Data Communications and Networking Fourth Edition

Forouzan

Chapter 7

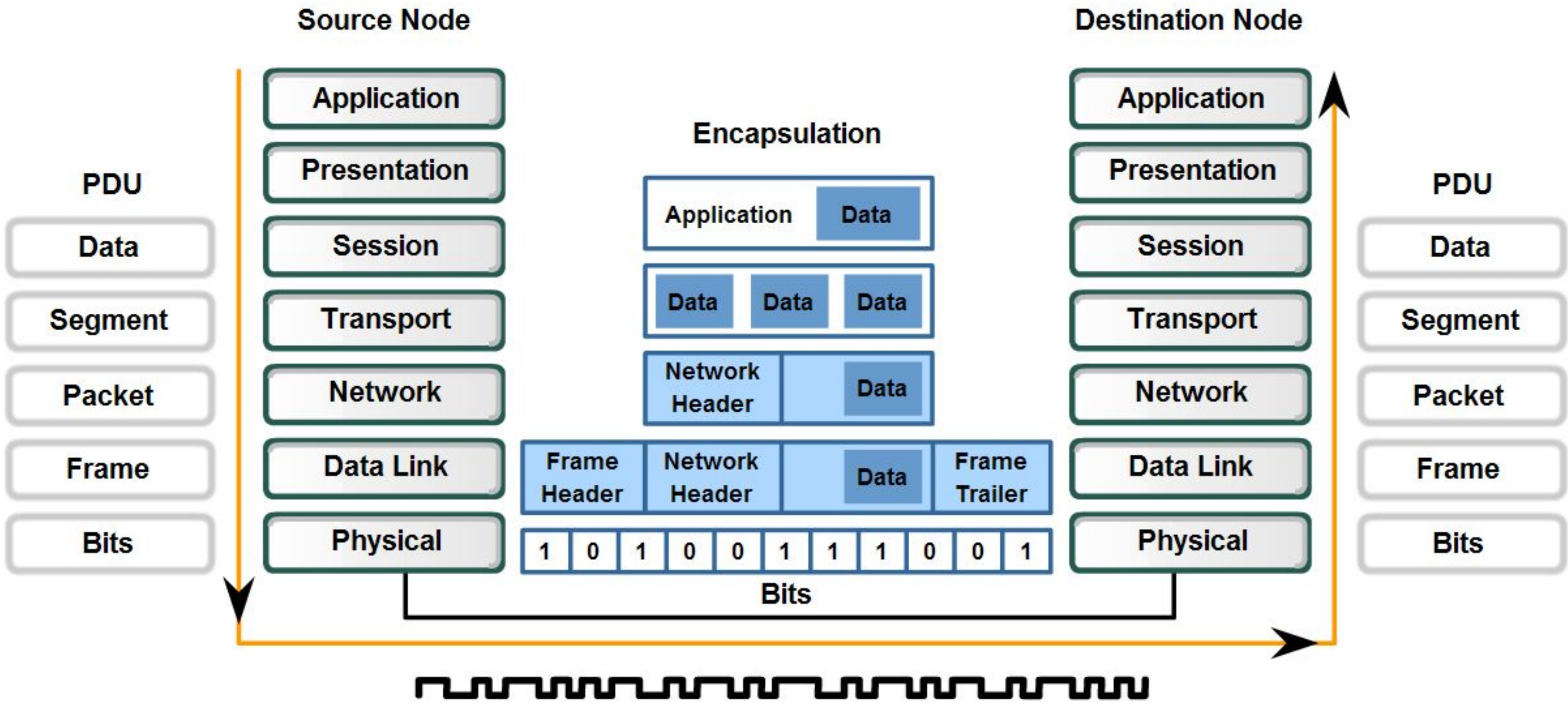
Transmission Media

Presented By NTR

Physical Layer

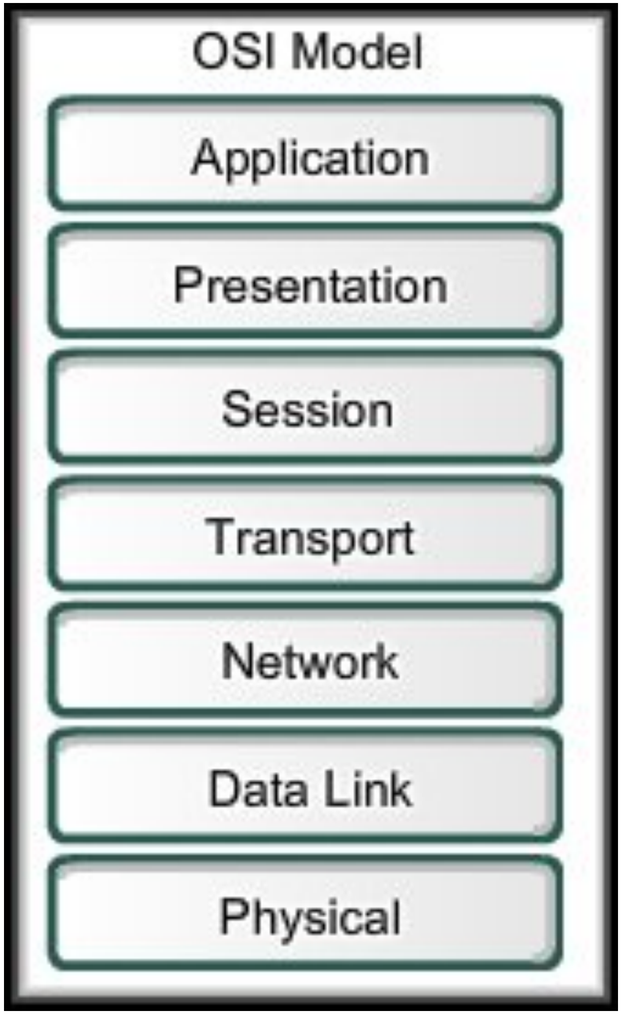
The purpose of the Physical layer is to create the electrical, optical, or microwave signal that represents the bits in each frame.

Transforming Human Network Communications to Bits



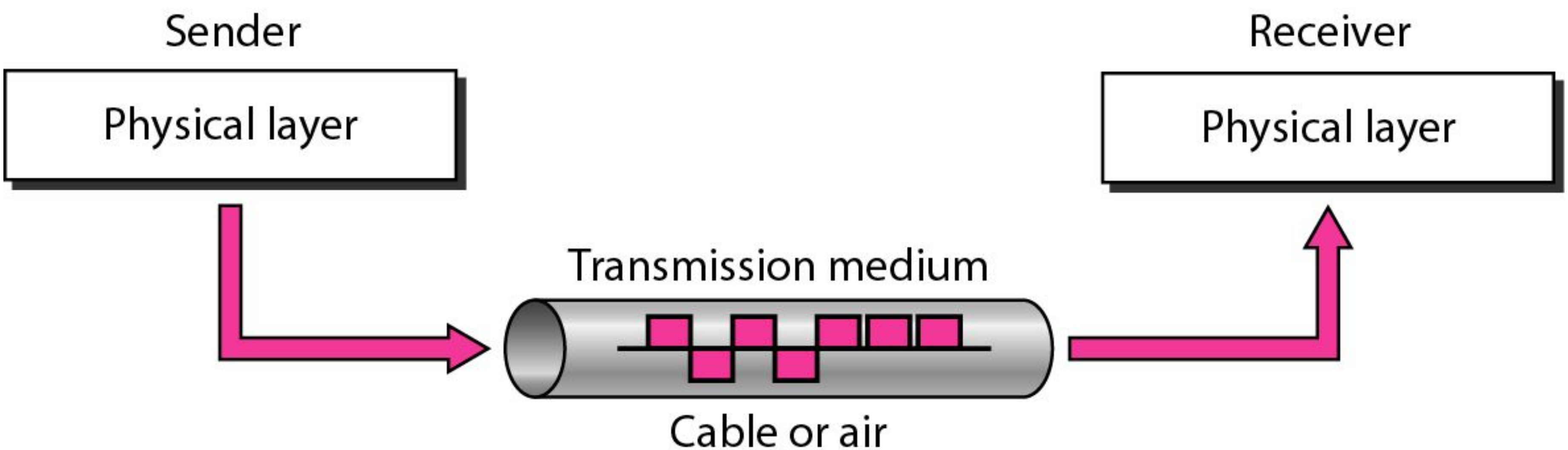
Physical Layer Elements

- Requires:
  - Primary Purpose:
    A representation of the bits of a frame on the media in the form of signals.
  - The physical media and associated connectors.
  - Encoding of data and control information.
  - Transmitter and receiver circuitry on the network devices.



Transmission medium and physical layer

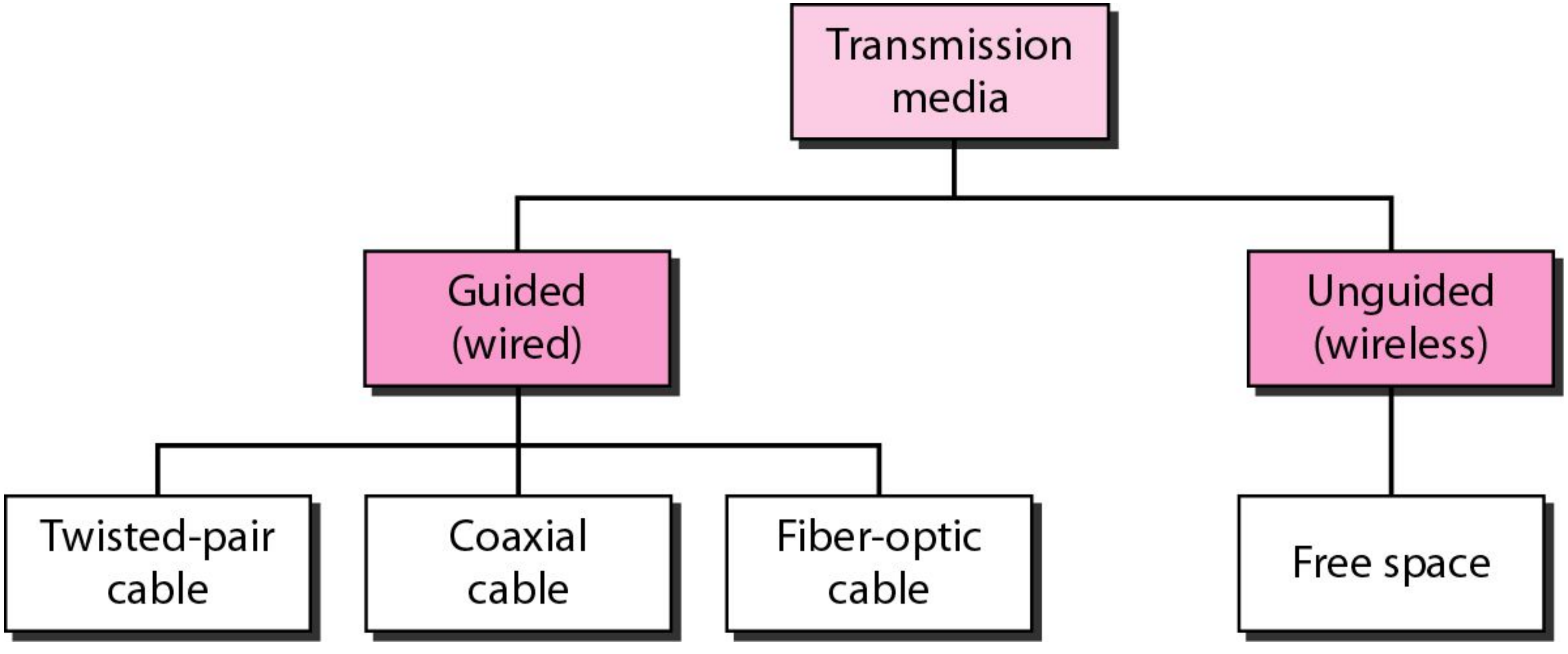
- Transmission media are located below the physical layer and directly controlled by the physical layer.



Transmission Media

- A transmission medium is a physical path between the transmitter and the receiver.
- 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.

Classes of transmission media



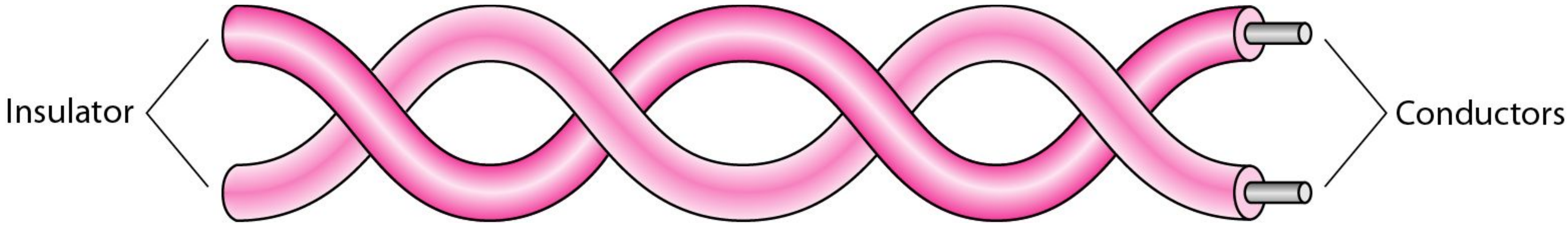
GUIDED MEDIA

- *Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.*
- *Also referred to as Wired or Bounded transmission media.*
- *Signals being transmitted are directed and confined 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.*

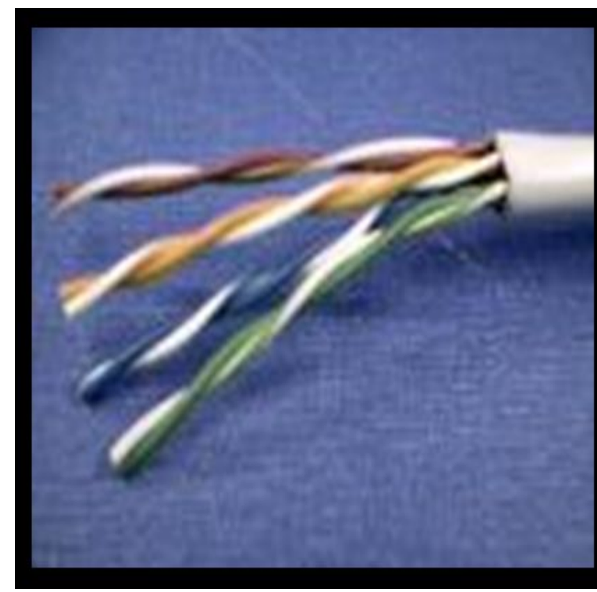
Topics discussed in this section:

Twisted-Pair Cable
Coaxial Cable
Fiber-Optic Cable

Twisted-pair cable

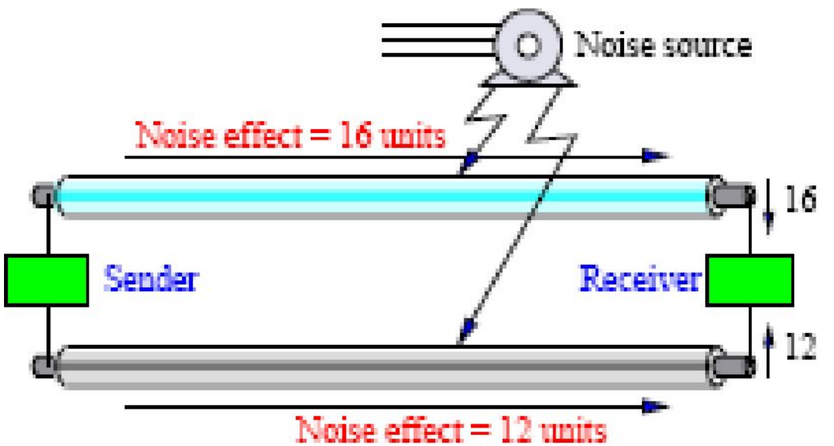


- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together.
- Often “bundled” into cables.
- One to carry signals to the receiver, and the other is used as a ground reference



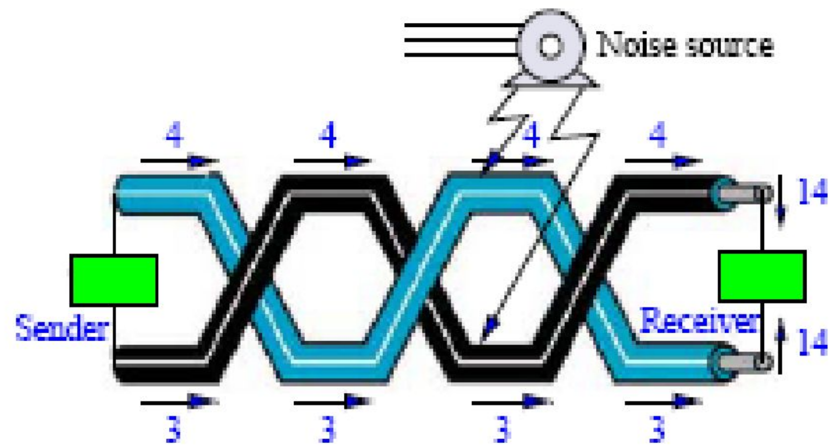
Effect of Noise on Parallel and Twisted-Pair Lines

- receiver uses the difference between the two
- Twisting allows each wire to have approximately the same noise level and reduces crosstalk.
- This means that the receiver, which calculates the difference between the two, receives no unwanted signals. The unwanted signals are mostly canceled out.



Effect of noise is more in the wire closer to noise source than the one further away

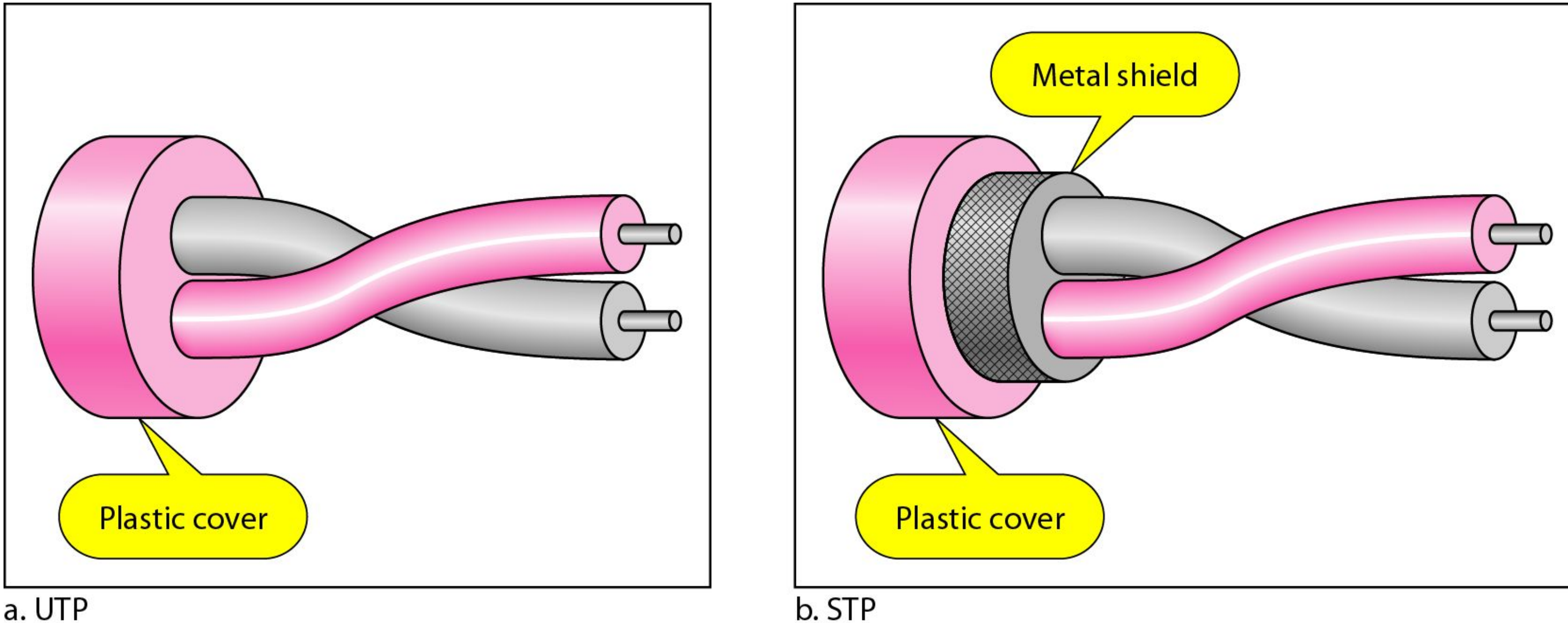
Total effect is 16 − 12 = 4



Effect of noise on both the wire is same.

Total effect is 14 − 14 = 0

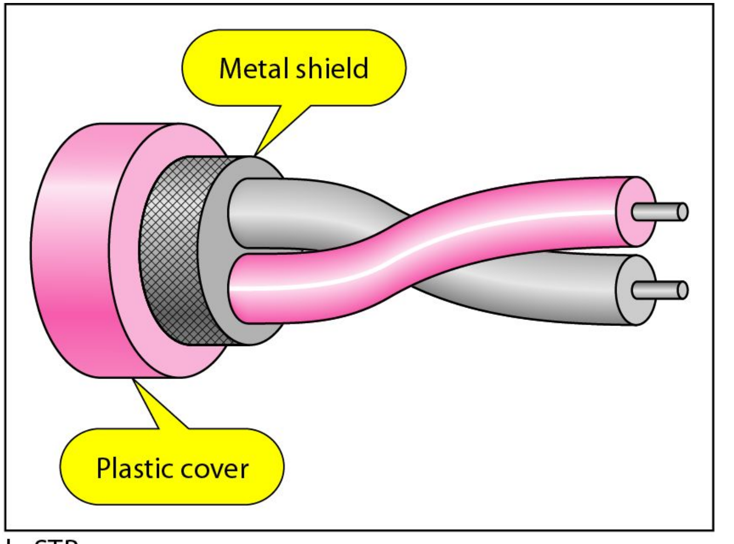
UTP and STP cables



The most common twisted-pair cable used in communications is referred to as ***unshielded twisted-pair*** **(UTP) and** ***shielded twisted-pair*** **(STP).**

STP cables

STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors.



b. STP

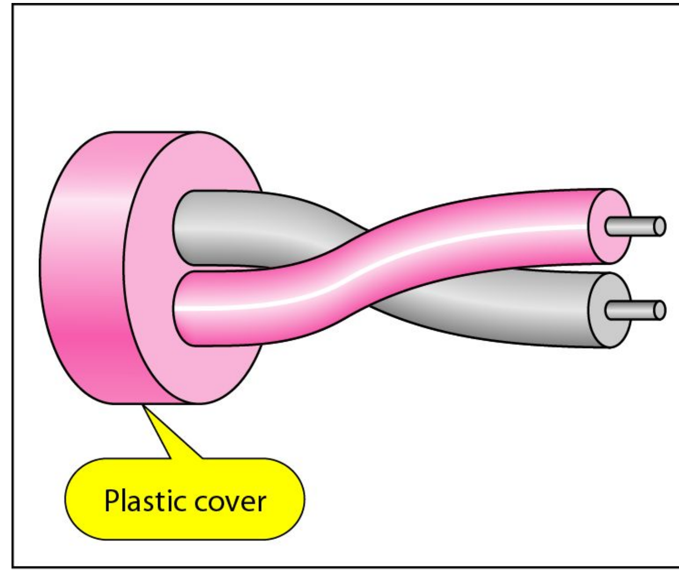
Advantages:

- Eliminate crosstalk
- Better performance at a higher data rate in comparison to UTP

Disadvantages:

- Bulky
- More expensive
- Comparatively difficult to manufacture and Install

UTP cables



a. UTP

Advantages:

•Least expensive
•Easy to install
•High speed capacity

Disadvantages:

•Susceptible to external interference
•Lower capacity and performance in comparison to STP.
•Short distance transmission due to attenuation.

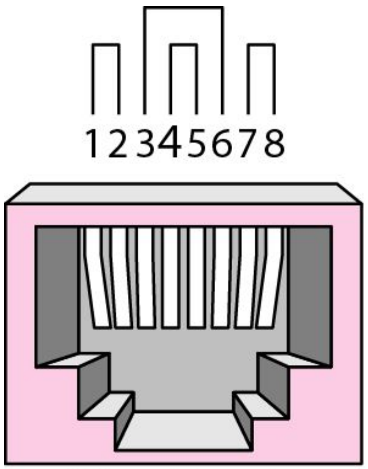
Table 7.1Categories of unshielded twisted-pair cables

- 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.

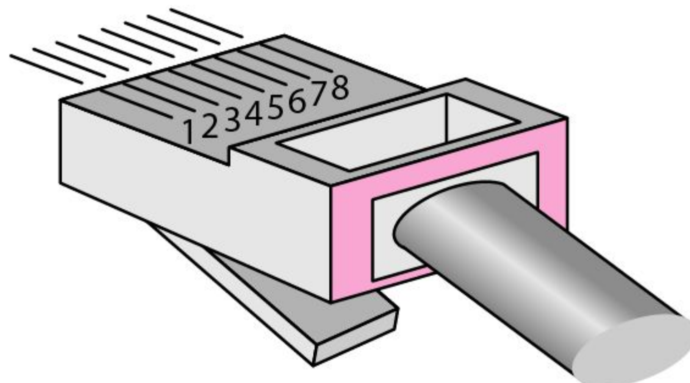
Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	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

UTP connector

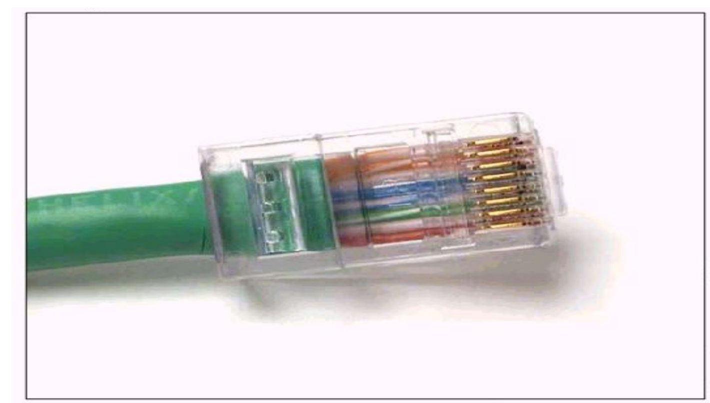
The most common UTP connector is **RJ45** (RJ stands for registered jack)



RJ-45 Female

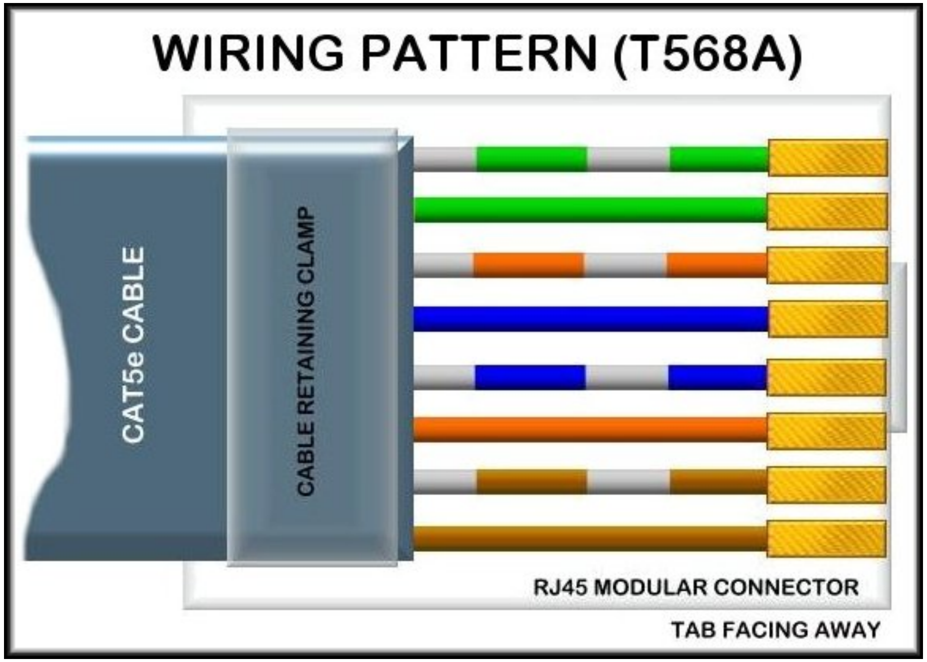


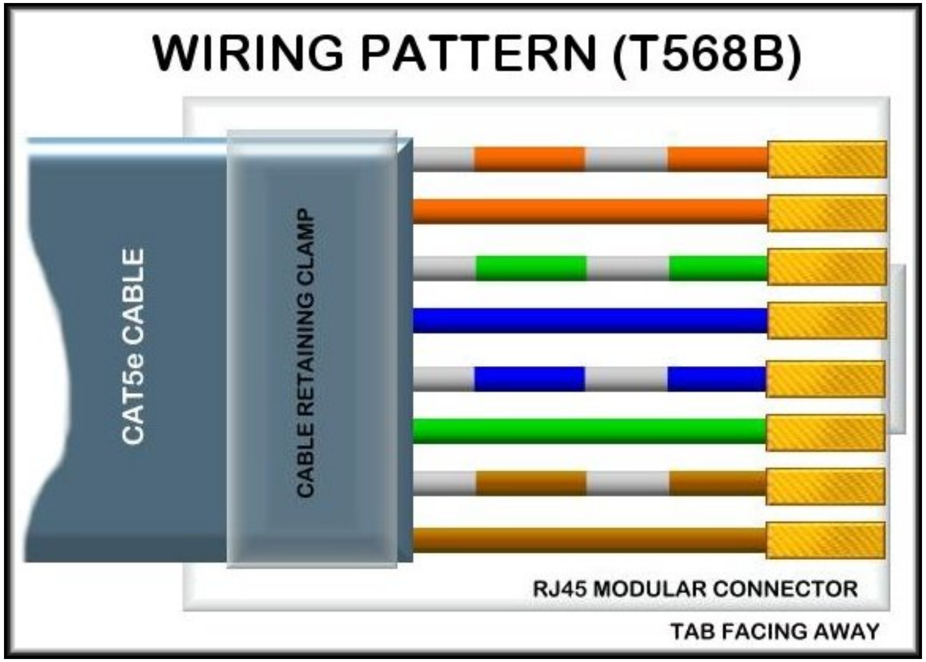
RJ-45 Male



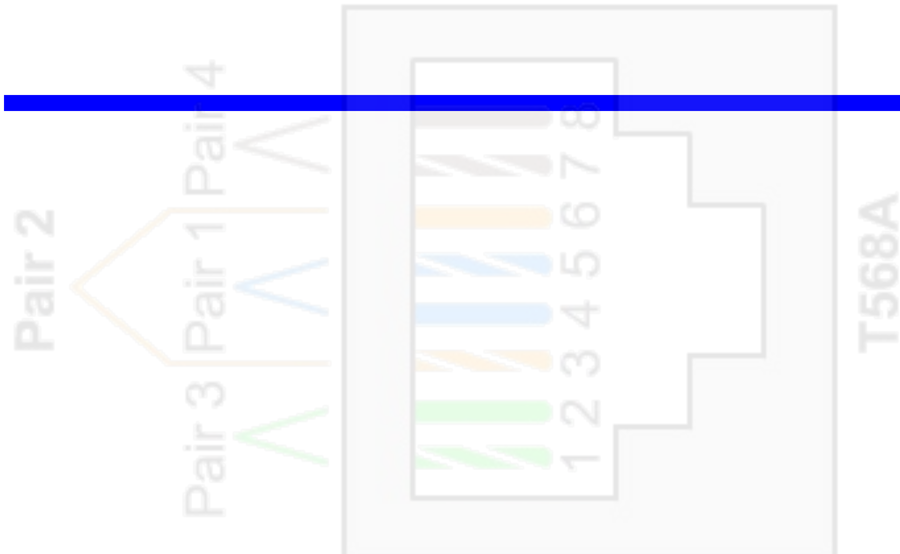
UTP Cable

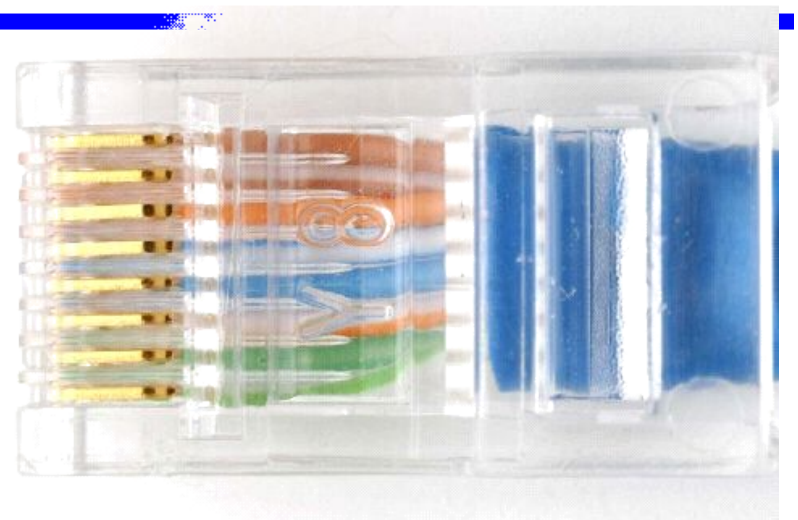
- Wiring Patterns:
  - There are two specific TIA/EIA standard wiring patterns:





This is the Jack

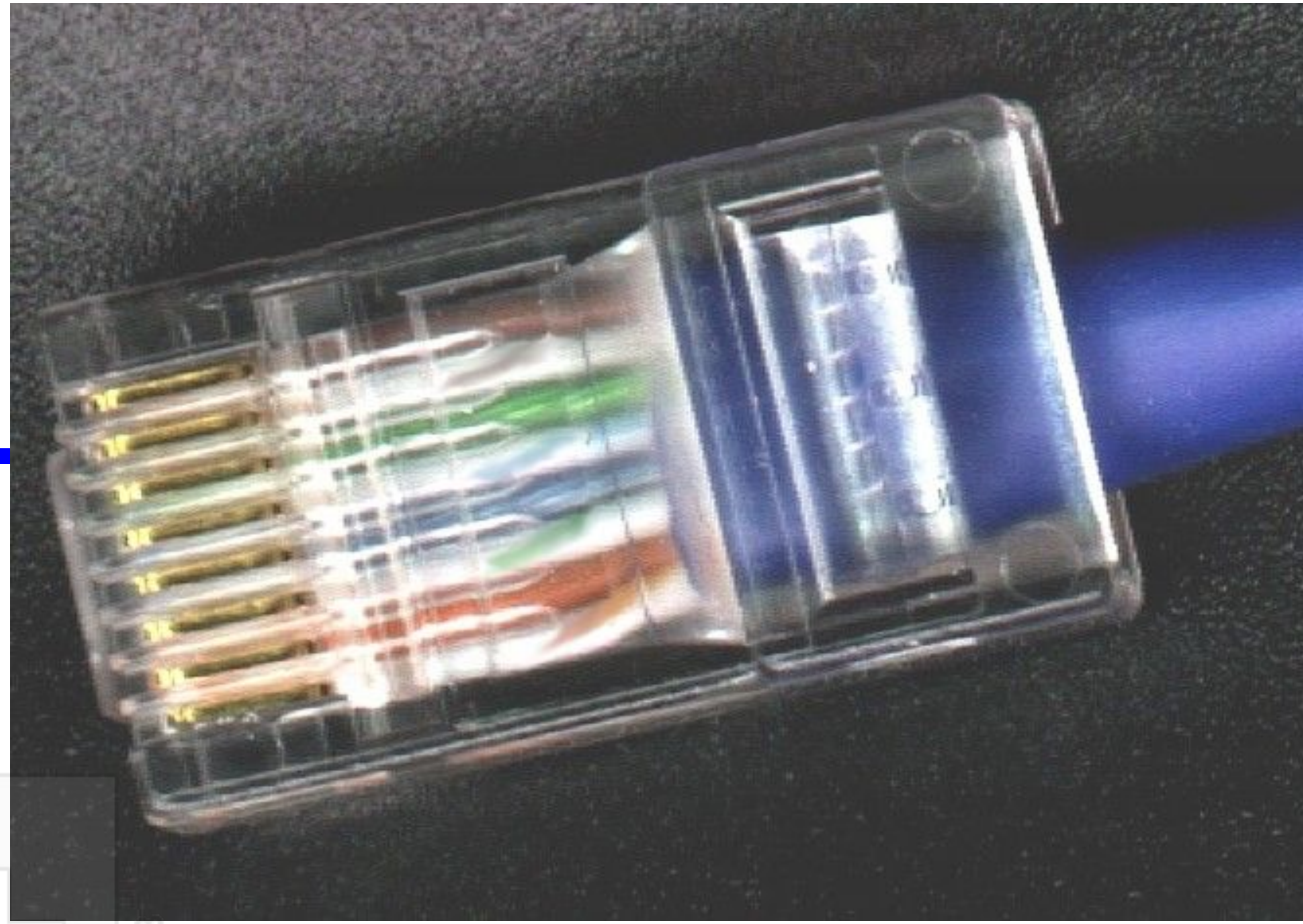


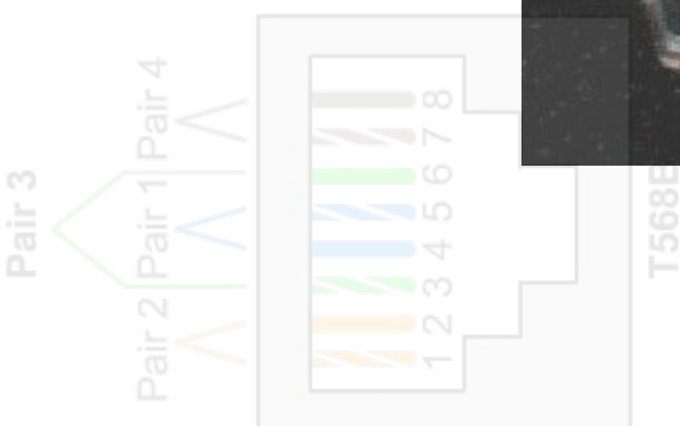


568A

This is the Connector

This is the Jack





568B

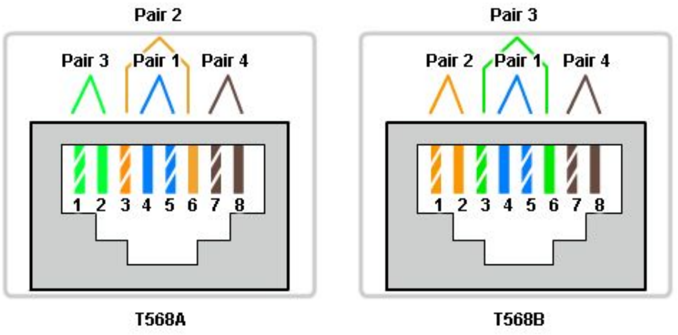
This is the Connector

UTP Cable Types

—Different situations may require UTP cables to be wired according to different wiring patterns:

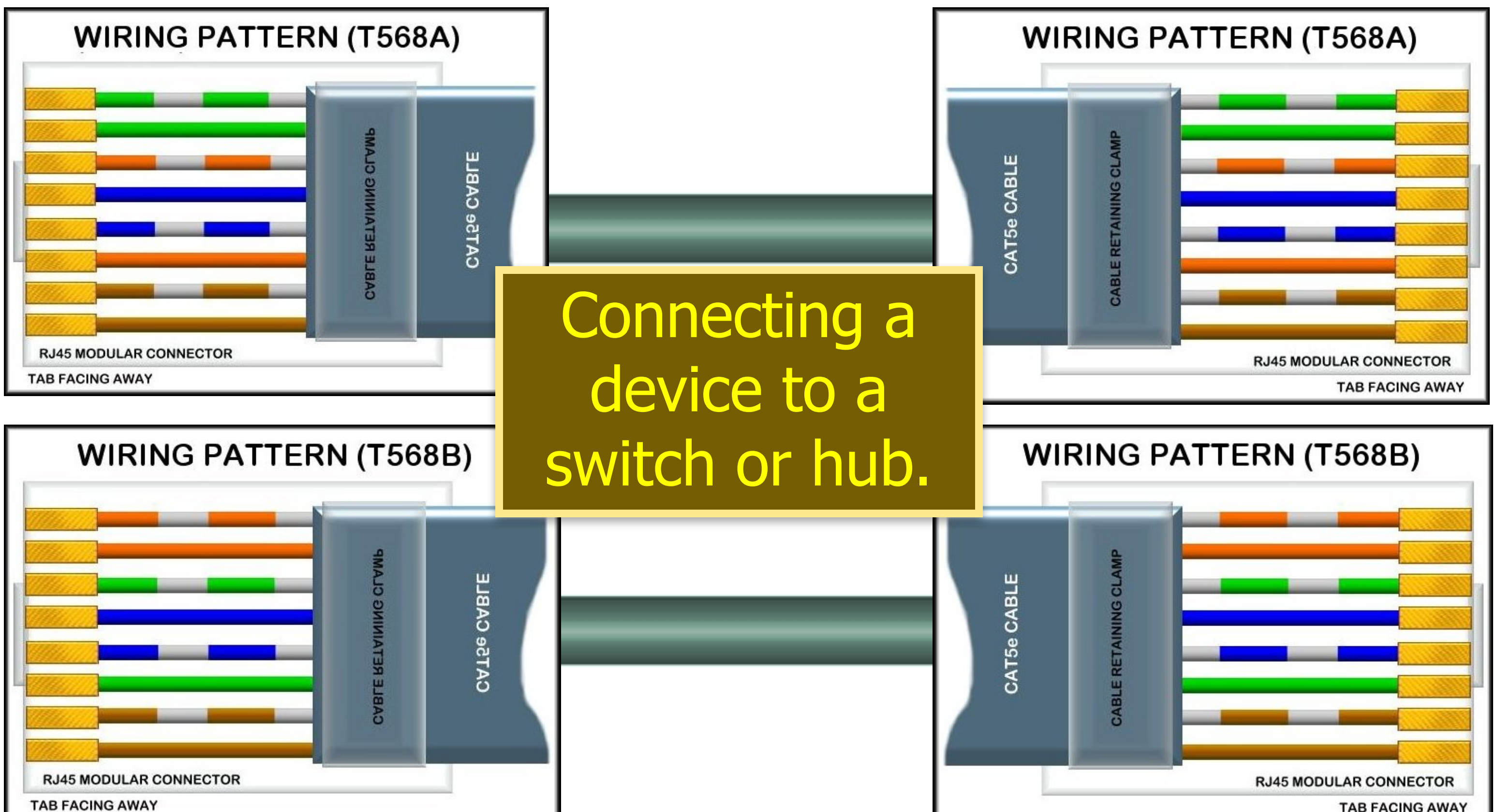
Straight-through, Crossover, and Rollover Cable Types

Cable Type	Standard	Application
Ethernet Straight-through	Both end T568A or both end T568B	Connecting a network host to a network device such as a switch or hub.
Ethernet Crossover	One end T568A, other end T568B	Connecting two network hosts. Connecting two network intermediary devices (switch to switch, or router to router).
Rollover	Cisco proprietary	Connect a workstation serial port to a router console port, using an adapter.



UTP Cable Types

- Ethernet Straight-through:
  - T568A or T568B may be used as long as the same pattern is used at both ends of the cable.



UTP Cable Types

- Ethernet Crossover:
  - T568A and T568B are used at either end of the cable.
  - Connecting two workstations together.
  - Connecting two networking devices.
    - Switch to a switch
    - Router to a router

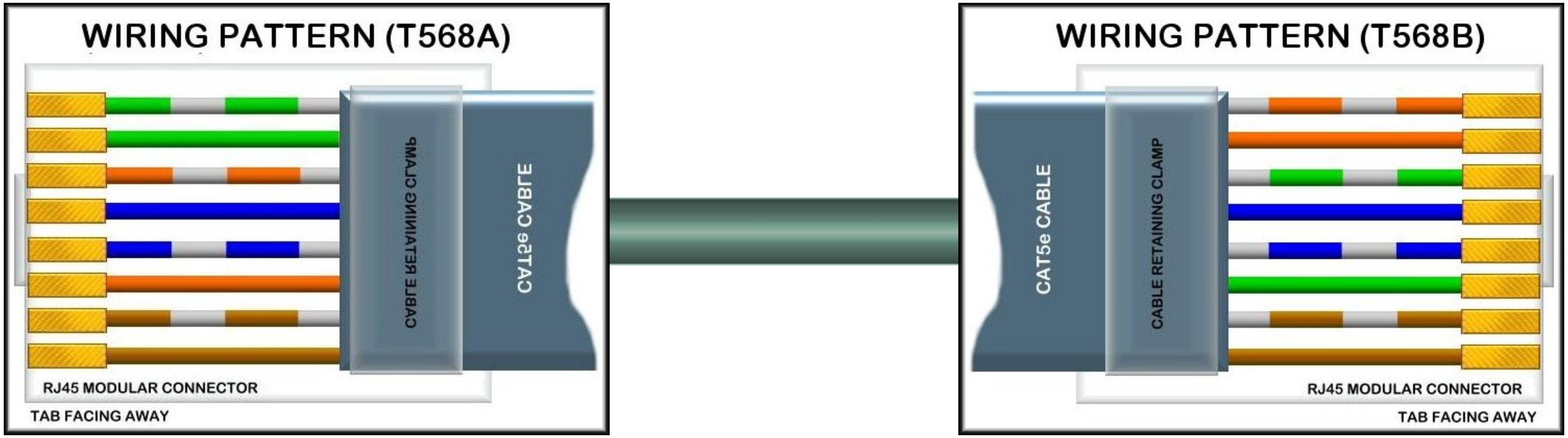
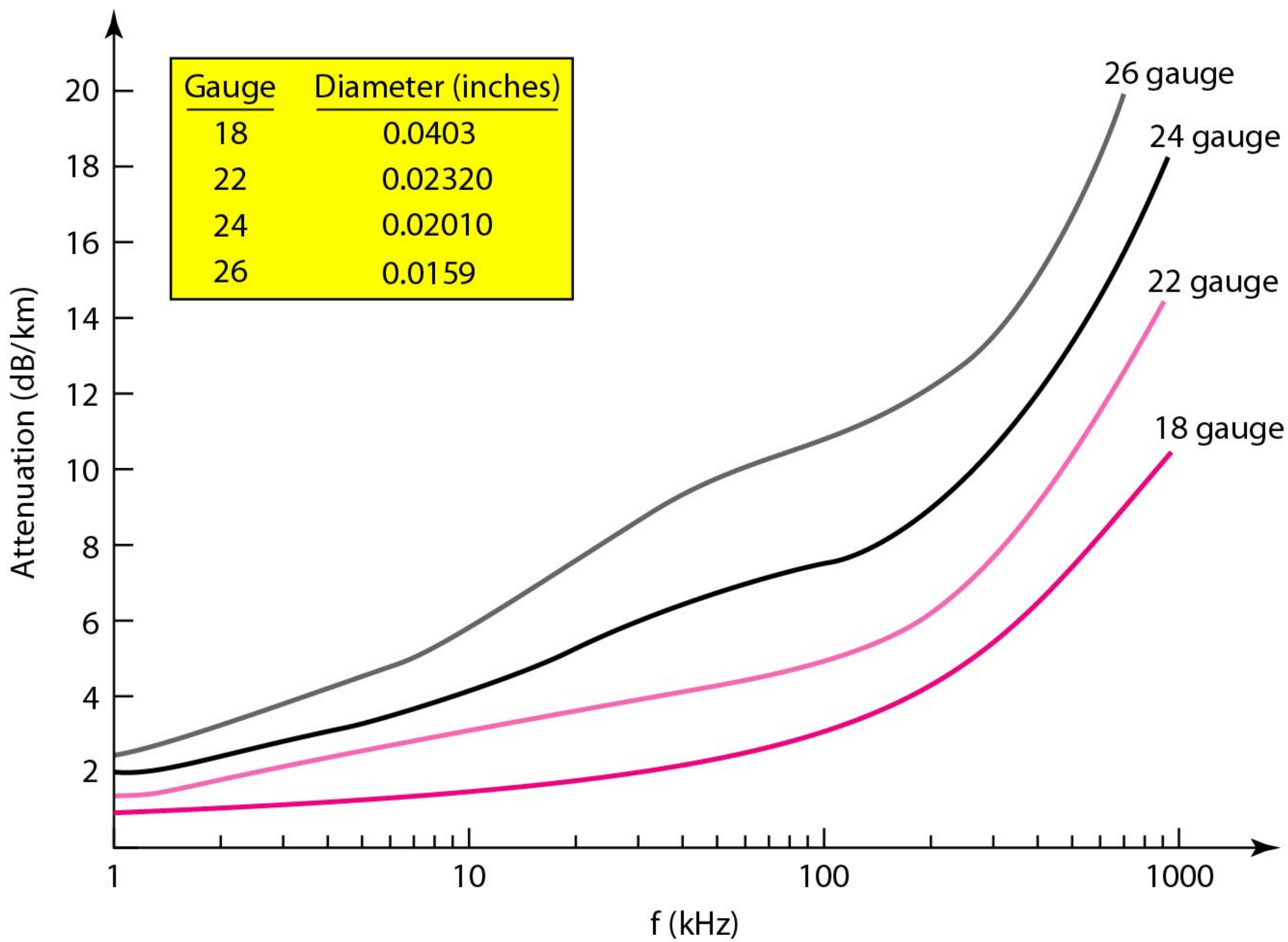


Figure: UTP performance



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 ,100Mbps, 1Gbps

Pros

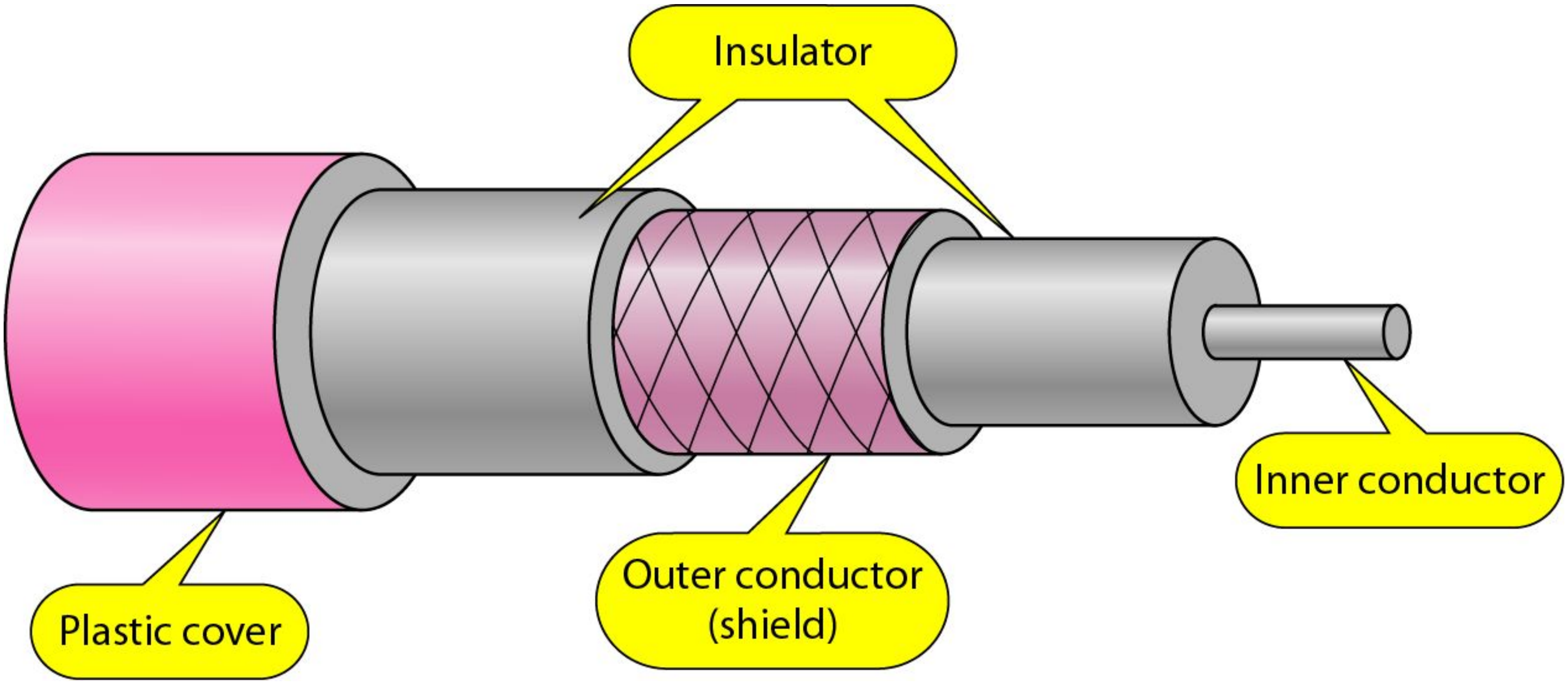
- Cheap and easy to work with

Cons

- Low data rate and short range

Coaxial cable

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



Coaxial Cable Standards

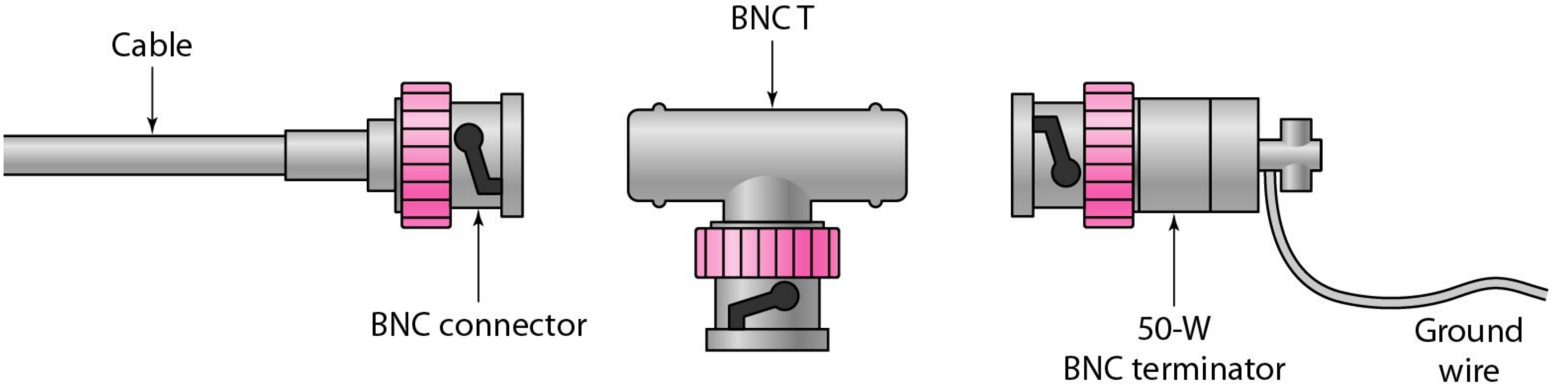
- Coaxial cables are categorized by their **Radio Government (RG)** ratings. Each RG number denotes a unique set of physical specifications. Each cable defined by an RG rating is adapted for a specialized function.

Table 7.2 ***Categories of coaxial cables***

Category	*Impedance*	*Use*
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

BNC connectors

The most common type of connector used today is the **Bayonet Neill-Concelman (BNC)** connector. In figure shows three popular types of these connectors: the BNC connector, the BNC T connector, and the BNC terminator.

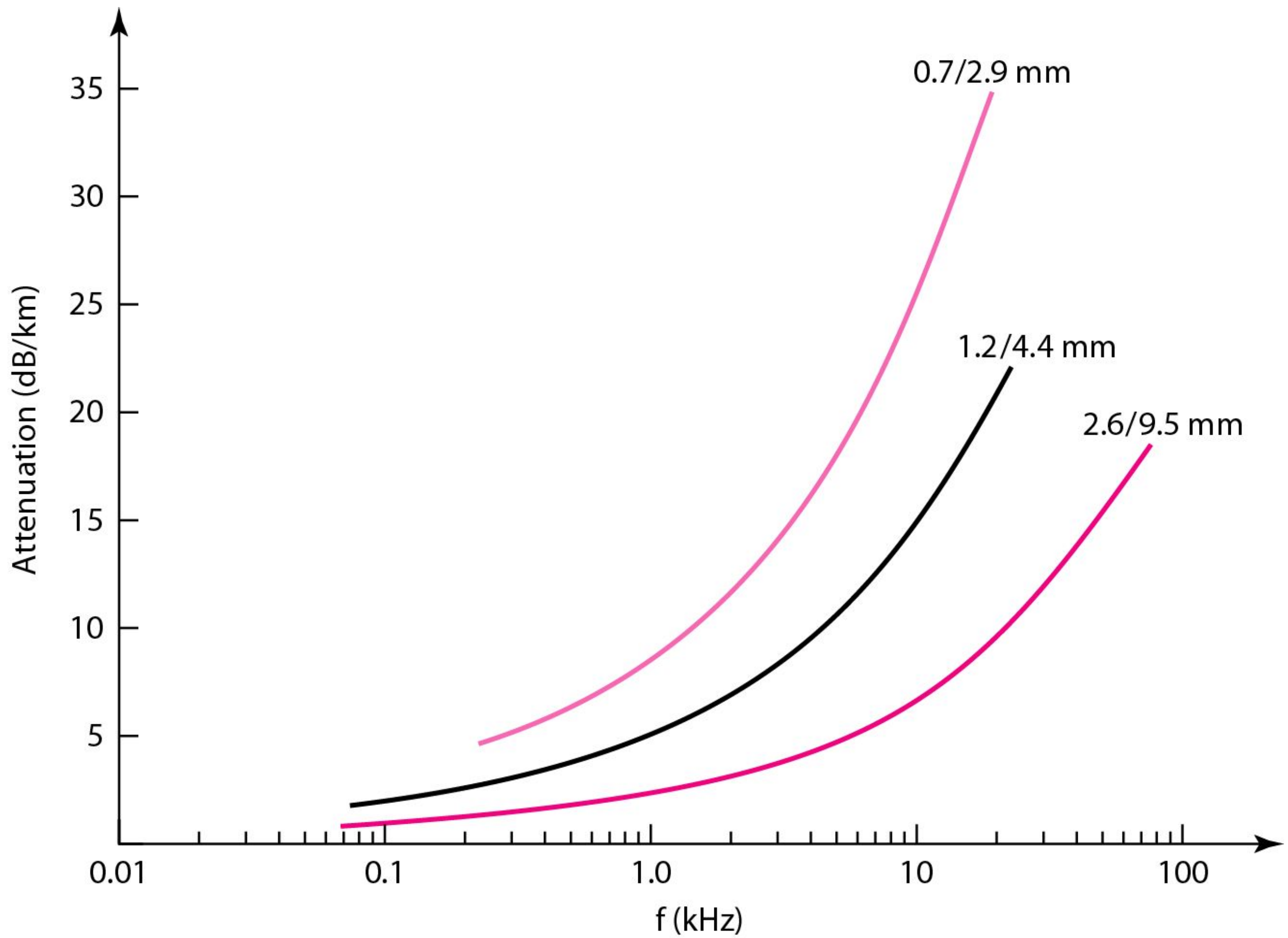


used to connect the end of the cable to a device, such as a TV set

used in Ethernet networks to branch out to a connection to a computer or other device

used at the end of the cable to prevent the reflection of the signal.

Figure: Coaxial cable performance



Coaxial cable

Applications:

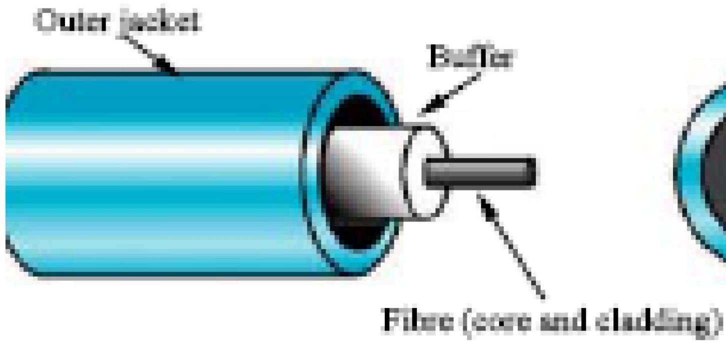
- Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals.
- Also used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps.
- Cable TV networks use coaxial cables. Cable TV uses RG-59coaxial cable.

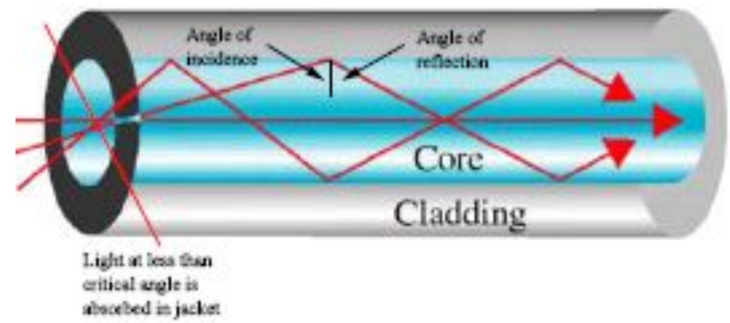
- *Pros*
- High Bandwidth
- Easy to install
- Inexpensive

Cons

- Single cable failure can disrupt the entire network

Fiber Optic Cable

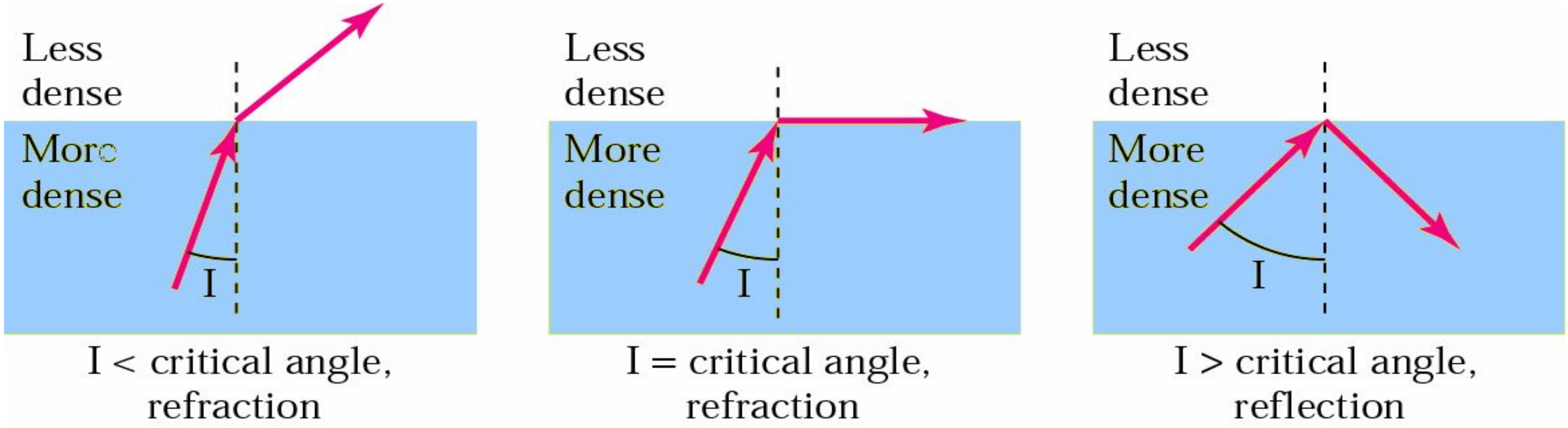




Fiber optic cable is made of glass/plastic and transmit signal in form of light

- **Physical description:**
  - ***Optical Signal*** is carried by photon pulses through thin (8 to 10 microns) ***glass*** strands (optical fibers)
  - light waves are produced either by Light emitting diodes (LEDs) or injection ***laser diode*** (ILD).
  - at transmitting and receiving end, signal is converted from and reconverted to electrical form by optical modems such as an avalanche ***photo diode***.

Bending of light ray

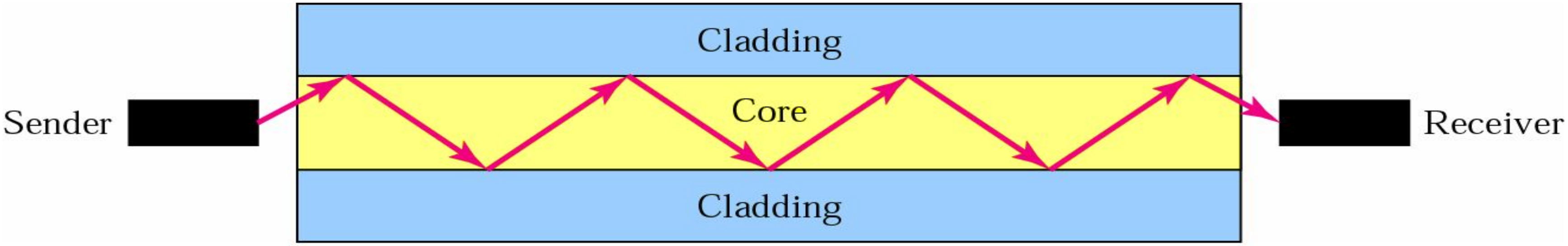


if the **angle of incidence** *I* is less than the **critical angle,** the ray **refracts** and moves closer to the surface. If the angle of incidence is equal to the critical angle, the light bends along the interface. If the angle is greater than the critical angle, the ray **reflects** (makes a turn) and travels again in the denser substance.

The critical angle is a property of the substance, and its value differs from one substance to another.

Optical fiber

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.



Optical Fiber

<u>Applications:</u>

- Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective. 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.

Advantages and Disadvantages of Optical Fiber

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

Fiber Optic Cable

Fiber construction or Cable composition

The outer jacket is made of either PVC or Teflon. Inside the jacket are Kevlar strands to strengthen the cable. 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.

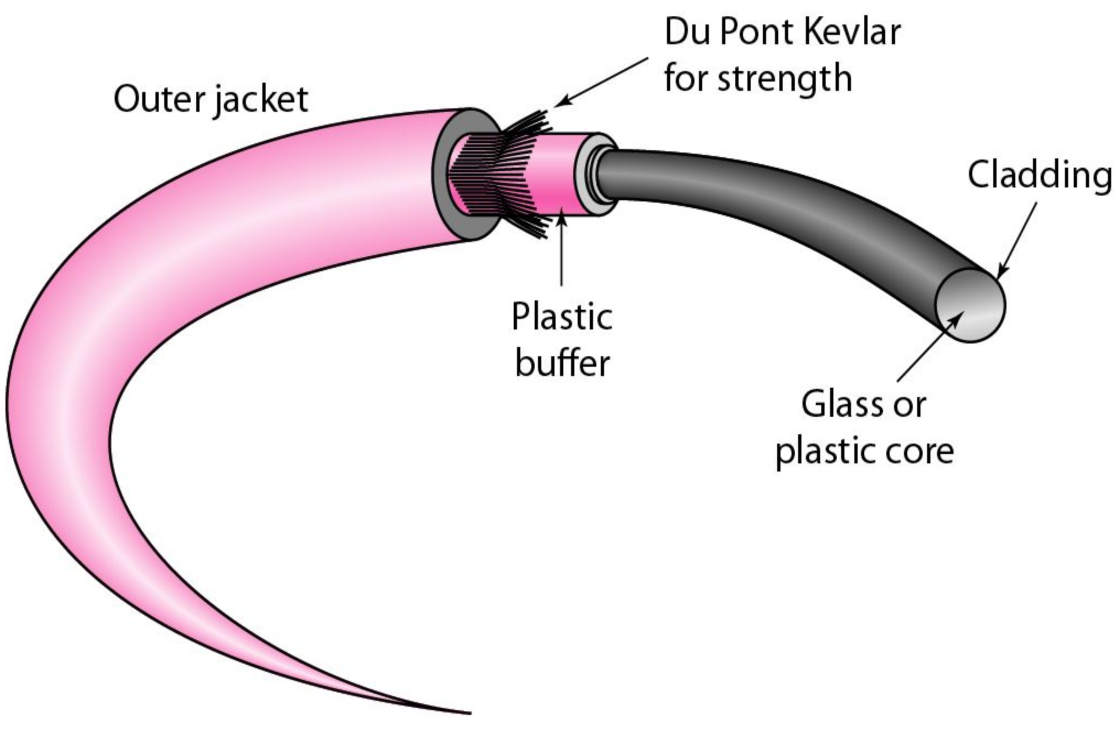
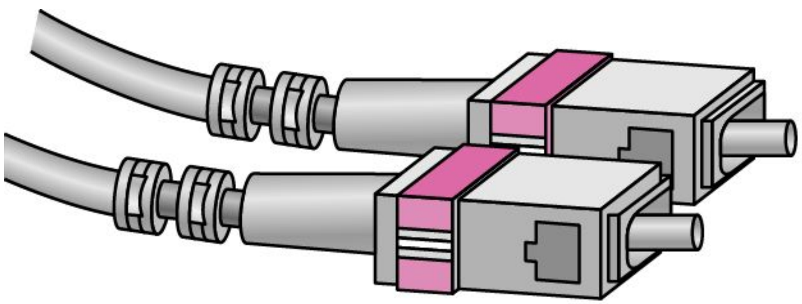
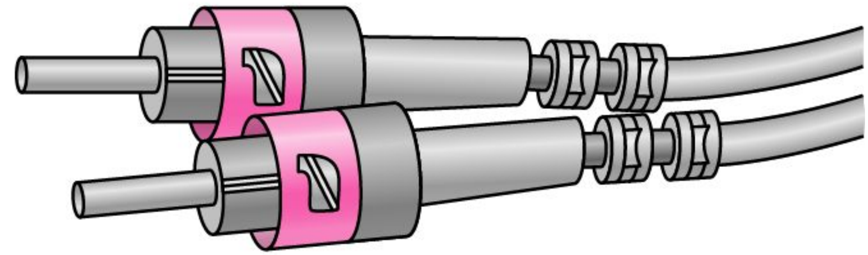


Figure: Fiber-optic cable connectors



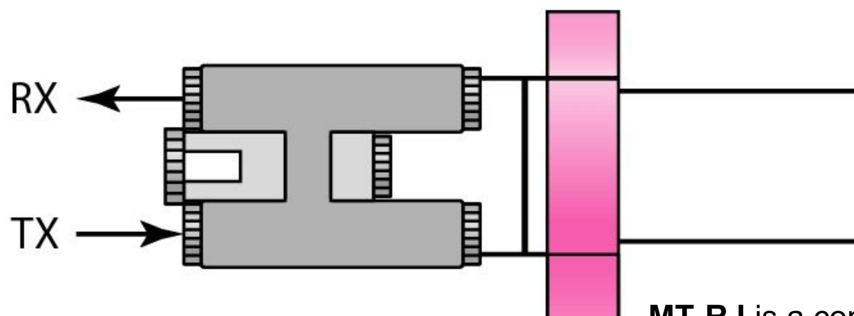
SC connector

The **subscriber channel (SC) connector** is used for cable TV. It uses a push/pull locking system.



ST connector

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 connector

MT-RJ is a connector that is the same size as RJ45.

Propagation modes

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

Figure: Propagation modes

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

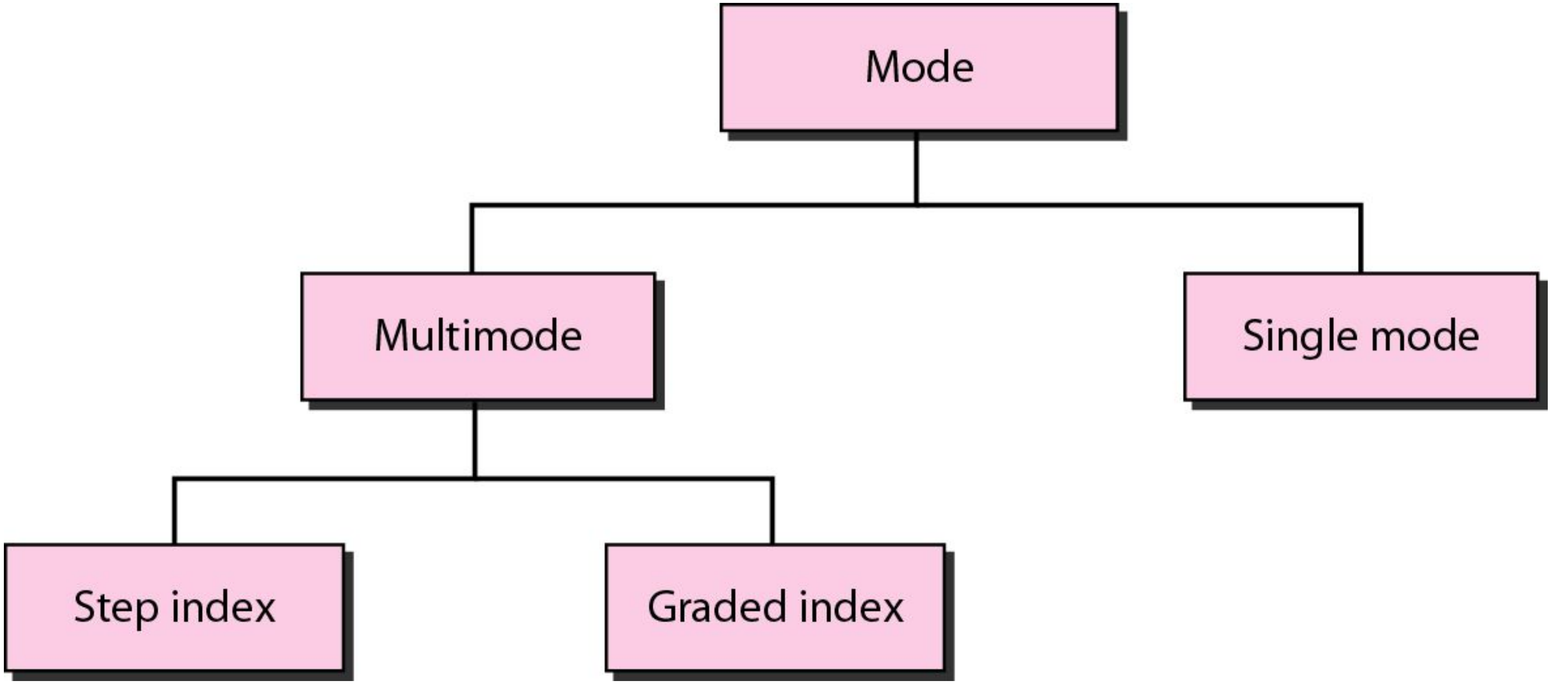
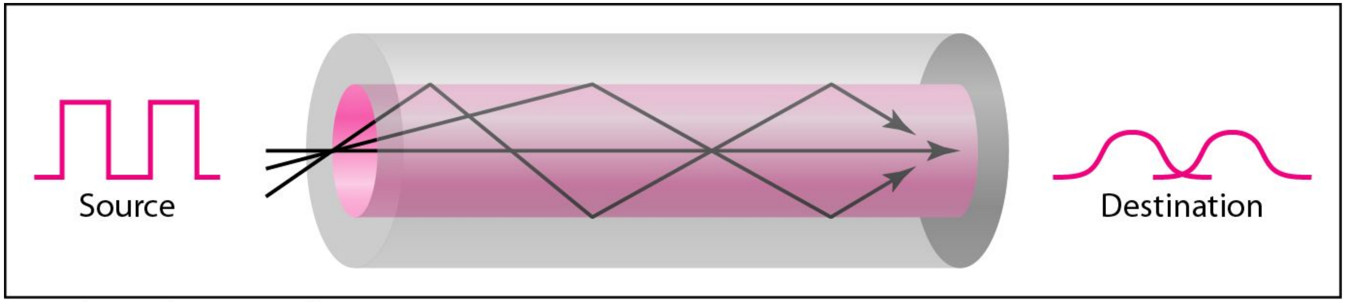
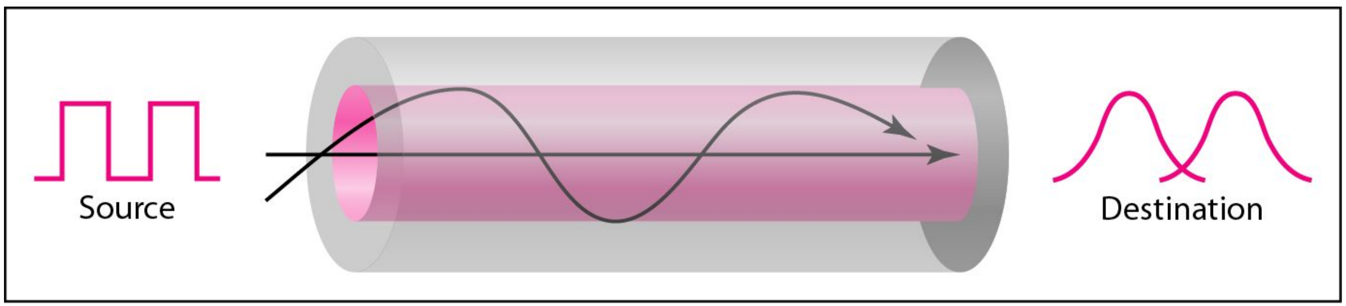


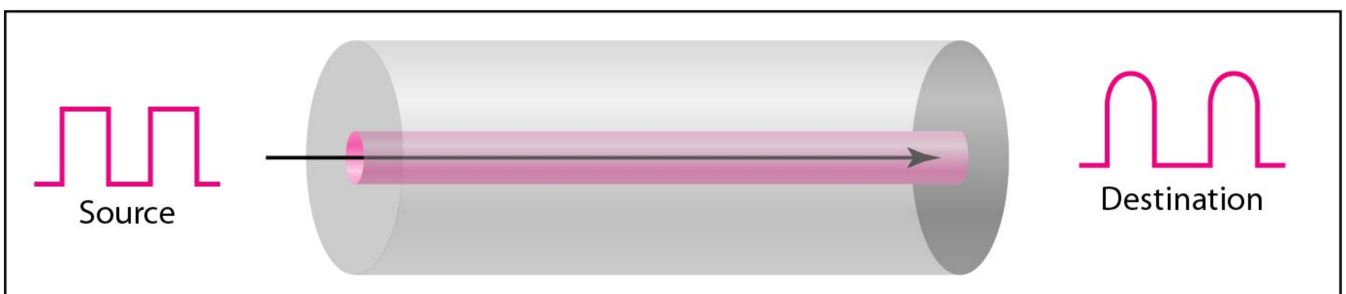
Figure: Modes



a. Multimode, step index



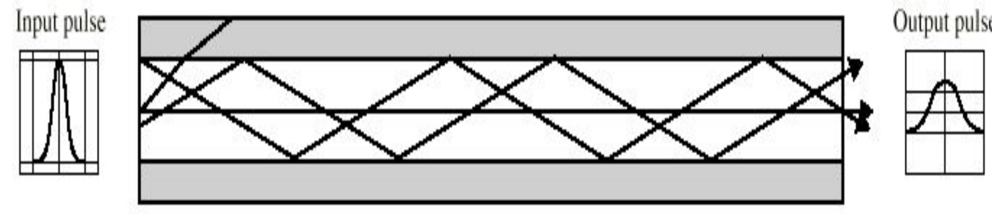
b. Multimode, graded index



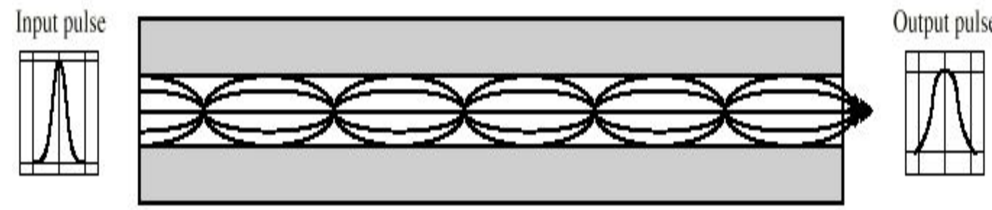
c. Single mode

Optical Fiber Transmission 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.
- multimode graded-index fiber
- 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 fiber
  - the light is guided down the center of an extremely narrow core



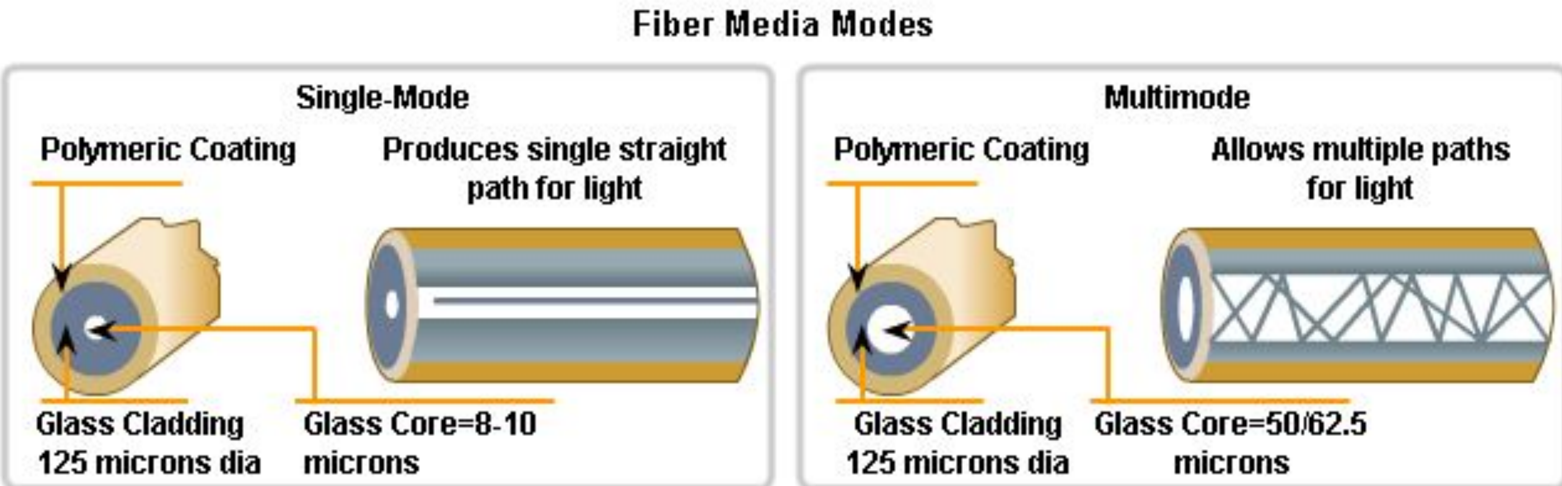
(a) Step-index multimode



(b) Graded-index multimode

(c) Single mode

Single Mode Vs Multimode



- Small Core
- Less Despersion
- Suited for long distance applications (up to 100 km, 62,14 mi.)
- Uses lasers as the light source often within campus backbones for distance of several thousand meters

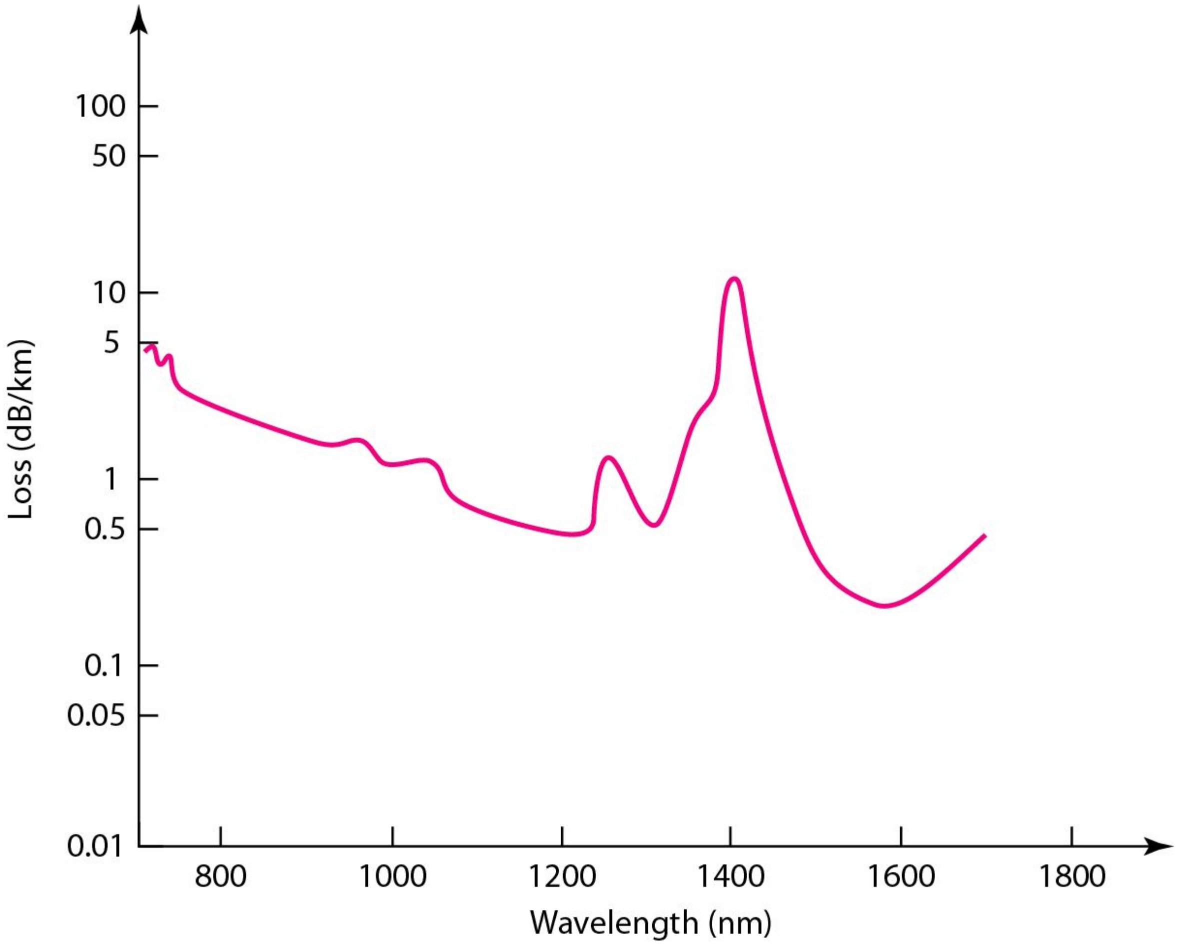
- Larger core than single-mode cable (50 microns or greater)
- Allows greater dipersion and therefore, loss of signal
- Used for long distance appllication, but shorter than single-mode (up to ~2km, 6560 ft)
- Uses LEDs as the light source often within LANs or distances of couple hundred meters within a campus network

Table 7.3 Fiber types

Optical fibers are defined by the ratio of the diameter of their core to the diameter of their cladding, both expressed in micrometers. The common sizes are shown here:

Type	*Core (μm)*	*Cladding (μm)*	*Mode*
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

Figure: Optical fiber performance



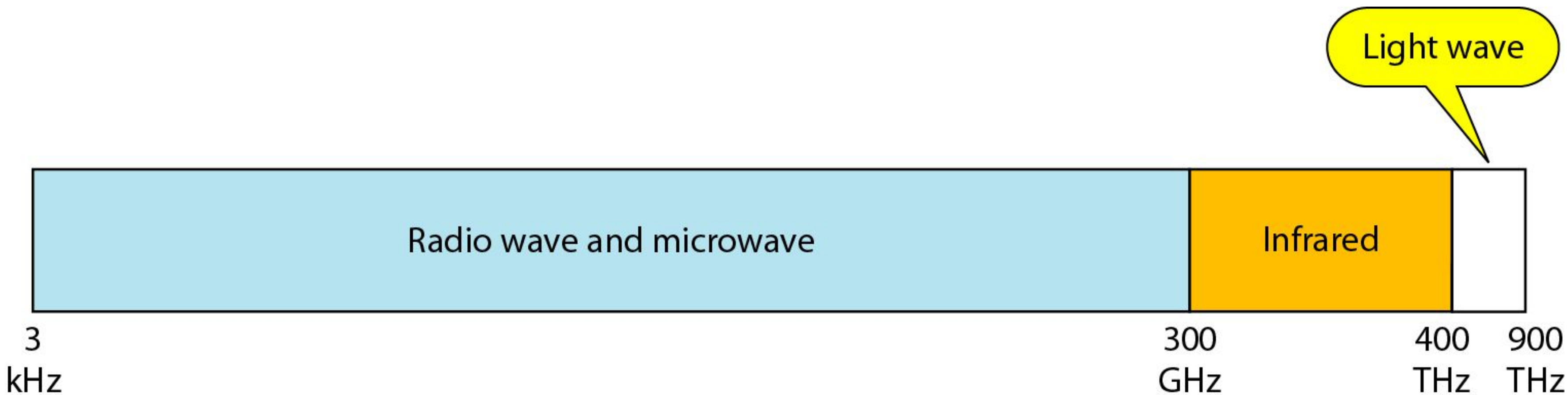
UNGUIDED MEDIA: WIRELESS

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

Topics discussed in this section:

Radio Waves
Microwaves
Infrared

Figure: Electromagnetic spectrum for wireless communication



Propagation methods

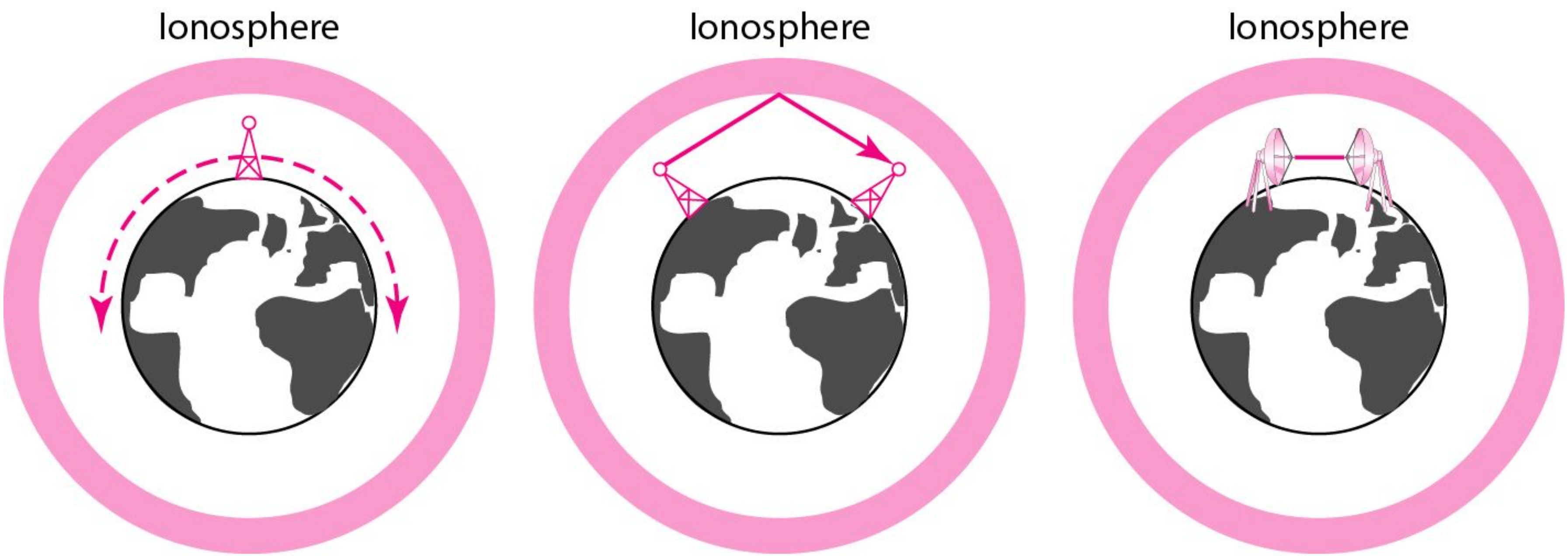
Unguided signals can travel from the source to destination in several ways:

Ground Propagation

Sky Propagation

Line of Sight Propagation

Figure: Propagation methods



Ground propagation (below 2 MHz)

Sky propagation (2–30 MHz)

Line-of-sight propagation (above 30 MHz)

Ground propagation

- Radio waves travel through the lowest point 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 power of the signal. The greater the power, the greater the distance

Sky propagation

- High frequency radio waves radiate upward into the ionosphere where they are reflected back to earth
- Allows greater distances with lower output power

Line-of-sight propagation

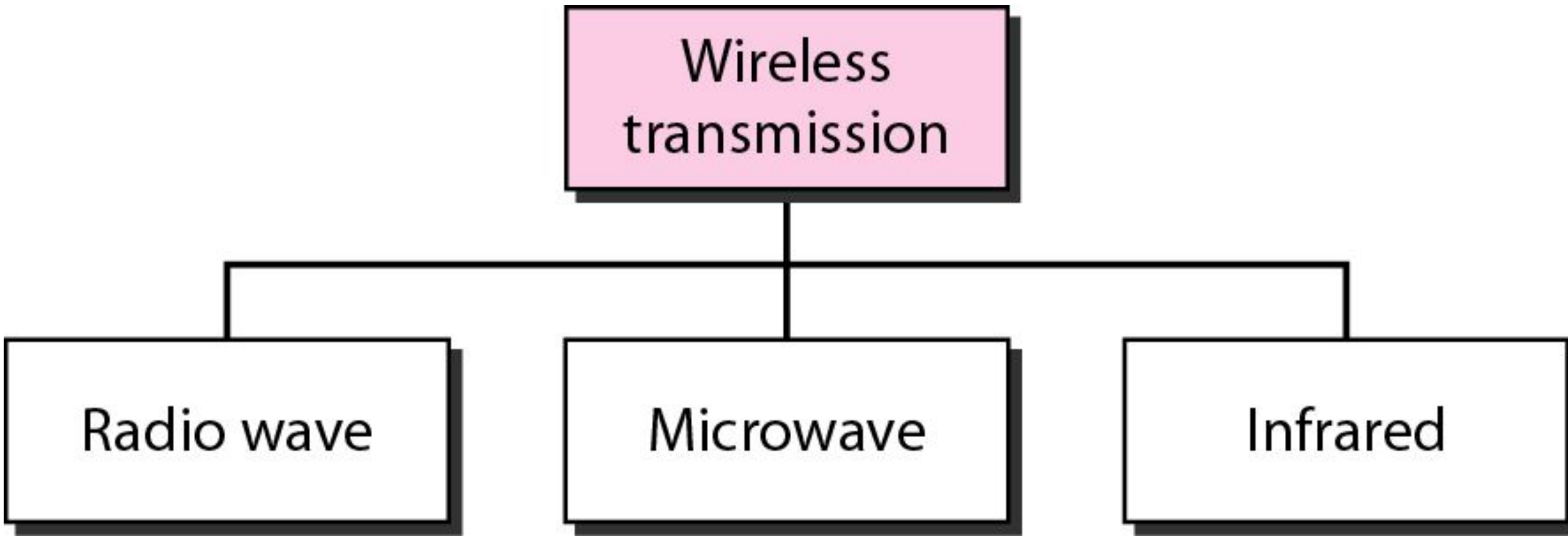
- Very high frequency signals are transmitted in straight lines directly from antenna to antenna
- Antennas must be directional, facing each other, and either tall enough or close enough together to not be affected by the curvature of the earth

Table 7.4 Bands

- The section of the electromagnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called *bands,* each regulated by government authorities. These bands are rated from *very low frequency* (VLF) to *extremely high frequency* (EHF).

Band	*Range*	*Propagation*	*Application*
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

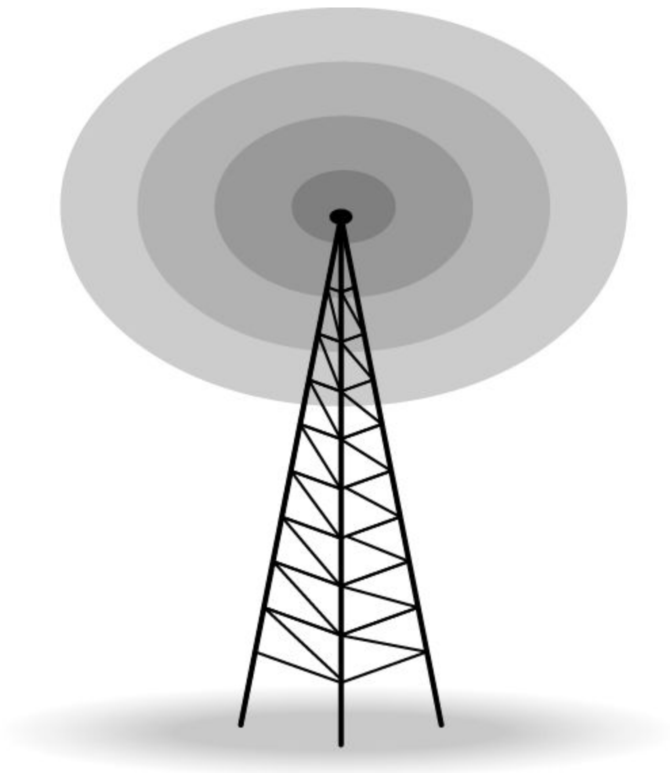
Figure: Wireless transmission waves



Radio Waves

- Frequency range 3kHz -- 1 GHz
- Omnidirectional
- When an antenna propagates radio waves, they are propagated in all directions which can be received by a receiving antenna.
- Radio waves transmitted by one antenna is susceptible to interference by another antenna that may send signals using the same frequency.
- Radio waves, particularly those waves of low and medium frequencies, can penetrate walls.
- Using any part of the band requires permission from the authorities.

Figure: Omnidirectional antenna



Microwaves

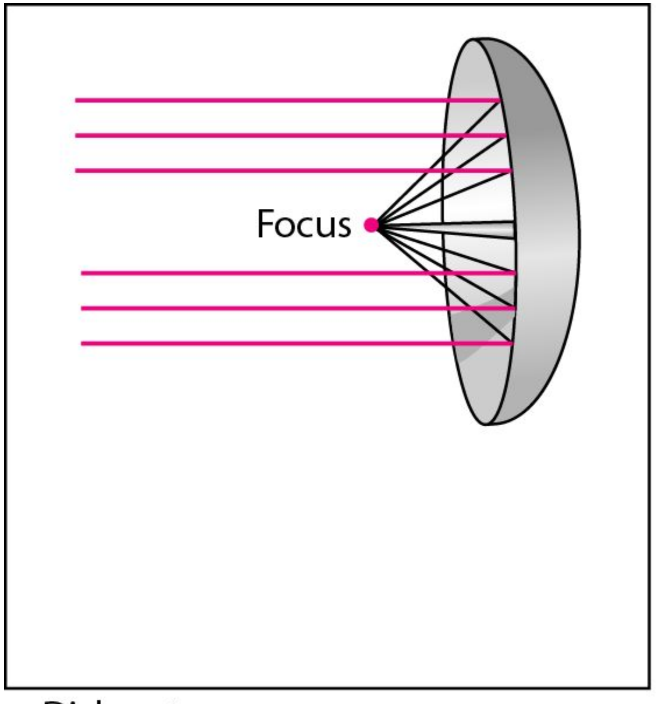
- Microwaves are generally an electromagnetic wave
- Frequencies range 1GHz -- 300 GHz
- Unidirectional
- Microwave propagation is line-of-sight
- Very high frequency microwaves can't penetrate walls
- Microwave band is relatively wide

Two types of microwave data communication system-

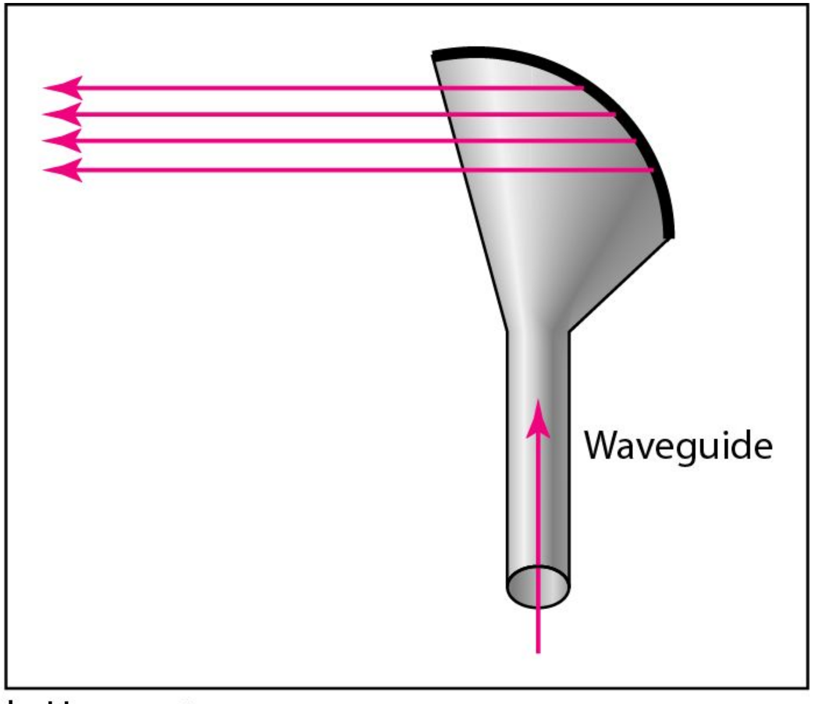
Terrestrial-which transmits the focused beam of a radio signal from one ground-based microwave transmission antenna to another antenna.

Satellite-A microwave transmission system that uses geosynchronous satellites to send and relay signals between sender and receiver

Figure: Unidirectional antennas



a. Dish antenna



b. Horn antenna

Note

Radio waves are used for multicast communications, such as radio and paging systems.

Microwaves are used for unicast communication such as cellular telephones, satellite networks, television, and wireless LANs.

Infrared

- Frequencies from 300Ghz to 400THz
- High frequencies, cannot penetrate walls
- Used for short range communication.

Note

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.


THE
END