

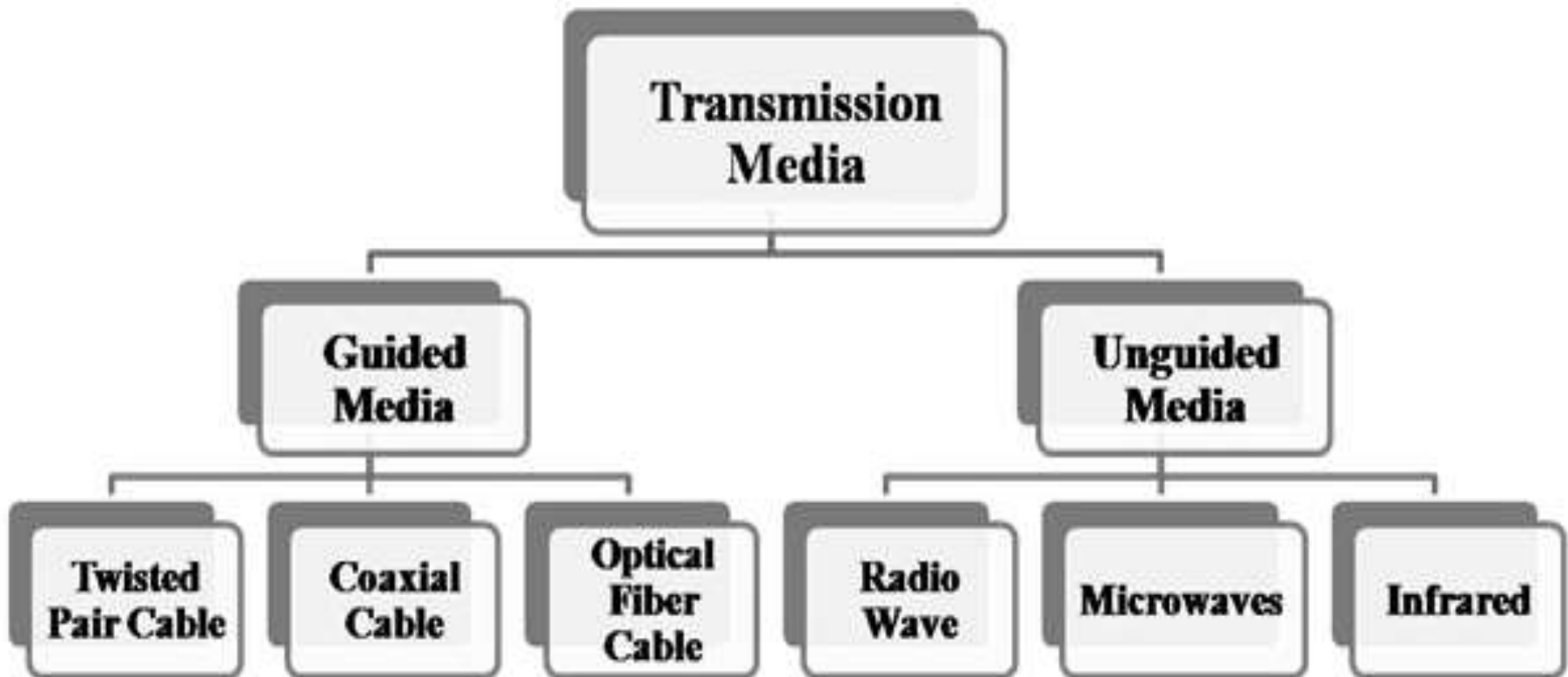
# Transmission Media

# Transmission Media

- A transmission **medium can be broadly defined as anything that can carry information** from a source to a destination.
- For example, the transmission medium for two people having a dinner conversation is the air. The air can also be used to convey the message in a smoke signal or semaphore.
- For a written message, the transmission medium might be a mail carrier, a truck, or an airplane.

- The transmission medium is usually free space, metallic cable, or fiber-optic cable.
- The information is usually a signal that is the result of a conversion of data from another form.
- The use of long-distance communication using electric signals started with the invention of the telegraph by Morse in the 19th century.
- Communication by telegraph as slow and dependent on a metallic medium. Extending the range of the human voice became possible when the telephone was invented in 1869.
- Telephone communication at that time also needed a metallic medium to carry the electric signals that were the result of a conversion from the human voice.

- In telecommunications, transmission media can be divided into two broad categories: guided and unguided.

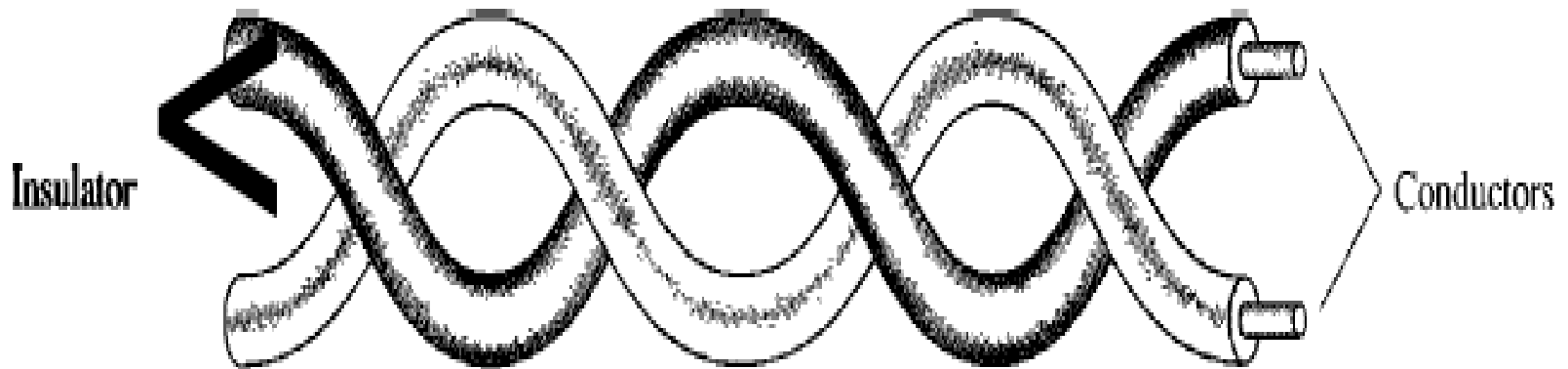


# Guided Media

- Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.
- A signal traveling along any of these media is directed and contained by the physical limits of the medium.
- Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current.
- Optical fiber is a cable that accepts and transports signals in the form of light.

# Twisted-Pair Cable

- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in Figure



# Twisted-Pair Cable

- 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.

- If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relative to the noise or crosstalk sources(e,g., one is closer and the other is farther).
- This results in a difference at the receiver. By twisting the pairs, a balance is maintained.



- For example, suppose in one twist, one wire is closer to the noise source and the other is farther; in the next twist, the reverse is true.
- Twisting makes it probable that both wires are equally affected by external influences (noise or crosstalk).
- This means that the receiver, which calculates the difference between the two, receives no unwanted signals.
- The unwanted signals are mostly canceled out.
- From the discussion, it is clear that the number of twists per unit of length (e.g., inch) has some effect on the quality of the cable.

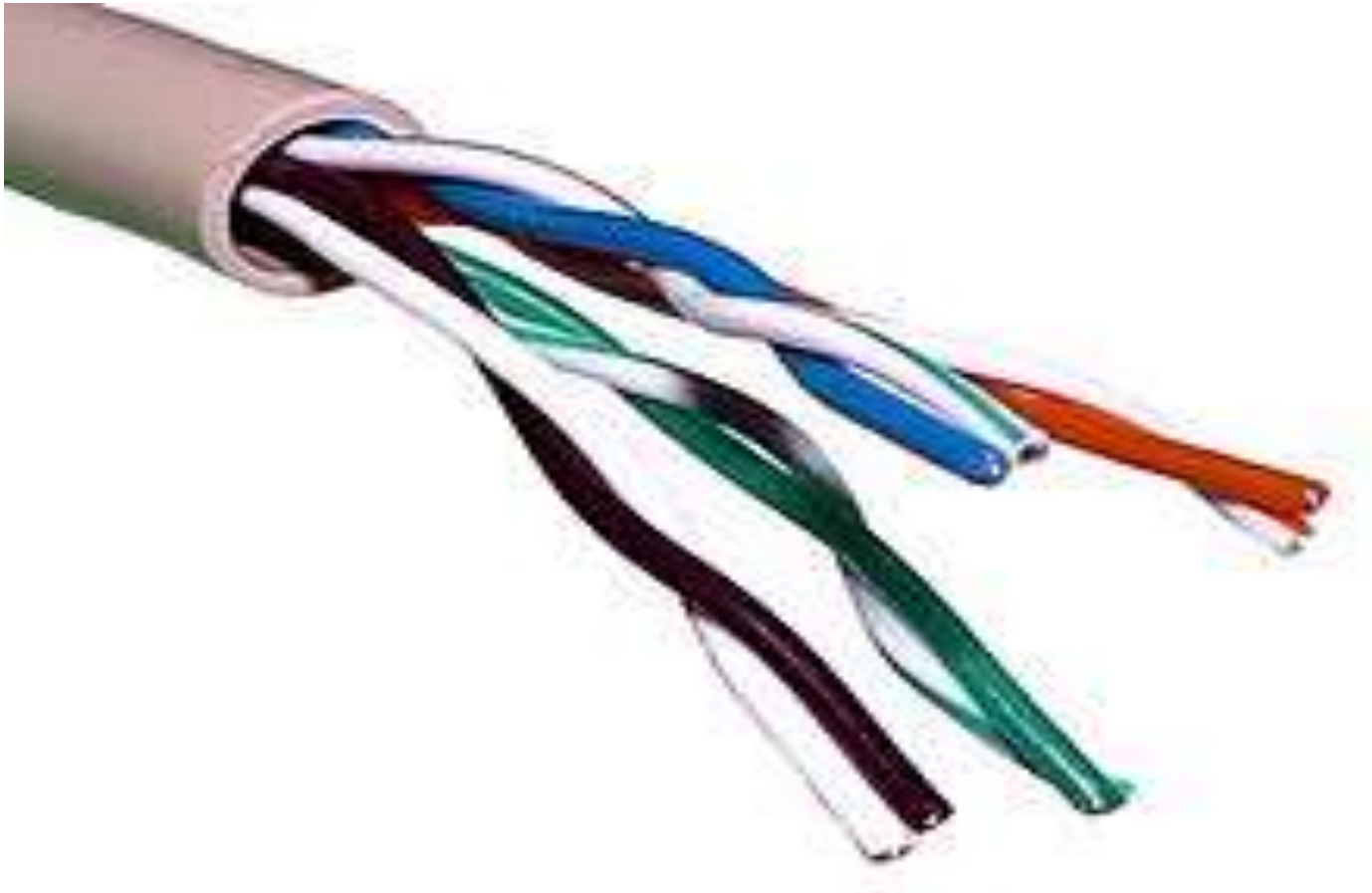
# *Unshielded Versus Shielded Twisted-Pair Cable*

- 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.

# *Shielded Twisted-Pair Cable*



# *Unshielded Twisted-Pair Cable*



# *Category of Unshielded Twisted-Pair Cable*

- The Electronic Industries Association (EIA) has developed standards to classify unshielded twisted-pair cable into seven categories.
- Categories are determined by cable quality, with 1 as the lowest and 7 as the highest. Each EIA category is suitable for specific uses.

<i>Category</i>	<i>Specification</i>	<i>Data Rate (Mbps)</i>	<i>Use</i>
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-llines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
SE	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk: and increases the data rate.	600	LANs

# *Connectors*

- The most common UTP connector is RJ45 (RJ stands for registered jack). The RJ45 is a keyed connector, meaning the connector can be inserted in only one way.

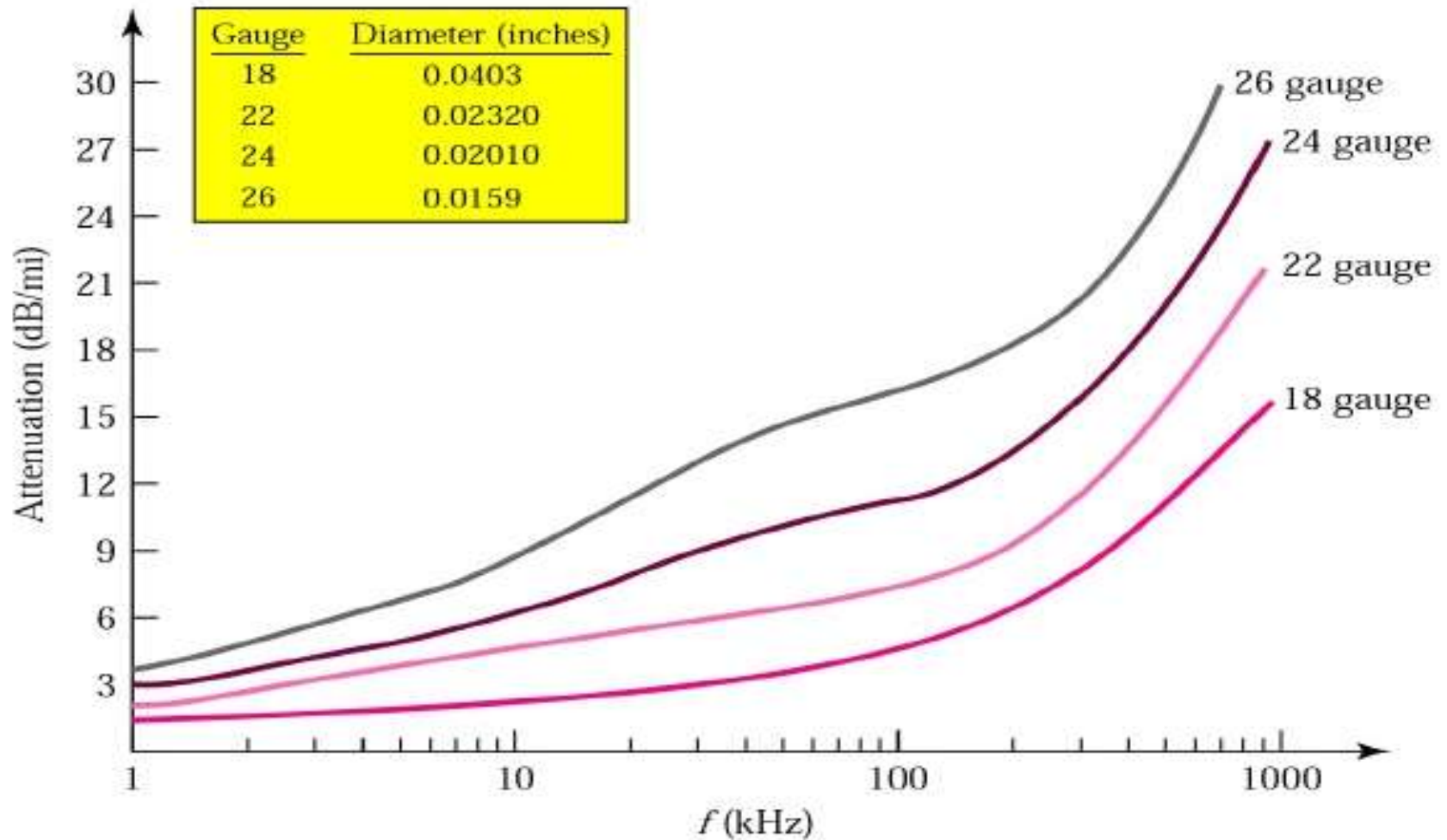


# *Performance*

- One way to measure the performance of twisted-pair cable is to compare attenuation versus frequency and distance.
- A twisted-pair cable can pass a wide range of frequencies. However, with the increasing frequency, the attenuation, measured in decibels per kilometer (dB/km), sharply increases with frequencies above 100 kHz.
- Note that *gauge is a measure of the thickness of the wire.*



# Performance



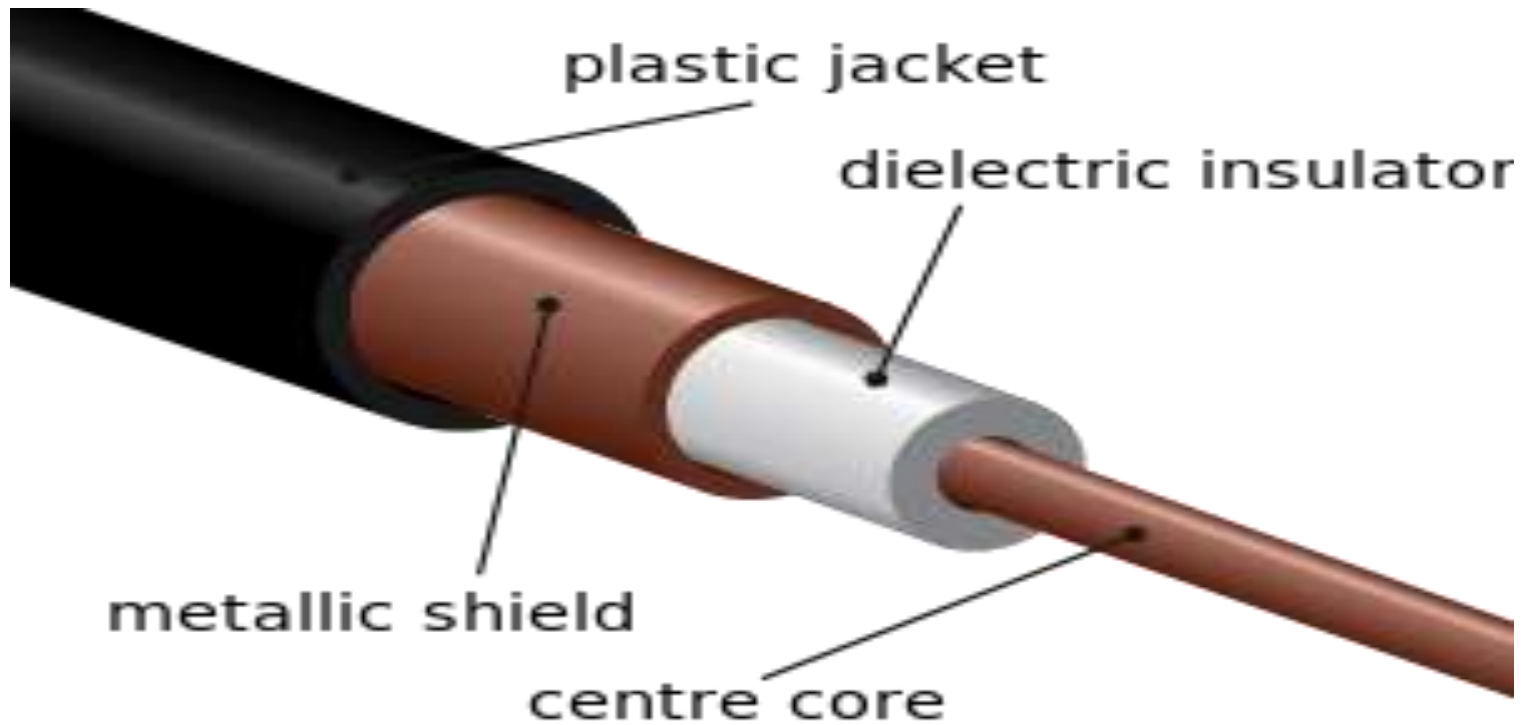
# *Applications*

- Twisted-pair cables are used in telephone lines to provide voice and data channels.
- The local loop-the line that connects subscribers to the central telephone office---commonly consists of unshielded twisted-pair cables.
- The DSL lines that are used by the telephone companies to provide high-data-rate connections also use the high-bandwidth capability of unshielded twisted-pair cables.
- Local-area networks, such as 10Base-T and 100Base-T, also use twisted-pair cables.

# Coaxial Cable

- Coaxial cable (or *coax*) carries signals of higher frequency ranges than those in twisted pair cable, in part because the two media are constructed quite differently.
- Instead of having two wires, coax has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid, or a combination of the two.
- The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit.
- This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover

# Coaxial cable



# *Coaxial Cable Standards*

- Coaxial cables are categorized by their radio government (RG) ratings.
- Each RG number denotes a unique set of physical specifications, including the wire gauge of the inner conductor, the thickness and type of the inner insulator, the construction of the shield, and the size and type of the outer casing.
- Each cable defined by an RG rating is adapted for a specialized function

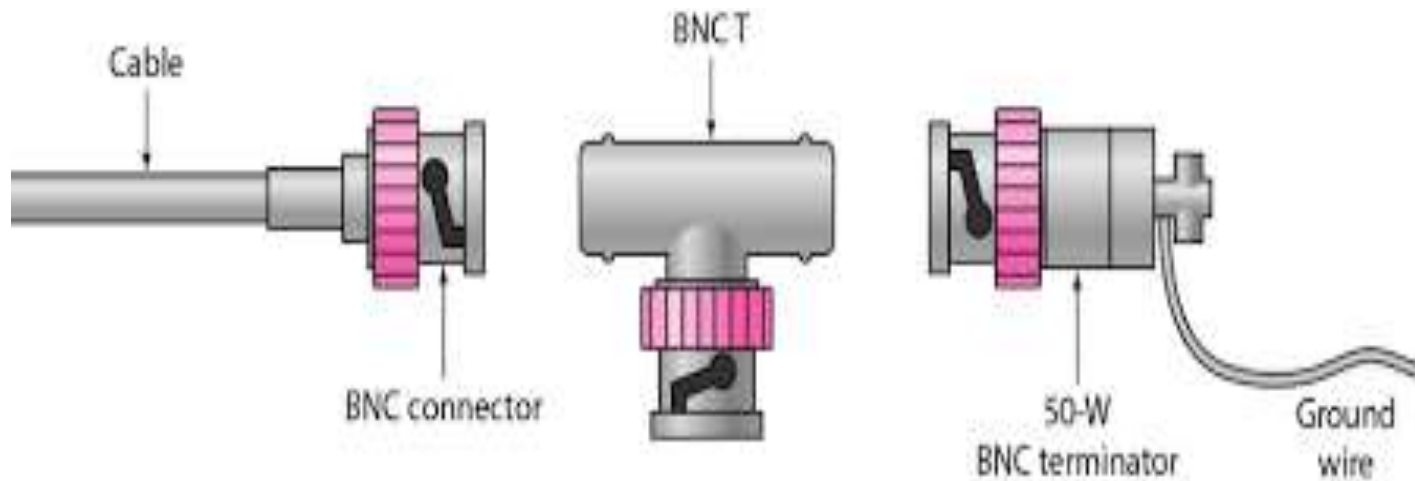
# *Coaxial Cable Standards*

<i>Category</i>	<i>Impedance</i>	<i>Use</i>
RG-59	75 $\Omega$	Cable TV
RG-58	50 $\Omega$	Thin Ethernet
RG-11	50 $\Omega$	Thick Ethernet

# *Coaxial Cable Connectors*

- To connect coaxial cable to devices, we need coaxial connectors. The most common type of connector used today is the Bayonet-Neill-Concelman (BNC), connector.
- Three popular types of these connectors: the BNC connector, the BNC T connector, and the BNC terminator.
- The BNC connector is used to connect the end of the cable to a device, such as a TV set.
- The BNC T connector is used in Ethernet networks to branch out to a connection to a computer or other device.
- The BNC terminator is used at the end of the cable to prevent the reflection of the signal.

# *Coaxial Cable Connectors*

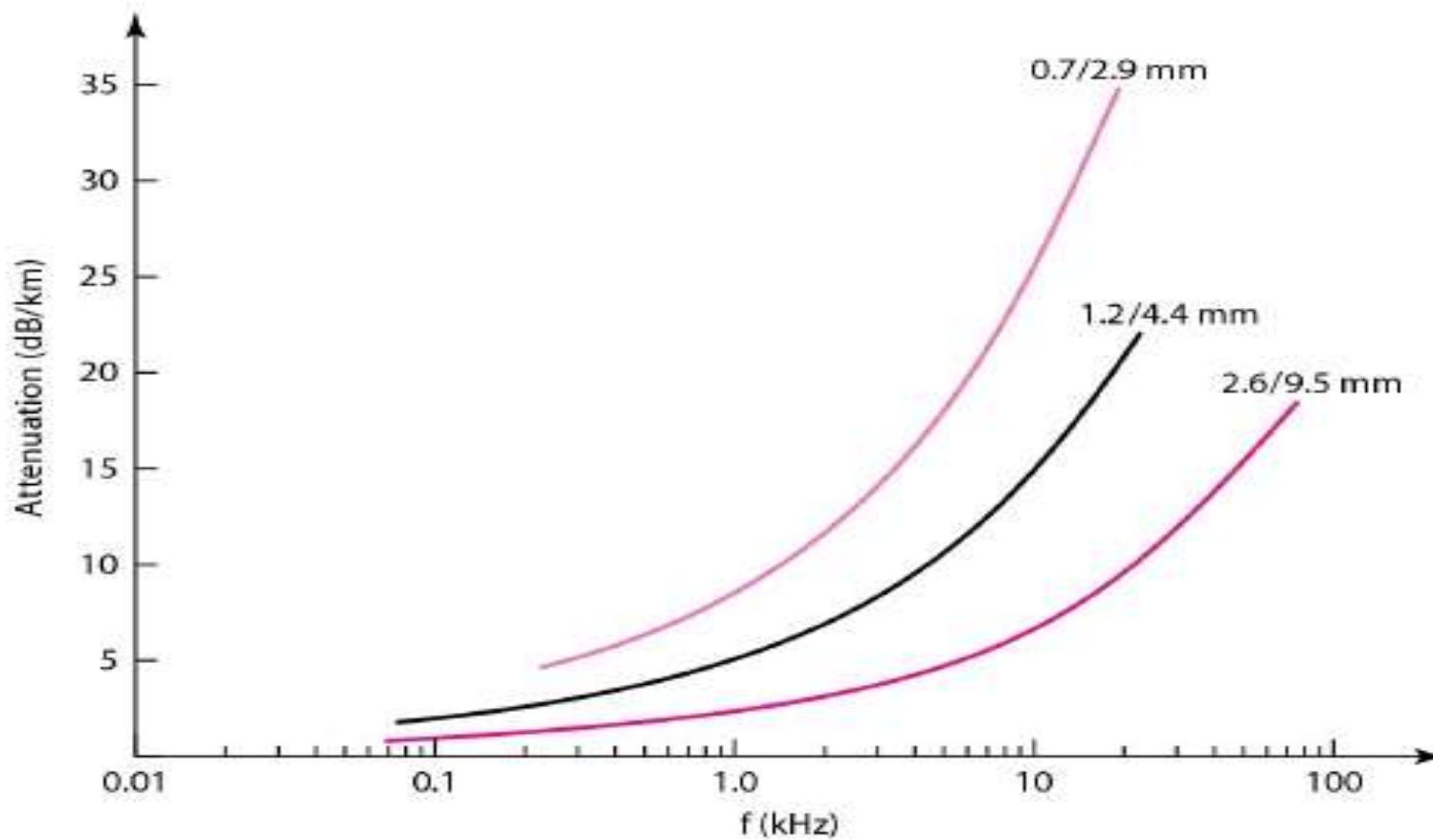




# *Performance*

- We notice that the attenuation is much higher in coaxial cables than in twisted-pair cable. In other words, although coaxial cable has a much higher bandwidth, the signal weakens rapidly and requires the frequent use of repeaters.

# *Performance*

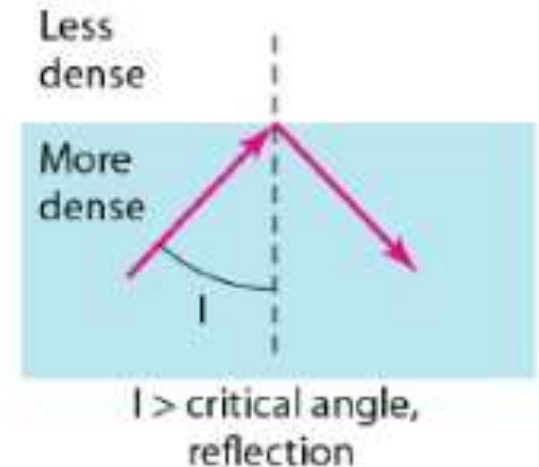
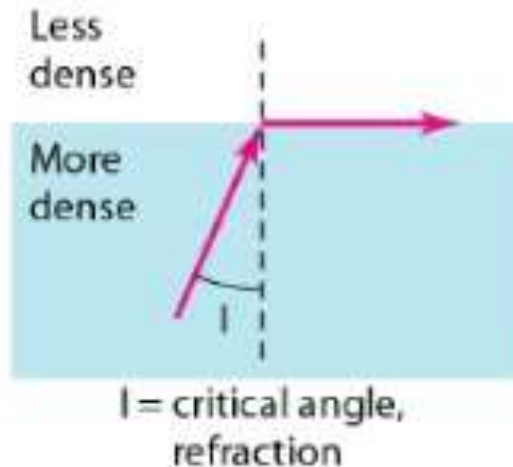
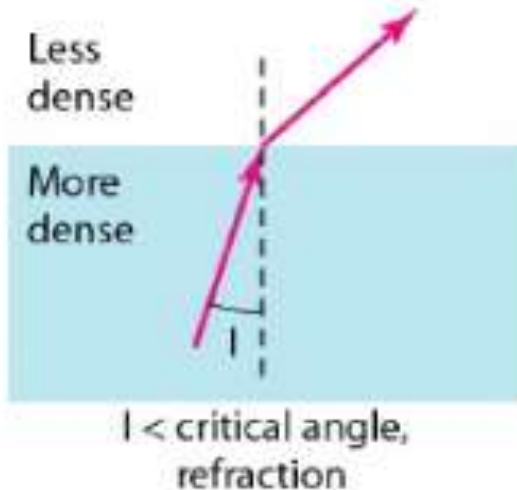


# *Applications*

- Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals.
- Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps. However, coaxial cable in telephone networks has largely been replaced today with fiber-optic cable.
- Cable TV networks also use coaxial cables.
- In the traditional cable TV network, the entire network used coaxial cable.
- Later, however, cable TV providers replaced most of the media with fiber-optic cable; hybrid networks use coaxial cable only at the network boundaries, near the consumer premises. Cable TV uses RG-59 coaxial cable.
- Another common application of coaxial cable is in traditional Ethernet LANs

# Fiber-Optic Cable

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- To understand optical fiber, we first need to explore several aspects of the nature of light.

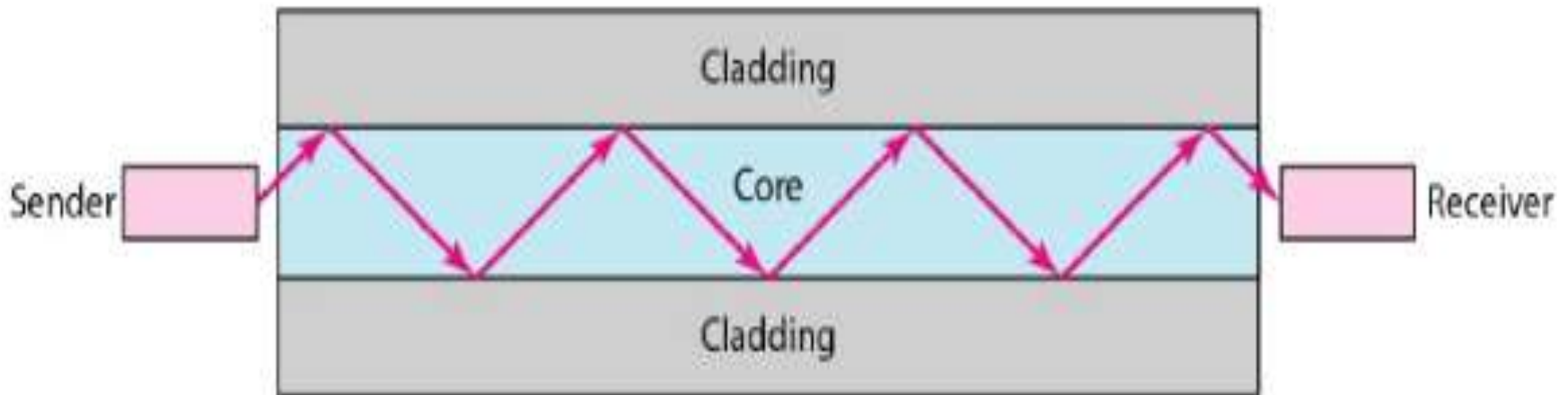


# Aspects of Natural Light

- If the angle of incidence  $i$  (*the angle the ray makes with the line perpendicular to the interface between the two substances*) is less than the critical angle, the ray refracts and moves closer to the surface.
- If the angle of incidence is equal to the critical angle, the light bends along the interface.
- If the angle is greater than the critical angle, the ray reflects (makes a turn) and travels again in the denser substance.
- **Note that the critical angle is a property of the substance, and its value differs from one substance to another.**

# Optical Fiber Cable

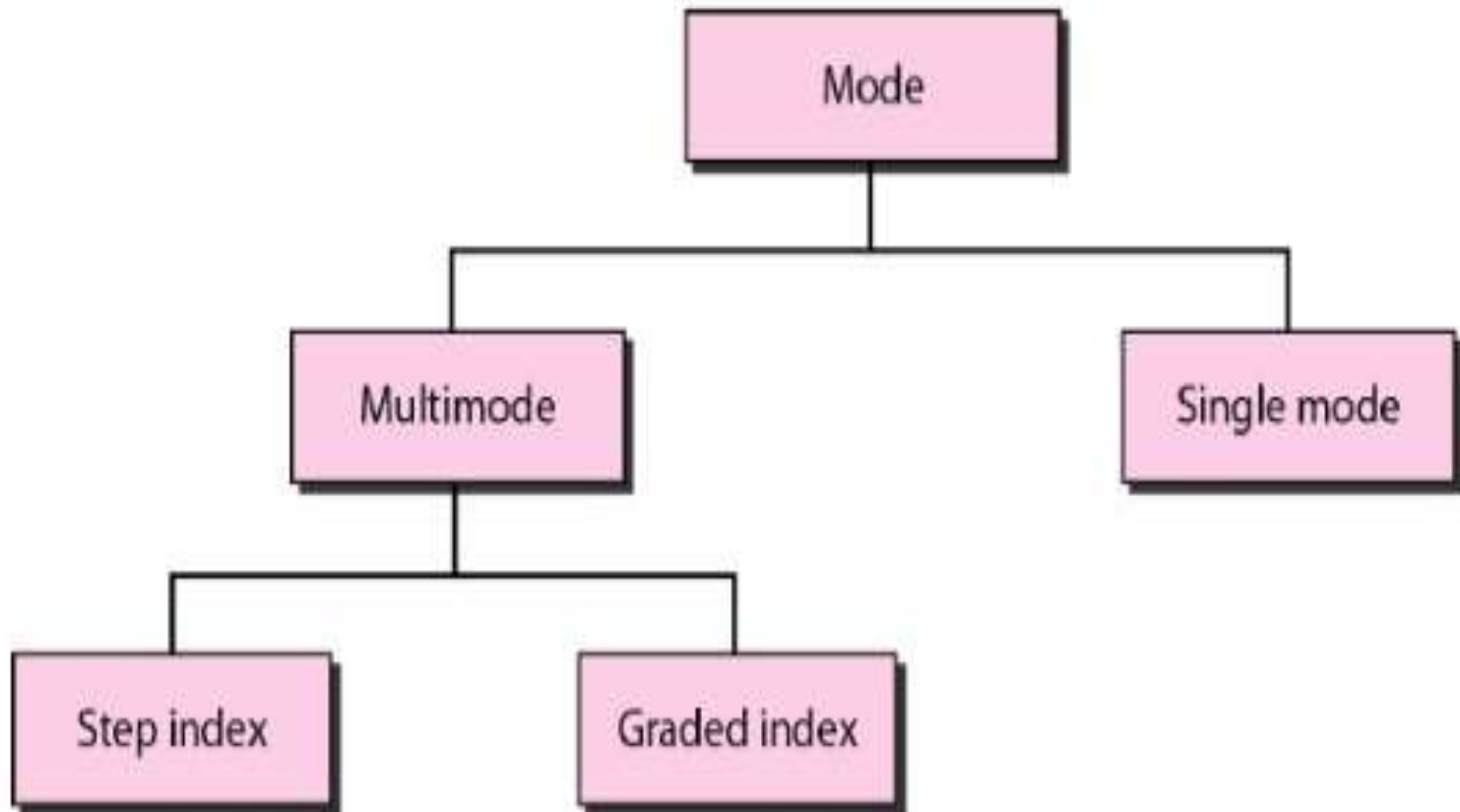
- Optical fibers use reflection to guide light through a channel.
- A glass or plastic core is surrounded by a cladding of less dense glass or plastic.
- The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being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



# *Propagation Modes*

- Current technology supports two modes (multimode and single mode) for propagating light along optical channels, each requiring fiber with different physical characteristics.
- Multimode can be implemented in two forms: step-index or graded-index

# Propagation Mode





# Multimode

- Multimode is so named because multiple beams from a light source move through the core in different paths.
- How these beams move within the cable depends on the structure of the core.

# Multimode Step-Index Fiber

- 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.

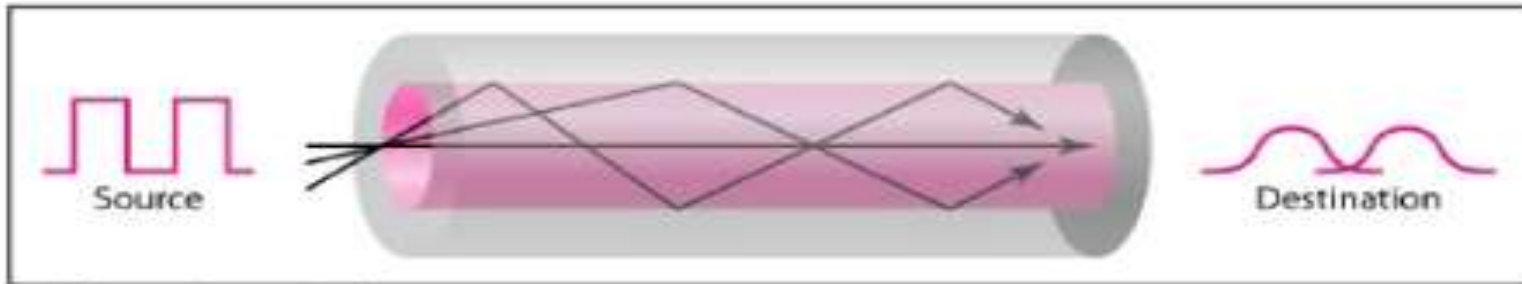
# Multimode Graded-Index Fiber

- Multimode graded-index fiber, decreases the distortion of the signal through the cable. The word *index* here refers to the index of refraction.
- As we know that 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.

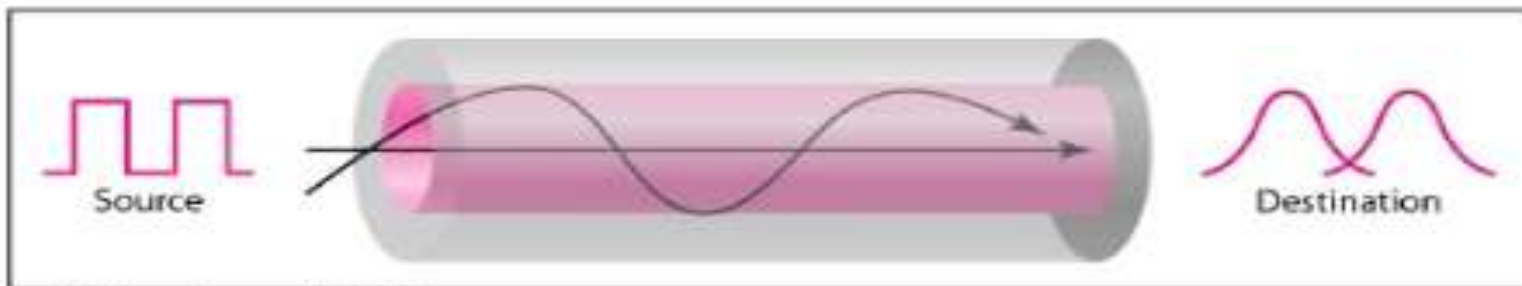
# Single-Mode

- 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  $90^\circ$  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

# Modes



a. Multimode, step index



b. Multimode, graded index



c. Single mode

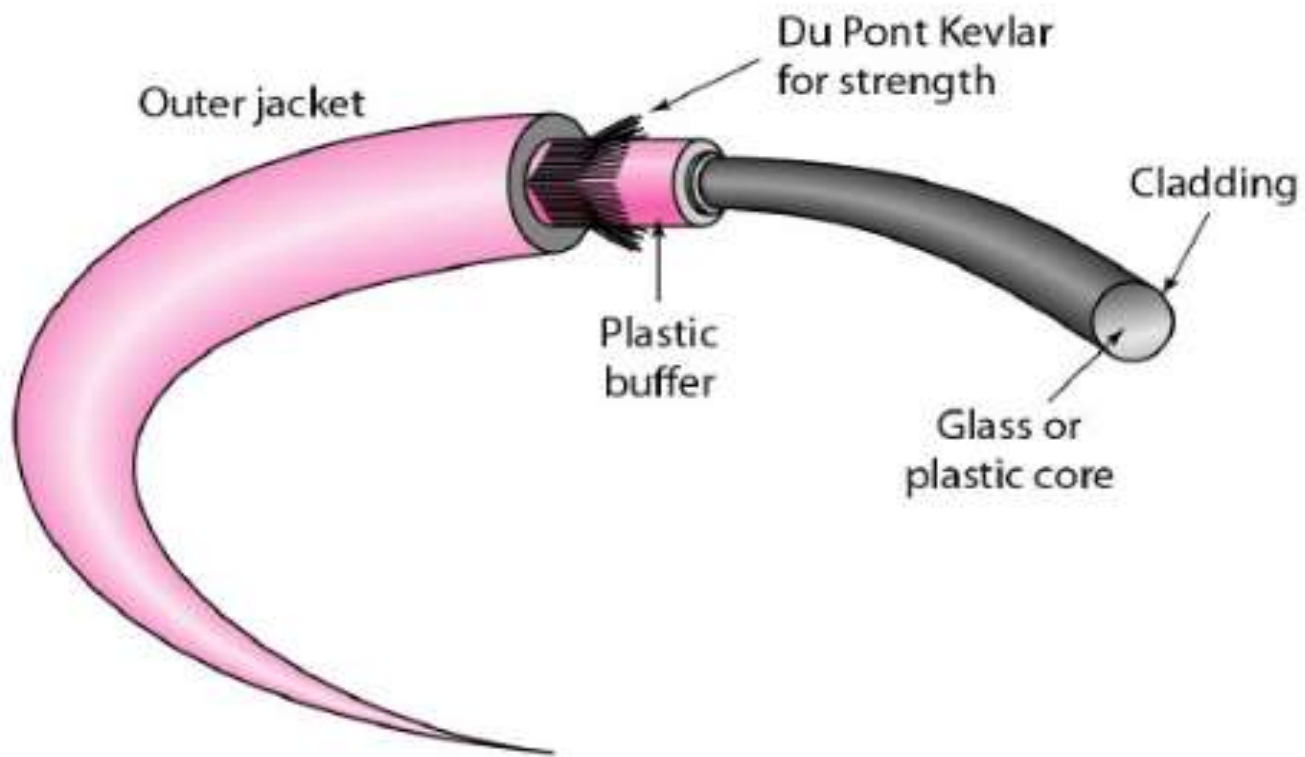
# Fiber Sizes

<i>Type</i>	<i>Core (<math>\mu\text{m}</math>)</i>	<i>Cladding (<math>\mu\text{m}</math>)</i>	<i>Mode</i>
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

# *Cable Composition*

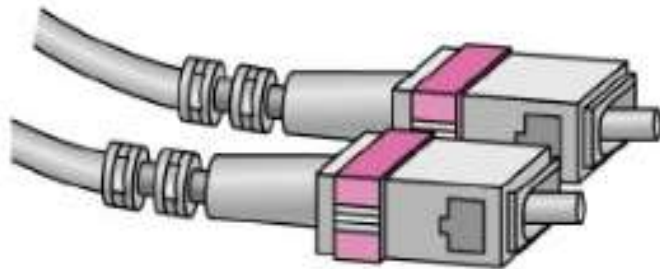
- The outer jacket is made of either PVC or Teflon. Inside the jacket are Kevlar strands to strengthen the cable.
- Kevlar is a strong material used in the fabrication of bulletproof vests.
- Below the Kevlar is another plastic coating to cushion the fiber.
- The fiber is at the center of the cable, and it consists of cladding and core.

# Fiber Construction

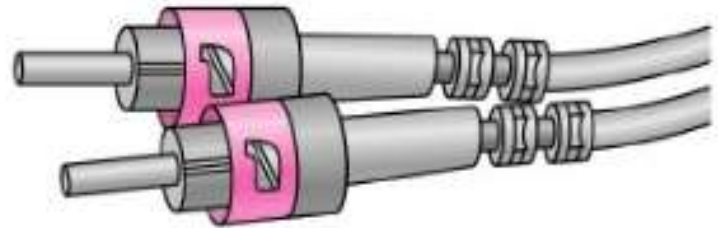




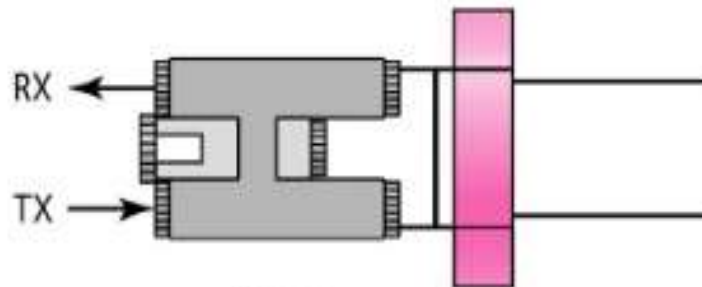
# Fiber Optic Connectors



SC connector

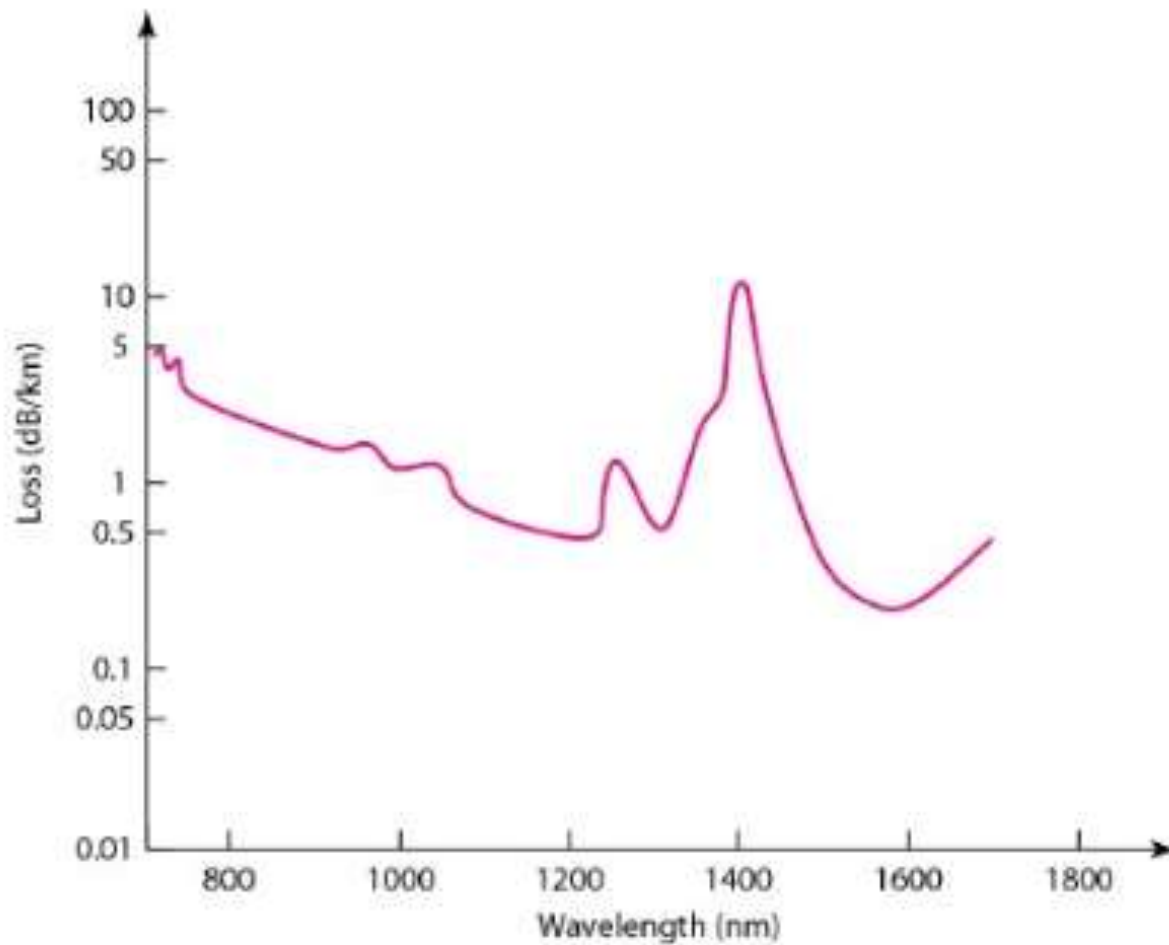


ST connector



MT-RJ connector

# Performance



# *Applications*

- Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective.
- Today, with wavelength-division multiplexing (WDM), we can transfer data at a rate of 1600 Gbps.
- Some cable TV companies use a combination of optical fiber and coaxial cable, thus creating a hybrid network.
- Optical fiber provides the backbone structure while coaxial cable provides the connection to the user premises.
- Local-area networks such as 100Base-FX network (Fast Ethernet) and 1000Base-X also use fiber-optic cable.

# Advantages

- Higher bandwidth.
- Less signal attenuation
- Immunity to electromagnetic interference
- Resistance to corrosive materials
- Light weight
- Greater immunity to tapping

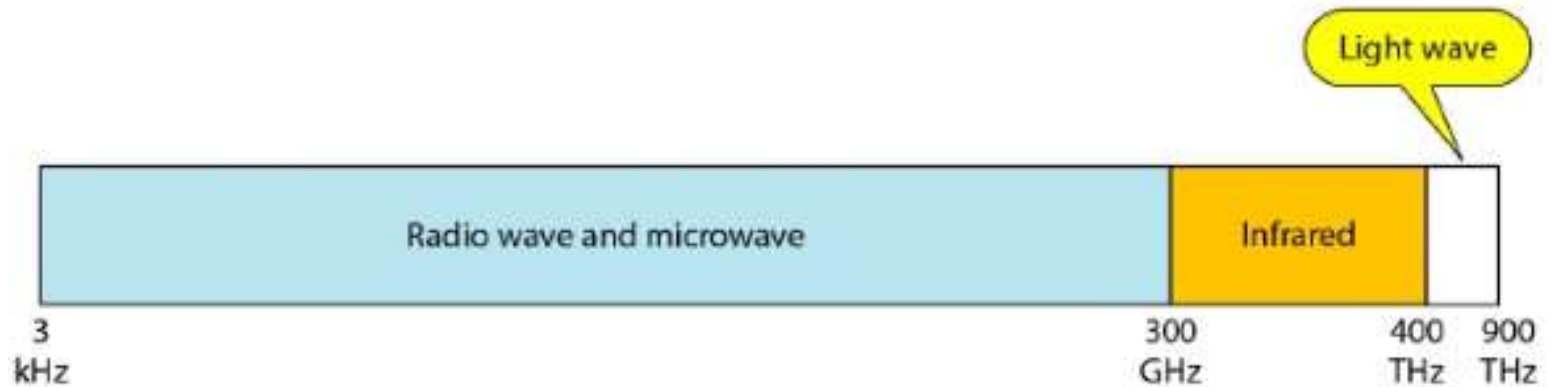
# Disadvantages

- Installation and maintenance
- Unidirectional light propagation
- Cost

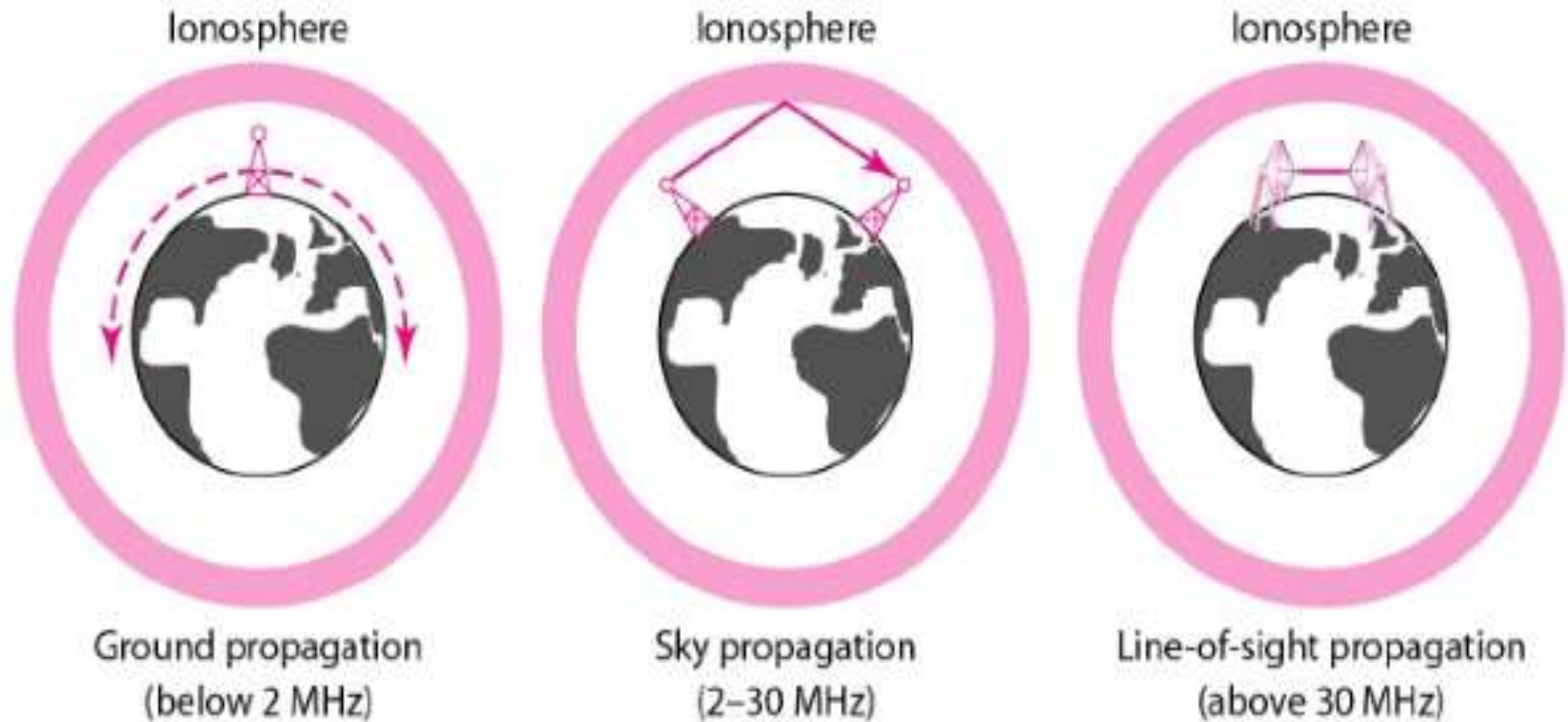
# UNGUIDED MEDIA: WIRELESS

- Unguided media transport electromagnetic waves without using a physical conductor.
- This type of communication is often referred to as wireless communication.
- Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them.

# *Electromagnetic spectrum for wireless communication*



# *Propagation methods*





# *Propagation methods*

- Unguided signals can travel from the source to destination in several ways: ground propagation, sky propagation, and line-of-sight propagation.
- In ground propagation, radio waves travel through the lowest portion of the atmosphere, hugging the earth.
- These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the planet.
- Distance depends on the amount of power in the signal: The greater the power, the greater the distance.

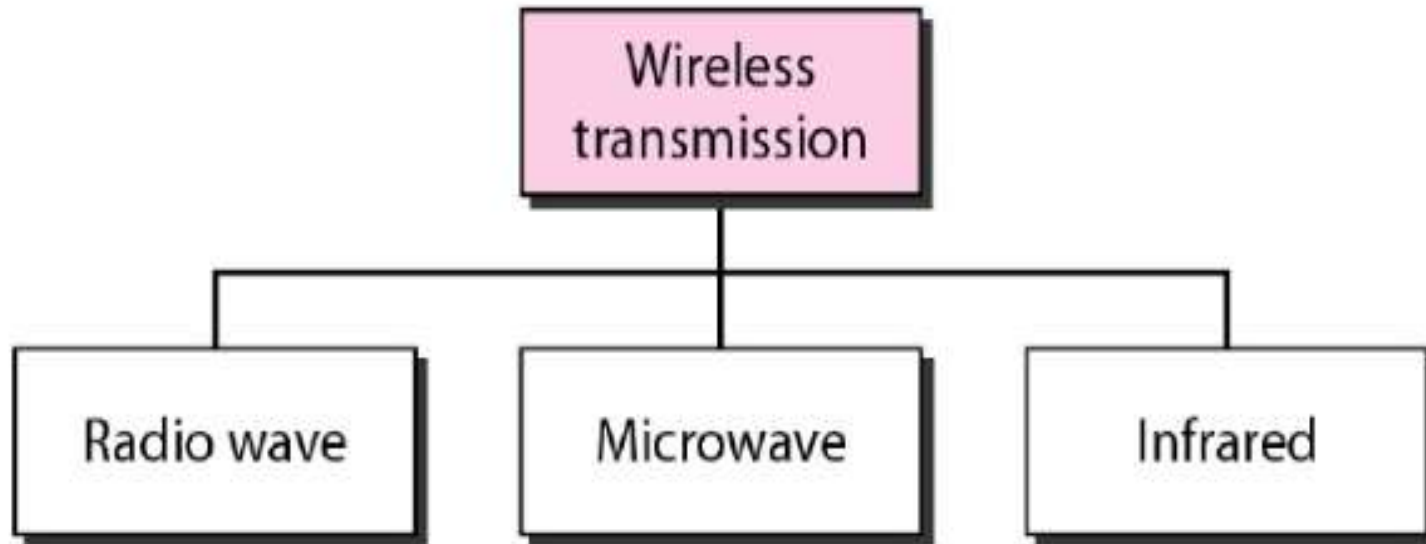
# *Propagation methods*

- In sky propagation, higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth.
- This type of transmission allows for greater distances with lower output power.
- In line-of-sight propagation, very high-frequency signals are transmitted in straight lines directly from antenna to antenna.
- Antennas must be directional, facing each other, and either tall enough or close enough together not to be affected by the curvature of the earth.
- Line-of-sight propagation is tricky because radio transmissions cannot be completely focused.

# *Bands*

<i>Band</i>	<i>Range</i>	<i>Propagation</i>	<i>Application</i>
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite

# *Wireless transmission waves*



# Radio Waves

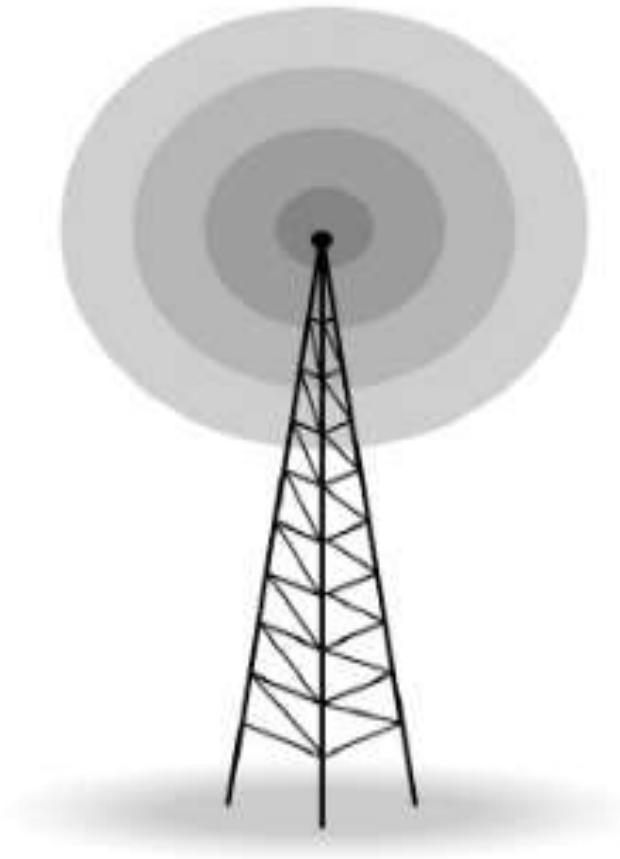
- Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves.
- Radio waves, for the most part, are omnidirectional.
- When an antenna transmits radio waves, they are propagated in all directions. This means that the sending and receiving antennas do not have to be aligned.

# Radio Waves

- The omnidirectional property has a disadvantage that when the radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band.
- Radio waves, particularly those waves that propagate in the sky mode, can travel long distances. This makes radio waves a good candidate for long-distance broadcasting such as AM radio.

- Radio waves, particularly those of low and medium frequencies, can penetrate walls.
- It is an advantage because, for example, an AM radio can receive signals inside a building.
- It is a disadvantage because we cannot isolate a communication to just inside or outside a building.
- The radio wave band is relatively narrow, just under 1 GHz, compared to the microwave band.
- When this band is divided into subbands, the subbands are also narrow, leading to a low data rate for digital communications.

# *Omnidirectional Antenna*





# *Applications*

- The omnidirectional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers.
- AM and FM radio, television, maritime radio, cordless phones, and paging are examples of multicasting.

# Microwaves

- Electromagnetic waves ranging in frequencies between 1 and 300 GHz are called microwaves.
- Microwaves are unidirectional.
- When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned.
- The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas

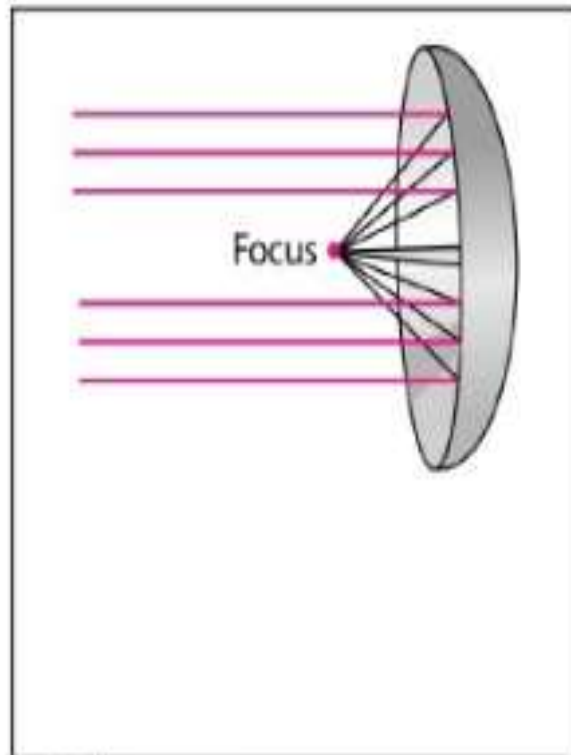
# Characteristics of microwave propagation

- Microwave propagation is line-of-sight. Since the towers with the mounted antennas need to be in direct sight of each other, towers that are far apart need to be very tall.
- The curvature of the earth as well as other blocking obstacles do not allow two short towers to communicate by using microwaves. Repeaters are often needed for long distance communication.

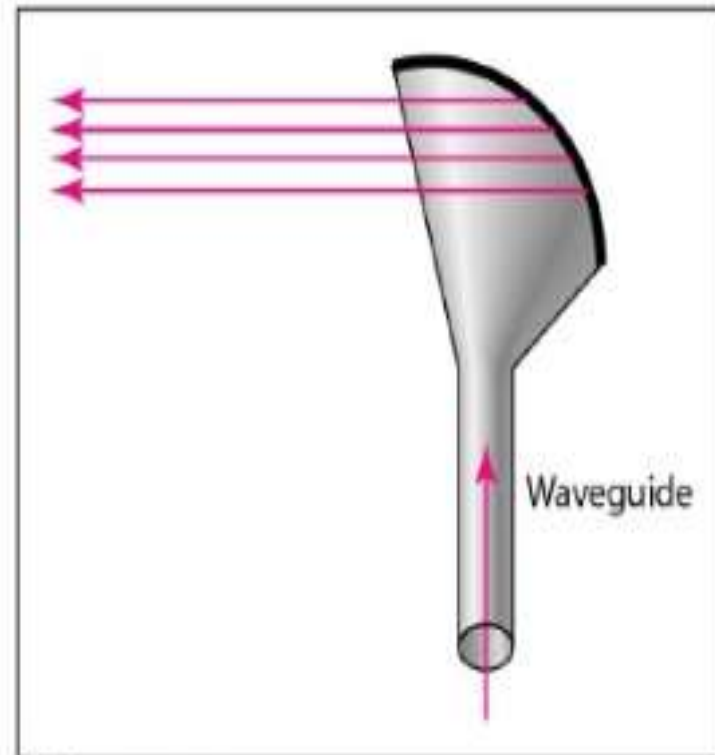
# Characteristics of microwave propagation

- Very high-frequency microwaves cannot penetrate walls. This characteristic can be a disadvantage if receivers are inside buildings.
- The microwave band is relatively wide, almost 299 GHz. Therefore wider subbands can be assigned, and a high data rate is possible.
- Use of certain portions of the band requires permission from authorities.

# *Unidirectional Antenna*



a. Dish antenna



b. Horn antenna

the parabolic dish and the horn

# Parabolic Dish Antenna

- Parabolic dish antenna is based on the geometry of a parabola: Every line parallel to the line of symmetry (line of sight) reflects off the curve at angles such that all the lines intersect in a common point called the focus.
- The parabolic dish works as a funnel, catching a wide range of waves and directing them to a common point.
- In this way, more of the signal is recovered than would be possible with a single-point receiver.

# Horn Antenna

- Outgoing transmissions are broadcast through a horn aimed at the dish.
- A horn antenna looks like a gigantic scoop.
- Outgoing transmissions are broadcast up a stem (resembling a handle) and deflected outward in a series of narrow parallel beams by the curved head.
- Received transmissions are collected by the scooped shape of the horn, in a manner similar to the parabolic dish, and are deflected down into the stem.

# *Applications*

- They are used in cellular phones. satellite networks, and wireless LANs



# Infrared

- Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication.
- Infrared waves, having high frequencies, cannot penetrate walls.
- This advantageous characteristic prevents interference between one system and another; a short-range communication system in one room cannot be affected by another system in the next room.
- Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

# *Applications*

- The Infrared Data Association (IrDA), an association for sponsoring the use of infrared waves, has established standards for using these signals for communication between devices such as keyboards, mice, PCs, and printers.
- For example, some manufacturers provide a special port called the IrDA port that allows a wireless keyboard to communicate with a PC. The standard originally defined a data rate of 75 kbps for a distance up to 8 m.
- The recent standard defines a data rate of 4 Mbps.
- Infrared signals defined by IrDA transmit through line of sight; the IrDA port on the keyboard needs to point to the PC for transmission to occur.