Data Communications and Networking Fourth Edition

Forouzan

Chapter 7

Transmission Media

Physical Layer

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

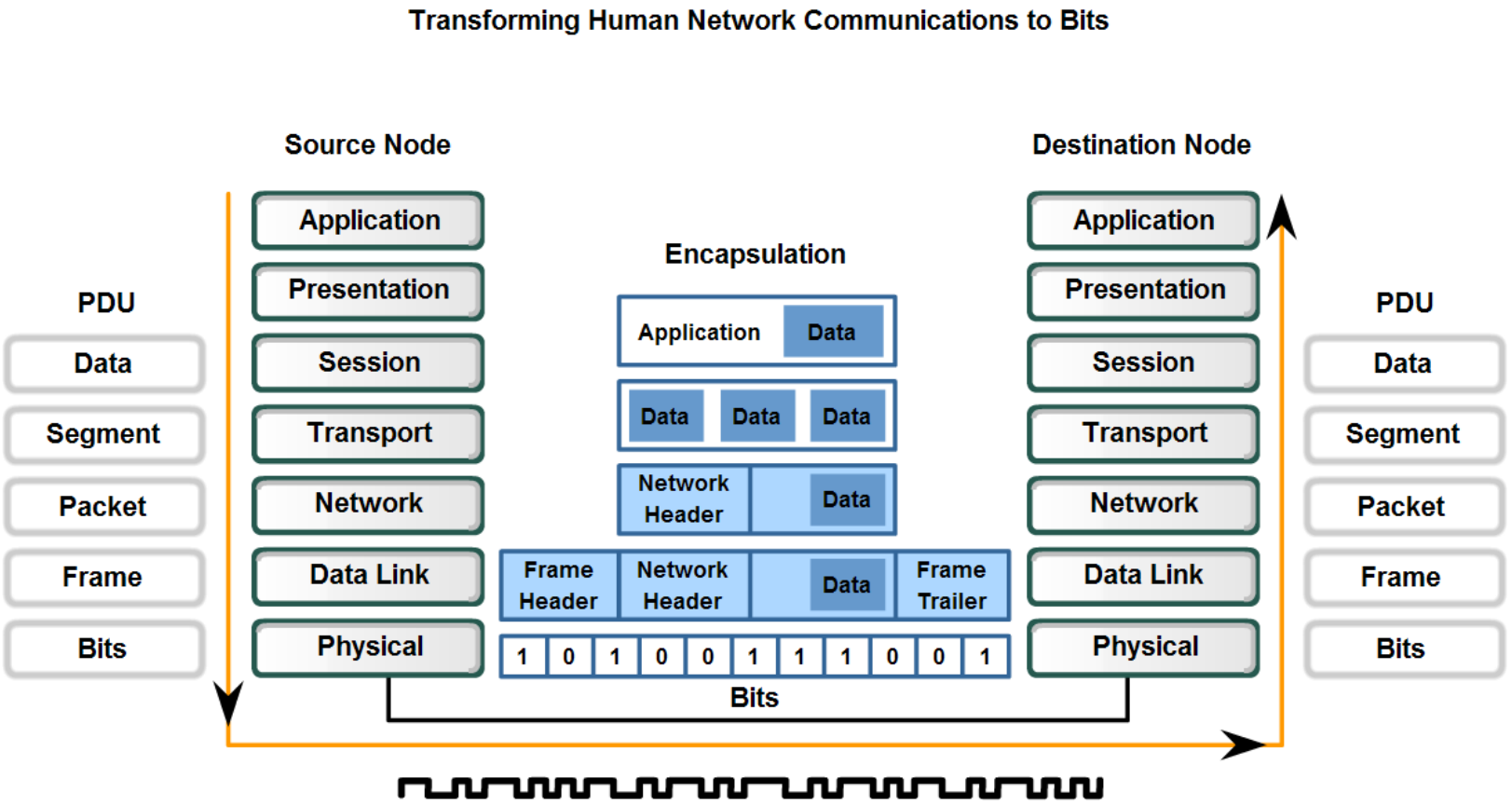
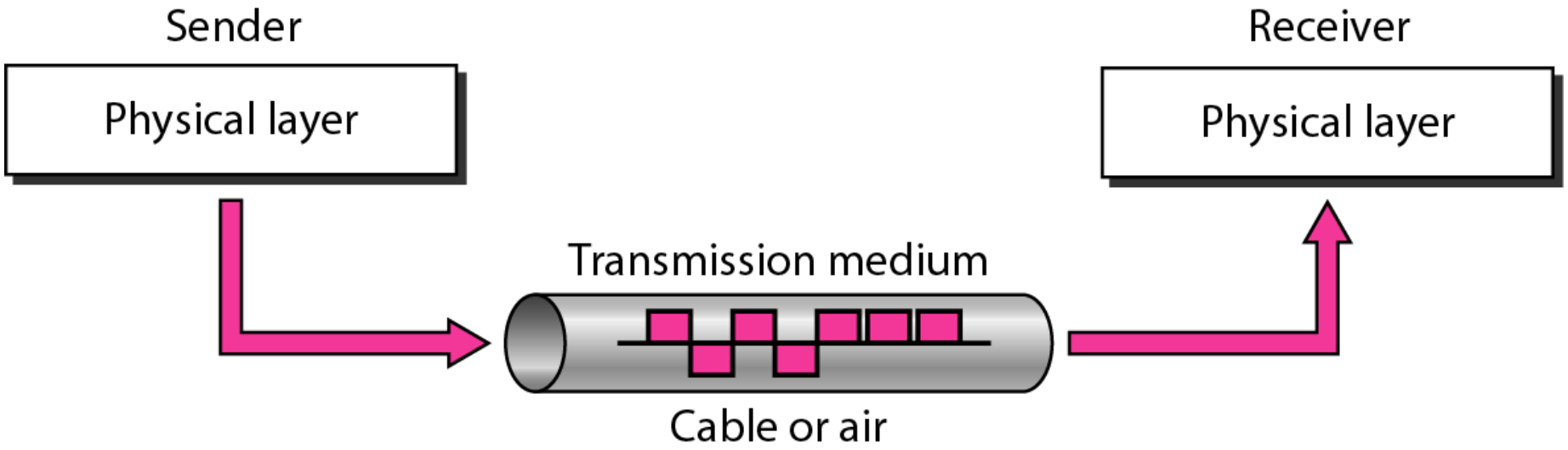


Figure 7.1 *Transmission medium and physical layer*

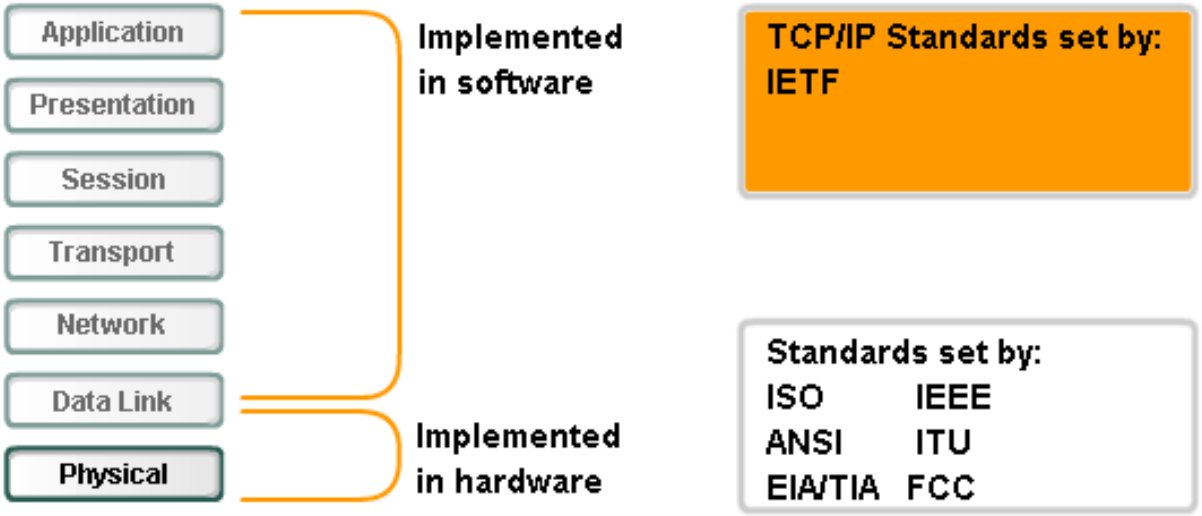
- Transmission media are located below the physical layer and directly controlled by the physical layer.



Physical Layer Elements

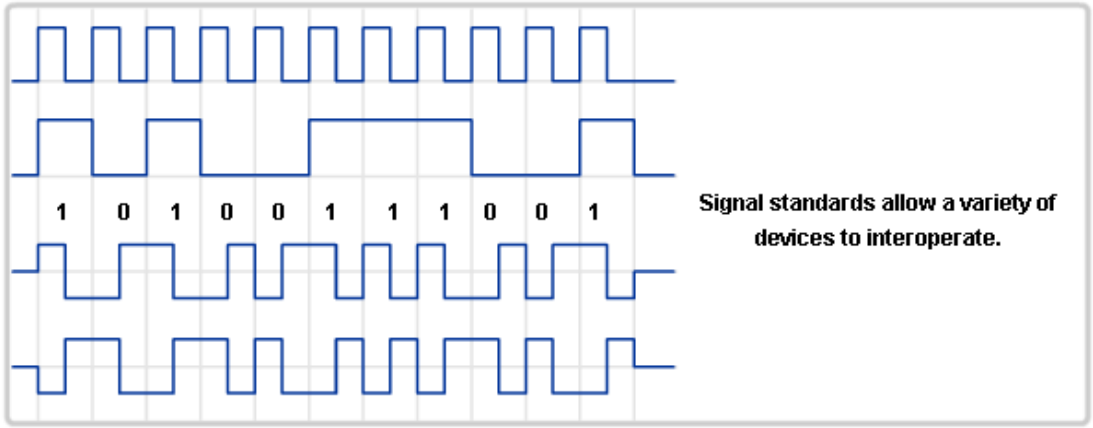
- Requires:
  - Primary Purpose:
    A representation of the bits of a frame on the media in the form of signals.
  - The physical media and associated connectors.
  - Encoding of data and control information.
  - Transmitter and receiver circuitry on the network devices.

Standards

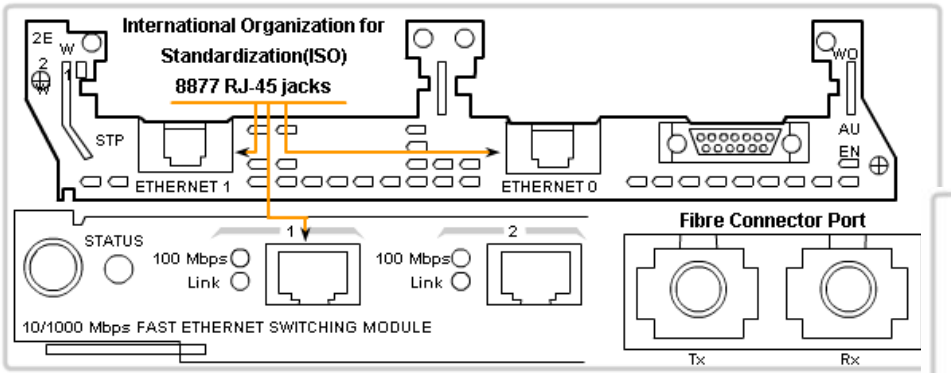


- Physical layer standards:
  - Physical and electrical properties of the media
  - Mechanical properties (materials, dimensions, pinouts) of the connectors
  - Bit representation by the signals (encoding)
  - Definition of control information signals

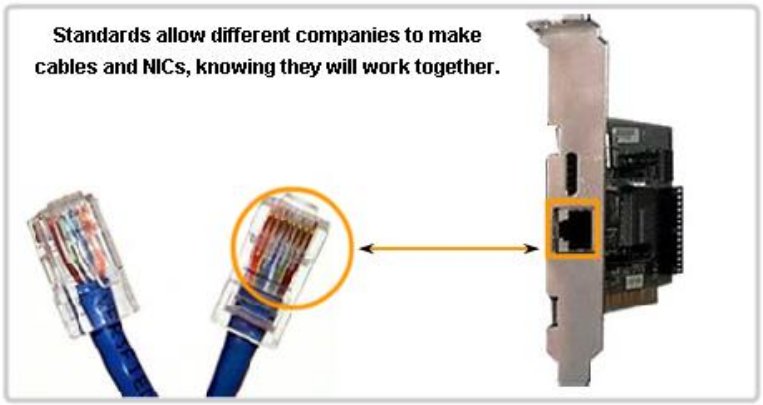
Standards



- Signals

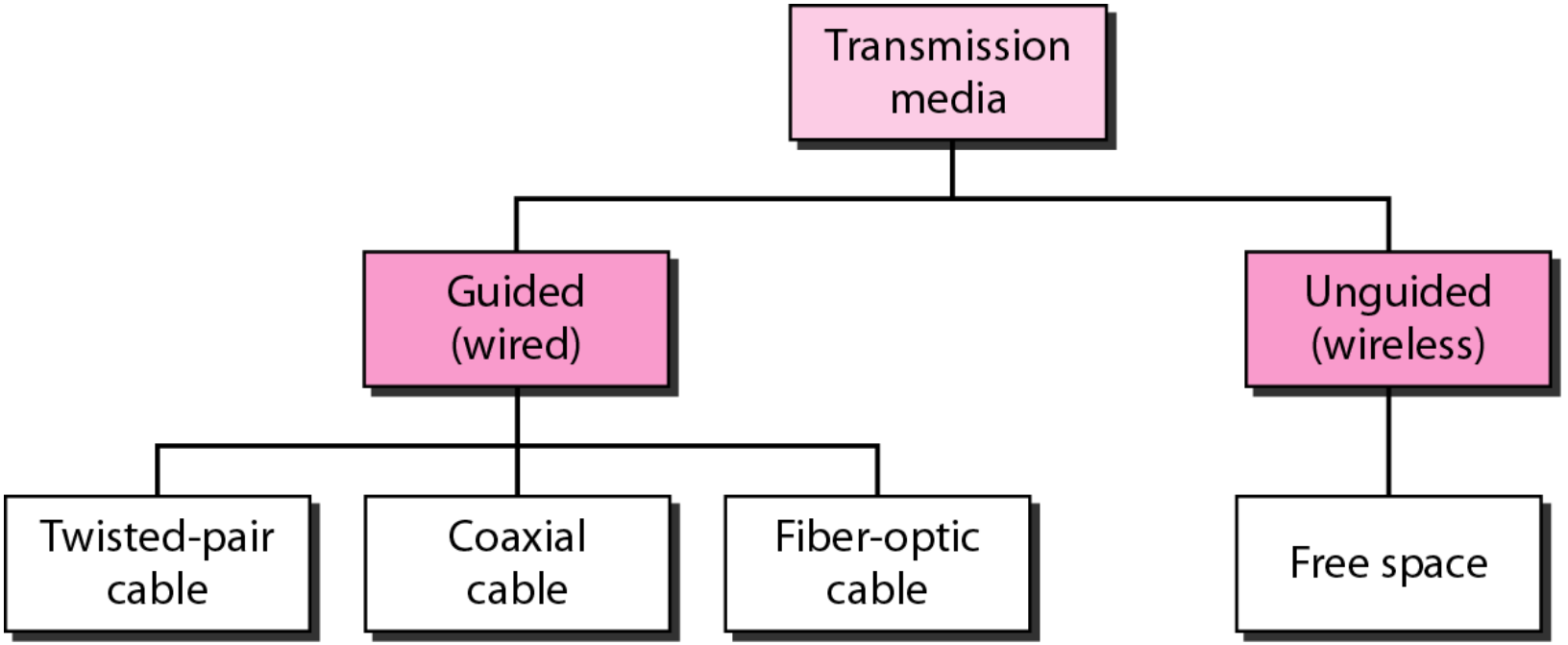


- **Connectors**



- **Cables**

Figure 7.2 *Classes of transmission media*



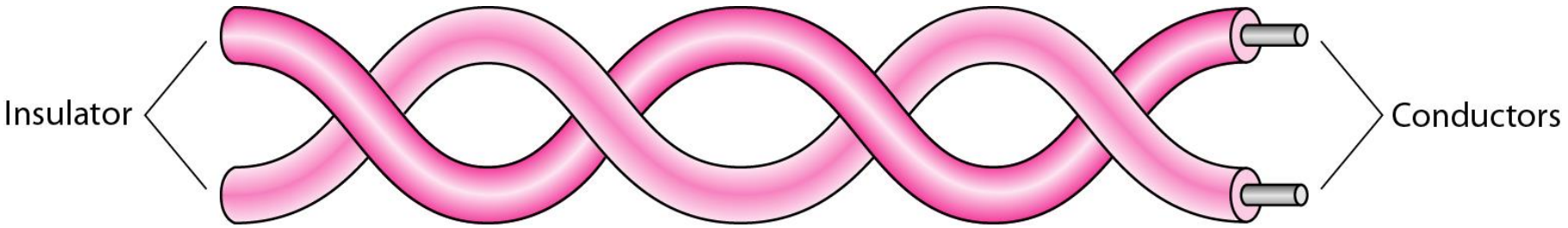
7-1 GUIDED MEDIA

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

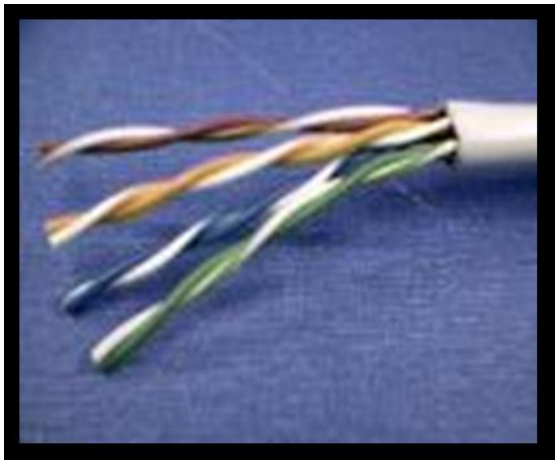
Topics discussed in this section:

Twisted-Pair Cable
Coaxial Cable
Fiber-Optic Cable

Figure 7.3 *Twisted-pair cable*

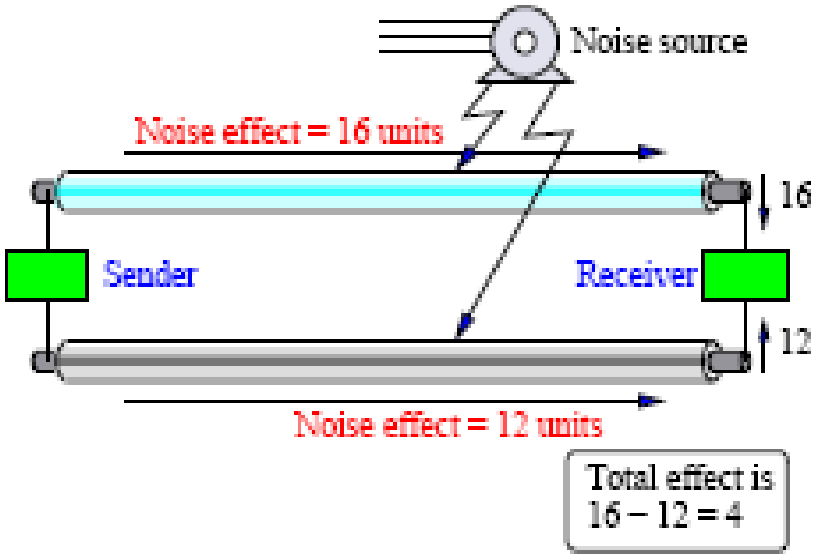


- Two separately insulated copper wires twisted together
- Often "bundled" into cables.



Effect of Noise on Parallel and Twisted-Pair Lines

- Twisting allows each wire to have approximately the same noise level and reduces crosstalk.



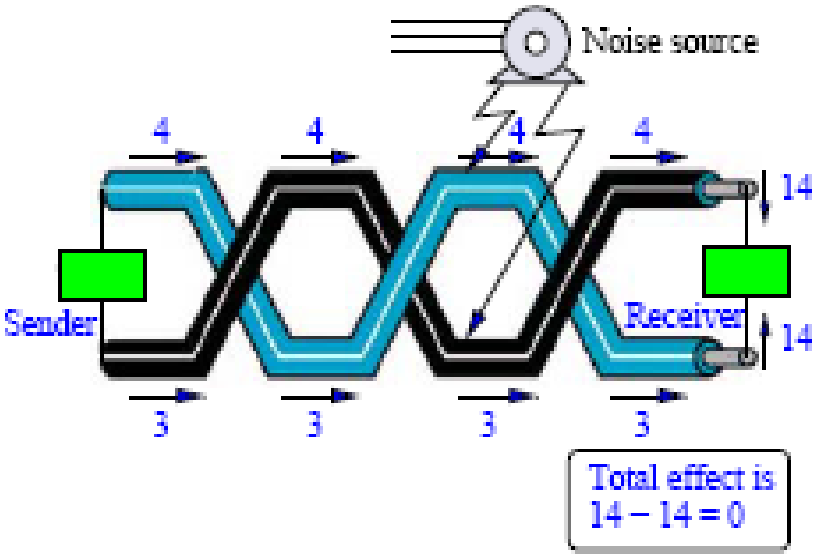
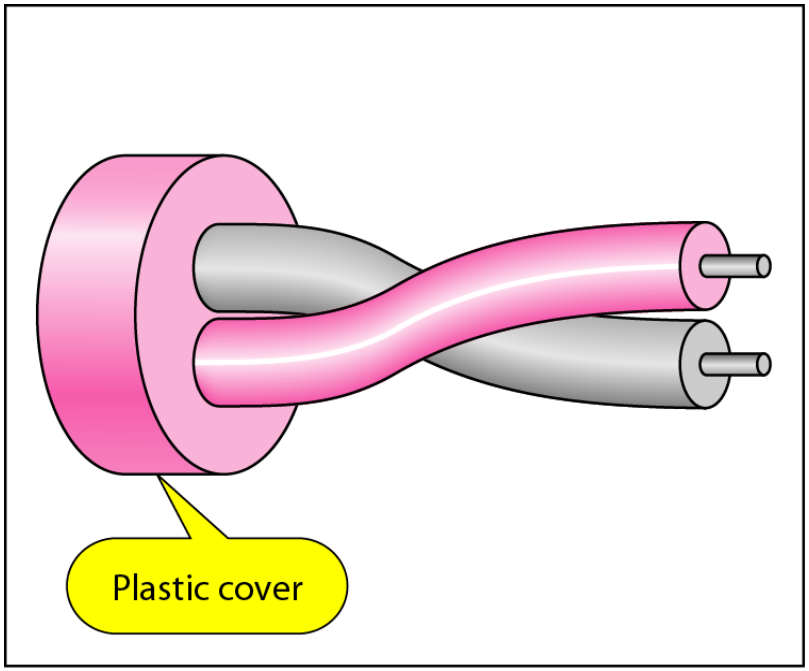
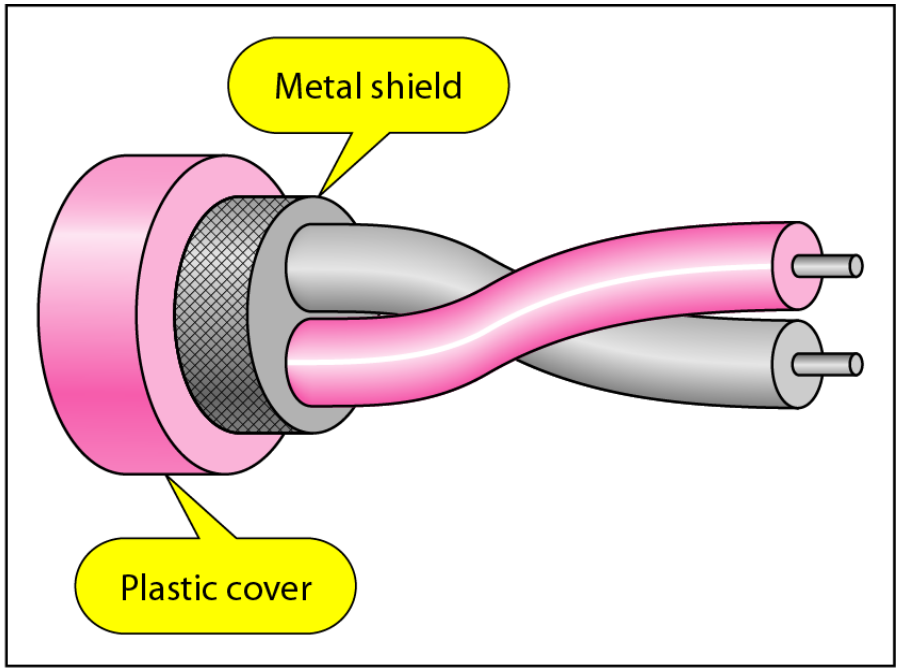


Figure 7.4 *UTP and STP cables*



a. UTP

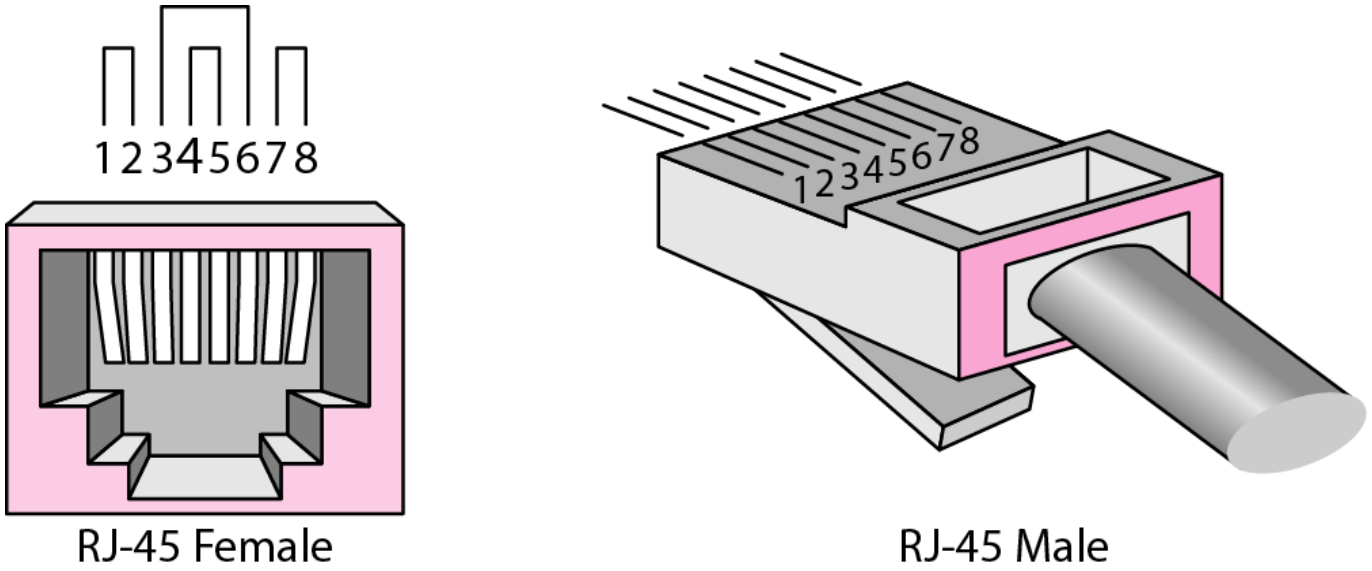


b. STP

Table 7.1 *Categories of unshielded twisted-pair cables*

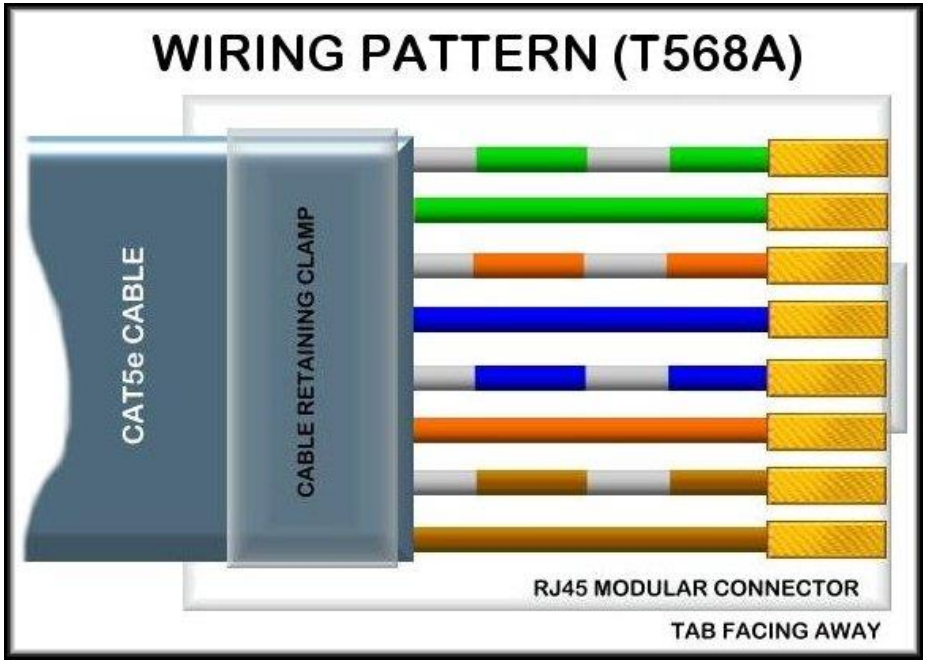
Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with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

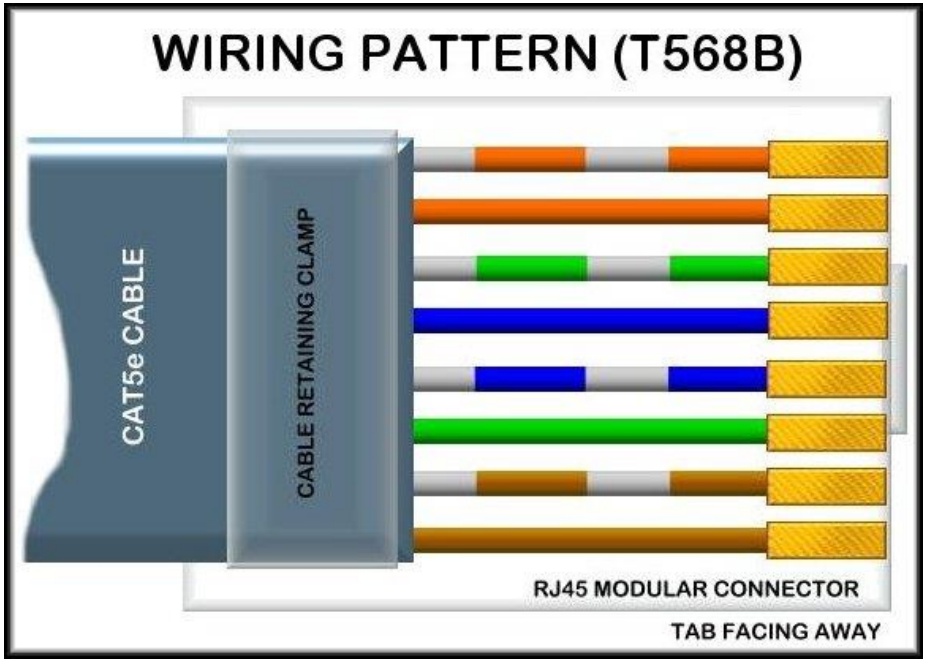
Figure 7.5 *UTP connector*

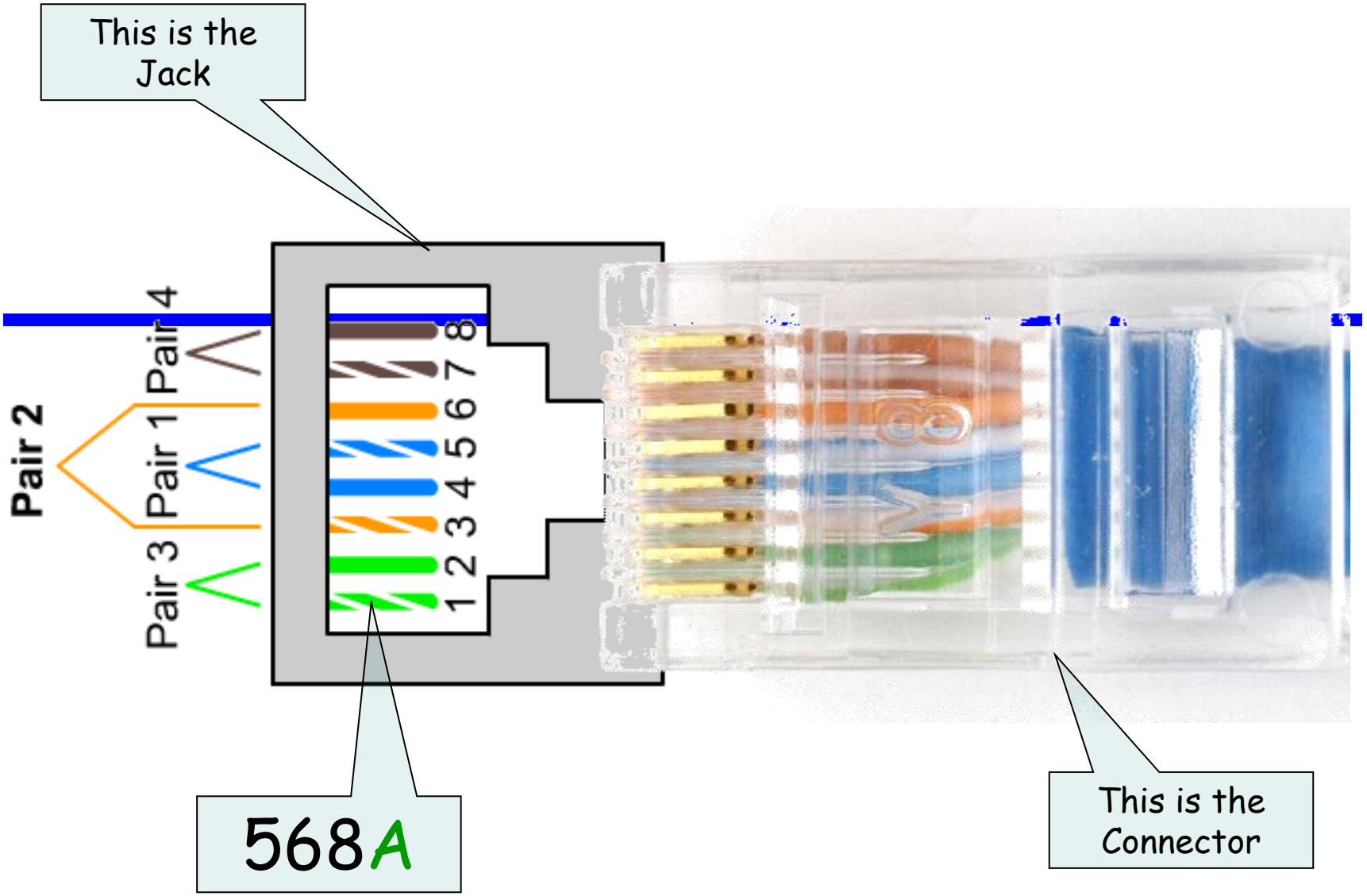


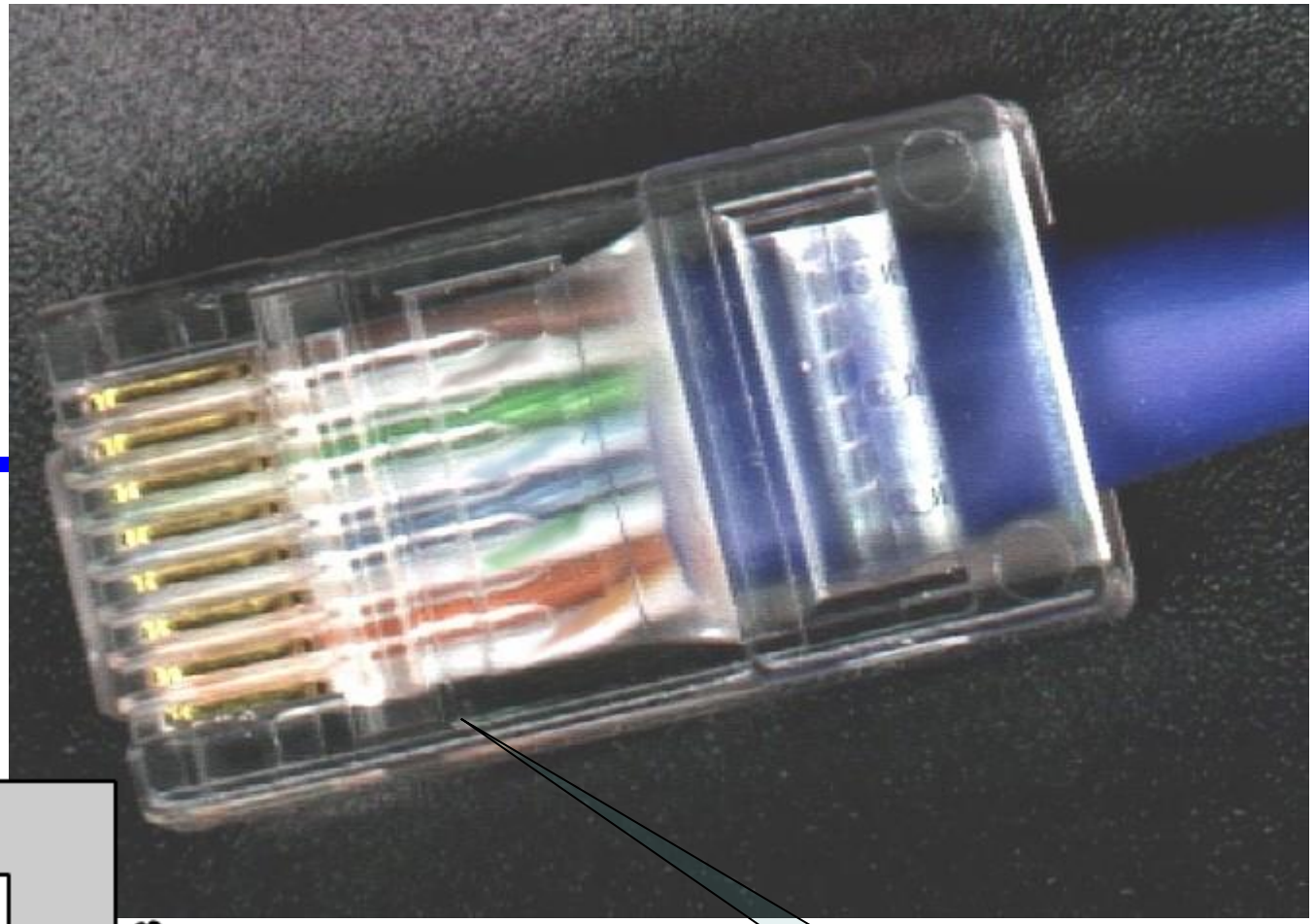
UTP Cable

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






This is the Jack
Pair 4
Pair 2
Pair 1
Pair 3
1 2 3 4 5 6 7 8
568A
This is the Connector



This is the Jack

Pair 3

Pair 2

Pair 1

Pair 4

1 2 3 4 5 6 7 8

T568B

568B

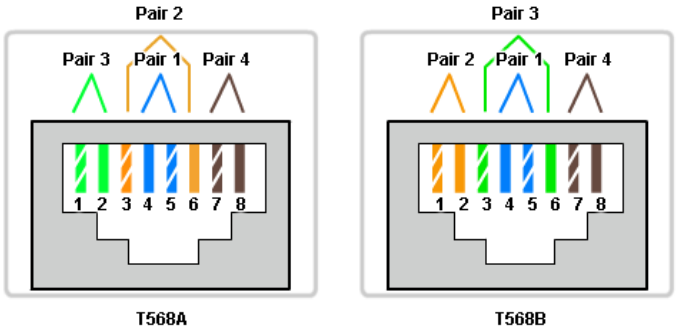
This is the Connector

UTP Cable Types

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

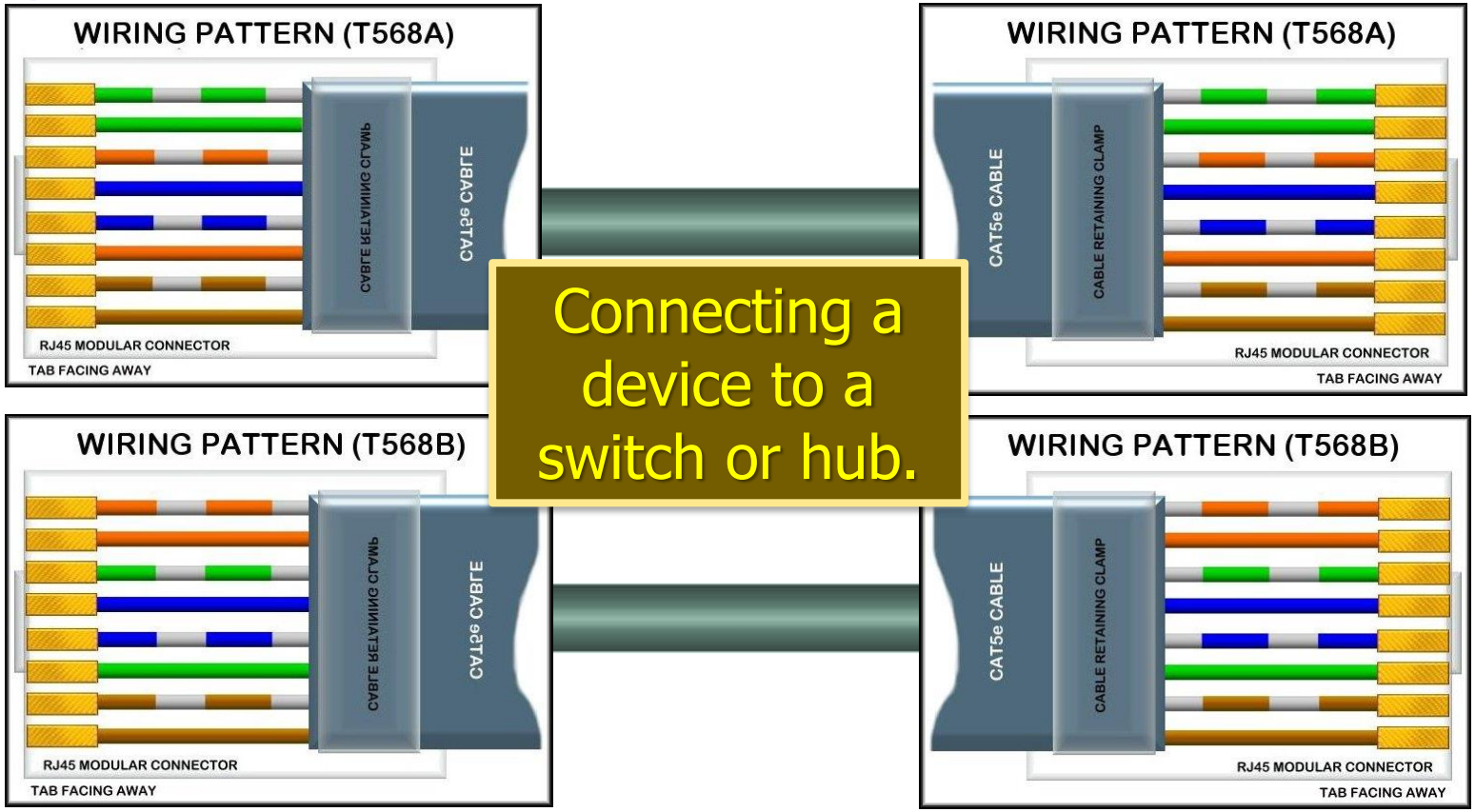
Straight-through, Crossover, and Rollover Cable Types

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.



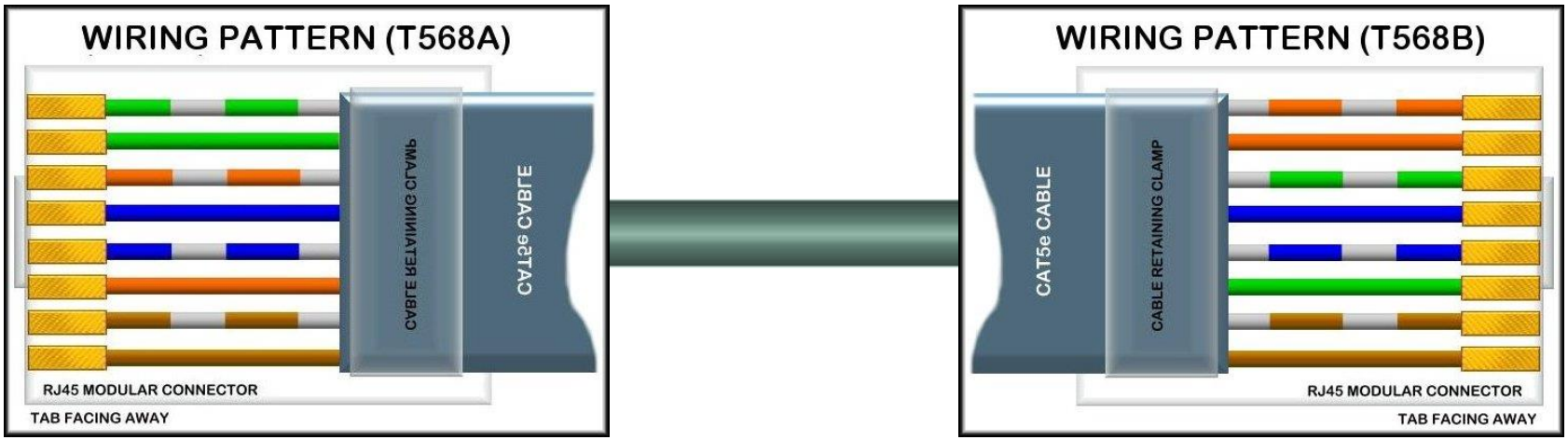
UTP Cable Types

- 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

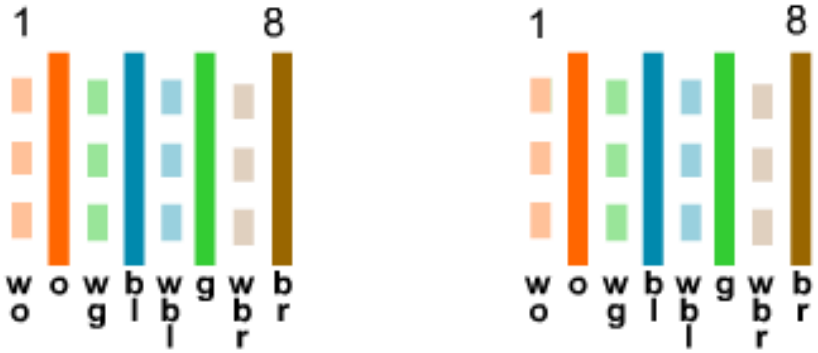


UTP Implementation - Straight-Through

FIGURES

1 2 3 4 5 6 7 8

Pin	Label
1	TD+
2	TD-
3	RD+
4	NC
5	NC
6	RD-
7	NC
8	NC

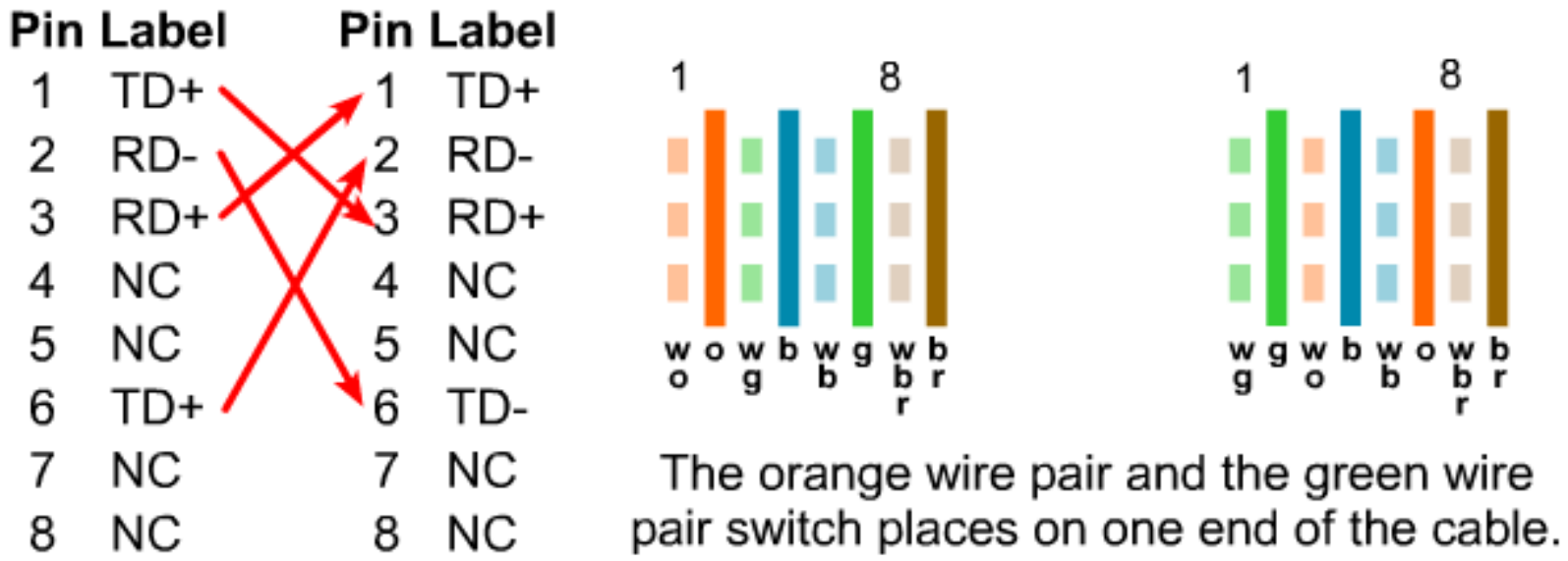


Wires on cable ends are in same order.

Interconnecting Devices Using Crossover Cable

FIGURES

1 2 3 4 5 6 7 8



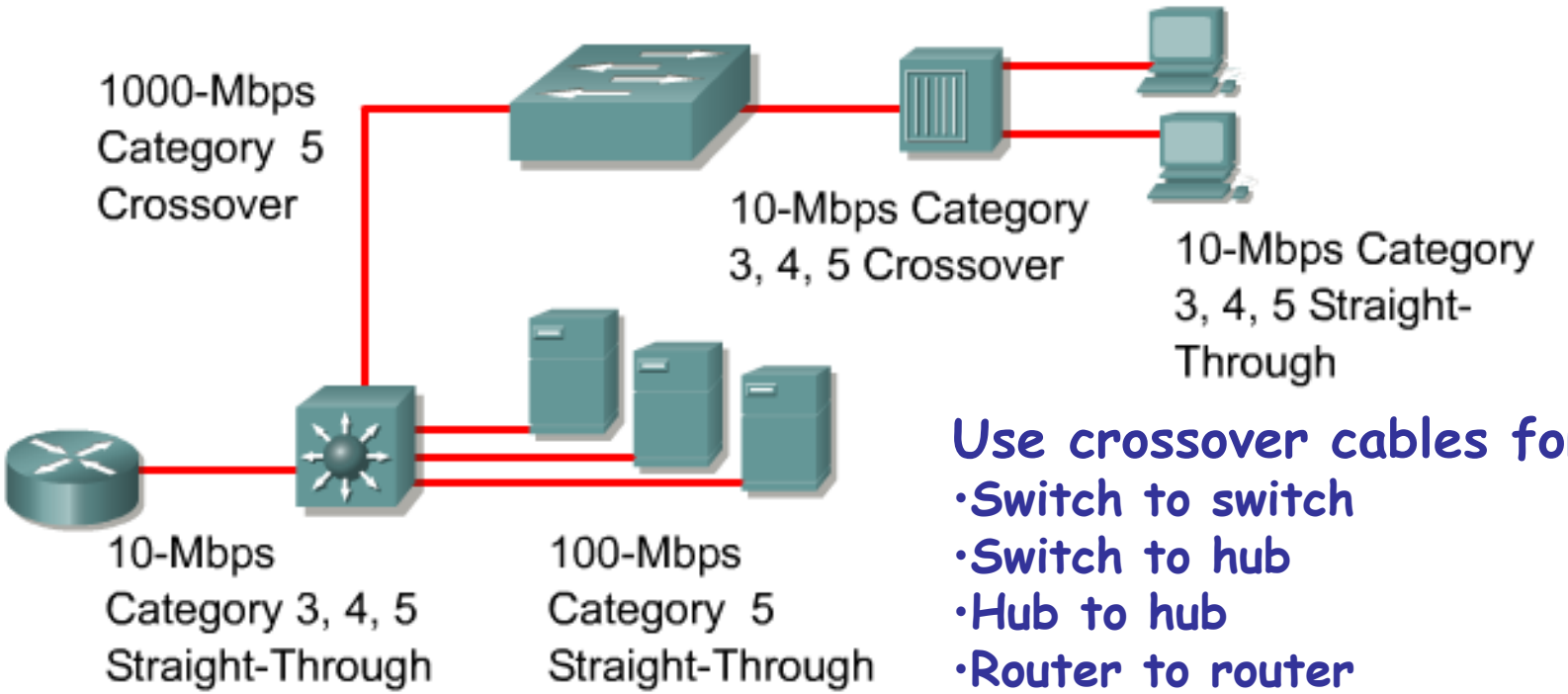
Interconnecting Devices Using Crossover Cable

FIGURES

1 2 3 4 5 6 7 8

Use straight-through cables for…

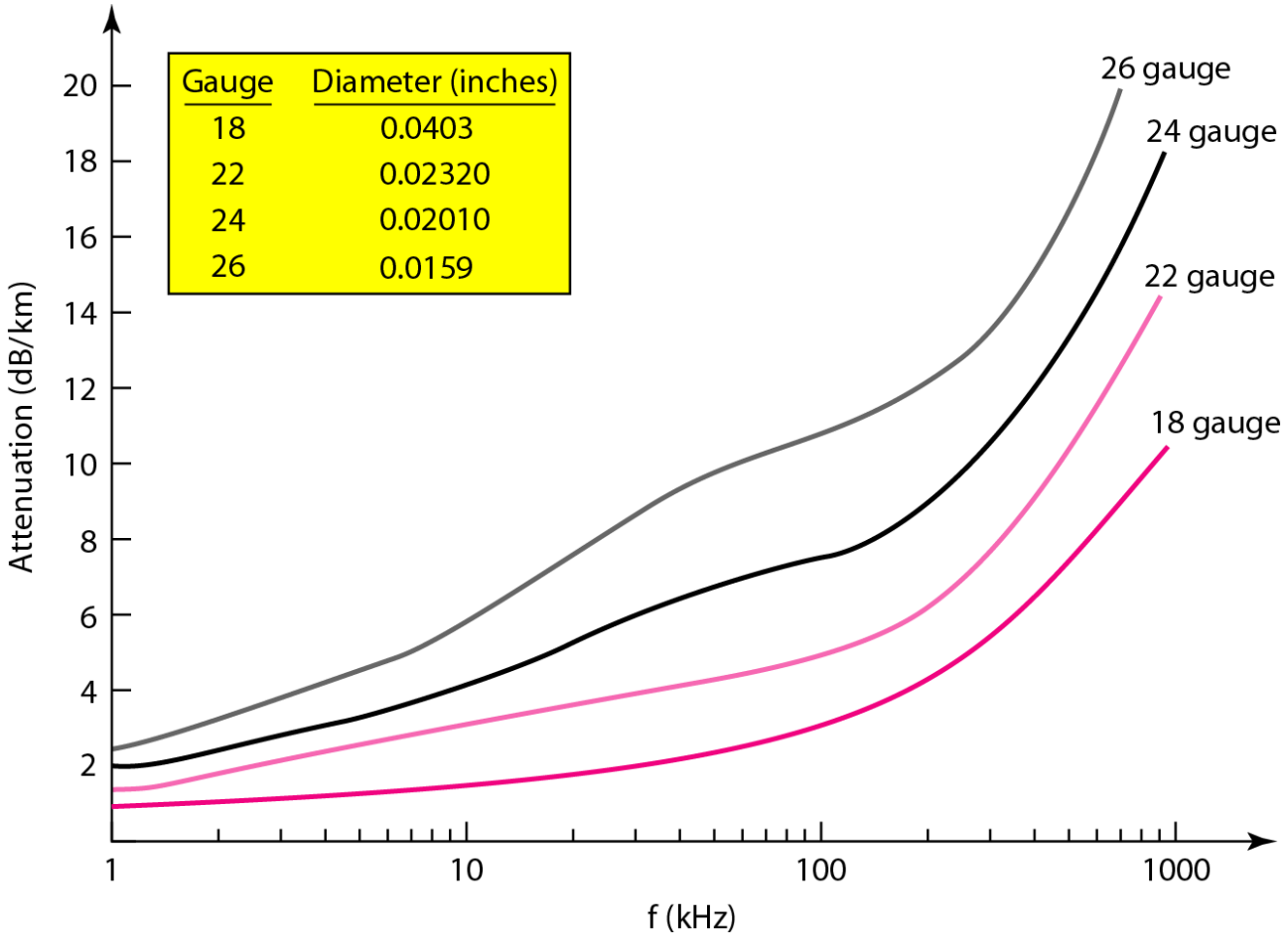
- Switch to router
- Switch to PC or server
- Hub to PC or server



Use crossover cables for…

- Switch to switch
- Switch to hub
- Hub to hub
- Router to router
- PC to PC
- Router to PC

Figure 7.6 *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

Figure 7.7 *Coaxial cable*

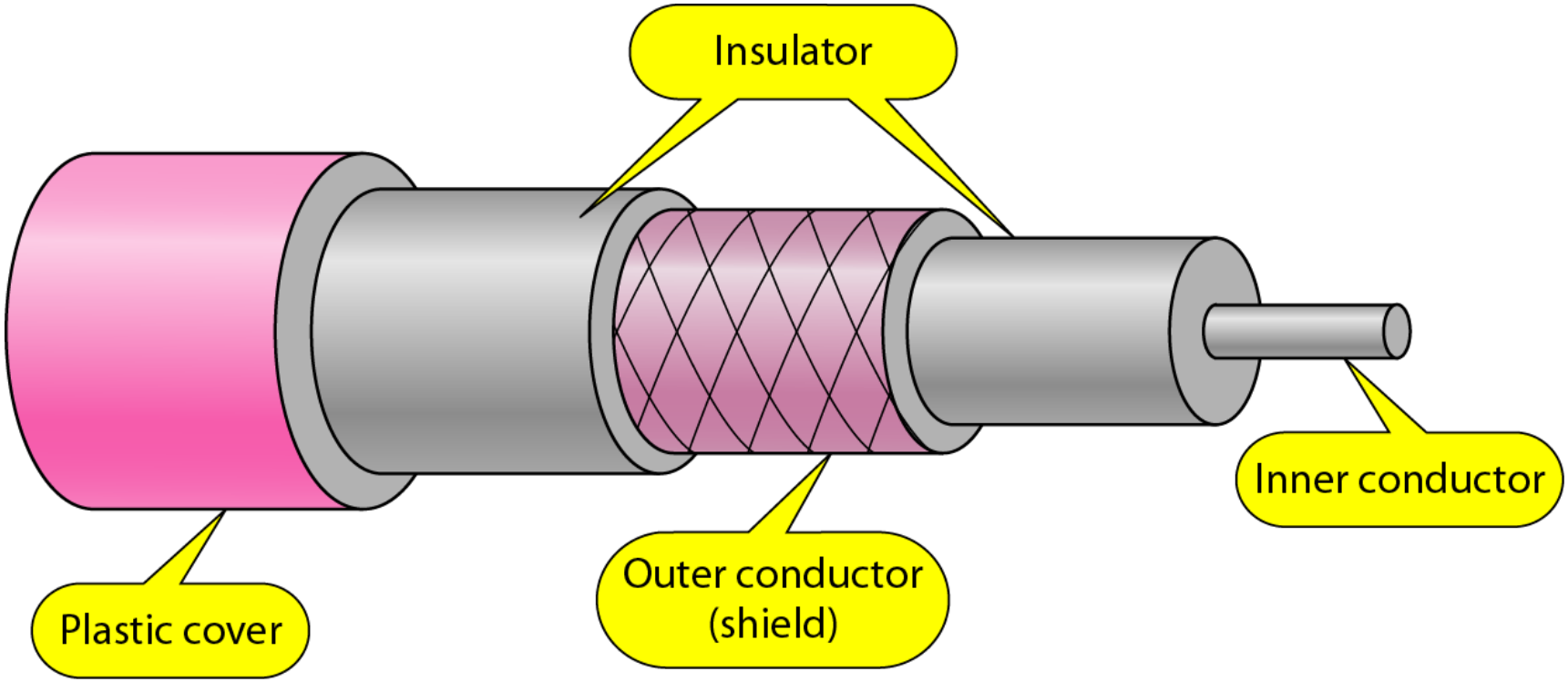


Table 7.2 *Categories of coaxial cables*

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

Figure 7.8 *BNC connectors*

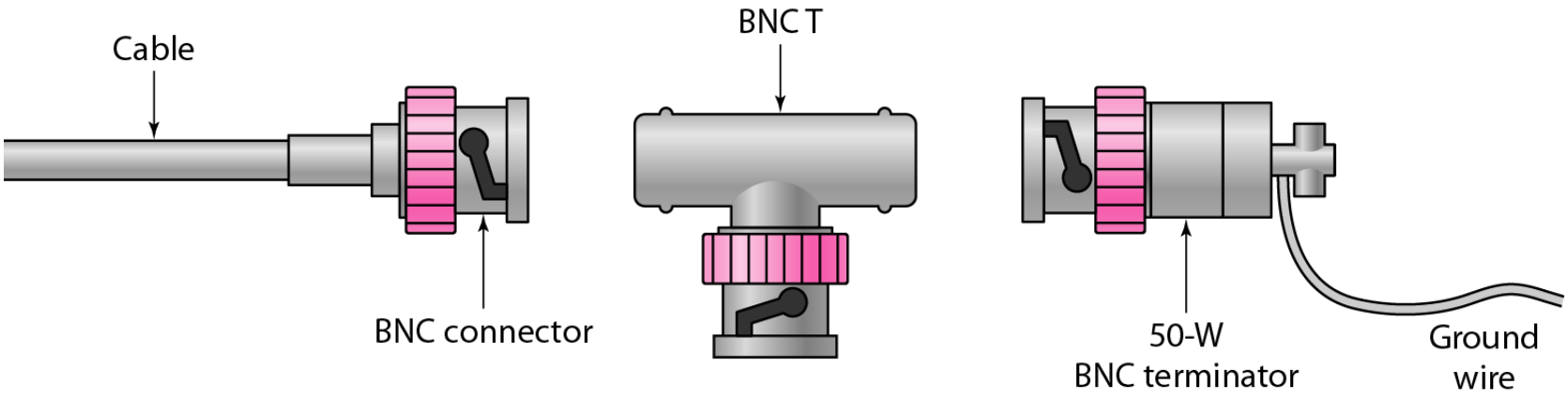
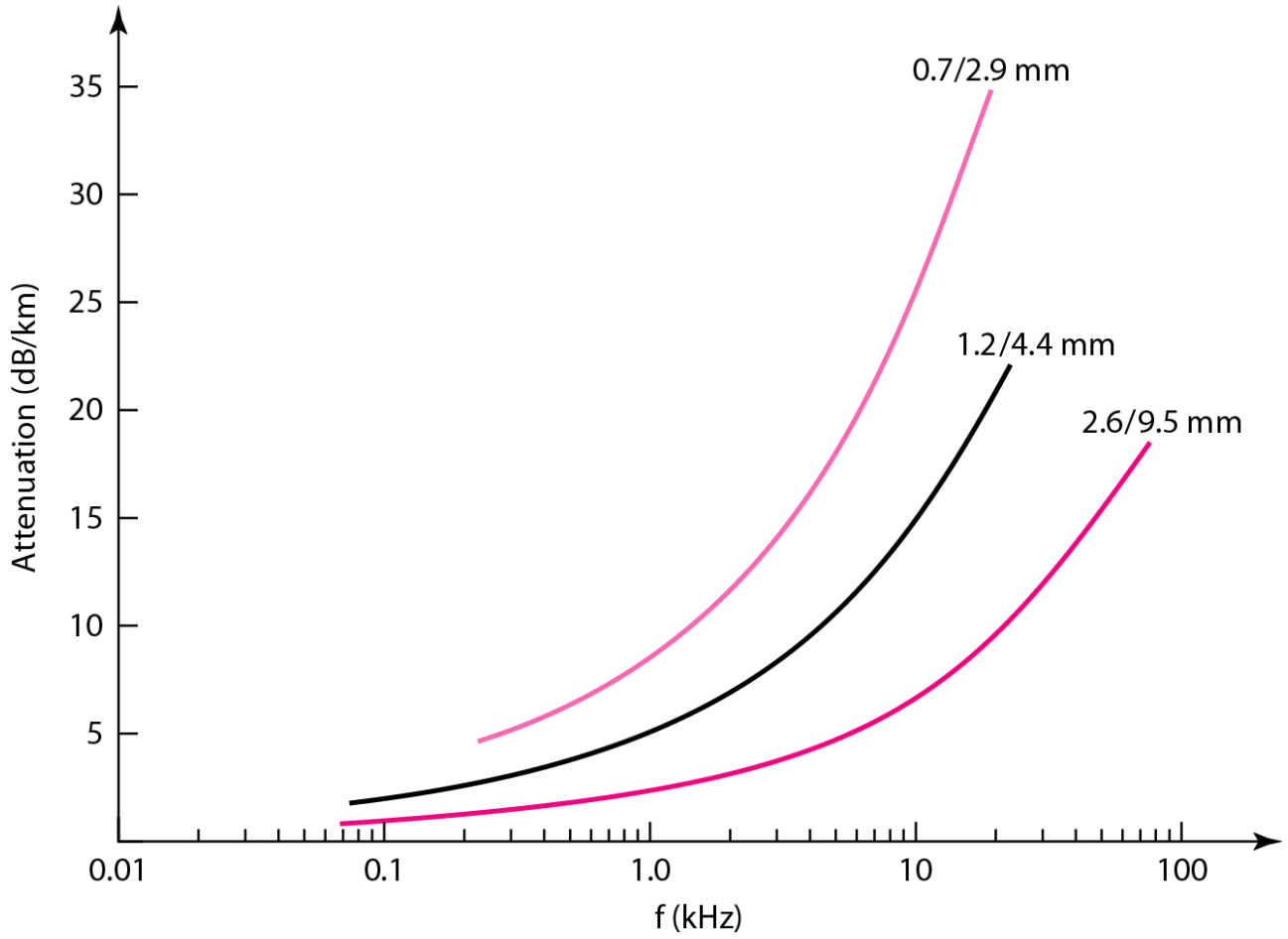
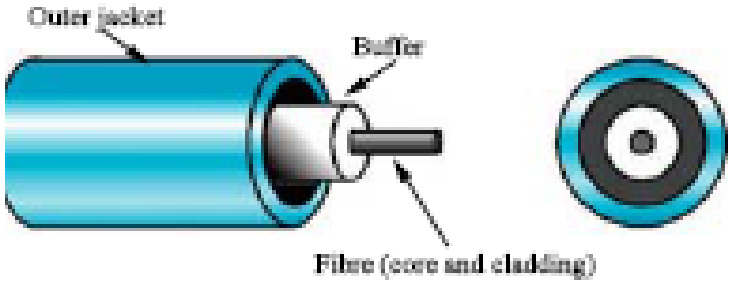
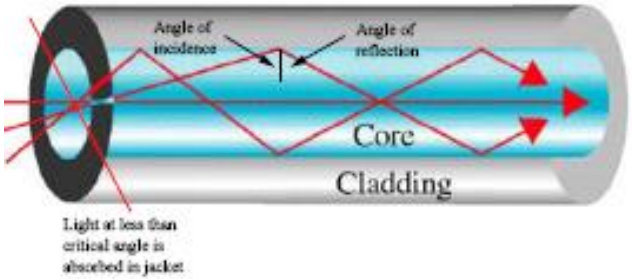


Figure 7.9 *Coaxial cable performance*



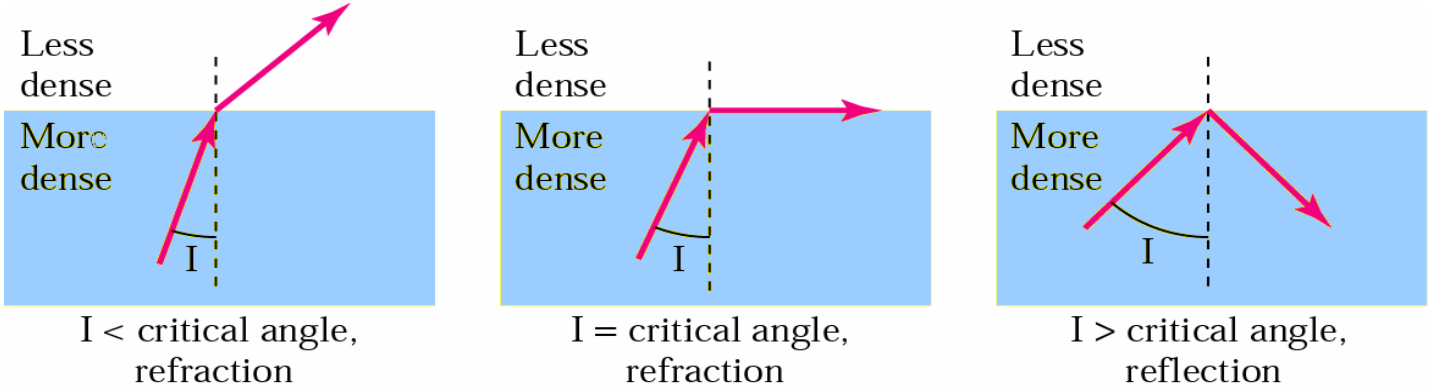
Fiber Optic Cable

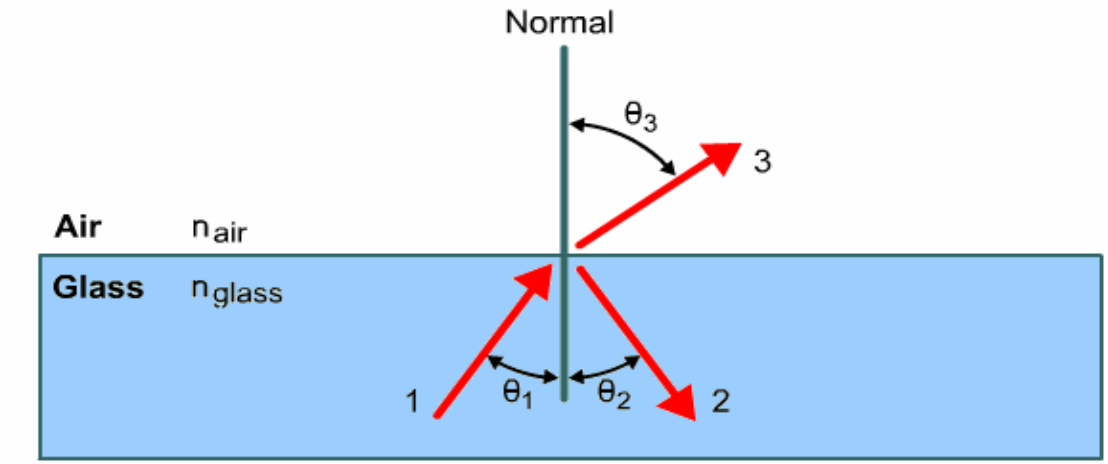




- Physical description:
  - Fiber optic cable is made of glass/plastic and transmit signal in form of light
  - ***Optical Signal*** is carried by photon pulses through thin (8 to 10 microns) ***glass*** strands (optical fibers)
  - light waves are produced either by Light emitting diodes (LEDs) or injection ***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***.

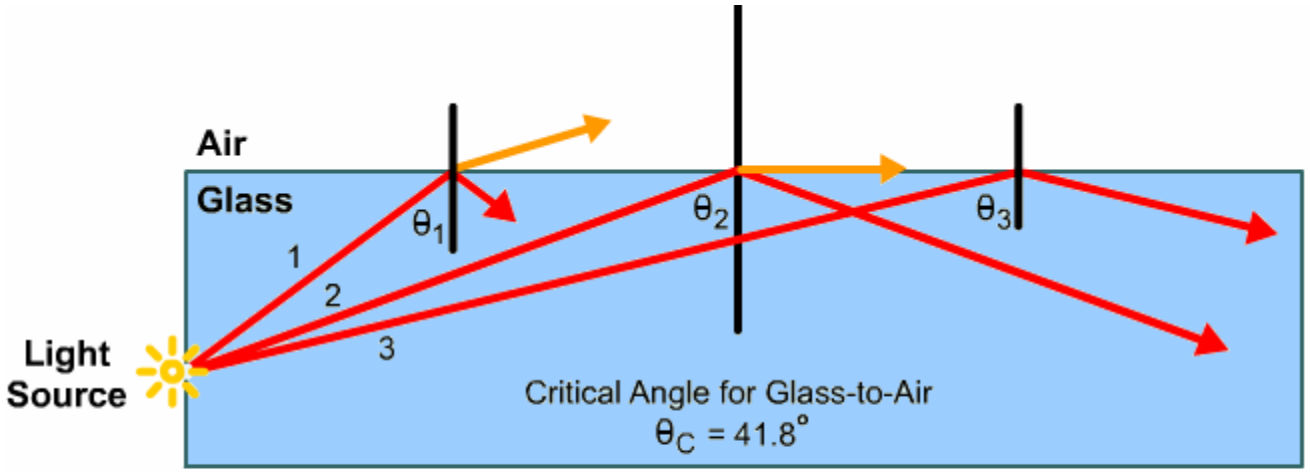
Bending of light ray



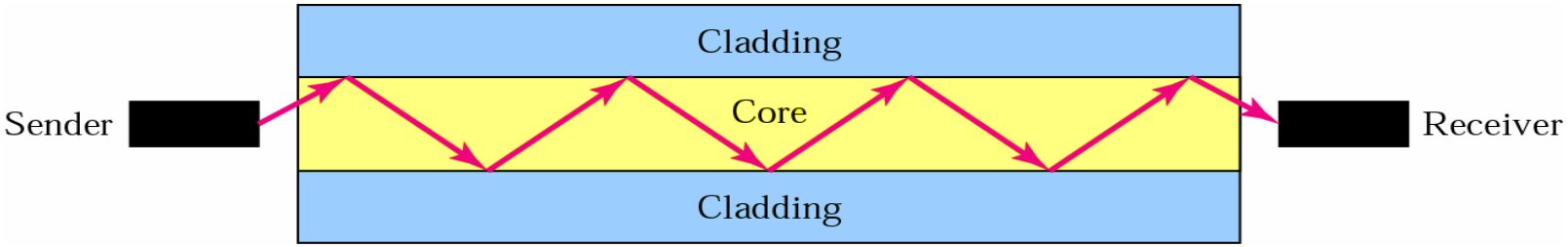


Ray 1: Incident ray
Ray 2: Reflected ray
Ray 3: Refracted ray
Law of Reflection: $\theta_1 = \theta_2$
Law of Refraction: since $n_{glass} > n_{air}$, $\theta_3 > \theta_1$

Optical fiber



Ray 1: $\theta_1 < \theta_C$, so ray reflects and refracts
Ray 2: $\theta_2 = \theta_C$, so ray reflects and refracts
Ray 3: $\theta_3 > \theta_C$, so ray is totally internally reflected



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
- Immunity to corrosive materials
- More immune to tapping

Challenges

- More expensive (usually) than copper media over the same distance (but for a higher capacity)
- Different skills and equipment required to terminate and splice the cable infrastructure
- More careful handling than copper media

Optical Fiber - Applications

- **Long-haul trunks**

  - about 1500 km in length & 20,000-60,000 voice channels.

  - undersea optical fiber

- **Metropolitan trunks.**

  - about 12 km in length & 100,000 voice channels.

  - underground conduits joining telephone exchanges.

- **Rural exchange trunks.**

  - about 40 – 160 km in length & less than 5000 voice channels.

- **Subscriber loops.**

  - handling voice, data, image and video.

- **LANs.**

  - Capacity of 100 Mbps to 1 Gbps.

Fiber Optic Cable

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

Figure 7.12 *Propagation modes*

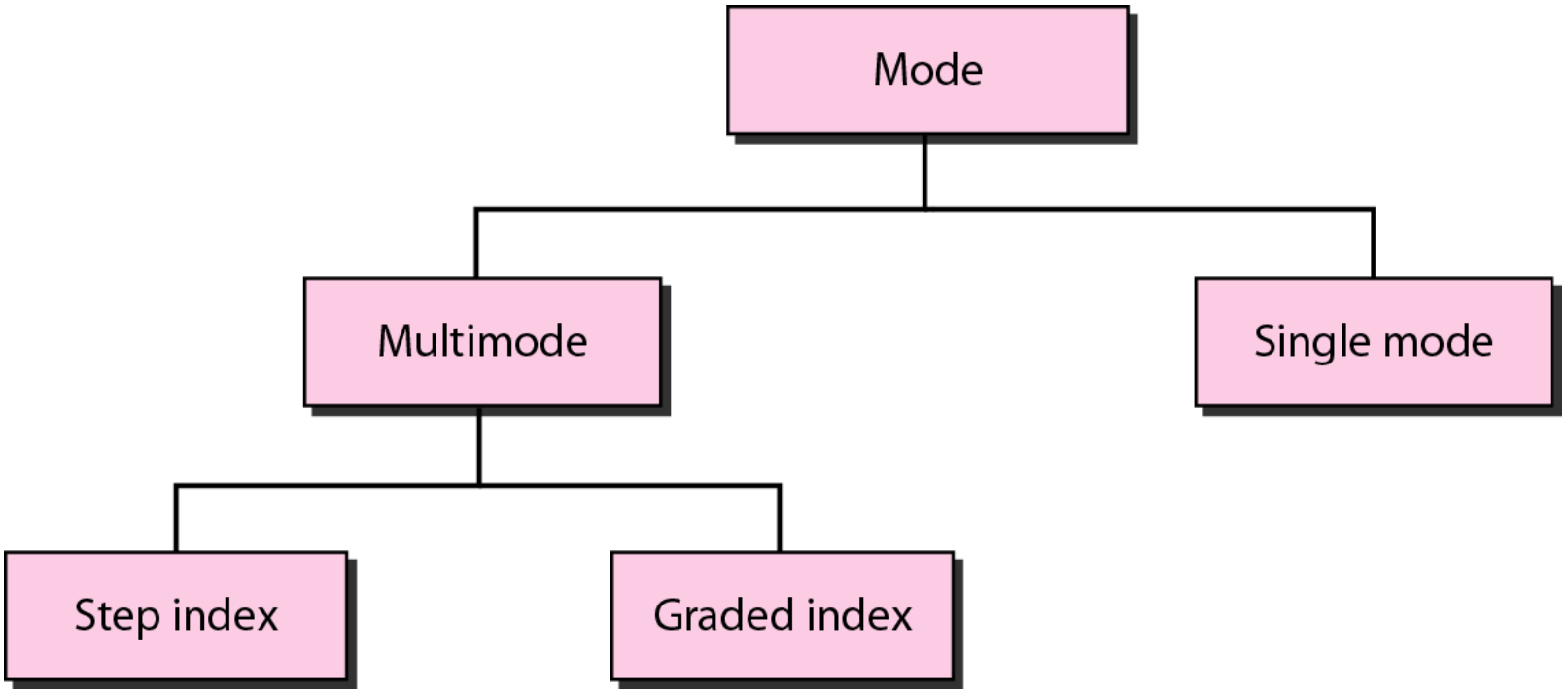
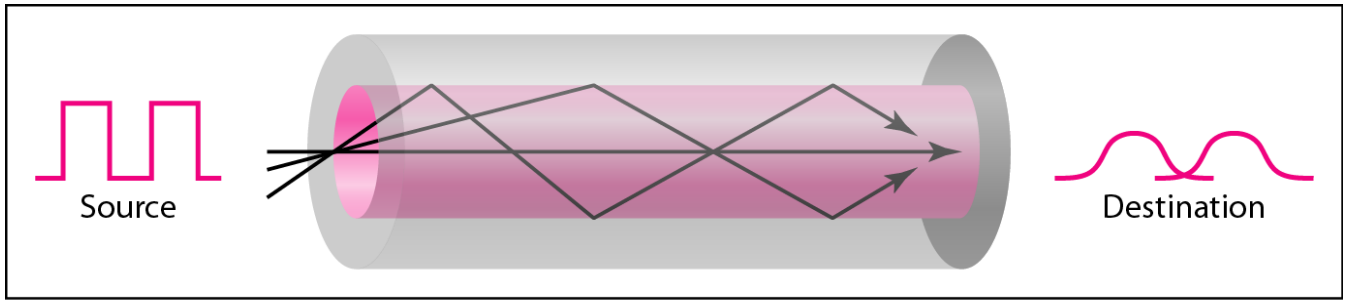
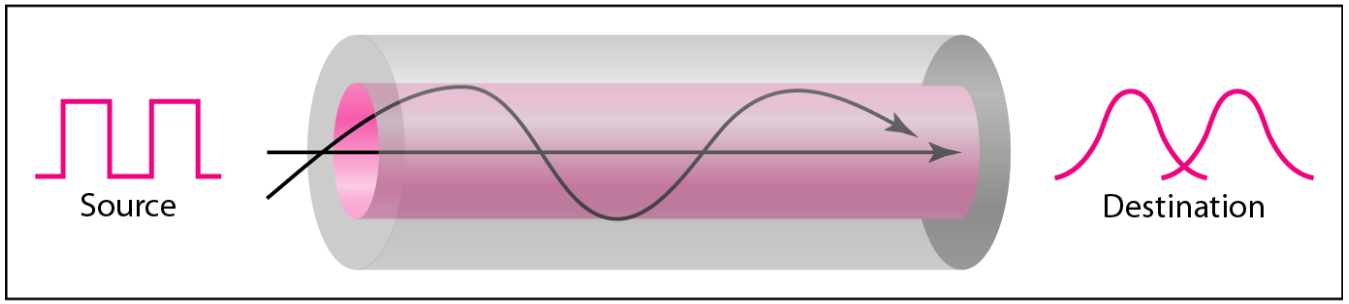


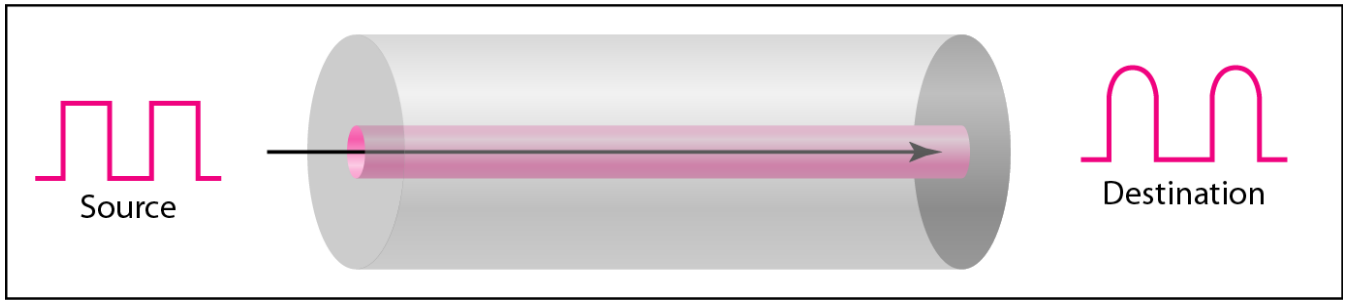
Figure 7.13 *Modes*



a. Multimode, step index



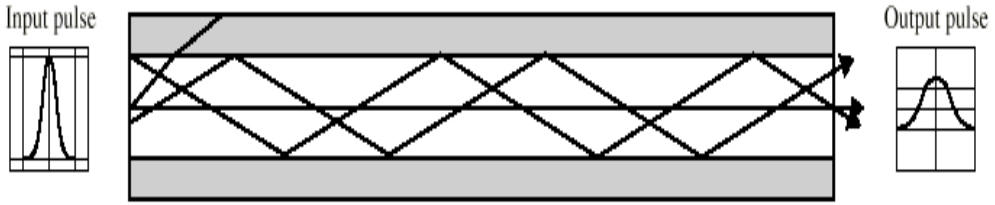
b. Multimode, graded index



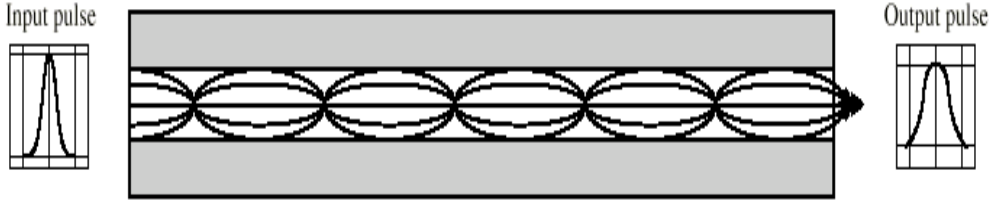
c. Single mode

Optical Fiber Transmission Modes

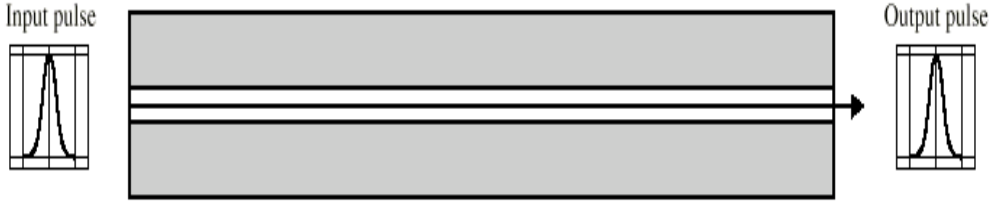
- multimode step-index fiber
  - the reflective walls of the fiber move the light pulses to the receiver
- multimode graded-index fiber
  - acts to refract the light toward the center of the fiber by variations in the density
- single mode fiber
  - the light is guided down the center of an extremely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



(a) Step-index multimode

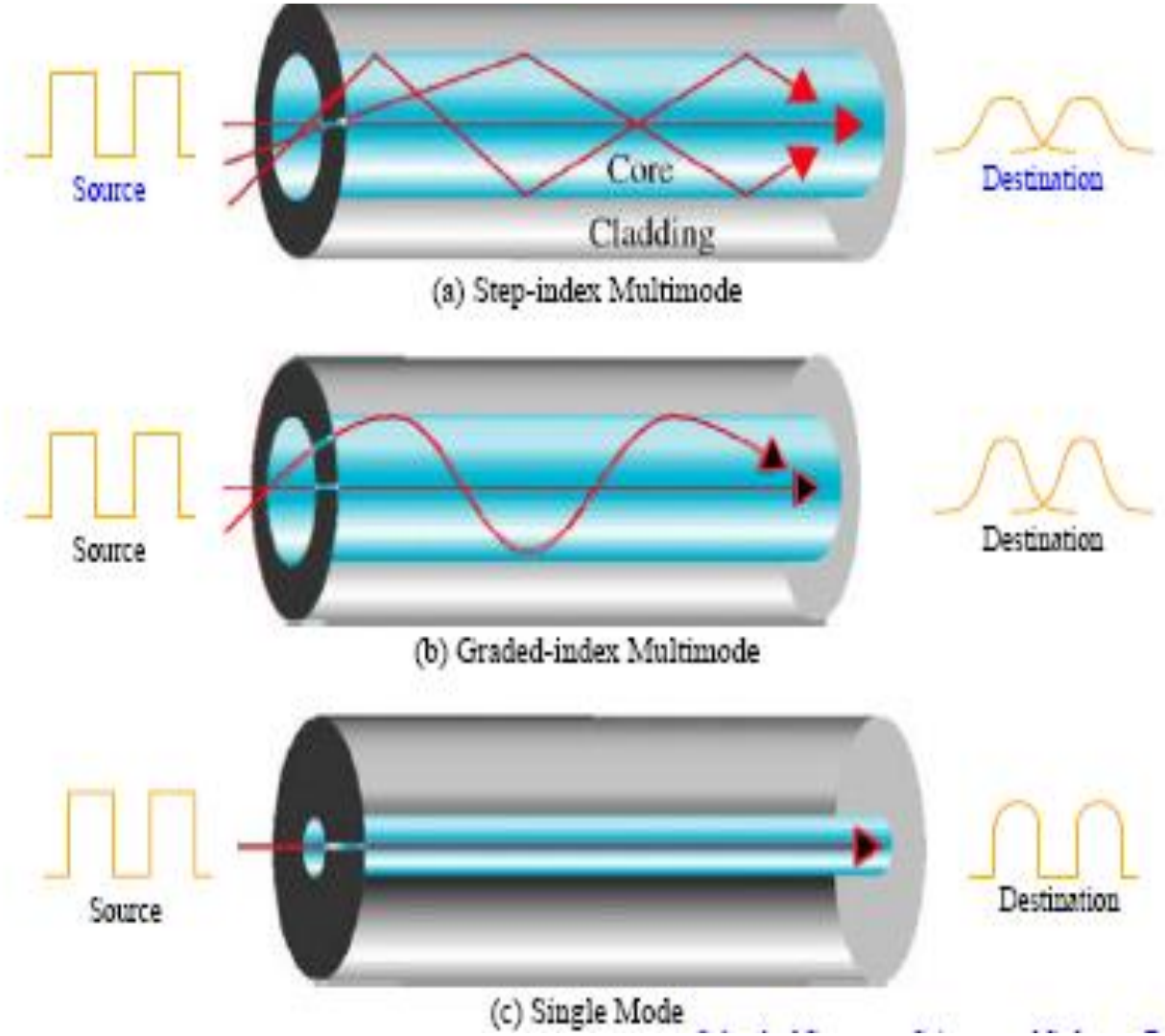


(b) Graded-index multimode

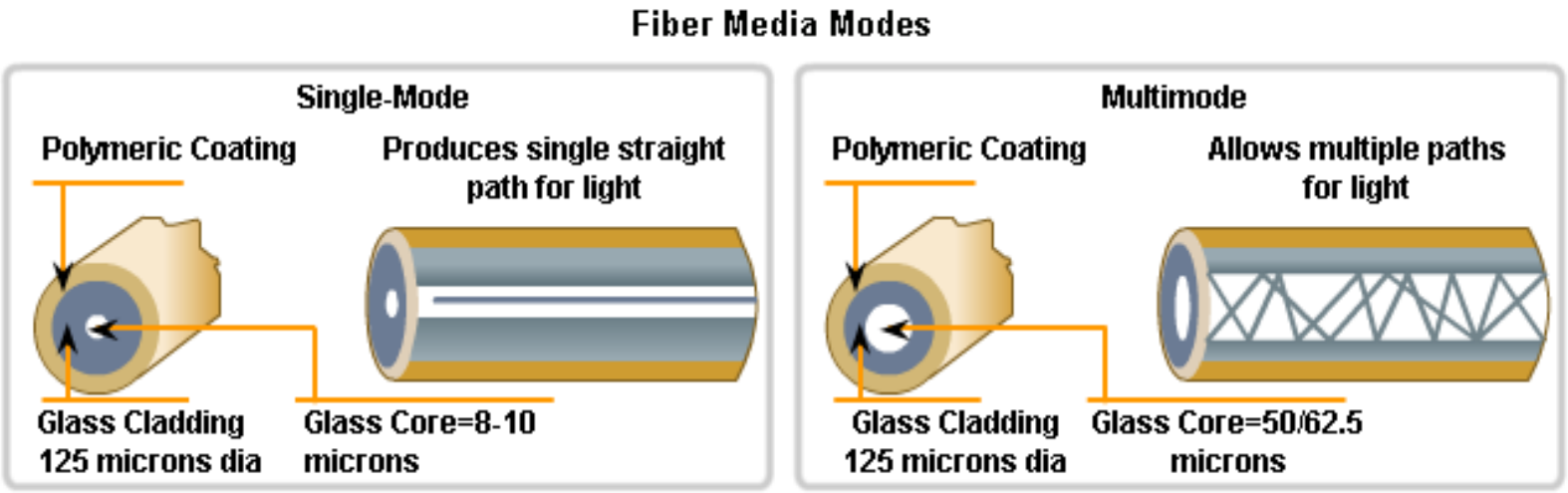


(c) Single mode

Optical Fiber Transmission Modes



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*

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 7.14 *Fiber construction*

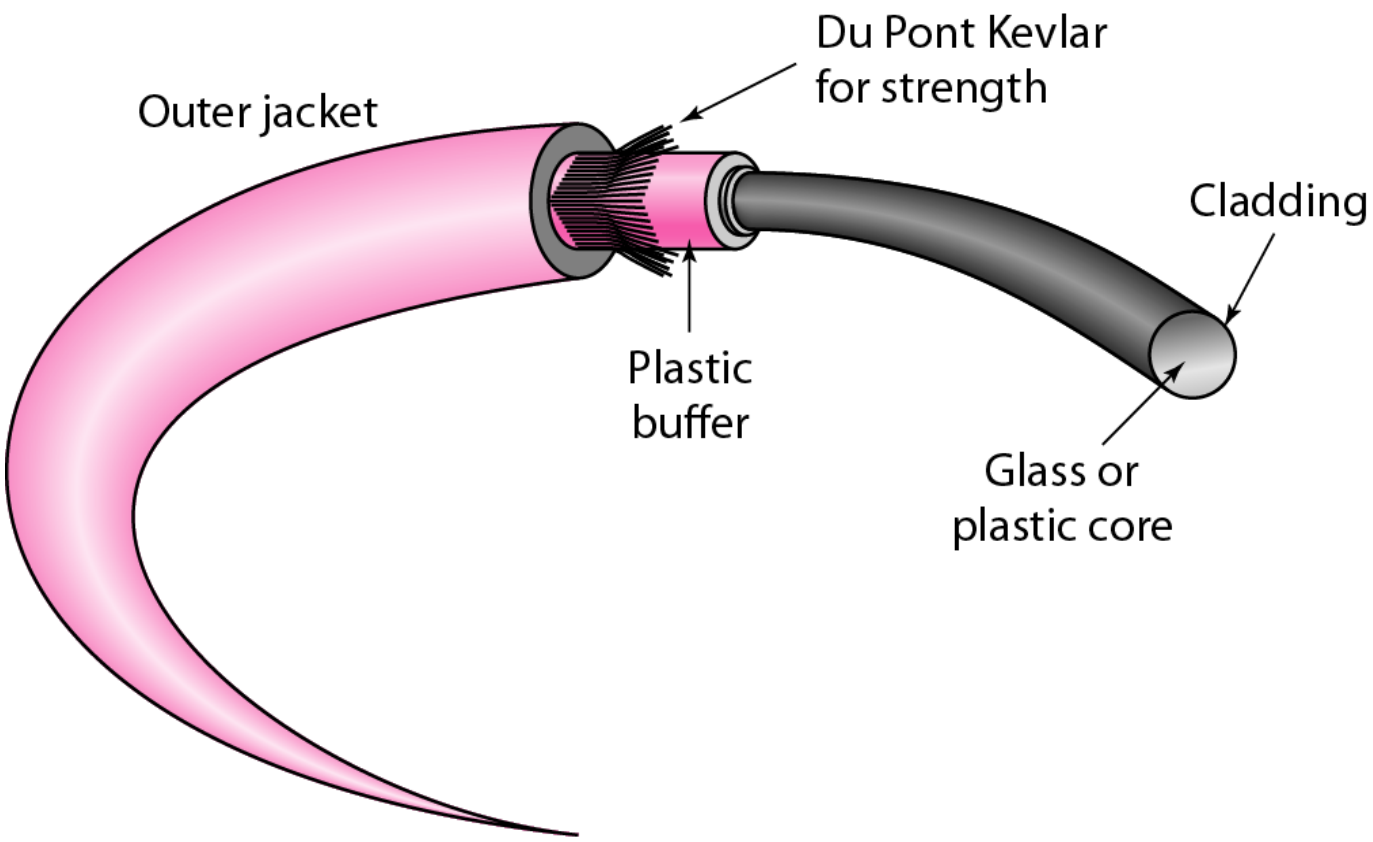


Figure 7.15 *Fiber-optic cable connectors*

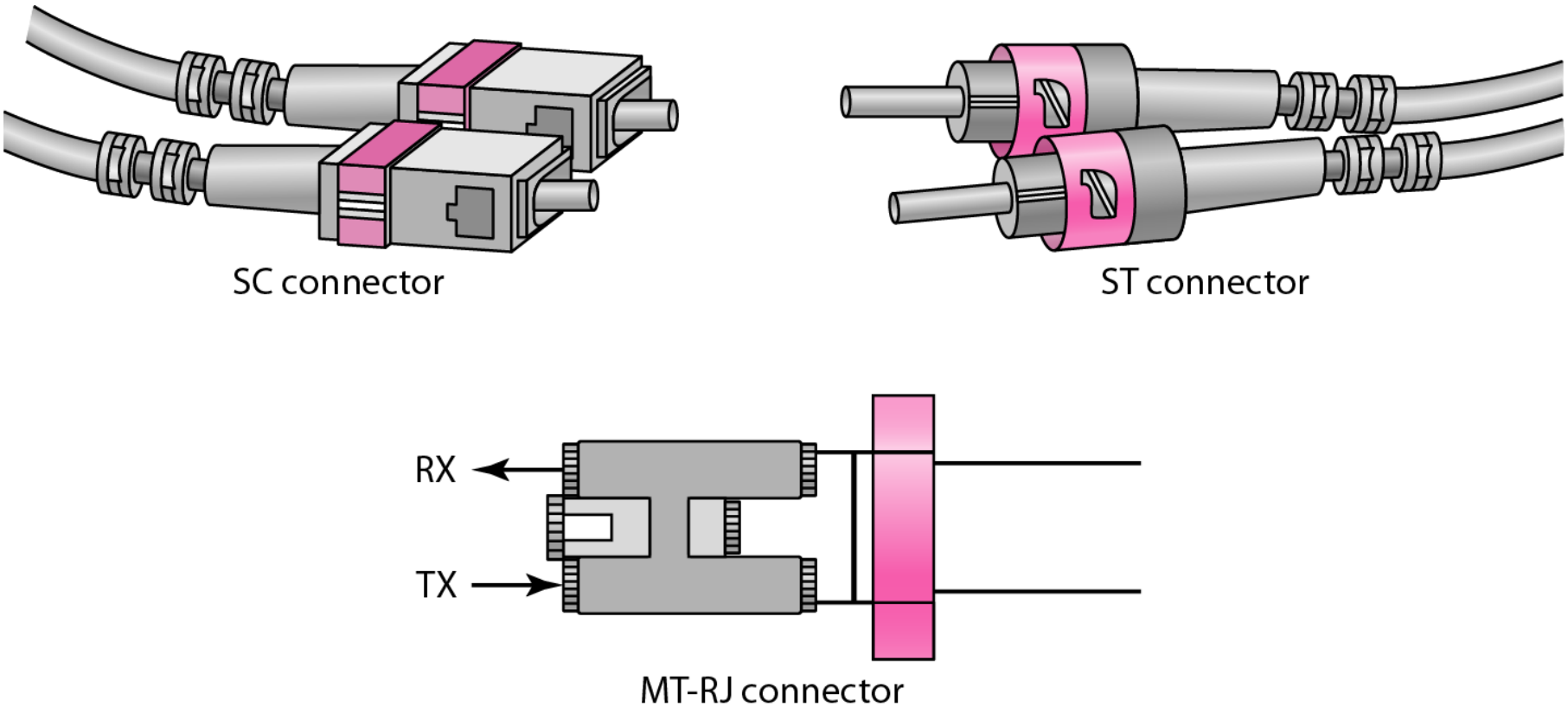
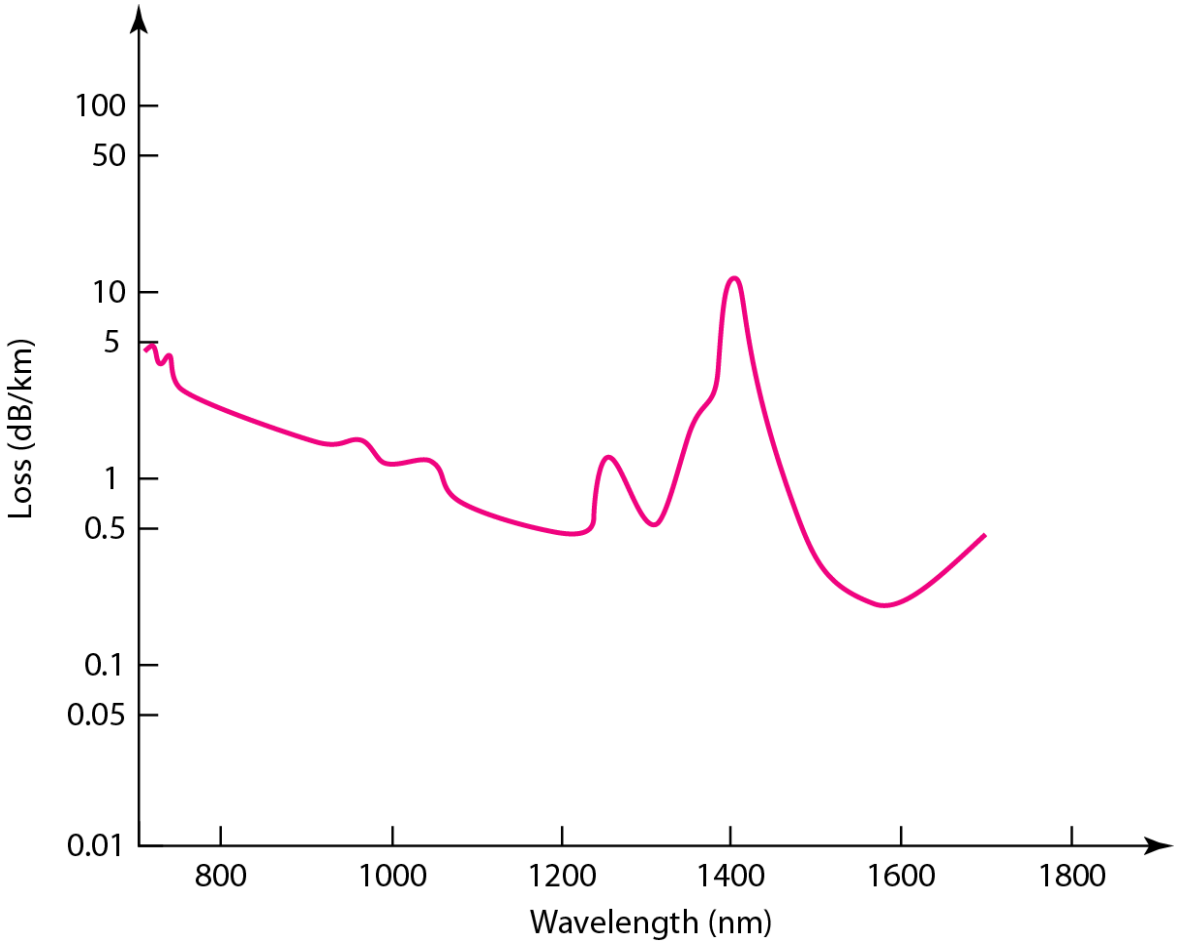


Figure 7.16 *Optical fiber performance*



7-2 UNGUIDED MEDIA: WIRELESS

Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication.

Topics discussed in this section:

Radio Waves
Microwaves
Infrared

Figure 7.17 *Electromagnetic spectrum for wireless communication*

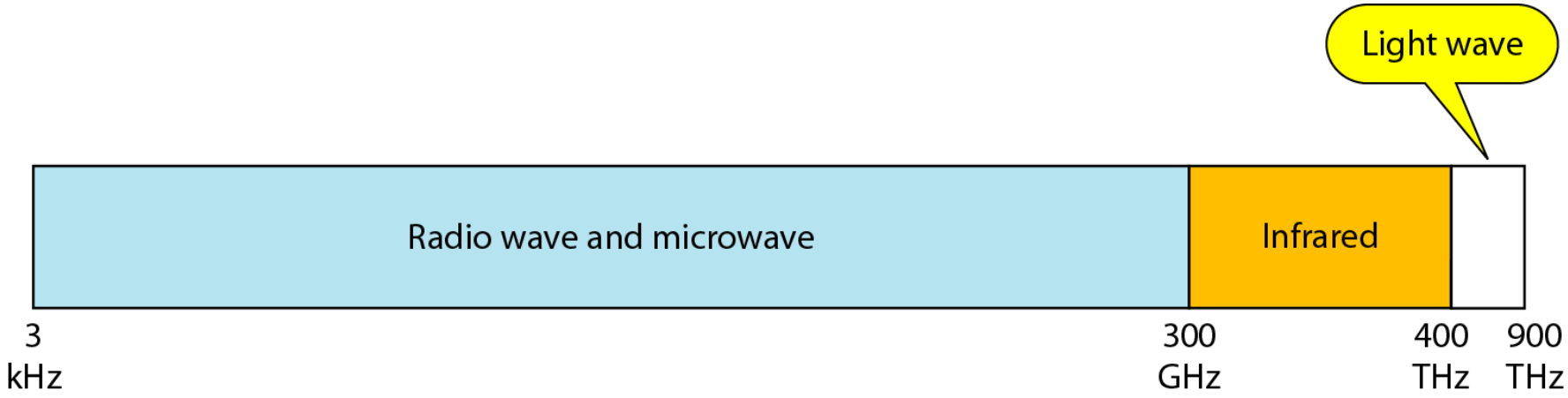
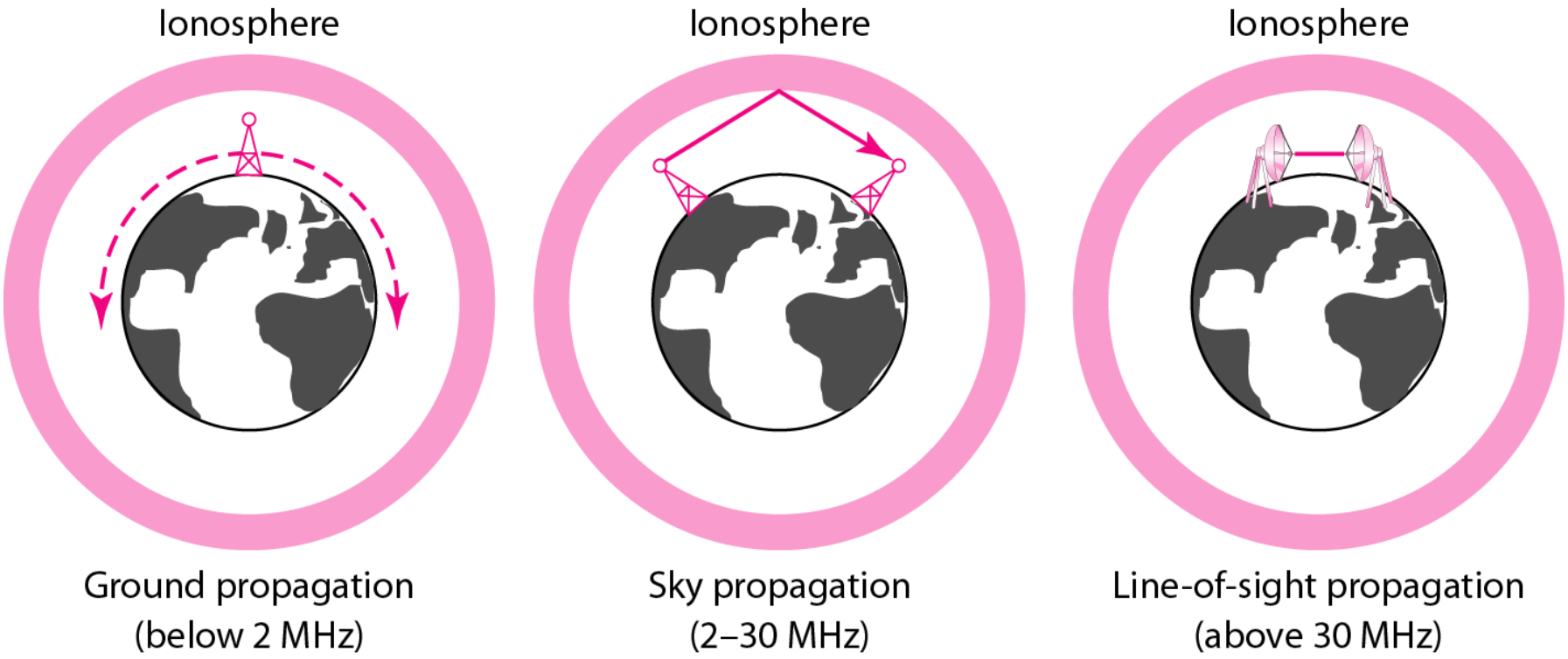


Figure 7.18 *Propagation methods*



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

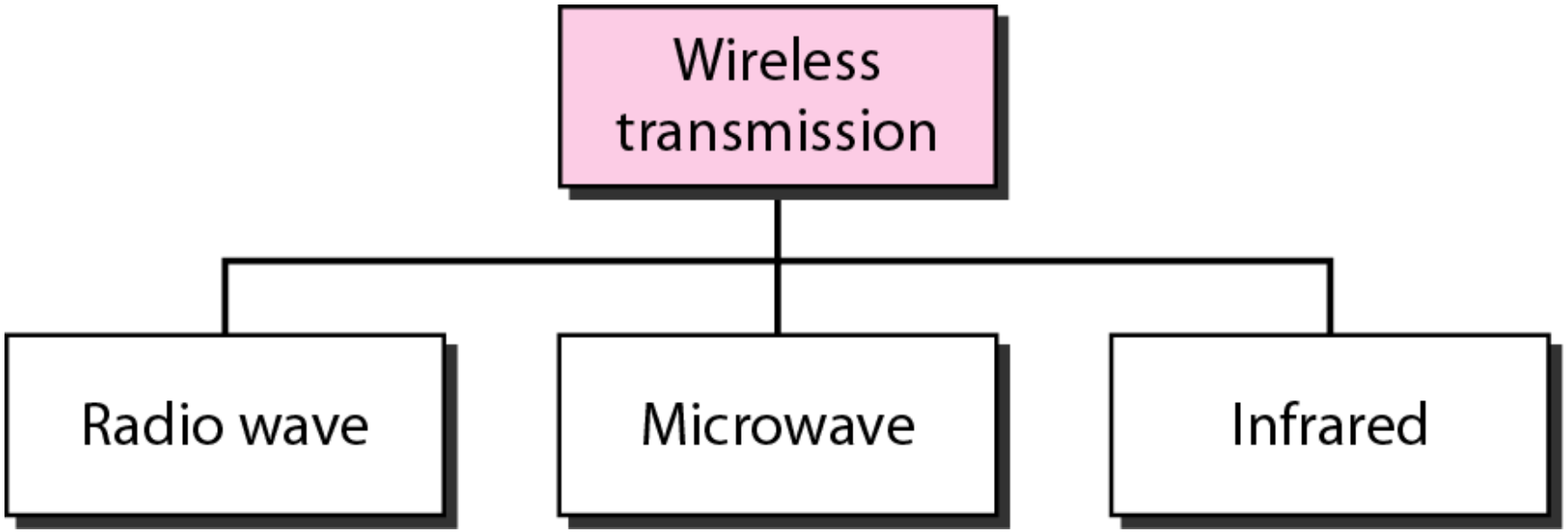
Line-of-sight propagation

- 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*

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

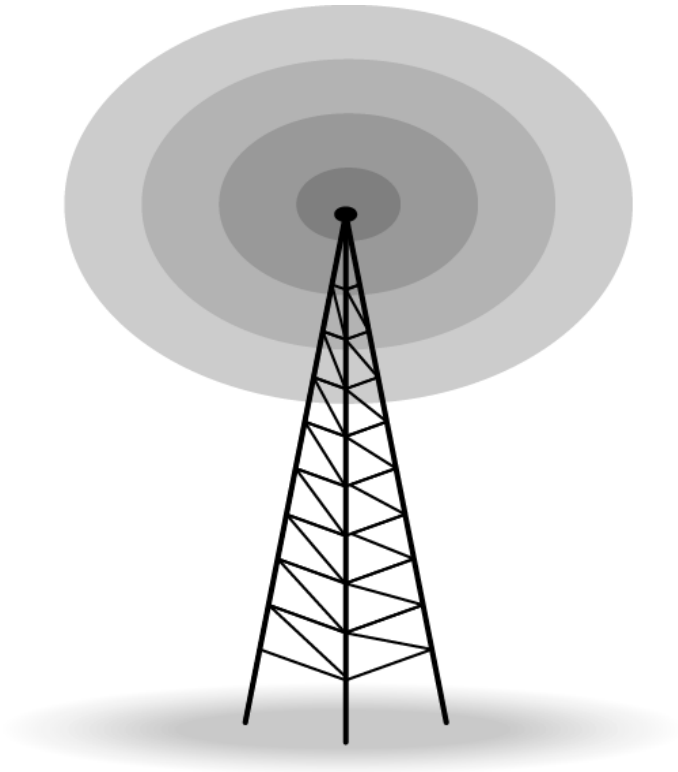
Figure 7.19 *Wireless transmission waves*



Radio Waves

- Waves typically ranging in frequencies between 3kHz and 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

Figure 7.20 *Omnidirectional antenna*



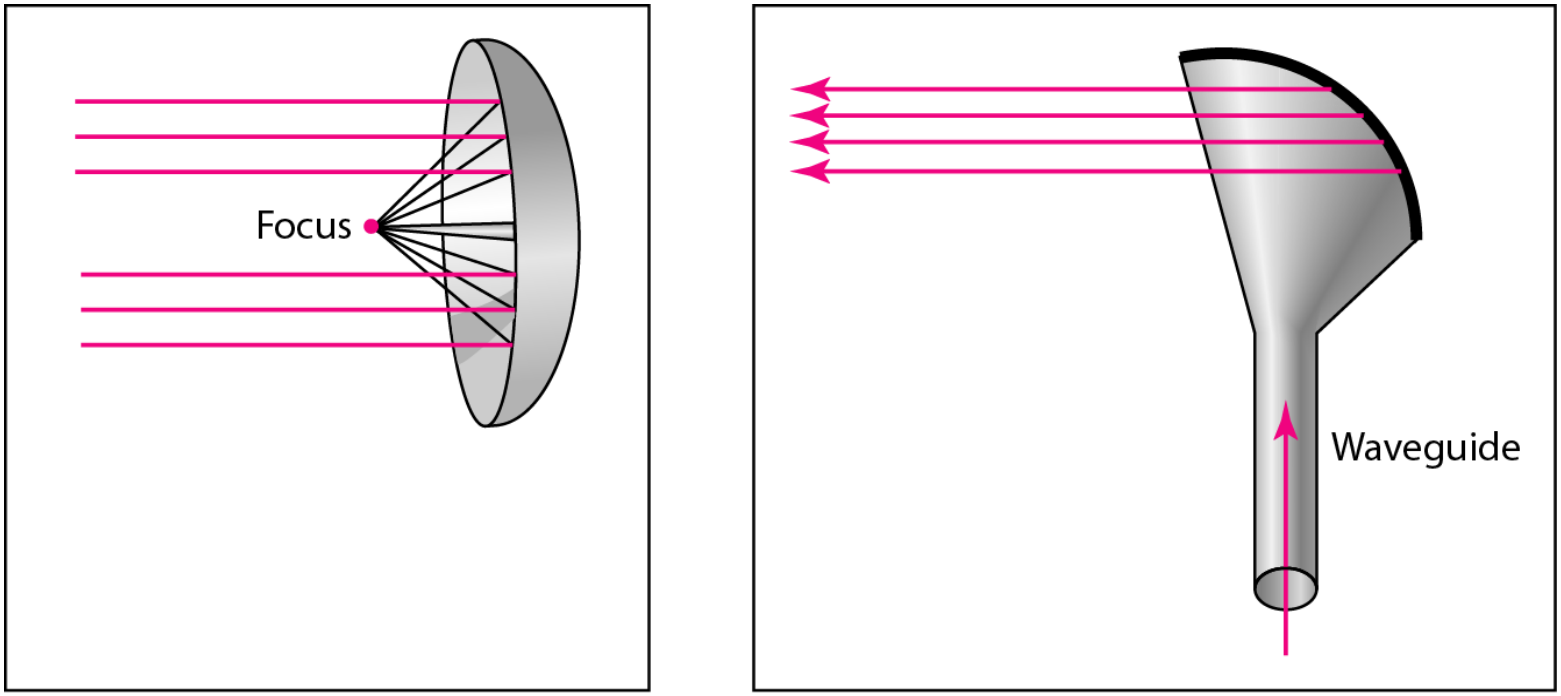
Microwaves

- Waves ranging in frequencies between 1GHz and 300 GHz
- Microwave propagation is line-of-sight
- Very high frequency microwaves can't penetrate walls
- Microwave band is relatively wide

Note

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

Figure 7.21 *Unidirectional antennas*

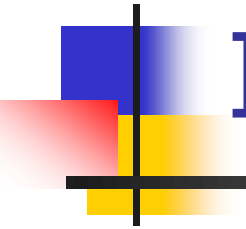


a. Dish antenna

b. Horn antenna

Note

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



Infrared

- Frequencies from 300Ghz to 400THz
- High frequencies, cannot penetrate walls

Note

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