Chapter 7: Transmission Media

Outline

7.1 INTRODUCTION

7.2 GUIDED MEDIA

7.3 UNGUIDED MEDIA

7-1 INTRODUCTION

Transmission media are located below the physical layer and directly controlled by the physical layer. We could say that transmission media belong to layer zero.

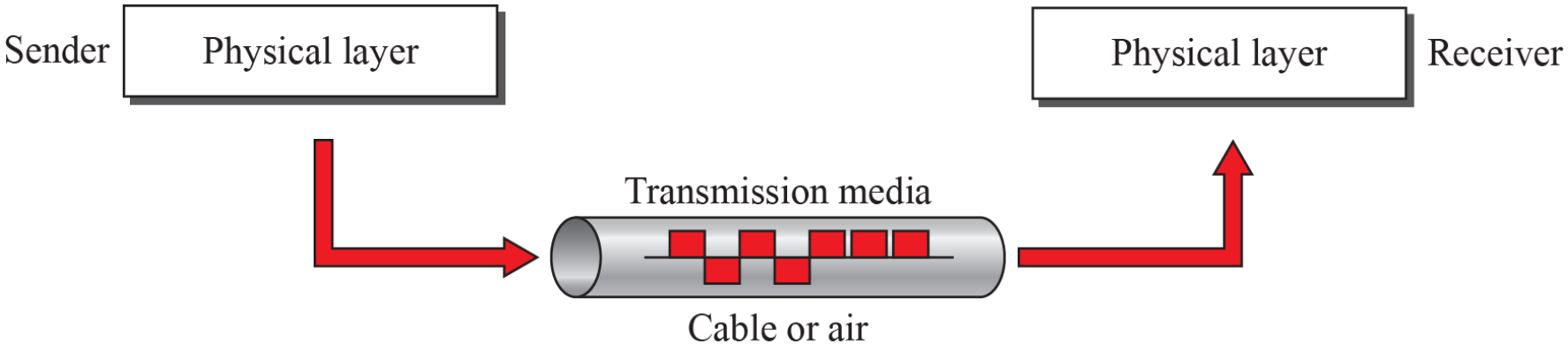
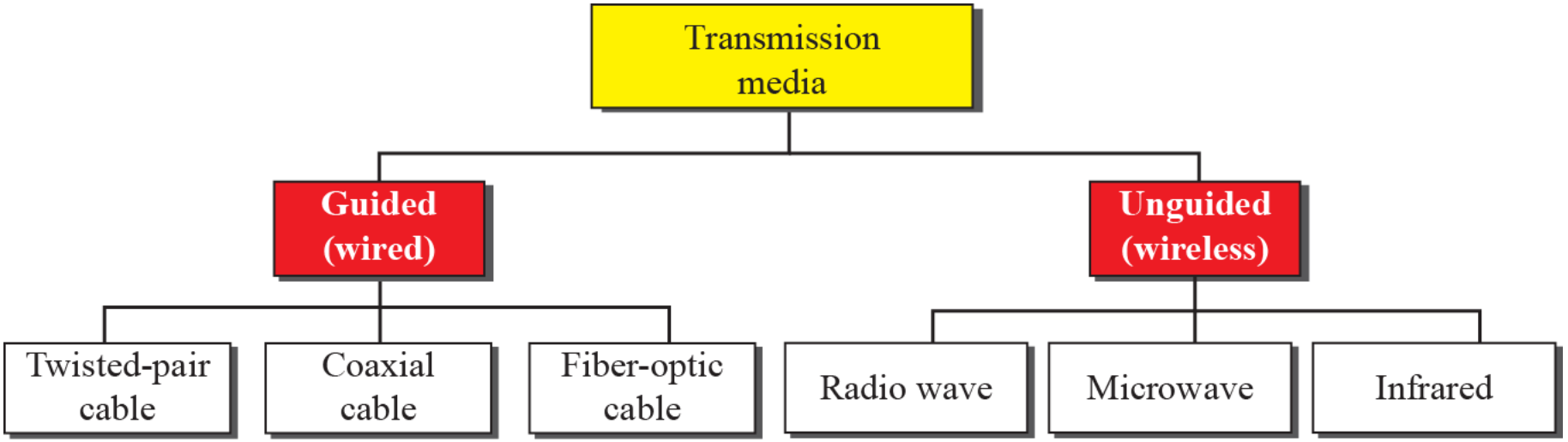


Figure 7.2: Taxonomy of transmission media

A transmission medium can be broadly defined as anything that can carry information from a source to a destination. Transmission media can be divided into two broad categories: guided and unguided.



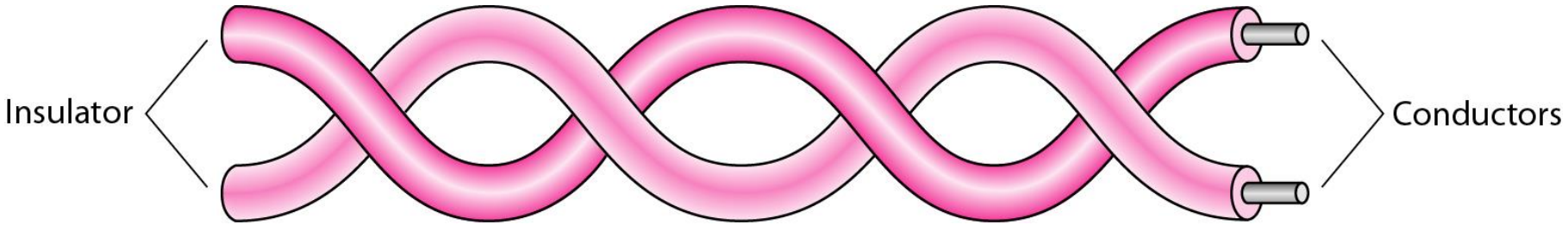
7-2 GUIDED MEDIA

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.

7.2.1 Twisted-Pair Cable

A twisted pair consists of two conductors (usually copper), each with its own plastic insulation, twisted together. One of the wires is used to carry signals (in the form of electric current) to the receiver, and the other is used only as a ground reference. The receiver uses the difference between the two.



Twisted-Pair Cable (cont'd)

Idea: Twisting the pair of wires makes it probable that both wires are equally affected by external impairments (noise or crosstalk):

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. The receiver, which calculates the difference between the two wires receives no unwanted signals as the unwanted signals are mostly cancelled out.

Figure 7.4: UTP and STP cables, RJ-45 Connectors

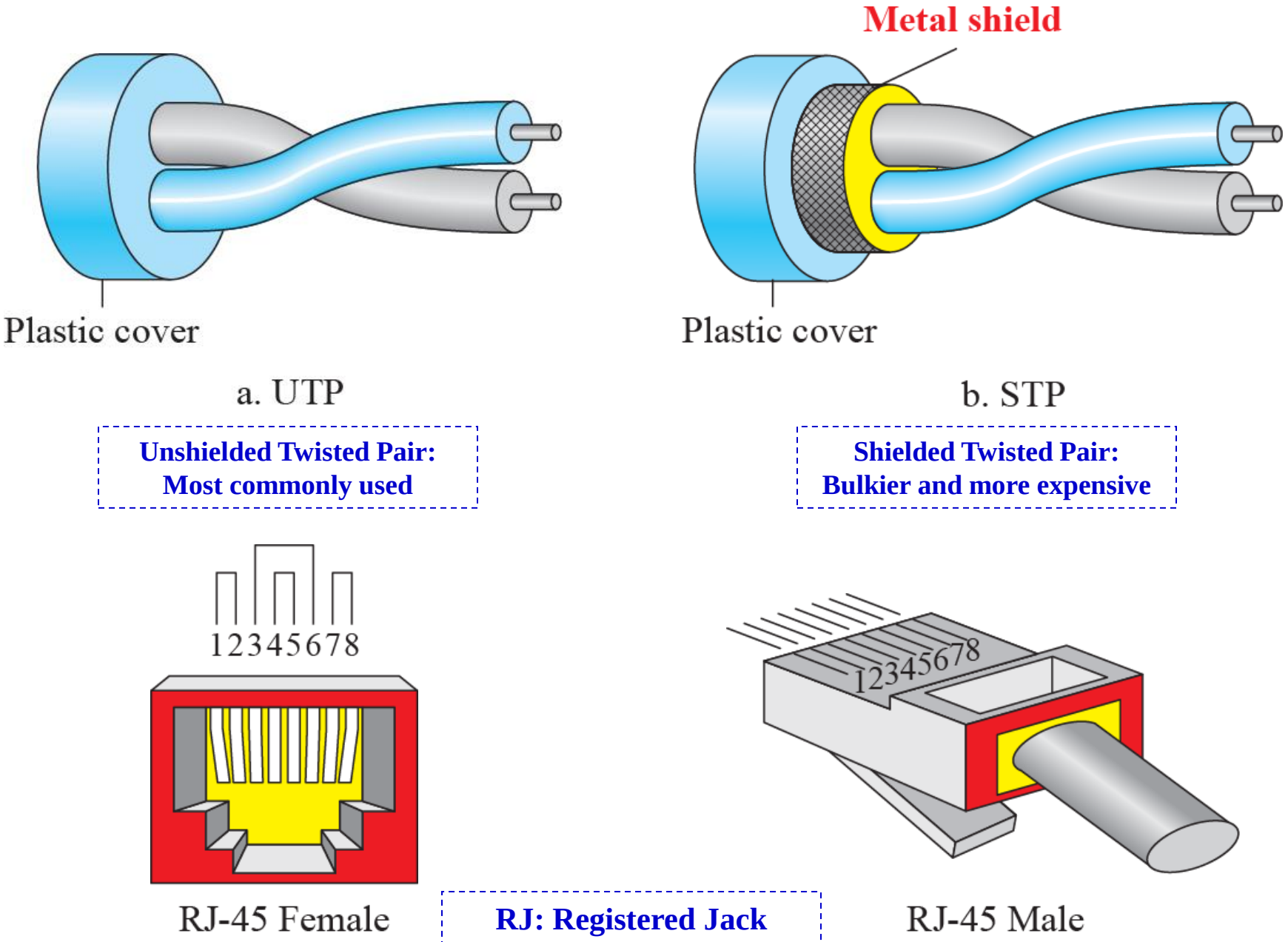
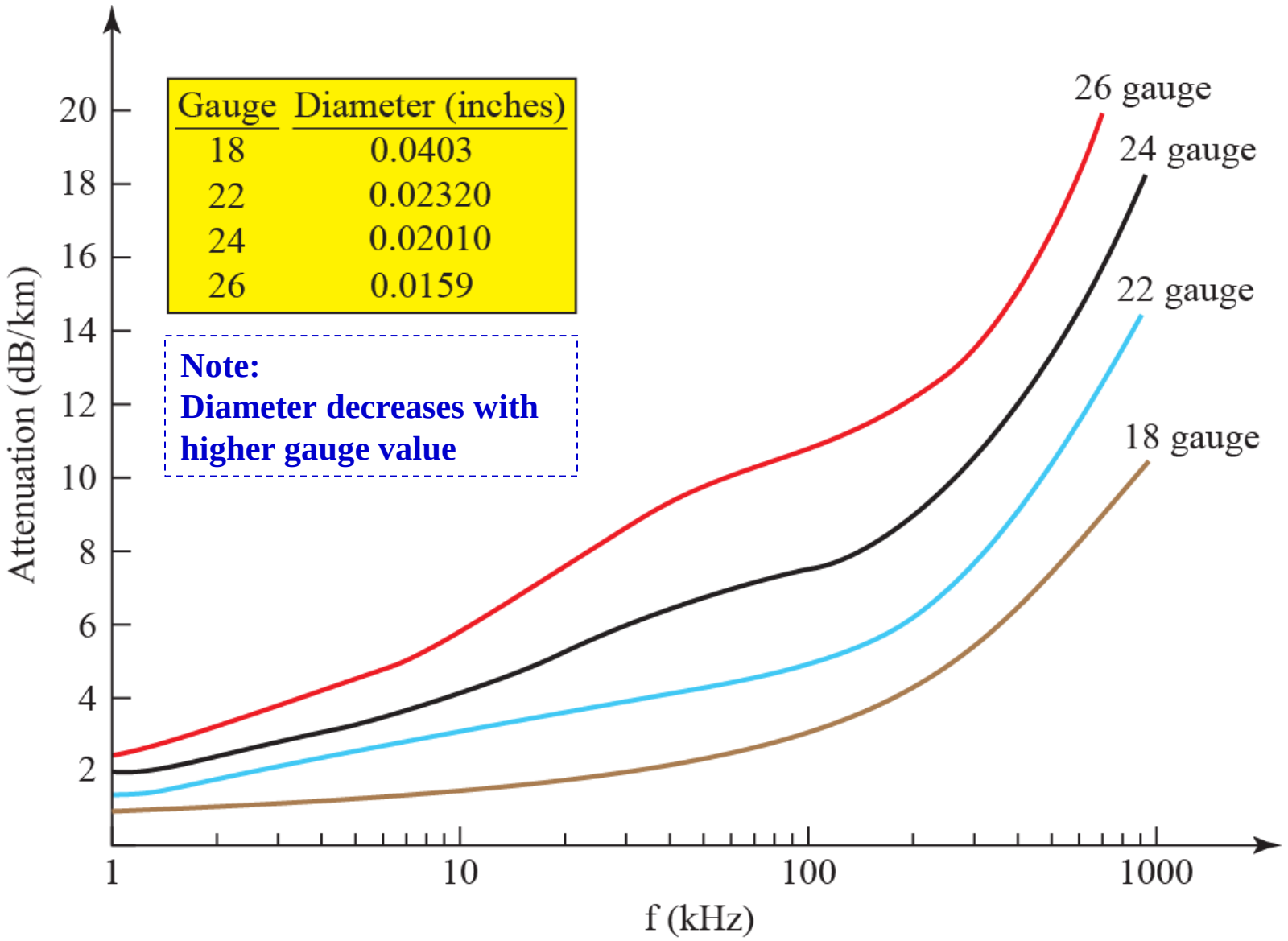


Figure 7.6: UTP Performance



7.2.2 Coaxial Cable

Coaxial cable carries signals of higher frequency ranges than those in twisted-pair cable. Instead of having two wires, coaxial cable has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is encased in an outer conductor of metal foil or 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. The outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.

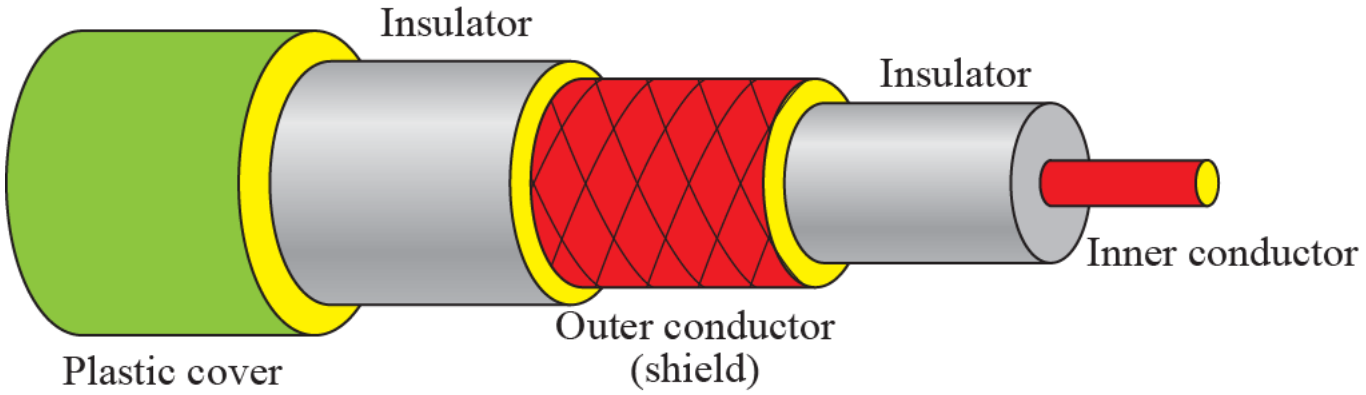
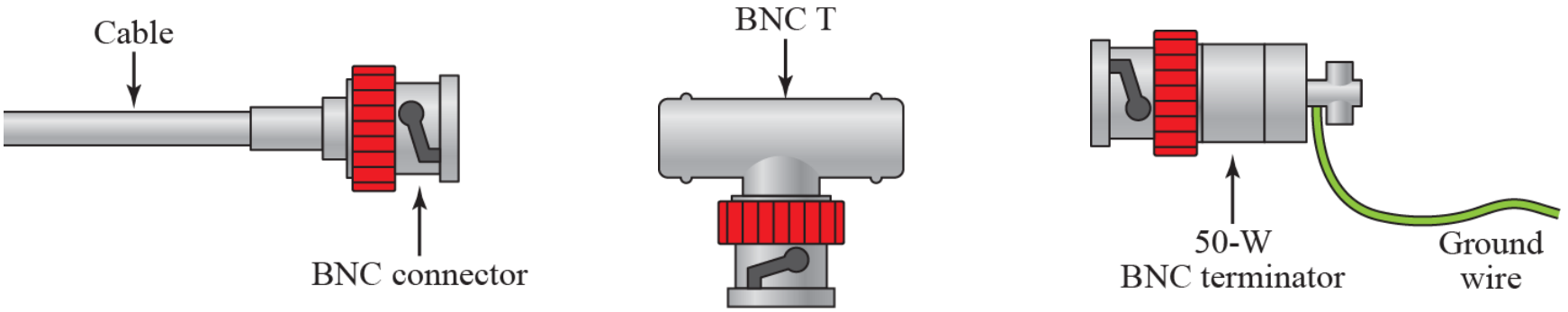


Figure 7.8: BNC connectors

The most common type of coaxial cable connector is the Bayonet Neill-Concelman (BNC) connector.

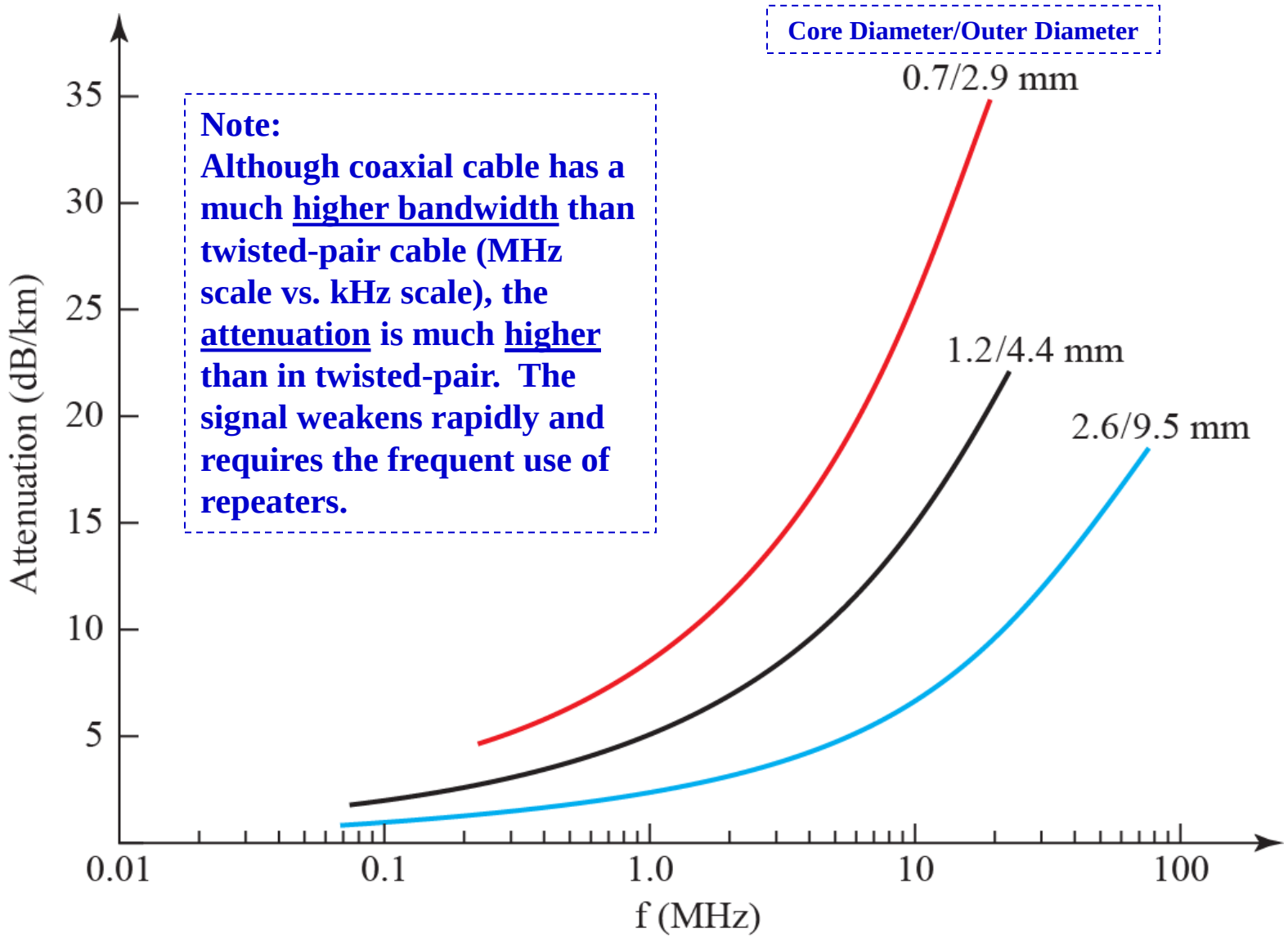


BNC Connector:
Used to connect the end of the cable to a device (e.g., TV set)

BNC T Connector:
Used in Ethernet networks to branch out a connection to a device (e.g., computer)

BNC Terminator:
Used at the end of the cable to prevent the reflection of the signal.

Figure 7.9: Coaxial cable performance



7.2.3 Fiber-Optic Cable

A fiber-optic cable is made of glass or plastic and transmits signals in the form of light. It uses reflection to guide light through a channel.

The glass or plastic core is surrounded by a cladding of less dense glass or plastic. The difference in density of the two material ensures the beam of light moving through the core is reflected off the cladding instead of being refracted into it.

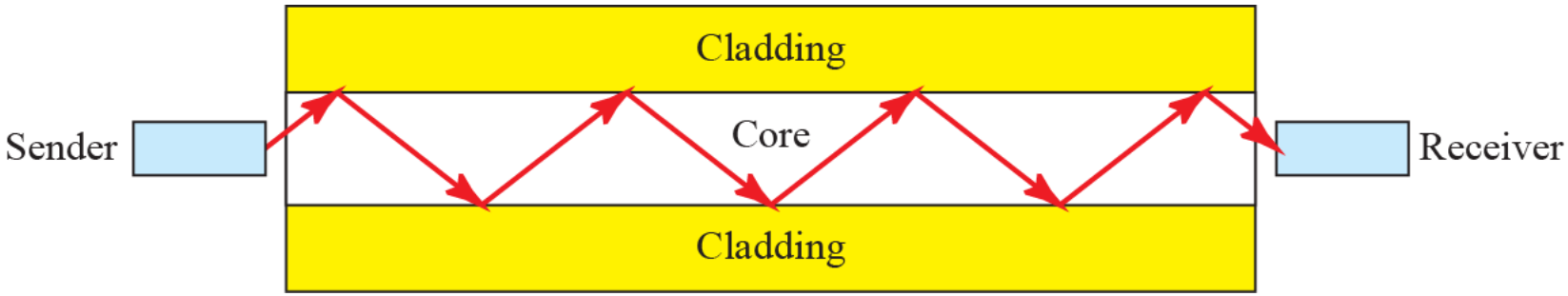
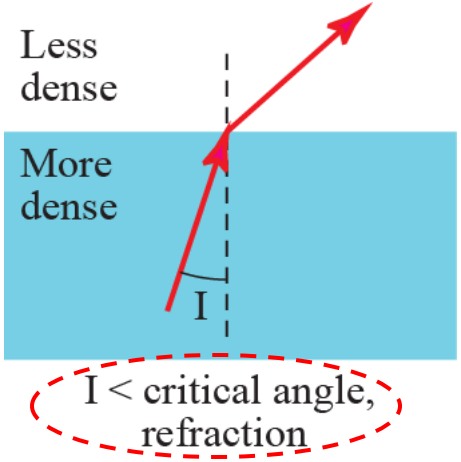
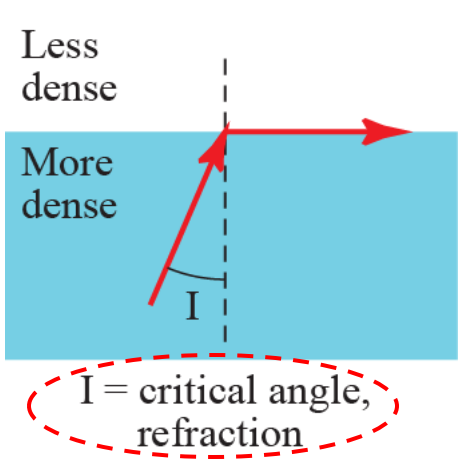
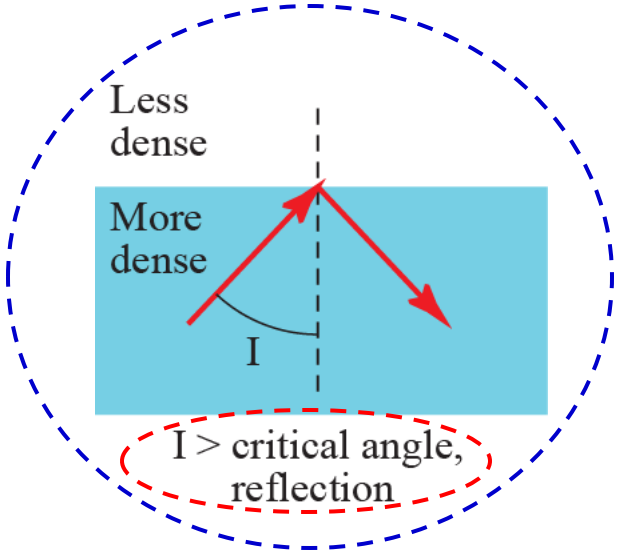


Figure 7.10: Bending of light ray

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 enters another substance of a different density, the ray changes direction. The figures below show how a ray of light changes direction when going from a more dense to a less dense substance.





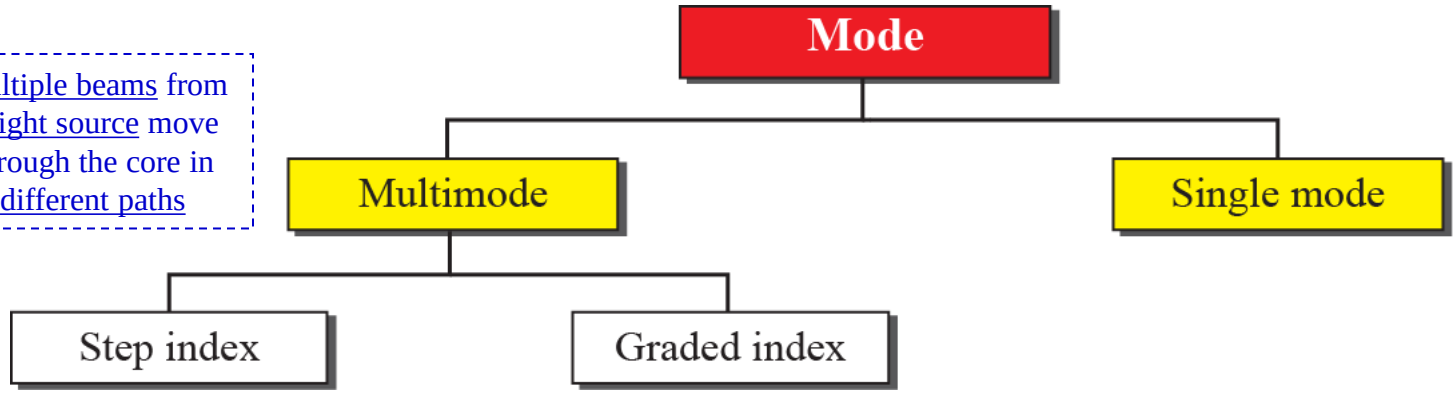


Note that the critical angle is a property of the substance and its value differs from one substance to another.

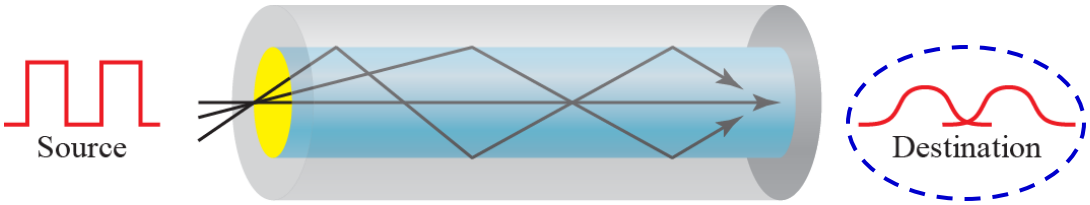
Total Internal Reflection (TIR)

Figure 7.12: Propagation modes

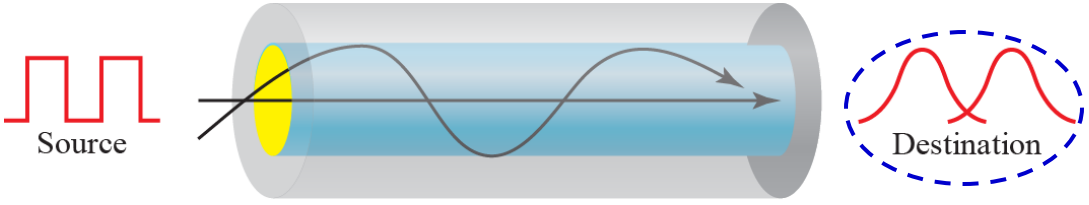
Multiple beams from a light source move through the core in different paths



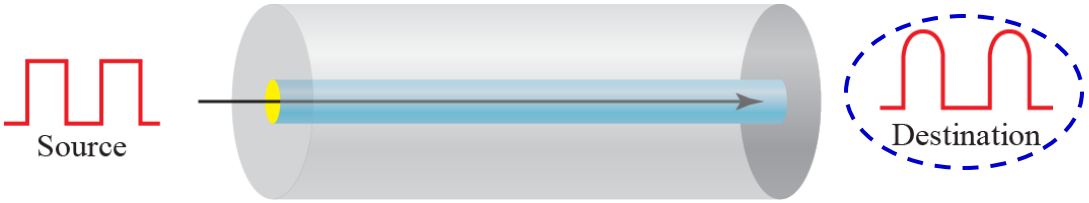
Single beam from a light source move through the core



a. Multimode, step index



b. Multimode, graded index



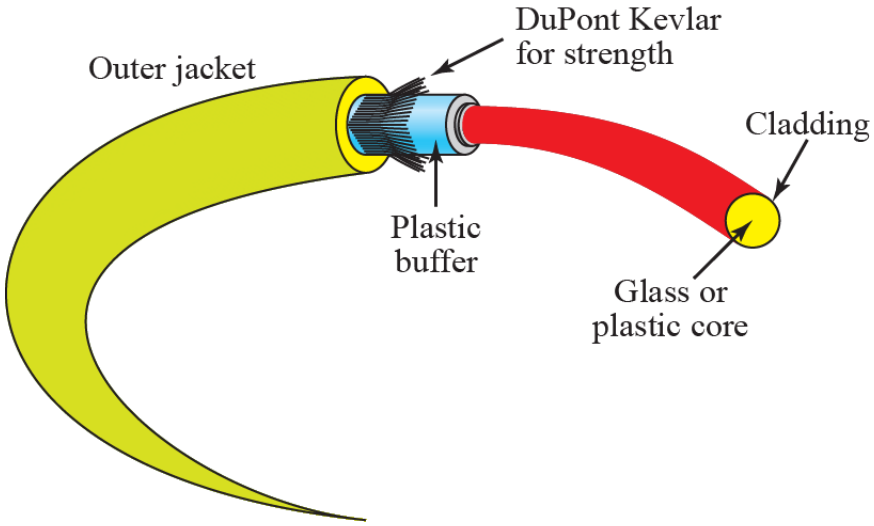
c. Single mode

Multimode, step-index fiber: density of the core remains constant from the center to the edges ➔ distortion of the signal as it passes through the fiber.

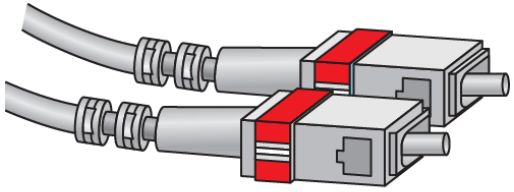
Multimode, graded-index fiber: density is highest at the center of the core and decreases gradually to its lowest at the edge ➔ decreases the distortion experienced in multimode, step-index fiber.

Single mode, step-index fiber: much smaller diameter than multimode fiber and substantially lower density (index of refraction) ➔ critical angle close to 90° to make the propagation of beams almost horizontal with negligible delays.

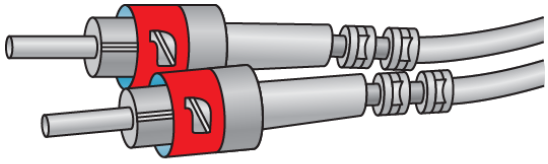
Figure 7.14: Fiber-optic cable construction, connectors



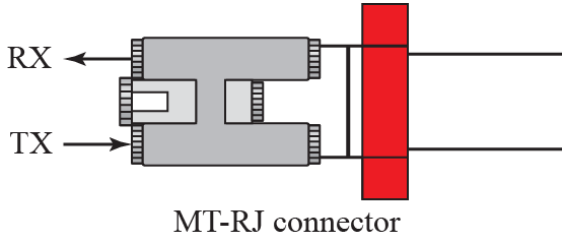
Composition of a typical fiber-optic cable



Subscriber Channel (SC) Connector: Used for cable TV

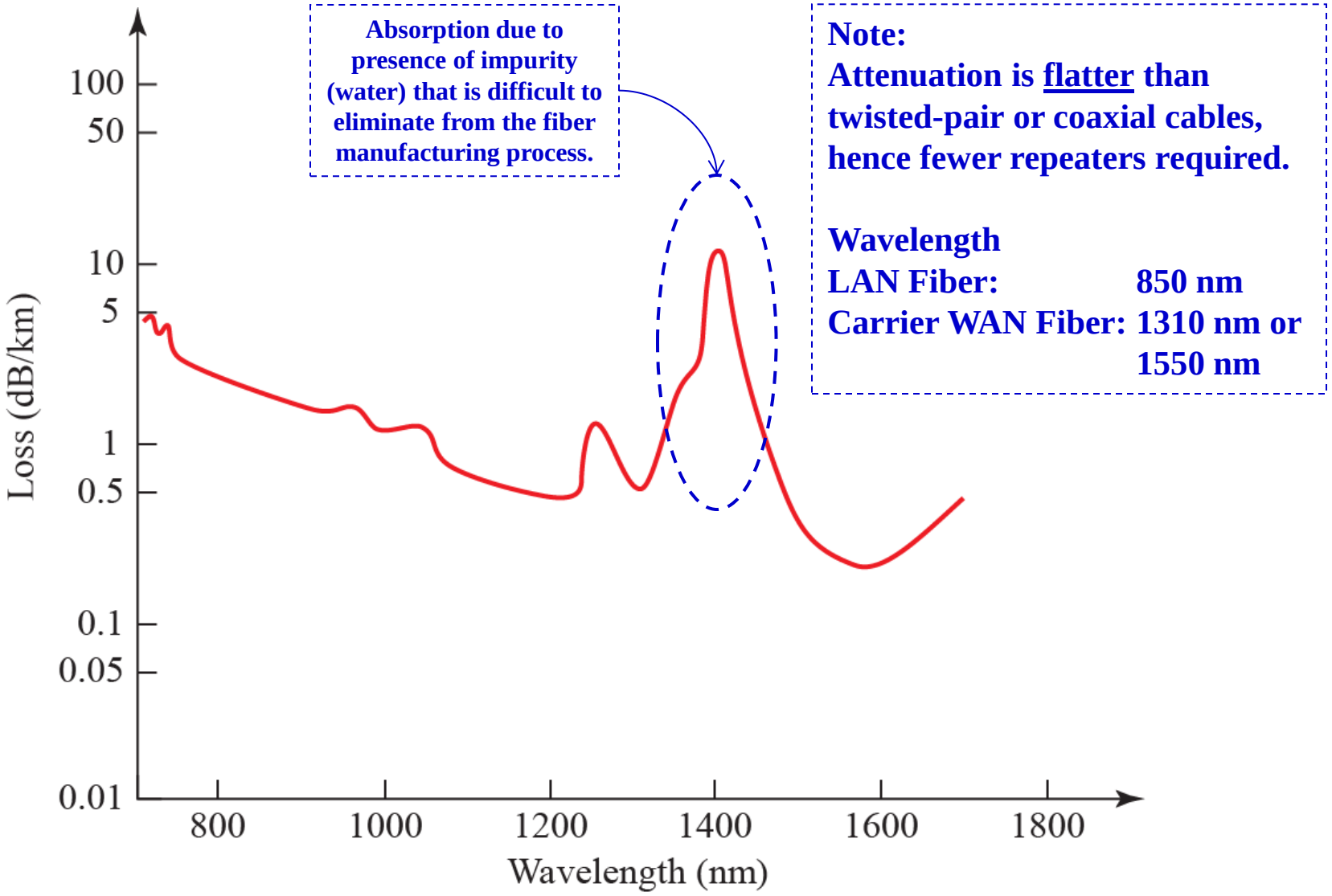


Straight Tip (ST) Connector: Used for networking devices



Mechanical Transfer Registered Jack (MT-RJ) Connector: Used for duplex multimode connections

Figure 7.16: Optical fiber performance

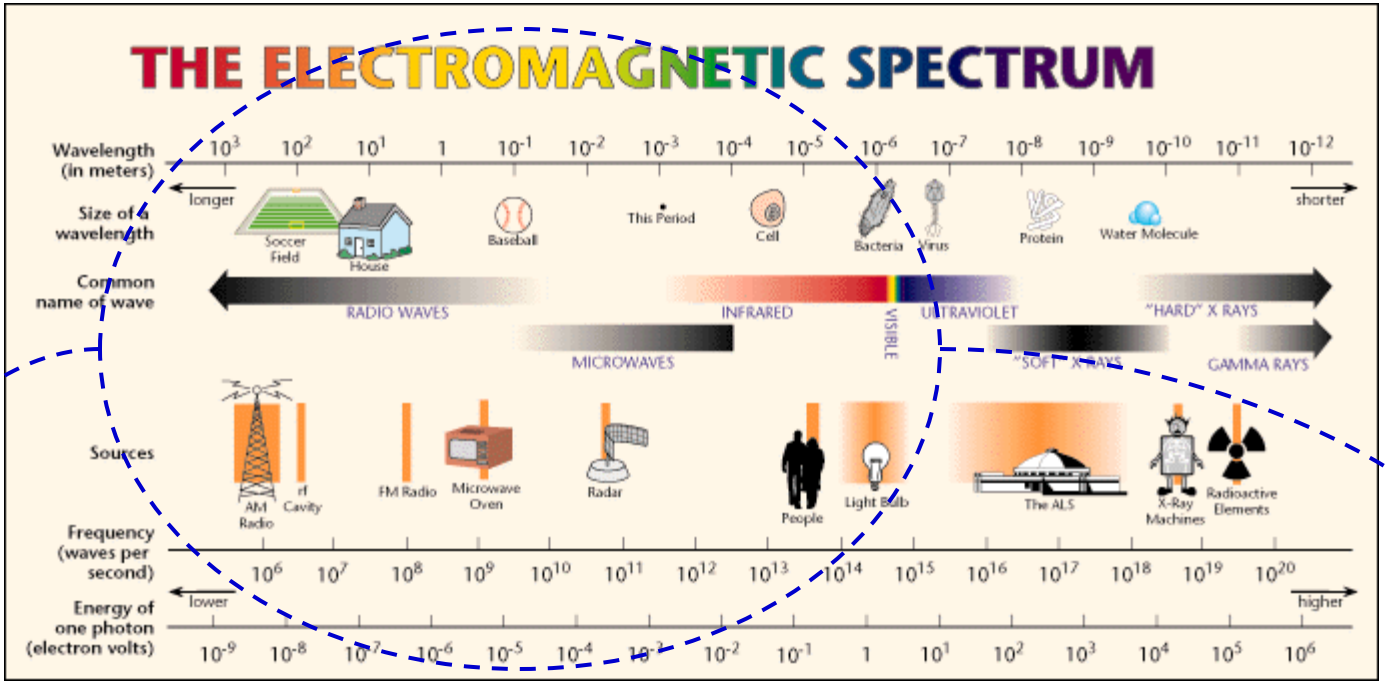


7-3 UNGUIDED MEDIA

Unguided medium transport 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



Source: U.S. Department of Energy

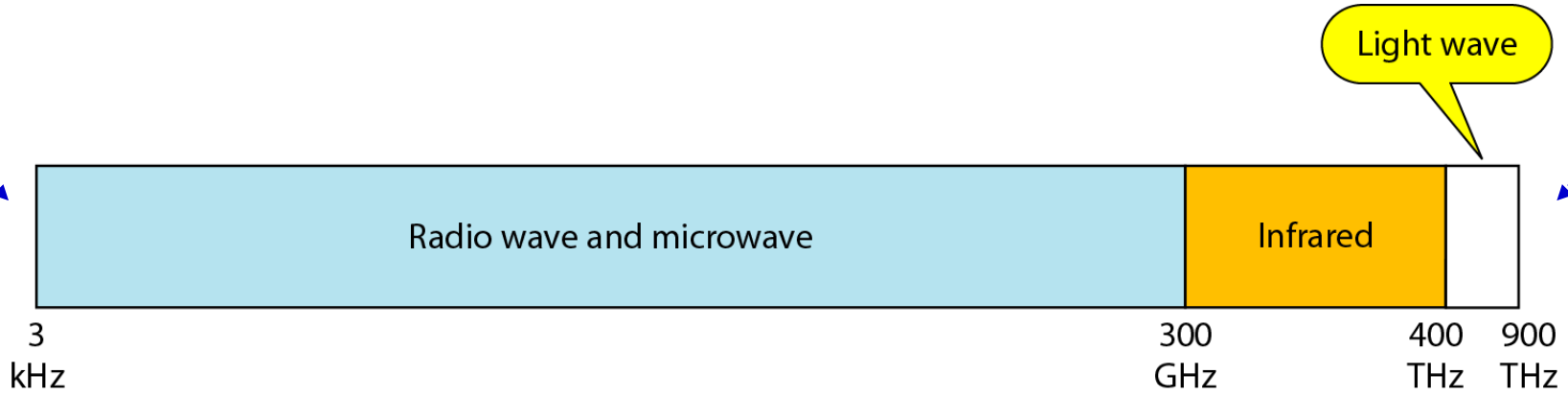
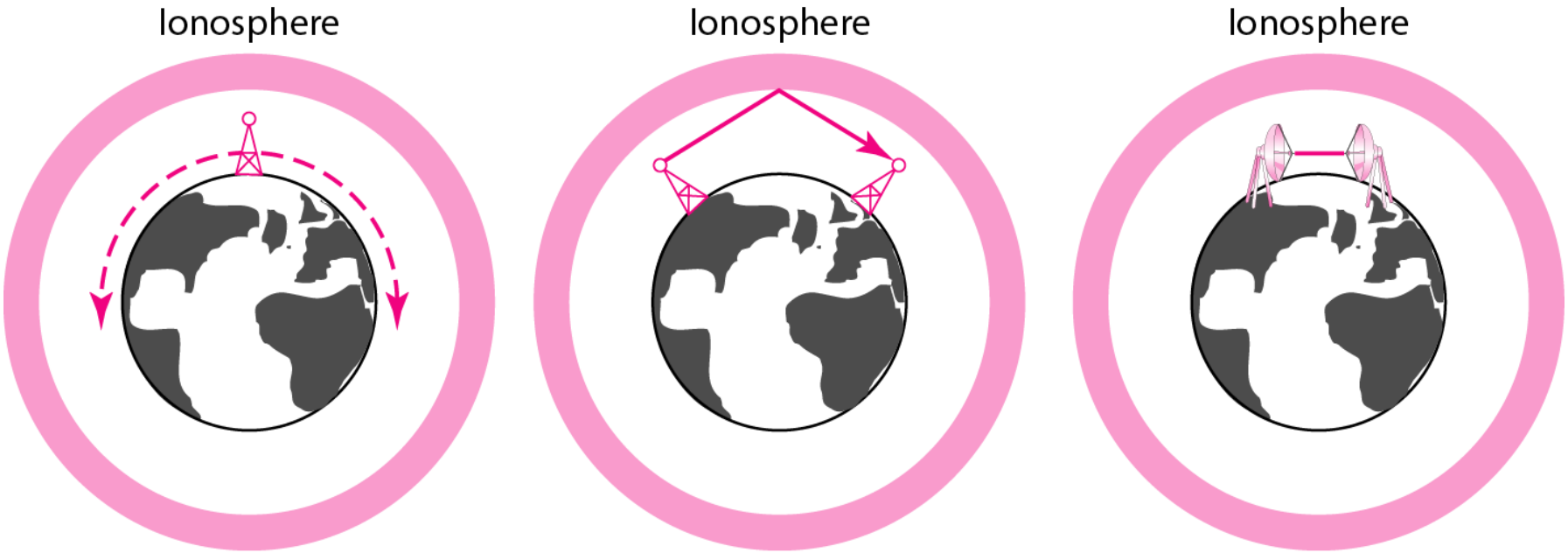


Figure 7.18: Propagation methods

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



Radio waves propagate through the lowest portion of the atmosphere. Low frequency signals emanate in all directions and follow the curvature of the earth. Distance depends on the amount of power in the signal.

Higher frequency signals radiate upward into the ionosphere where they are reflected back to earth. This type of transmission allows for greater distances with lower output power.

Very high frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other, and not be affected by the curvature of the earth.

7.3.1 Radio Waves

Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves. Radio waves

- *propagate (for the most part) in all directions (omnidirectional) but is susceptible to interference by another antenna using the same frequency*
- *can travel long distances (sky propagation) for long-distance broadcasting (AM radio etc.)*
- *can penetrate walls (low and medium frequencies) allowing reception of AM radio signals inside a building*
- *have a relatively narrow band (under 1 GHz) leading to low data rate for digital communications in the subbands*
- *are used for multicast communications (radio, television, paging etc.)*
- *entire band (almost) is regulated by authorities (FCC)*

7.3.2 Microwaves

Electromagnetic waves ranging in frequencies between 1 GHz and 300 GHz are called microwaves. Microwaves

- *propagation is line-of-sight (antennas need direct sight of each other)*
- *are unidirectional and can be narrowly focused, i.e., a pair of antennas can be aligned without interfering with another pair of aligned antennas*
- *at very high-frequencies cannot penetrate walls*
- *have a relatively wide band (299 GHz)*
- *are used for unicast communication (satellite networks, cellular telephones, wireless LANs etc.)*
- *requires permission from authorities for certain portions of the band*

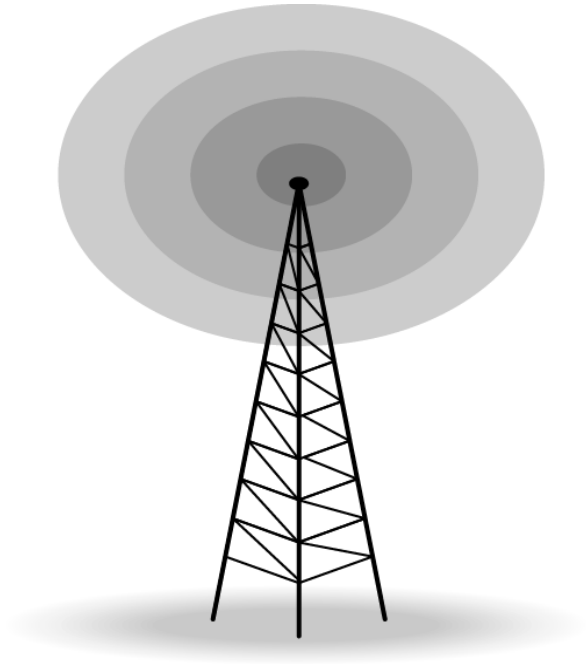
7.3.3 Infrared

Electromagnetic waves ranging in frequency from 300 GHz to 400 THz are called infrared waves. Infrared waves

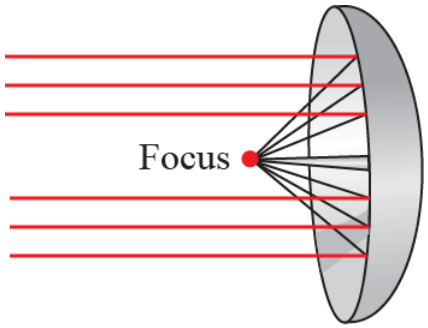
- *propagation is line-of-sight*
- *cannot penetrate walls which prevents interference between one system and another*
- *can be used for short-range communication but unsuitable for long-range communication*
- *cannot be used in open areas as they may be interfered by sun's rays (also contain infrared waves)*
- *have a wide band (~400 THz) with potential for high data rate transmission*

Figure 7.19: Omnidirectional and Unidirectional antenna

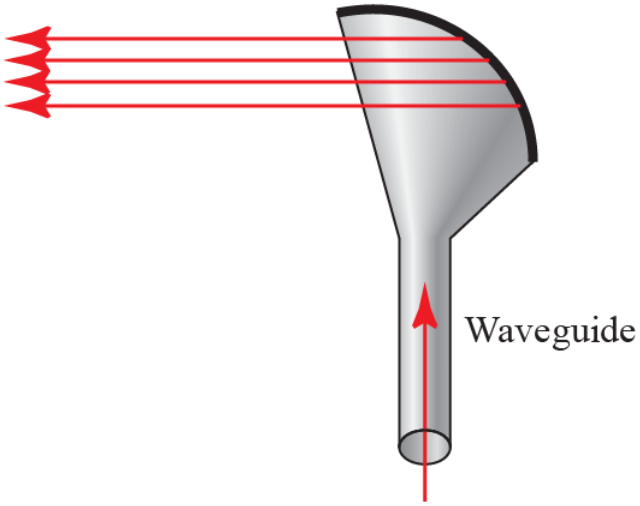
Omnidirectional Antenna:
Sends out signal in all directions



Unidirectional Antenna:
Sends out signal in one direction



a. Parabolic dish antenna



b. Horn antenna