Transmission Media

Transmission medium

A transmission medium can be broadly defined as anything that can carry information from a source to a destination.

Figure 7.1 *Transmission medium and physical layer*

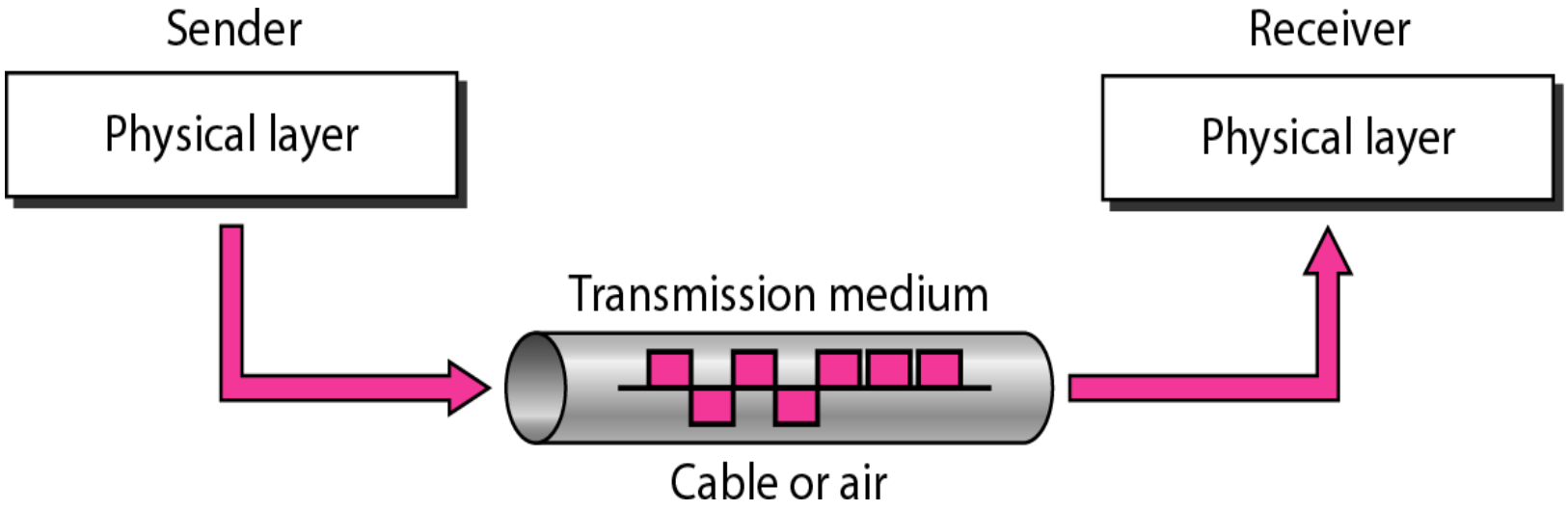
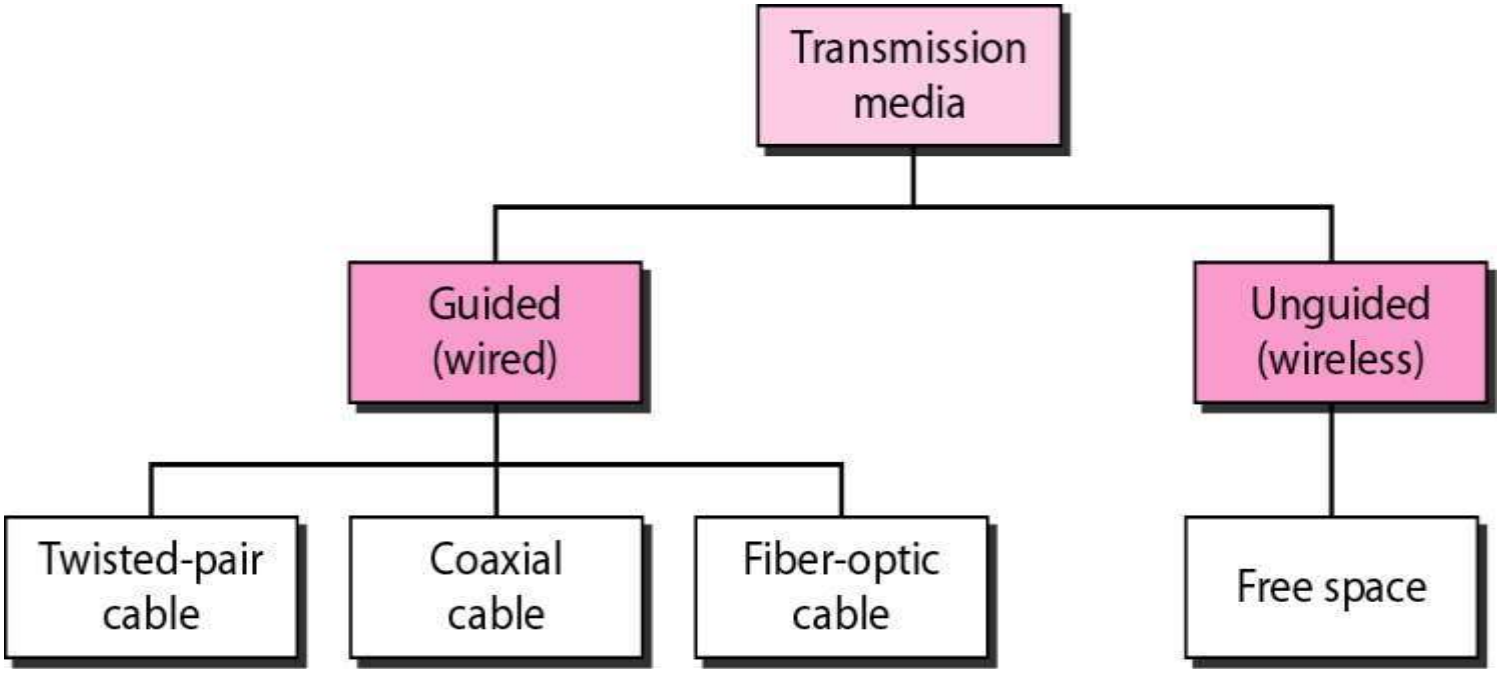


Figure 7.2 *Classes of transmission media*



7-1 GUIDED MEDIA

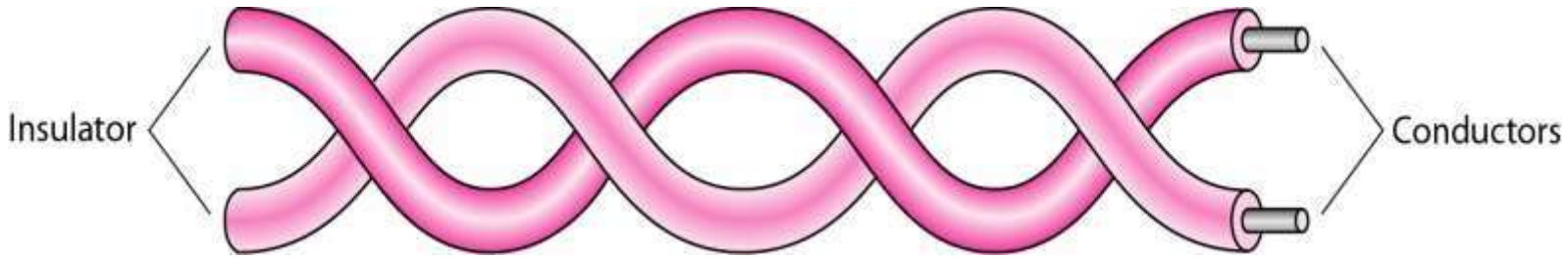
Guided media, which are those that provide a medium from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.

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.

Figure 7.3 *Twisted-pair cable*

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



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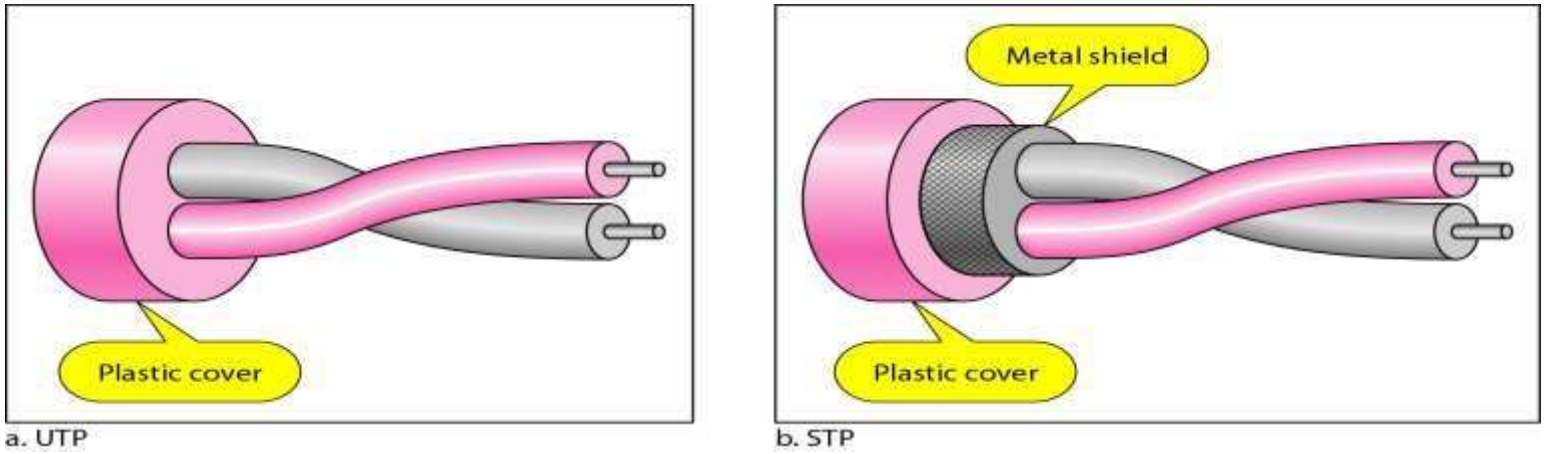
- interference (noise) and crosstalk may affect both wires and create unwanted signals.
- If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relative to the noise or crosstalk sources. By twisting the pairs, a balance is maintained.

Figure 7.4 *UTP and STP cables*

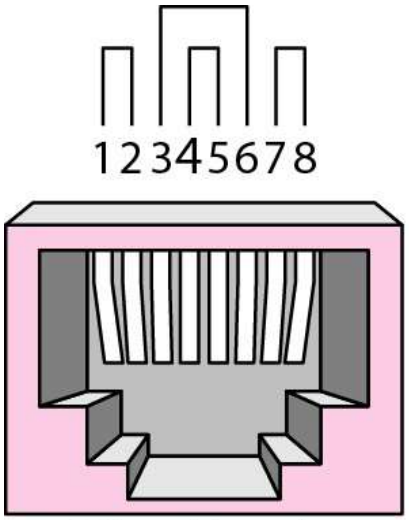
- STP cable has a metal foil that encases each pair of insulated conductors.
- Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is
- bulkier and more expensive.



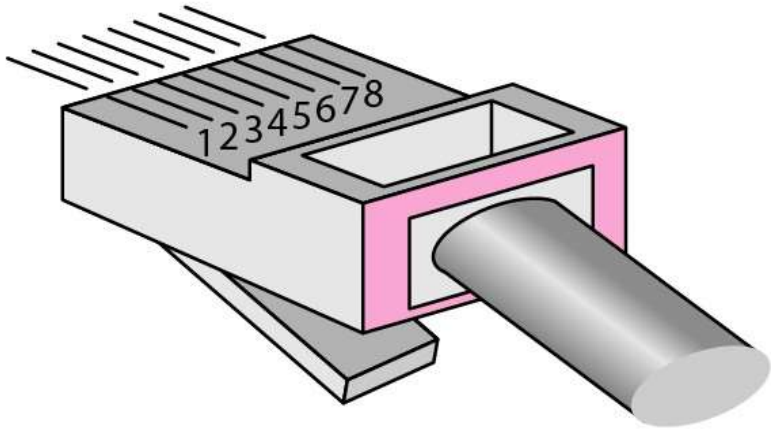
a. UTP b. STP

Figure 7.5 *UTP connector*

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



RJ-45 Female



RJ-45 Male

Performance

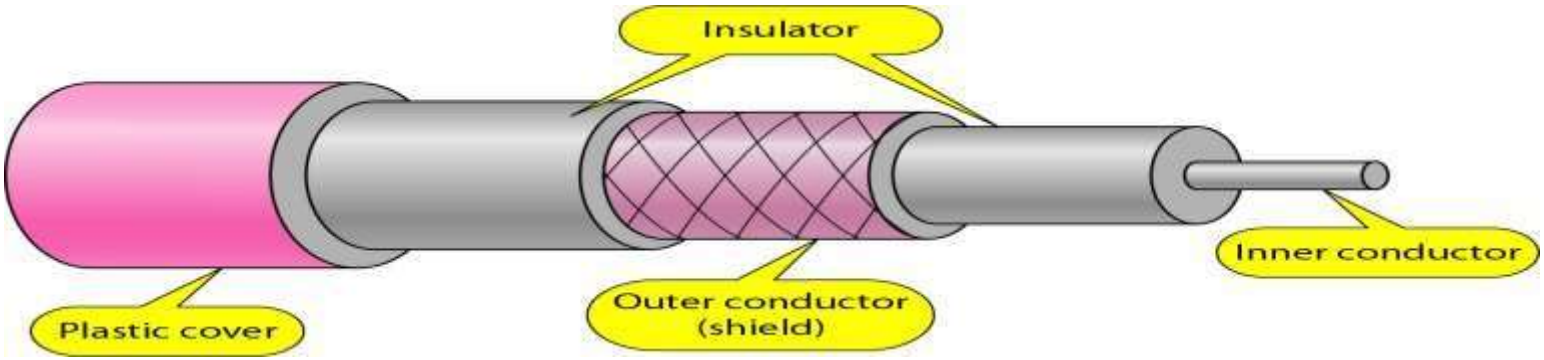
- One way to measure the performance of twisted-pair cable is to compare attenuation versus frequency and distance.
- With increasing frequency, the attenuation, measured in decibels per kilometer (dB/km), sharply increases with frequencies above 100 kHz.
- Note that gauge is a measure of the thickness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

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.

Figure 7.7 *Coaxial cable*

- Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted-pair cable.
- 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.



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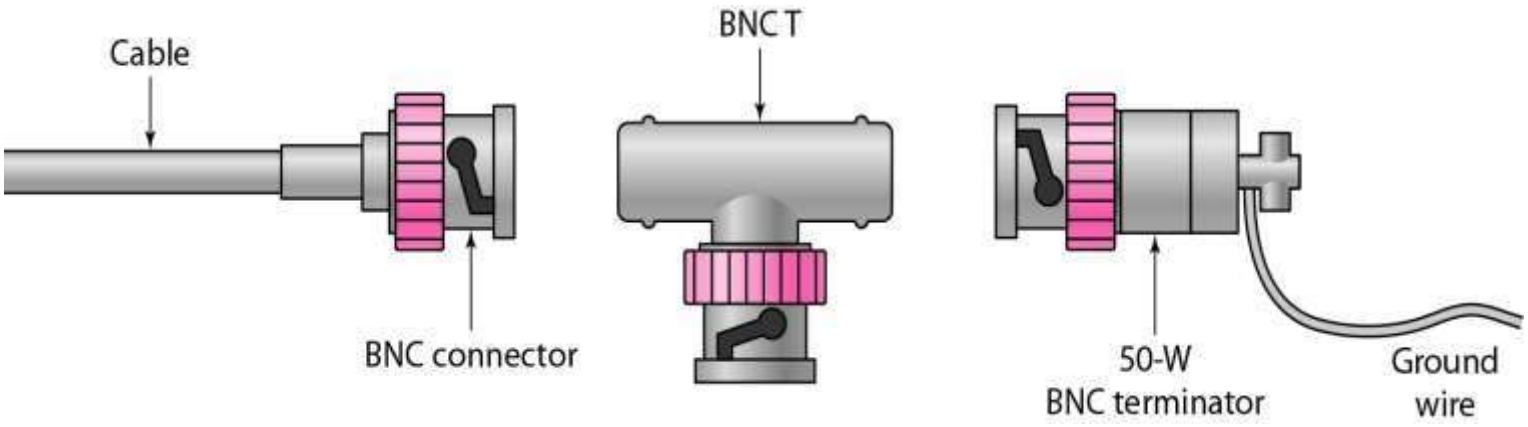
- The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit.
- This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.

Figure 7.8 *BNC 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.



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- 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.

Performance

- Attenuation is much higher in coaxial cable than in twisted-pair cable, although coaxial cable has a much higher bandwidth, the signal weakens rapidly and requires the frequent use of repeaters.

Applications

- Coaxial cable was widely used in analog telephone networks and then in digital telephone networks.
- Cable TV networks also use coaxial cables.
- 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.
- Light travels in a straight line as long as it is moving through a single uniform substance.
- If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction.

Continue..

- 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.

Continue..

- 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.

Figure 7.11 *Optical fiber*

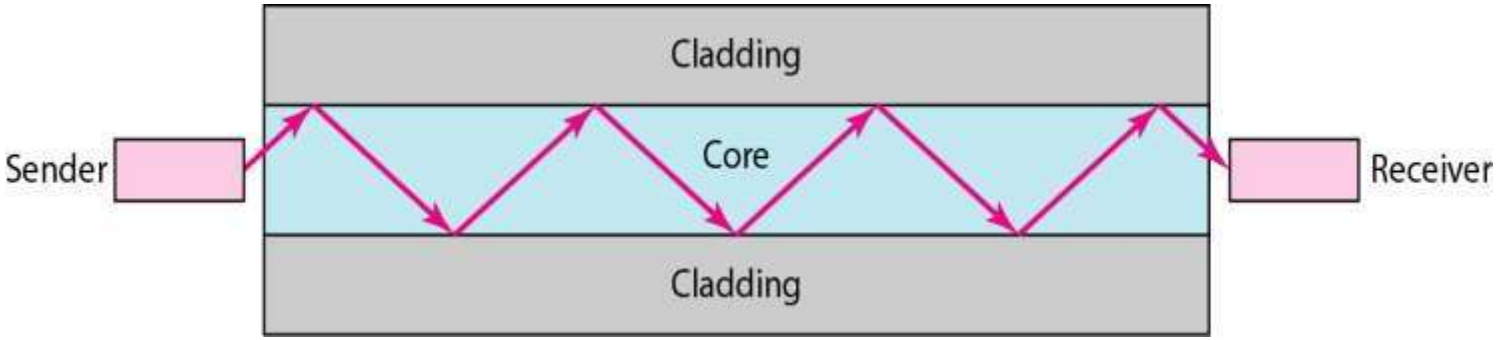
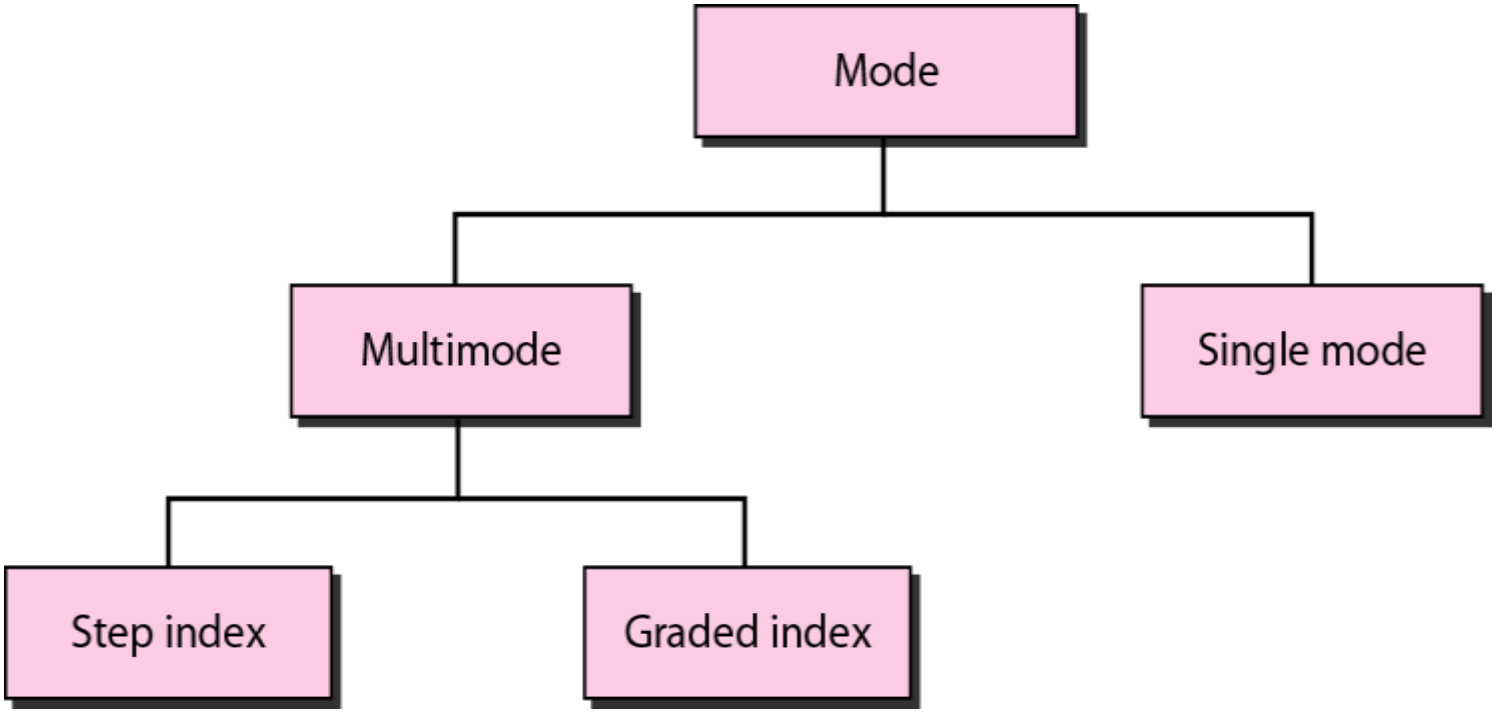


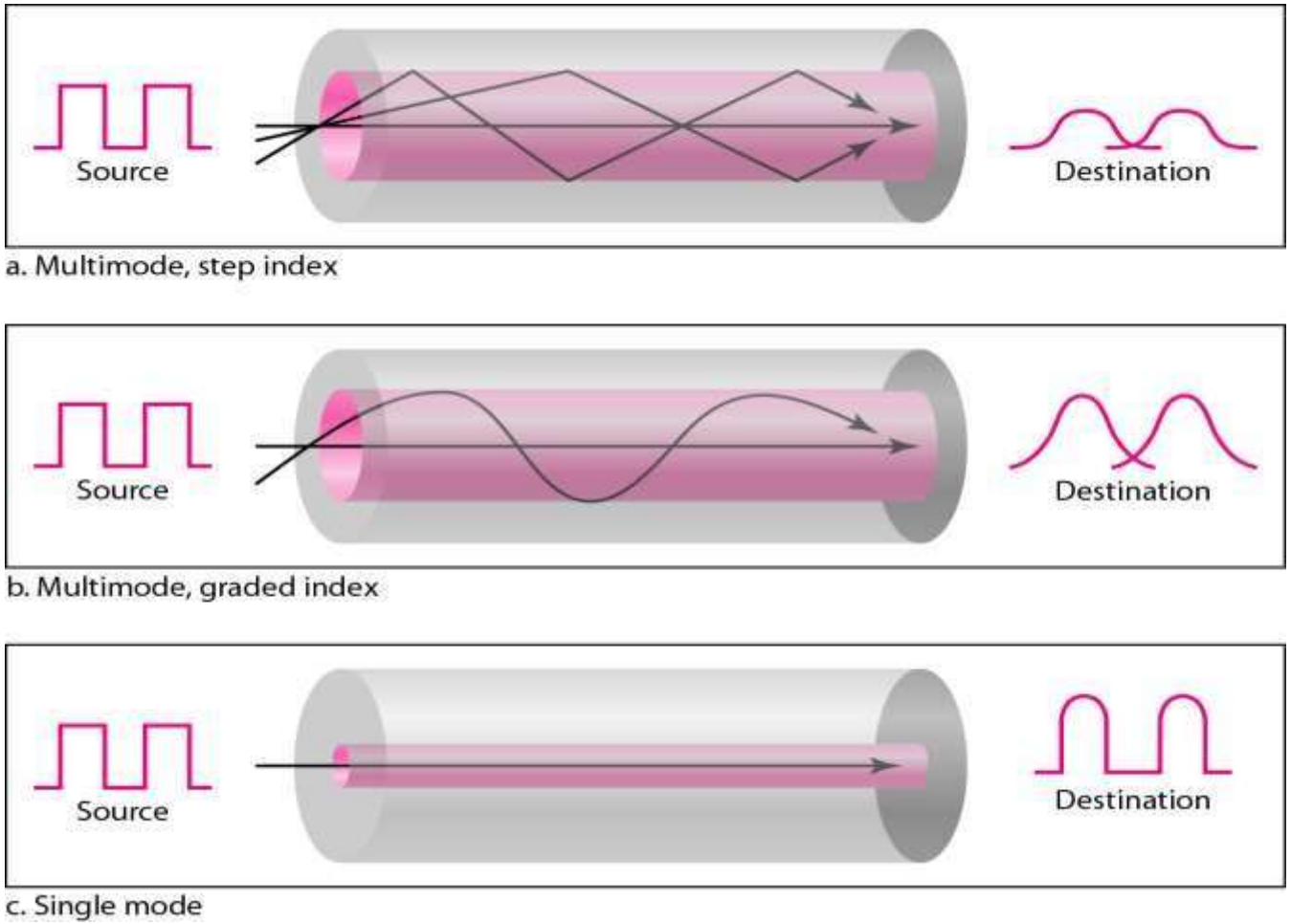
Figure 7.12 *Propagation modes*



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.

Figure 7.13 *Modes*



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 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

- 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.

Continue..

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.

Figure 7.14 *Fiber construction*

- 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.

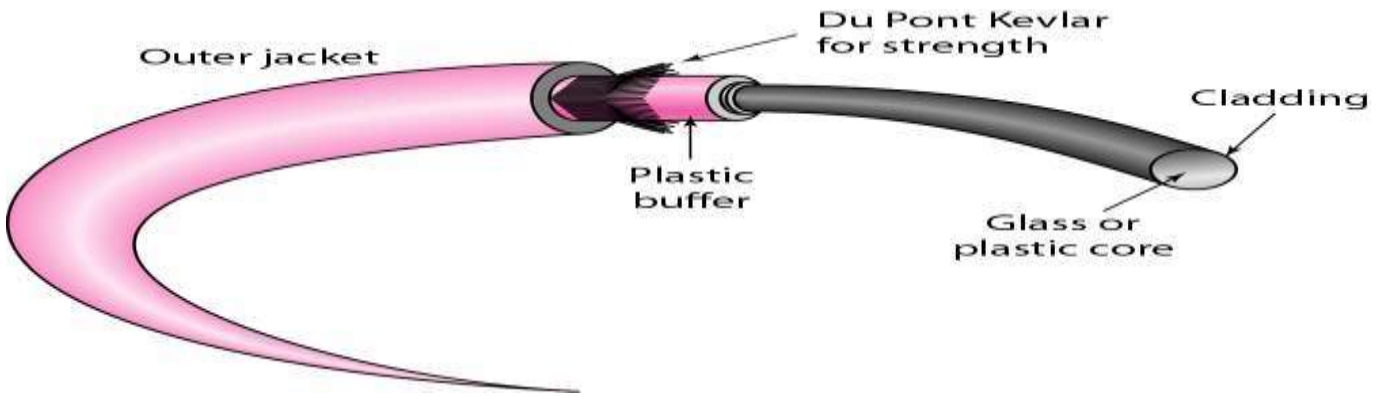
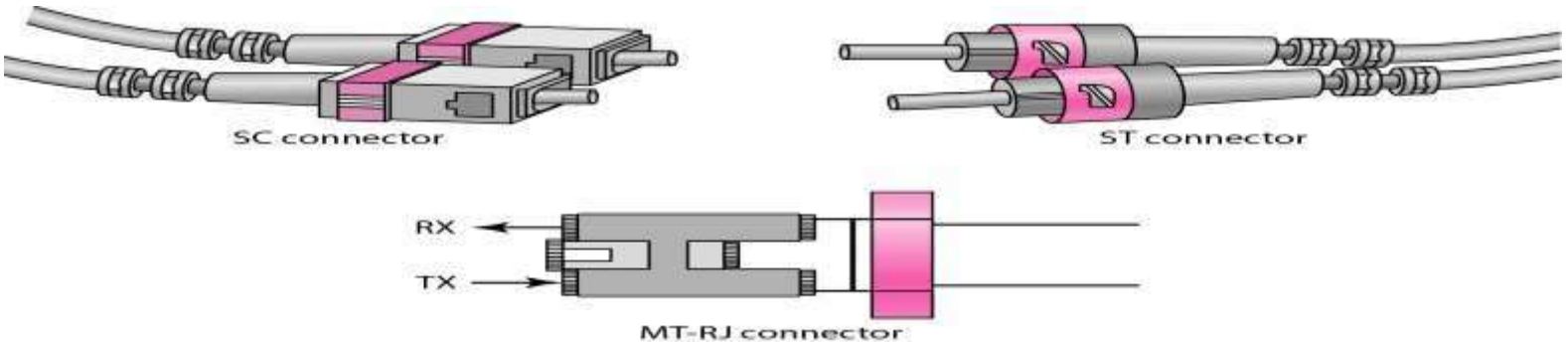


Figure 7.15 *Fiber-optic cable connectors*

- The subscriber channel (SC) connector is used for cable TV. It uses a push/pull locking system. The straight-tip (ST) connector is used for connecting cable to networking devices. It uses a bayonet locking system and is more reliable than SC. MT-RJ is a connector that is the same size as RJ45.



Performance

Attenuation is flatter than in the case of twisted-pair cable and coaxial cable. The performance is such that we need fewer (actually onetenth as many) repeaters when we use fiber-optic cable.

Applications

- Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective.
- Some cable TV companies use a combination of optical fiber and coaxial cable, thus creating a hybrid network.

Advantages

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

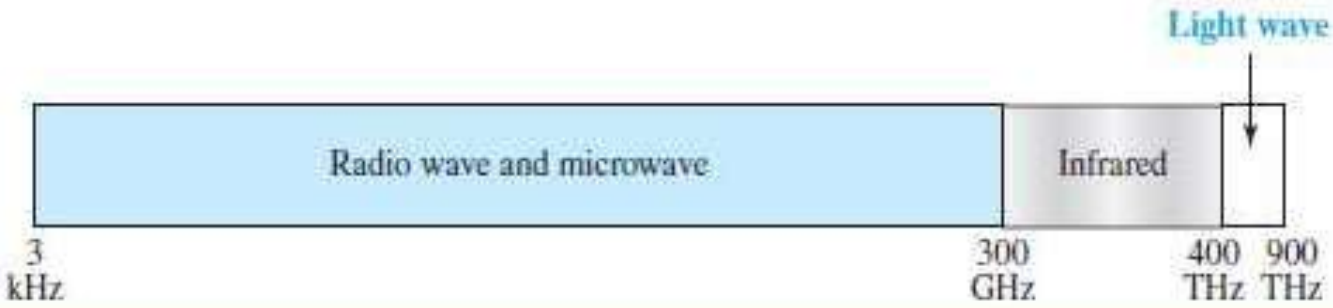
Disadvantages

- Installation and maintenance.
- Unidirectional light propagation.
- Cost.

UNGUIDED MEDIA: WIRELESS

- **Unguided medium** 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.

Figure 7.17 *Electromagnetic spectrum for wireless communication*



Continue…

- Unguided signals can travel from the source to the destination in several ways: ground propagation, sky propagation, and line-of-sight propagation.

Figure 7.18 *Propagation methods*

Continue…

- **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
- **Sky propagation,** higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to earth. This type of transmission allows for greater distances with lower output power.
- **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.

Continue…

- The section of the electromagnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called ***bands,*** each regulated by government authorities.

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

Continue…

Band	*Range*	*Propagation*	*Application*
superhigh frequency (SF)	3–30 GHz	Line-of-sight	Satellite
extremely high frequency (EHF)	30–300 GHz	Line-of-sight	Radar, Satellite

- We can divide wireless transmission into three broad groups: *radio waves*, *microwaves*, and *infrared waves*.

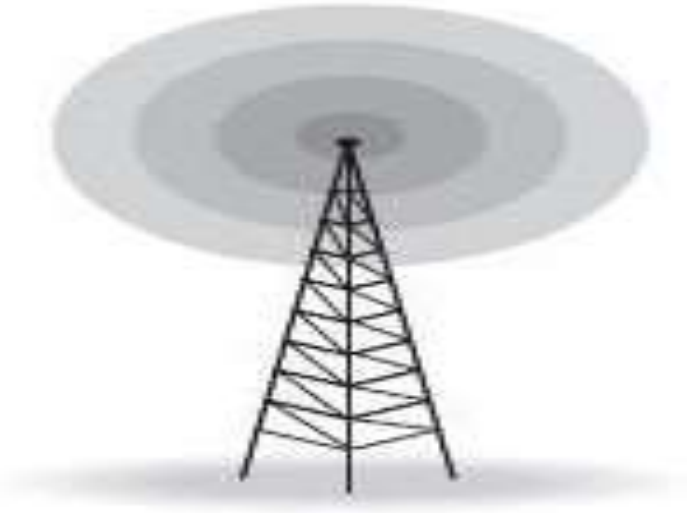
Radio Waves

- 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.
- The omnidirectional property has a disadvantage: 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. E.g. AM radio
- Radio waves, particularly those of low and medium frequencies, can penetrate walls.
- The radio wave band is relatively narrow, just under 1 GHz.
- Almost the entire band is regulated by authorities.

Continue…

Omnidirectional Antenna:

- 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

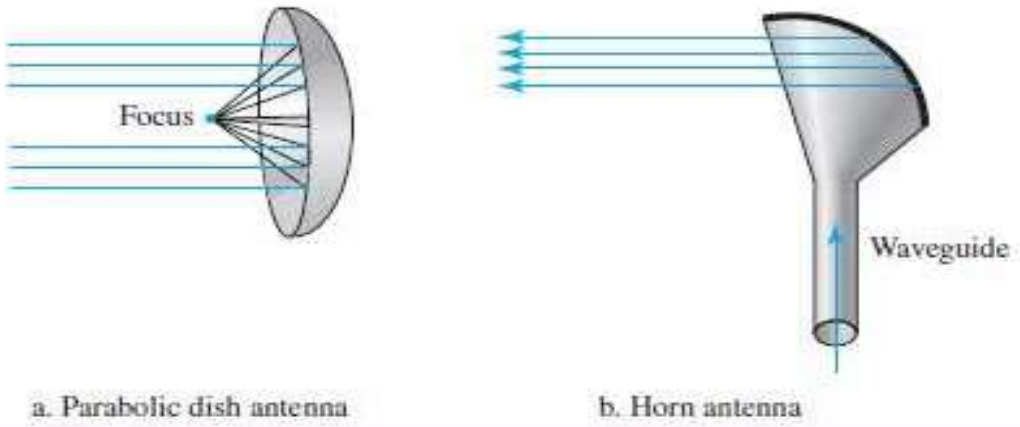
- Electromagnetic waves having frequencies between 1 and 300 GHz are called **microwaves**.
- Microwaves are **unidirectional**.
- When an antenna transmits microwaves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned.
- Advantage is a pair of antennas can be aligned without interfering with another pair of aligned antennas.
- Characteristics of microwave propagation:
  - Microwave propagation is line-of-sight. Repeaters are often needed for long distance communication.
  - Very high-frequency microwaves cannot penetrate walls.
  - The microwave band is relatively wide, almost 299 GHz. A high data rate is possible.
  - Use of certain portions of the band requires permission from authorities.

Continue…

Unidirectional Antenna:

- Microwaves need **unidirectional antennas** that send out signals in one direction.
- Two types of antennas are used for microwave communications: the ***parabolic dish*** and the ***horn***.

Figure 7.20 *Unidirectional antennas*



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- A **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. 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.

Continue…

Applications:

- Microwaves, due to their unidirectional properties, are very useful when unicast (one-to-one) communication is needed between the sender and the receiver. They are used in cellular phones, satellite networks, and wireless LANs

Infrared

- **Infrared waves,** with frequencies from 300 GHz to 400 THz 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.

Applications:

- The infrared band, almost 400 THz, has an excellent potential for data transmission. Such a wide bandwidth can be used to transmit digital data with a very high data rate.
- 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.

References

- Data Communications and Networking, Behrouz A. Forouzan, Fifth Edition, TMH, 2013.