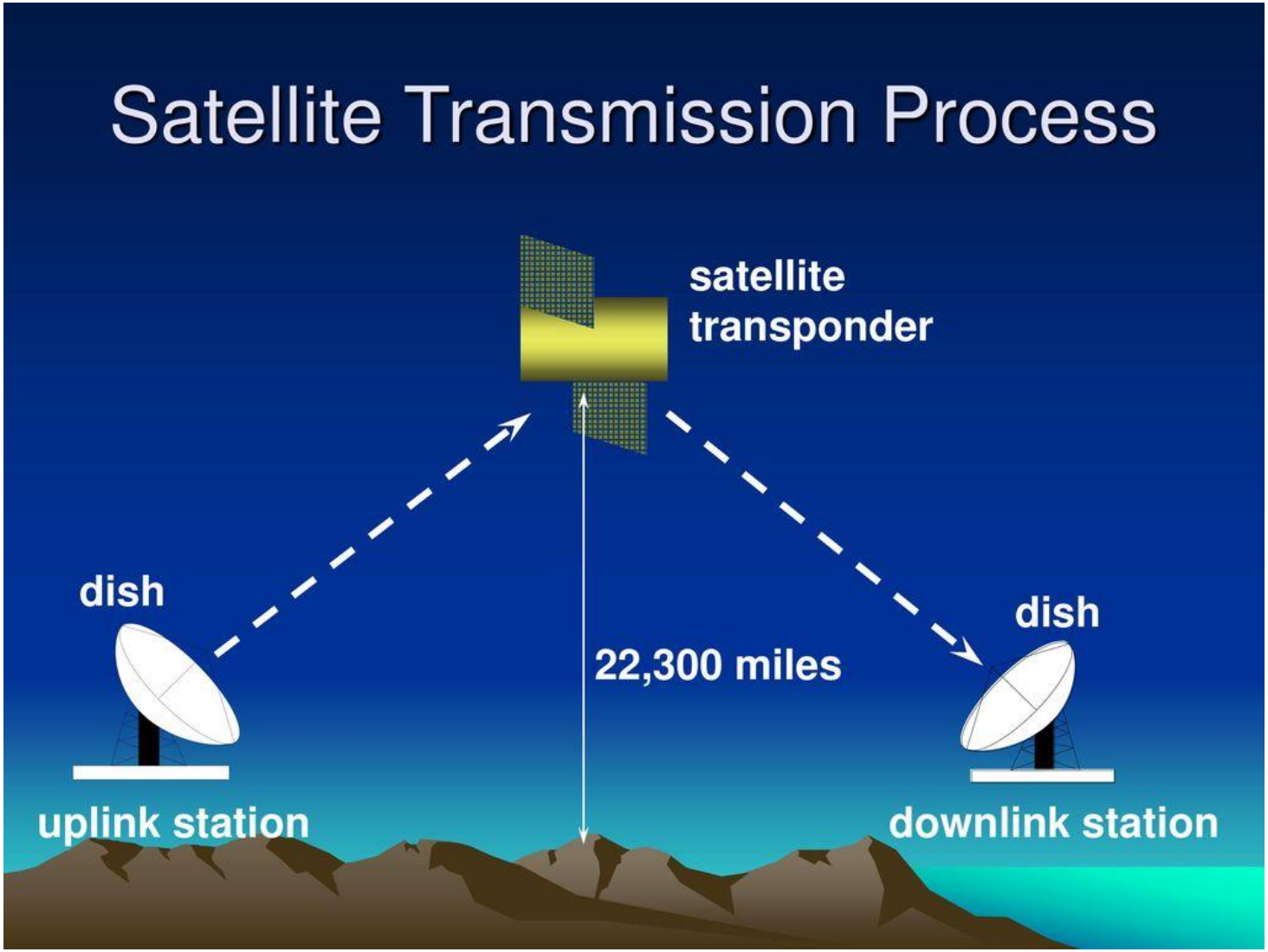
- line of sight requirement
- expensive towers and repeaters
- subject to interference such as passing airplanes and rain

Satellite Microwave

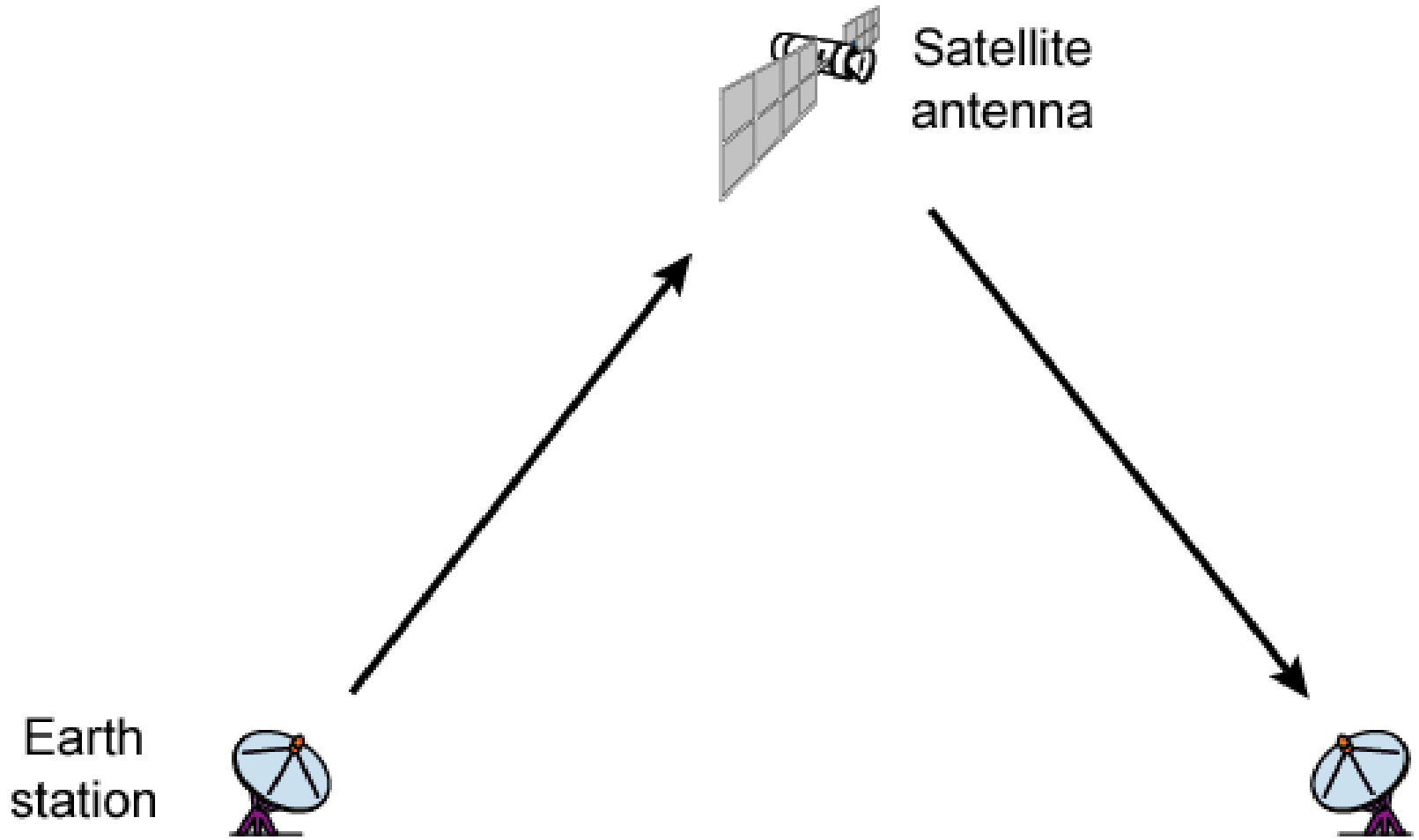
- Satellite is relay station
- Satellite receives on one frequency, amplifies or repeats signal and transmits on another frequency
- Requires geo-stationary orbit
  - Height of 35,784km
- Television
- Long distance telephone
- Private business networks

Satellite Transmission Links

- earth stations communicate by sending signals to the satellite on an uplink
- the satellite then repeats those signals on a downlink
- the broadcast nature of the downlink makes it attractive for services such as the distribution of television programming

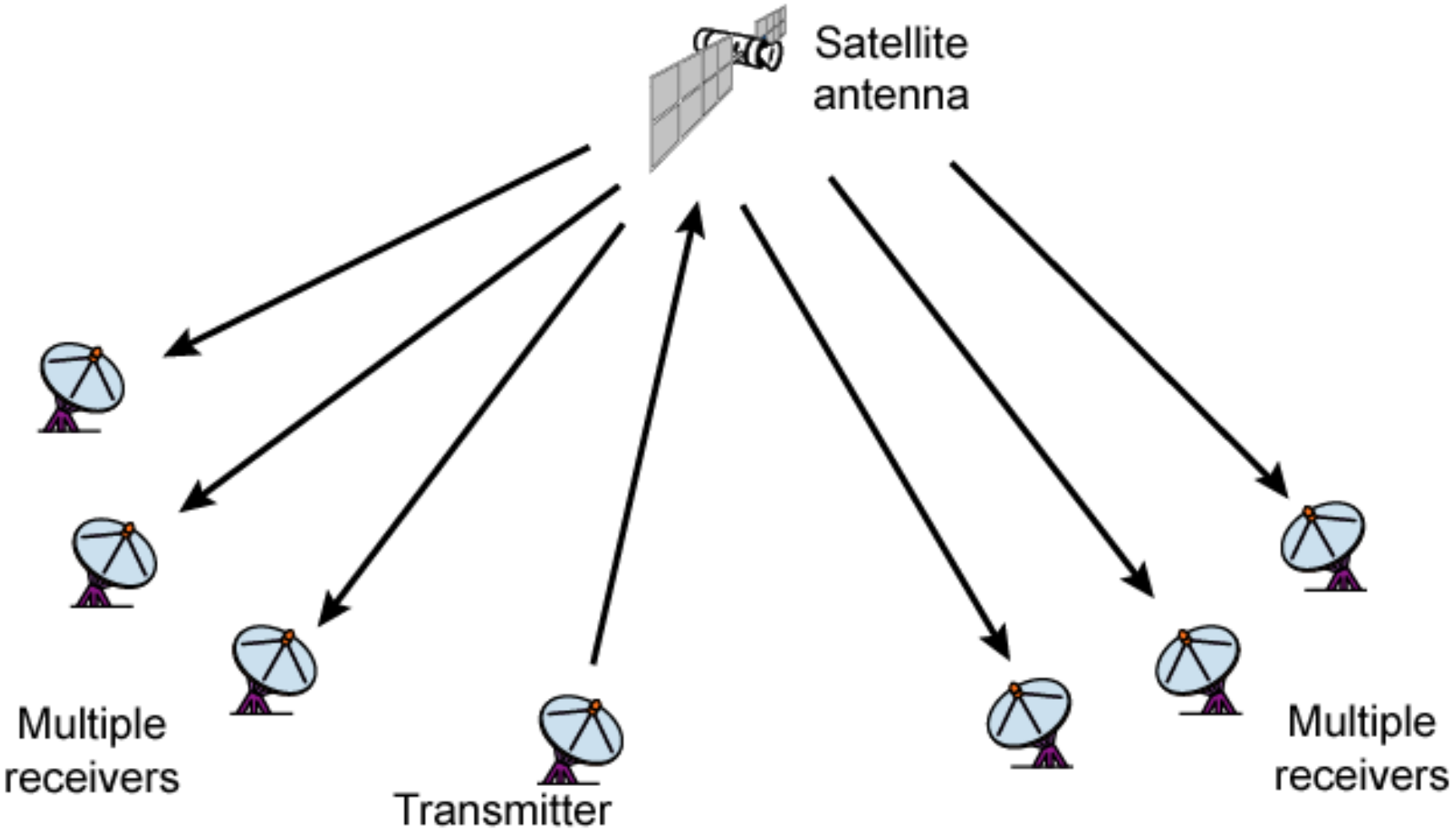

Satellite Transmission Process
satellite
transponder
dish
22,300 miles
dish
uplink station
downlink station

Satellite Point to Point Link



(a) Point-to-point link

Satellite Broadcast Link



(b) Broadcast link

Satellite Transmission Applications

- television distribution
  - —a network provides programming from a central location
  - —direct broadcast satellite (DBS)
- long-distance telephone transmission
  - —high-usage international trunks
- private business networks

Principal Satellite Transmission Bands

- C band: 4(downlink) - 6(uplink) GHz
  - —the first to be designated
- Ku band: 12(downlink) -14(uplink) GHz
  - —rain interference is the major problem
- Ka band: 19(downlink) - 29(uplink) GHz
  - —equipment needed to use the band is still very expensive

Fiber vs Satellite

Table 7.6 A Comparison of Optical Fiber and Satellite Transmission

Characteritic	Optical Fiber	Satellite
Bandwidth	Theoretical limit of 1 terahertz; currently 1–10 GHz	Typical transponder has a bandwidth of 36–72 MHz
Immunity to interference	Immune to electromagnetic interference	Subject to interference from various sources, including microwave
Security	Difficult to tap without detection	Signals must be encrypted for security
Multipoint capability	Primarily a point-to-point medium	Point-to-multipoint communications easily implemented
Flexibility	Difficult to reconfigure to meet changing demand	Easy to reconfigure
Connectivity to customer site	Local loop required	With antenna installed on customer premises, local loop not required

Broadcast Radio

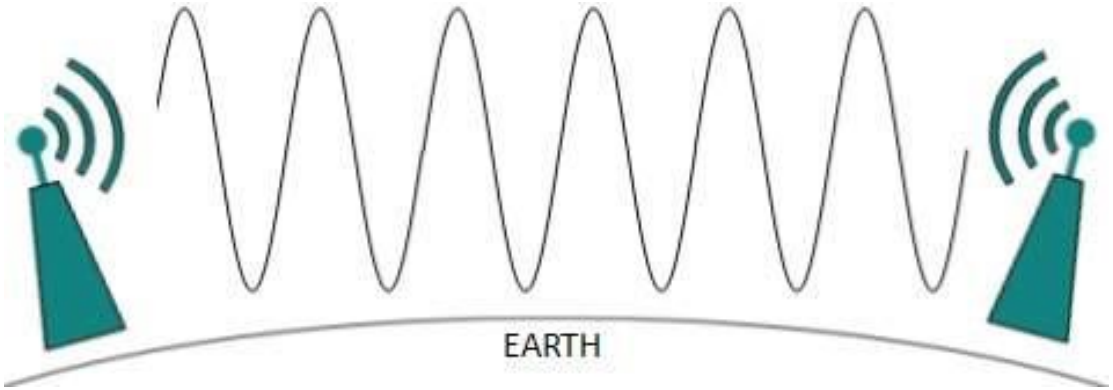
- Omnidirectional
- FM radio
- UHF and VHF television
- Line of sight
- Suffers from multipath interference
  - Reflections

Radio Transmission

- Radio frequency is easier to generate and because of its large wavelength it can penetrate through walls and structures alike.
- Radio waves can have wavelength from 1 mm – 100,000 km and have frequency ranging from 3 Hz (Extremely Low Frequency) to 300 GHz (Extremely High Frequency).
- Radio frequencies are sub-divided into six bands.

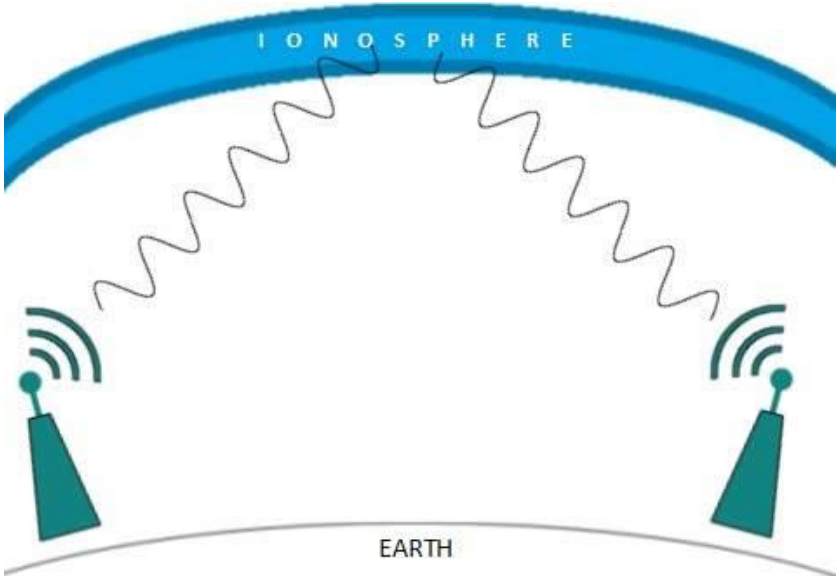
Radio Transmission

- Radio waves at lower frequencies can travel through walls whereas higher RF can travel in straight line and bounce back.
- The power of low frequency waves decreases sharply as they cover long distance.
- High frequency radio waves have more power.
- Lower frequencies such as VLF, LF, MF bands can travel on the ground up to 1000 kilometers, over the earth's surface.



Radio Transmission

- Radio waves of high frequencies are prone to be absorbed by rain and other obstacles.
- They use Ionosphere of earth atmosphere.
- High frequency radio waves such as HF and VHF bands are spread upwards.
- When they reach Ionosphere, they are refracted back to the earth.



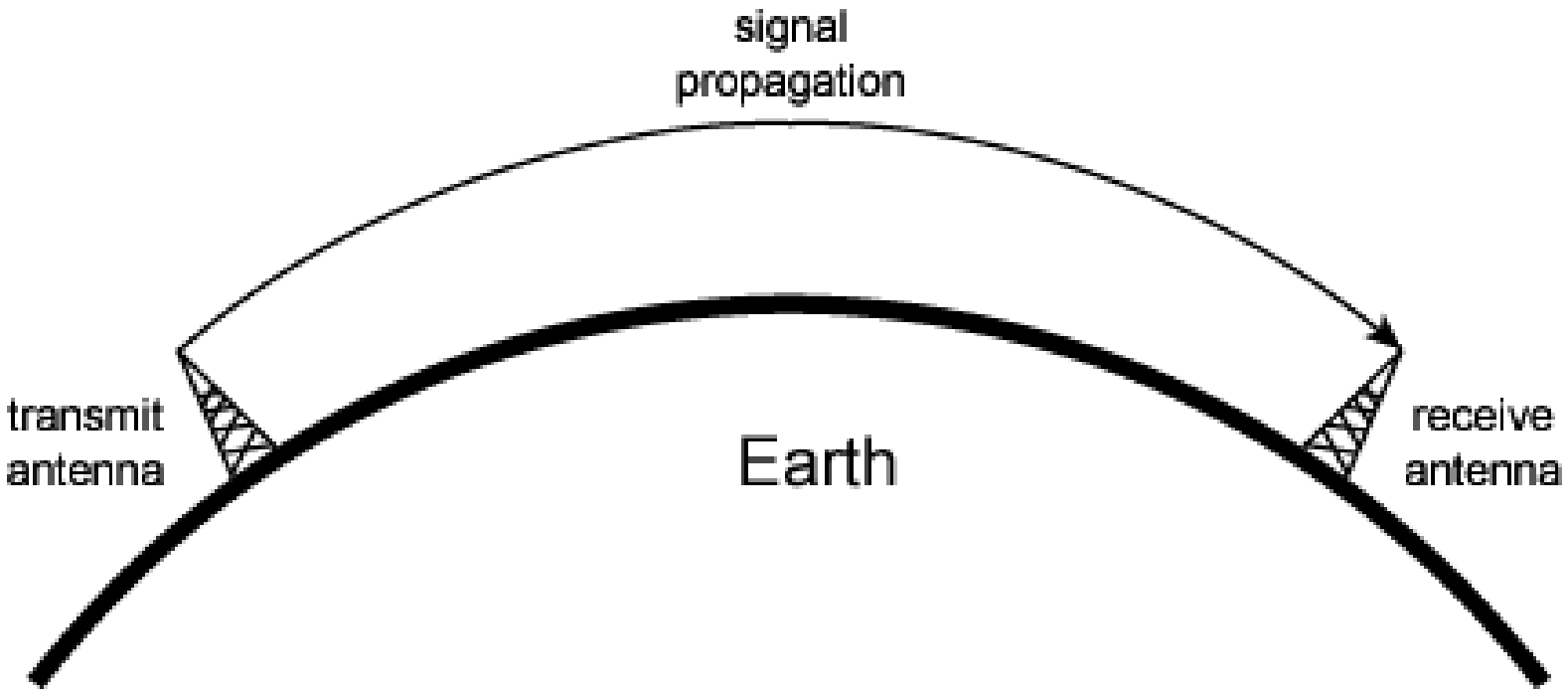
Infrared

- Modulate noncoherent infrared light
- Line of sight (or reflection)
- Blocked by walls
- e.g. TV remote control, IRD port

Wireless Propagation

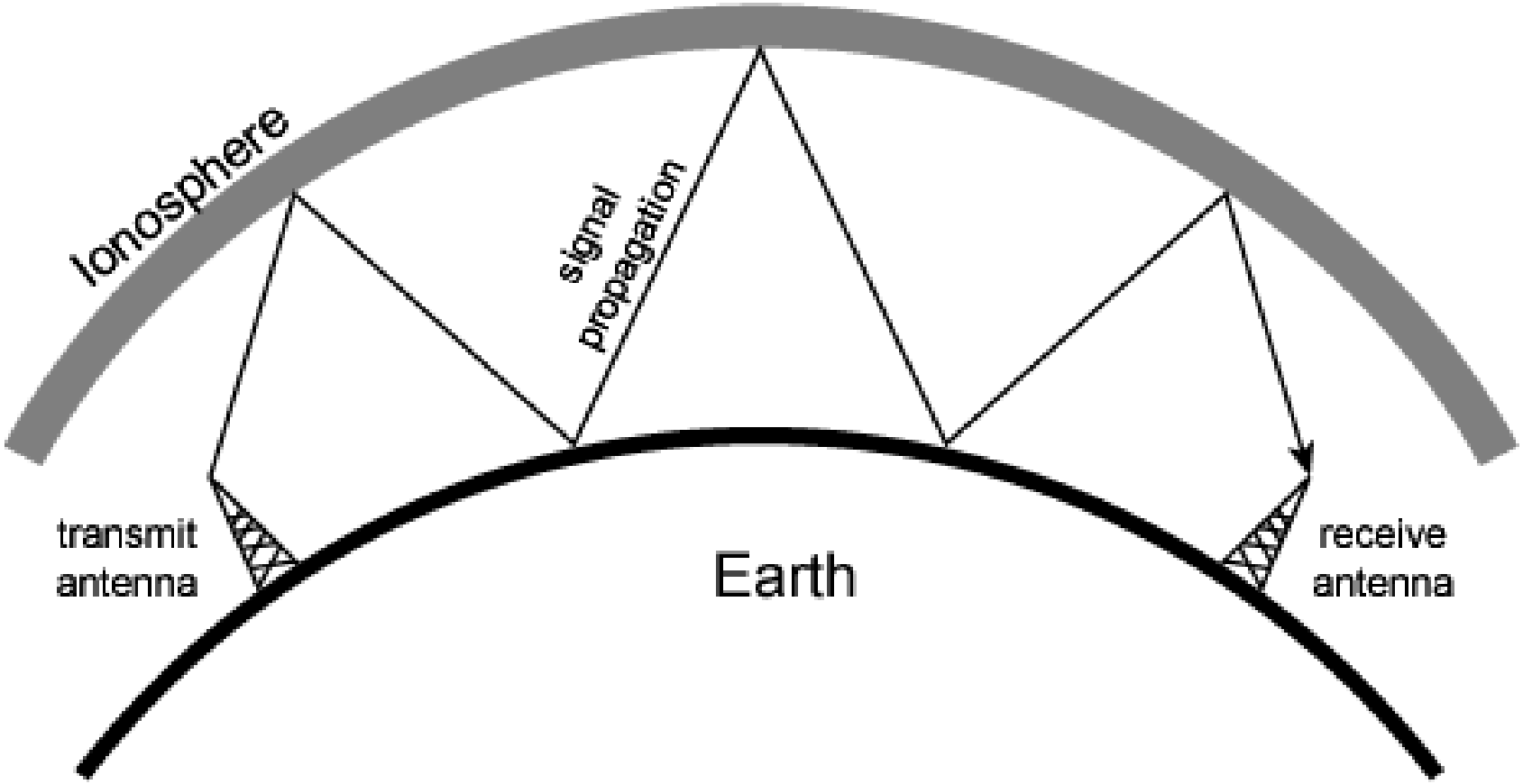
- Signal travels along three routes
  - Ground wave
    - Follows contour of earth
    - Up to 2MHz
    - AM radio
  - Sky wave
    - Amateur radio, BBC world service, Voice of America
    - Signal reflected from ionosphere layer of upper atmosphere
    - (Actually refracted)
  - Line of sight
    - Above 30Mhz
    - May be further than optical line of sight due to refraction
    - More later…

Ground Wave Propagation



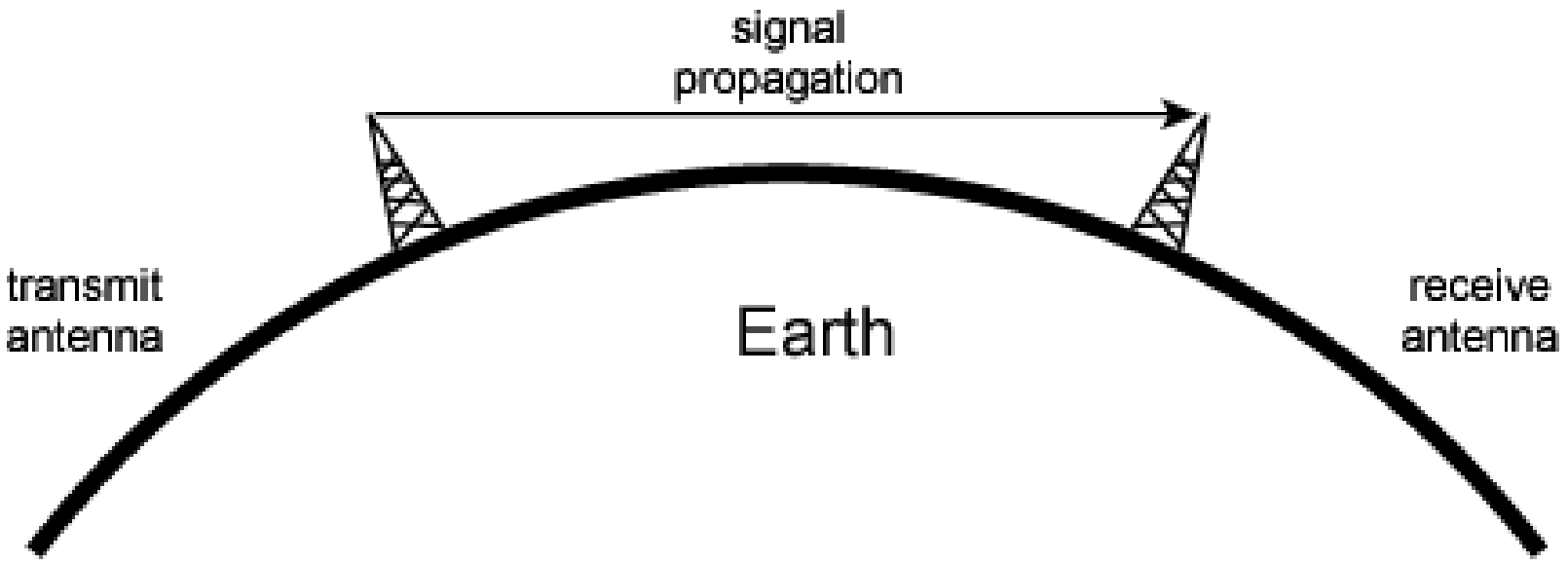
(a) Ground-wave propagation (below 2 MHz)

Sky Wave Propagation



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

Line of Sight Propagation

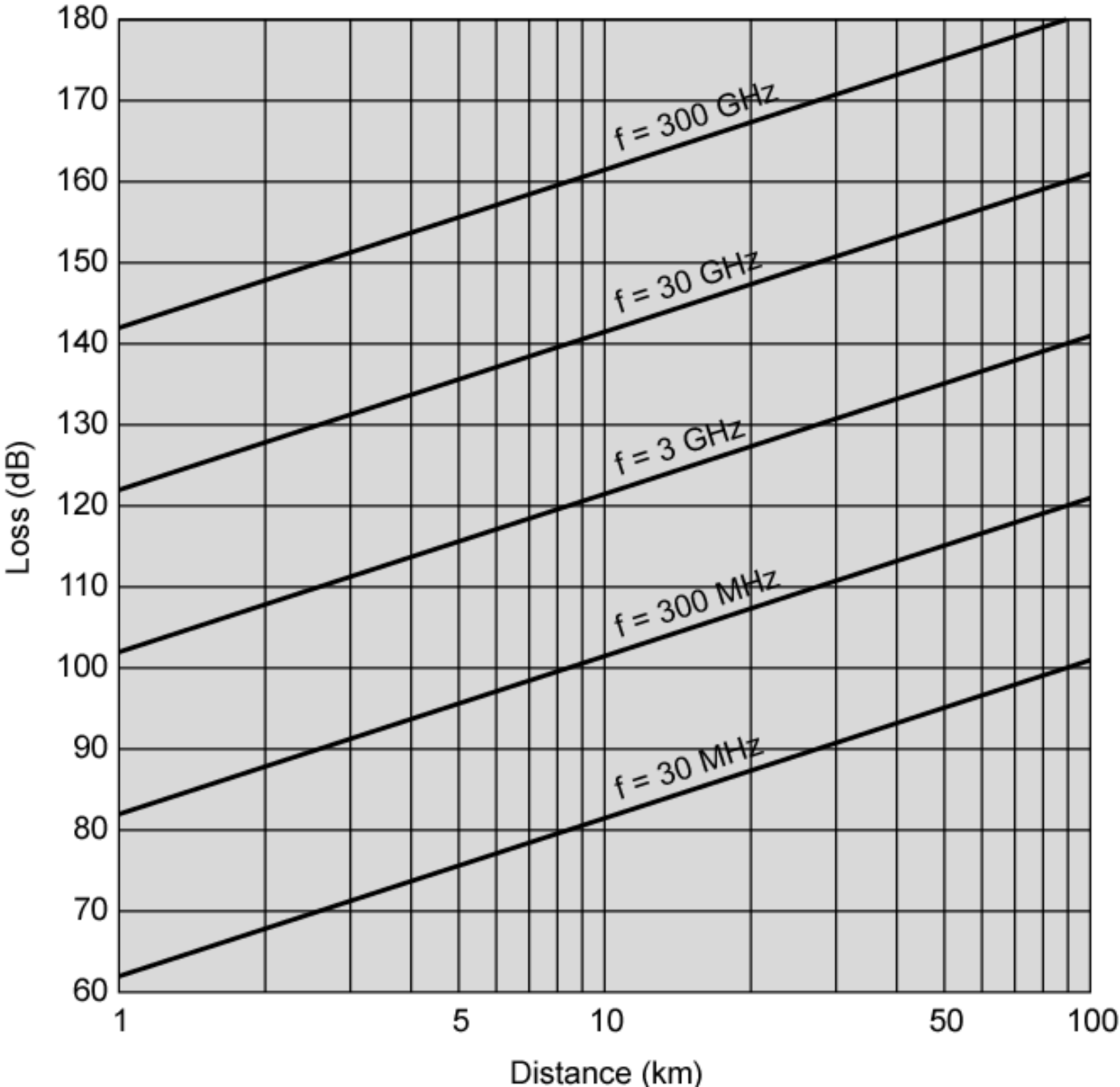


(c) Line-of-sight (LOS) propagation (above 30 MHz)

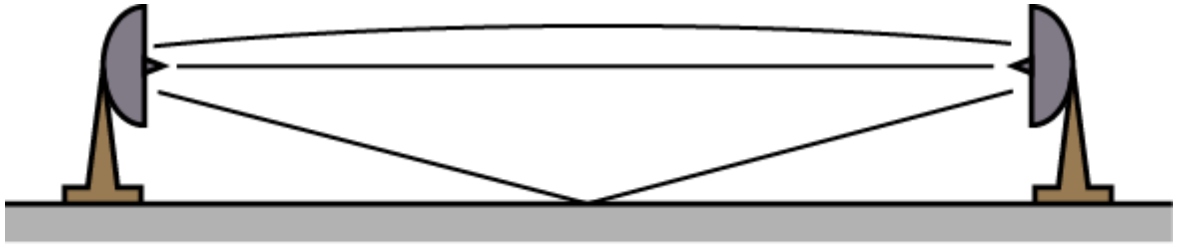
Line of Sight Transmission

- Free space loss
  - Signal disperses with distance
  - Greater for lower frequencies (longer wavelengths)
- Atmospheric Absorption
  - Water vapour and oxygen absorb radio signals
  - Water greatest at 22GHz, less below 15GHz
  - Oxygen greater at 60GHz, less below 30GHz
  - Rain and fog scatter radio waves
- Multipath
  - Better to get line of sight if possible
  - Signal can be reflected causing multiple copies to be received
  - May be no direct signal at all
  - May reinforce or cancel direct signal
- Refraction
  - May result in partial or total loss of signal at receiver

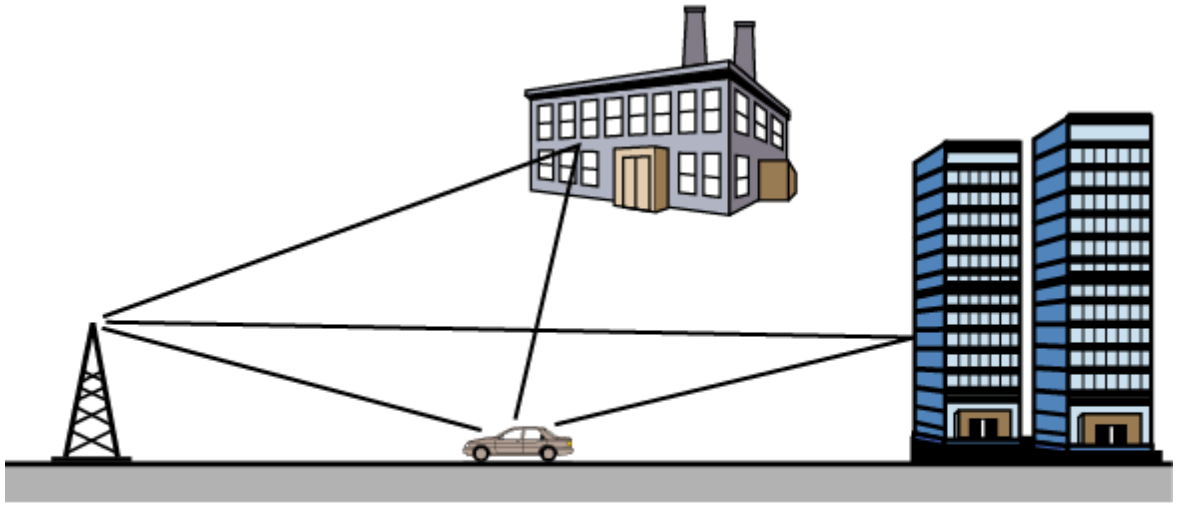
Free Space Loss



Multipath Interference



(a) Microwave line of sight

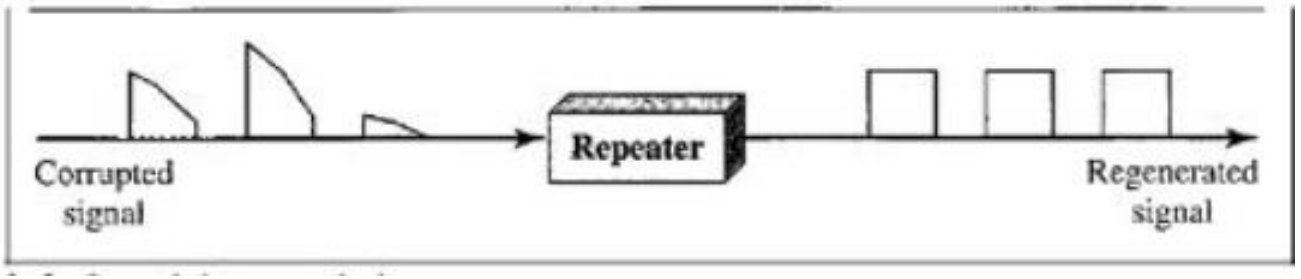


(b) Mobile radio

PARAMETER	WIRED	WIRELESS
Communication Medium	Copper, Fiber etc.	Air
Standard	IEEE 802.3	802.11 family
Mobility and Roaming	Limited	Higher
Security	High	Lower than Wired. Also easy to hack
Speed / Bandwidth	High Speed upto 1 Gbps	Lower speed than Wired Network.
Access to Network	Physical Access Required	Proximity Required
Delay	Low	High
Reliability	High	Lower than Wired
Flexibility to change	Less flexible to changes	More flexible configuration
Working principle	CSMA/CD, operates by detecting the occurrence of a collision.	CSMA/CA , hence reduces possibility of collision be avoiding collision from happening
Interference and Fluctuations vulnerability	Very Less	High
Installation activity	Cumbersome and manpower intensive	Less labor intensive and easy
Installation Time	Takes longer time to perform	Very less deployment time
Dedicated / Shared Connection	Dedicated	Shared
Installation Cost	High	Low
Maintenance (Upgrade) cost	High	Low
Related equipment	Router, Switch , Hub	Wireless Router, Access Point
Benefits	• Greater Speed • Higher noise immunity • Highly reliable • Greater Security	• No Hassles of Cable • Best for mobile devices • Greater mobility • Easy installation and management

Repeater

- A repeater operates at the physical layer.
- Its job is to regenerate the signal over the same network before the signal becomes too weak or corrupted so as to extend the length to which the signal can be transmitted over the same network.
- They do not amplify the signal.
- When the signal becomes weak, they copy the signal bit by bit and regenerate it at the original strength.
- It is a 2 port device.



Hub

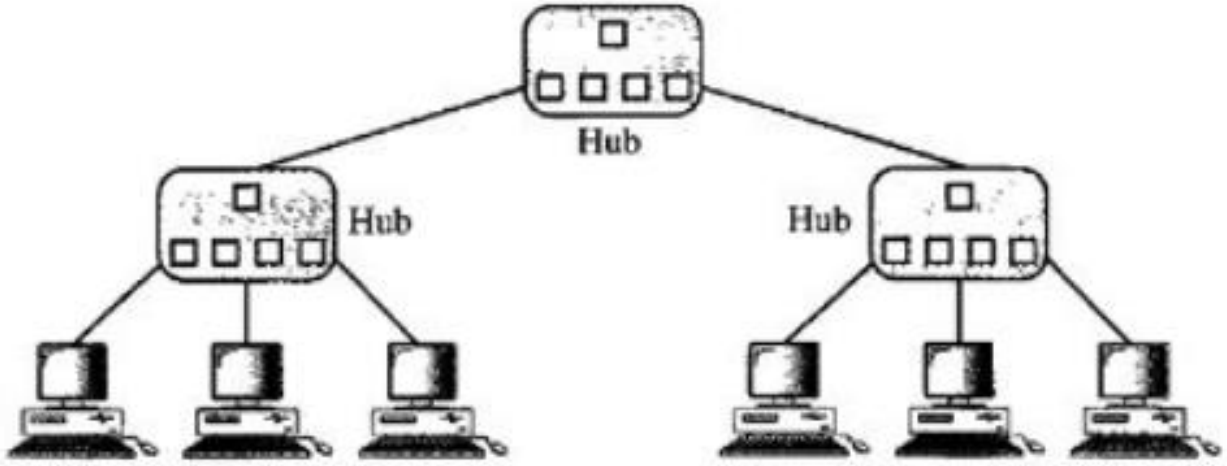
- A hub is basically a multiport repeater.
- A hub connects multiple wires coming from different branches, for example, the connector in star topology which connects different stations.
- Hubs cannot filter data, so data packets are sent to all connected devices.
- In other words, the collision domain of all hosts connected through Hub remains one.
- Also, they do not have the intelligence to find out the best path for data packets which leads to inefficiencies and wastage.

Types of Hub

- Active Hub:-
  - These are the hubs that have their own power supply and can clean, boost, and relay the signal along with the network.
  - It serves both as a repeater as well as a wiring center.
  - These are used to extend the maximum distance between nodes.
- Passive Hub :-
  - These are the hubs that collect wiring from nodes and power supply from the active hub.
  - These hubs relay signals onto the network without cleaning and boosting them and can’t be used to extend the distance between nodes.

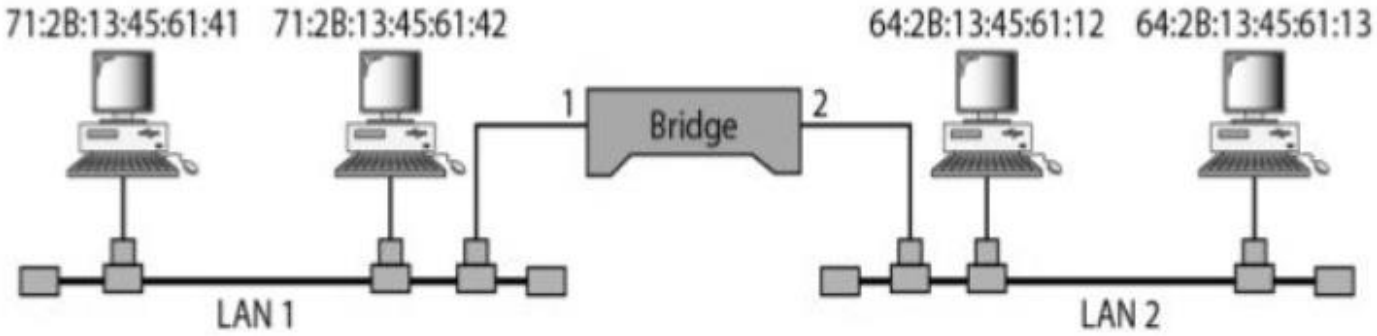
Types of Hub

- Intelligent Hub :-
  - It works like active hubs and includes remote management capabilities. They also provide flexible data rates to network devices. It also enables an administrator to monitor the traffic passing through the hub and to configure each port in the hub.



Bridge

- A bridge operates at the data link layer.
- A bridge is a repeater, with add on the functionality of filtering content by reading the MAC addresses of source and destination.
- It is also used for interconnecting two LANs working on the same protocol.
- It has a single input and single output port, thus making it a 2 port device.

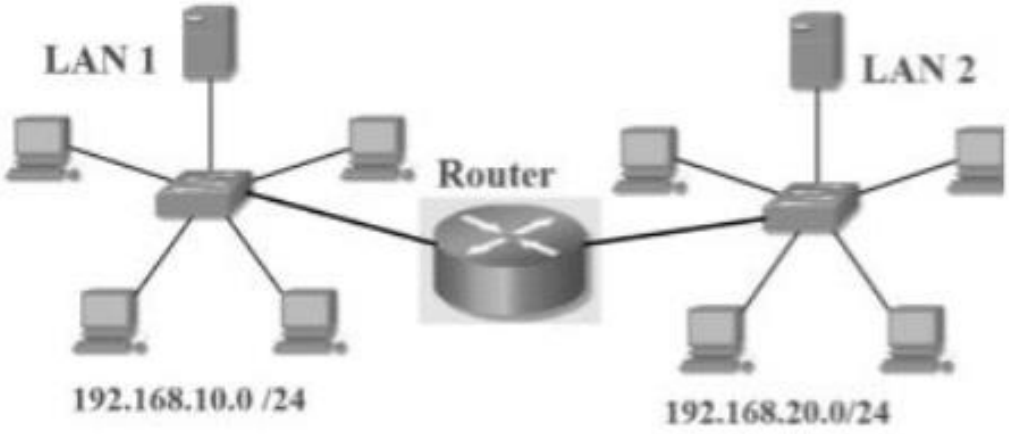


Switch

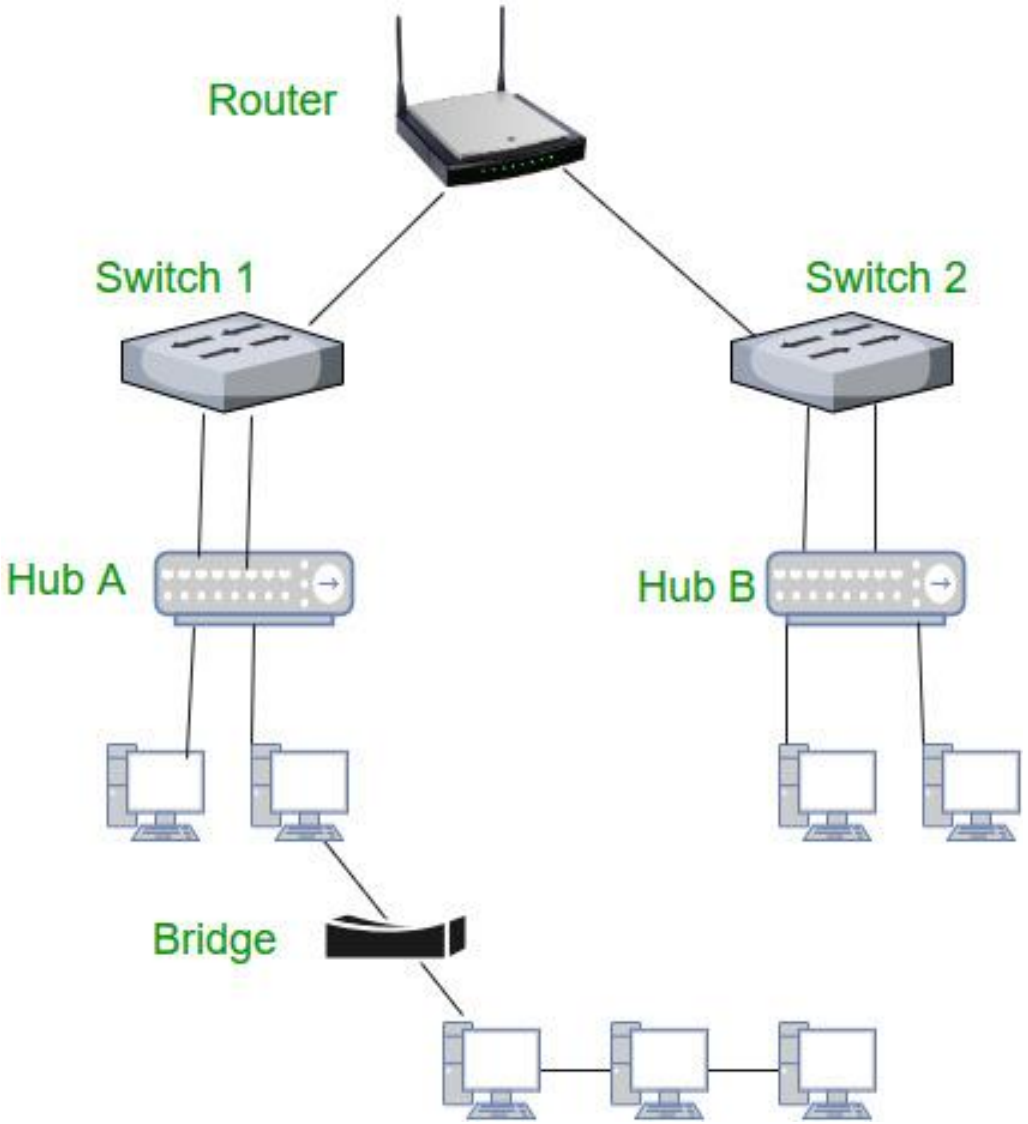
- A switch is a multiport bridge with a buffer and a design that can boost its efficiency(a large number of ports imply less traffic) and performance.
- A switch is a data link layer device.
- The switch can perform error checking before forwarding data, which makes it very efficient as it does not forward packets that have errors and forward good packets selectively to the correct port only.
- In other words, the switch divides the collision domain of hosts, but broadcast domain remains the same.

Router

- A router is a device like a switch that routes data packets based on their IP addresses.
- Router is mainly a Network Layer device.
- Routers normally connect LANs and WANs together and have a dynamically updating routing table based on which they make decisions on routing the data packets. Router divide broadcast domains of hosts connected through it.



Network Devices



Gateway

- A gateway, as the name suggests, is a passage to connect two networks together that may work upon different networking models.
- They basically work as the messenger agents that take data from one system, interpret it, and transfer it to another system.
- Gateways are also called protocol converters and can operate at any network layer.
- Gateways are generally more complex than switches or routers. Gateway is also called a protocol converter.

Brouter

- It is also known as the bridging router is a device that combines features of both bridge and router.
- It can work either at the data link layer or a network layer.
- Working as a router, it is capable of routing packets across networks, and working as the bridge, it is capable of filtering local area network traffic.