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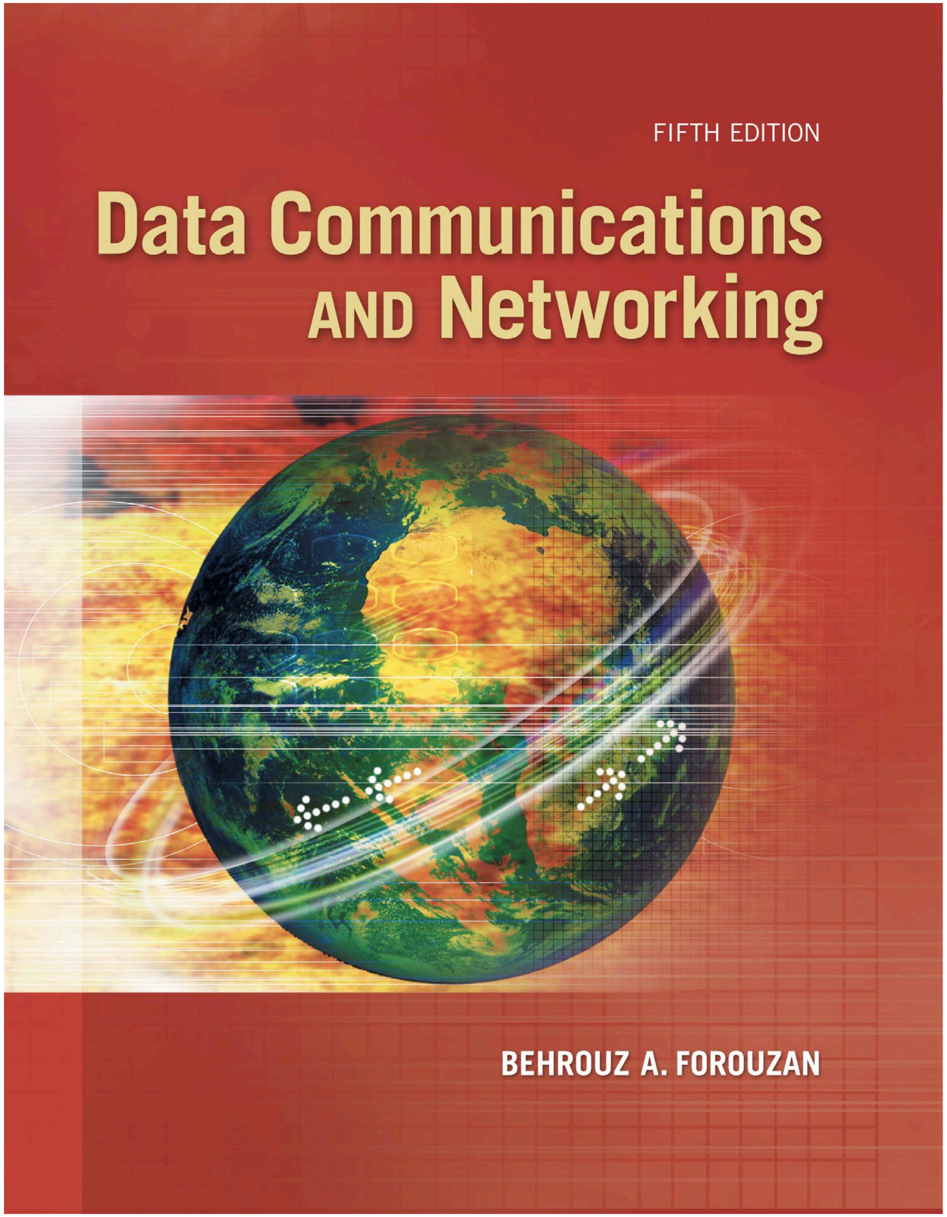
Chapter 7

Transmission Media



Chapter 7: Outline

Chapter 7: Objective

- The first section introduces the transmission media and defines its position in the Internet model. It shows that we can classify transmission media into two broad categories: guided and unguided media.

- The second section discusses guided media. The first part describes twisted-pair cables and their characteristics and applications. The second part describes coaxial cables and their characteristics and applications.

- The third section discusses unguided media. The first part describes radio waves and their characteristics and applications. The second part describes microwaves and their characteristics and applications.

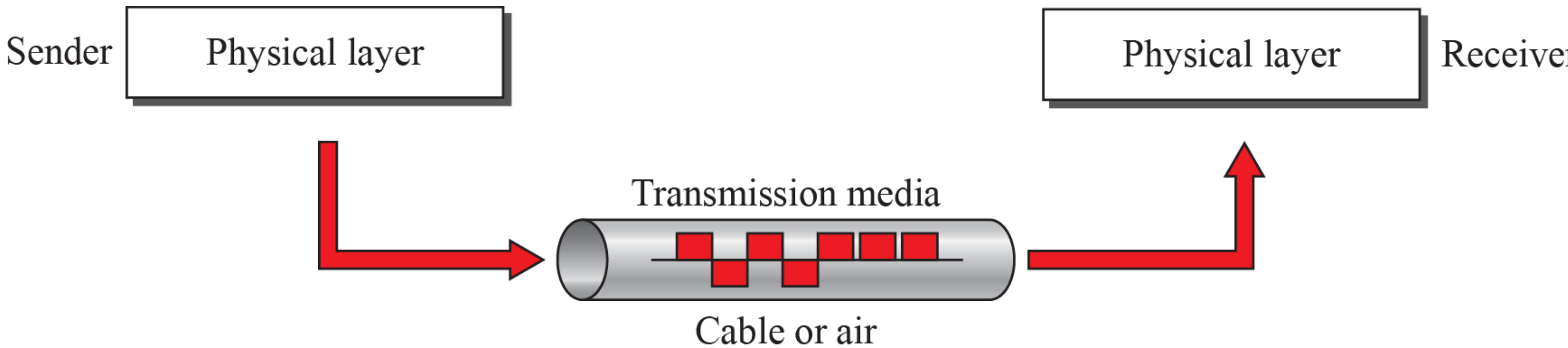
7-1 INTRODUCTION

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

We could say that transmission media belong to layer zero.

Figure 7.1 shows the position of transmission media in relation to the physical layer.

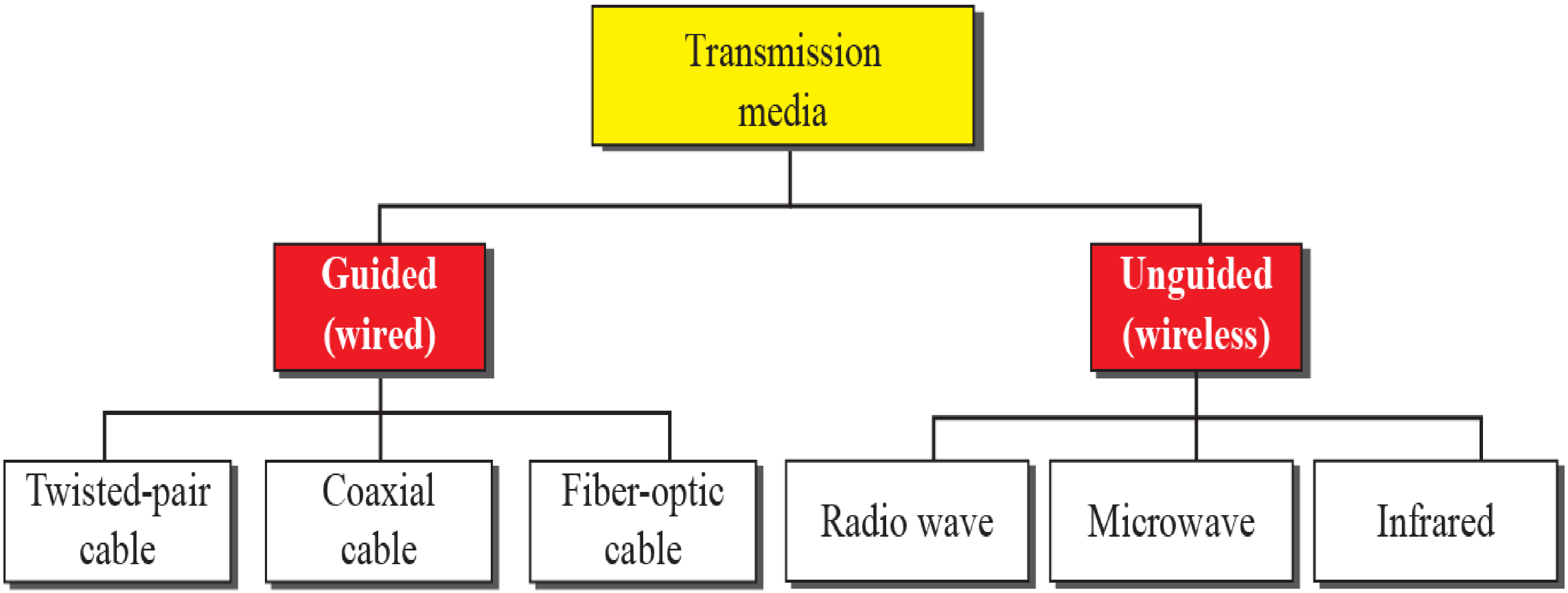
Figure 7.1: Transmission media and physical layer



In data communications, the transmission medium is usually free space, metallic cable, or fiber-optic cable.

Figure 7.2: Classes of transmission media

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



7-2 GUIDED MEDIA

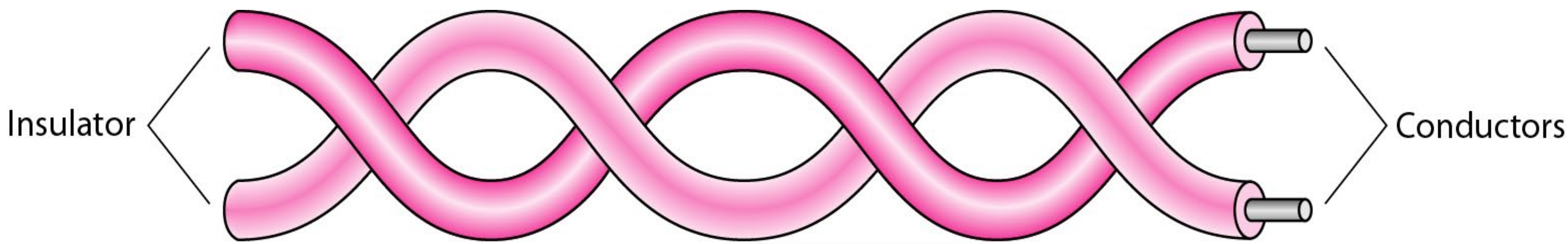
Guided media: provide a conduit from one device to another, include:

1. Twisted-pair cable.
2. Coaxial cable.
3. 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 (normally copper), each with its own plastic insulation, twisted together, as shown in Figure.



7.2.1 Twisted-Pair Cable

- One of the wires is used to carry signals to the receiver.
- The other is used only as a ground reference.
- Interference (noise) and crosstalk may affect both wires and create unwanted signals.
- The receiver uses the difference between the two. The unwanted signals are mostly canceled out.

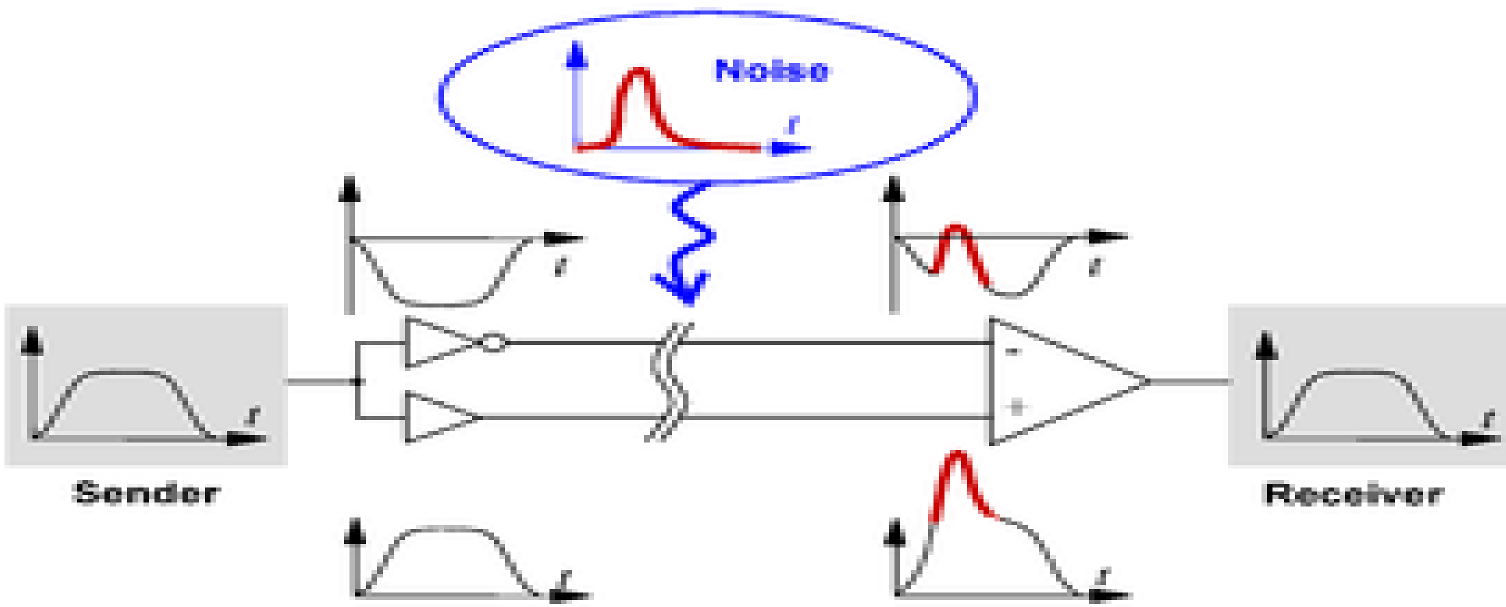
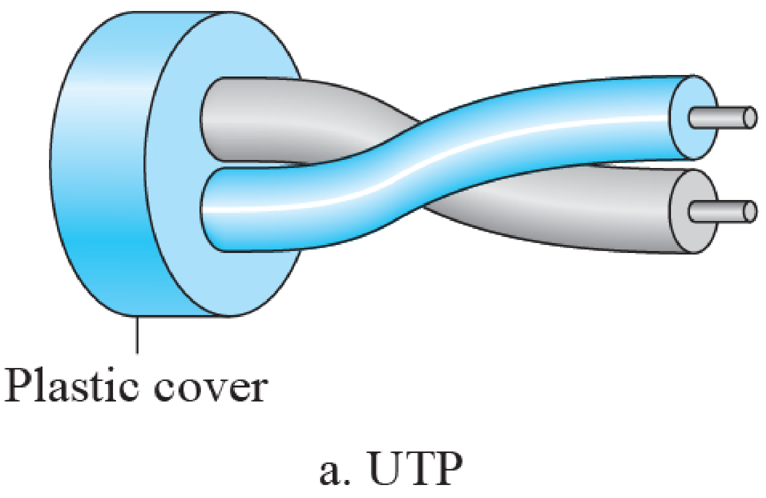
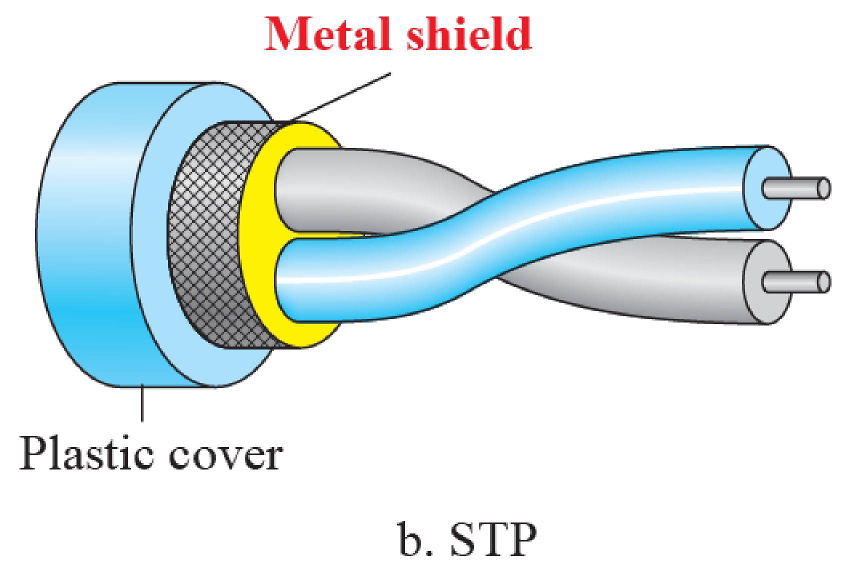


Figure 7.4: UTP and STP cables





metal foil or braided- mesh covering that encase each pair of insulated conductors.

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

Categories are determined by cable quality, with 1 as the lowest. Each category is suitable for specific uses.

UTP Connectors

The most common UTP connector: ***RJ45.***

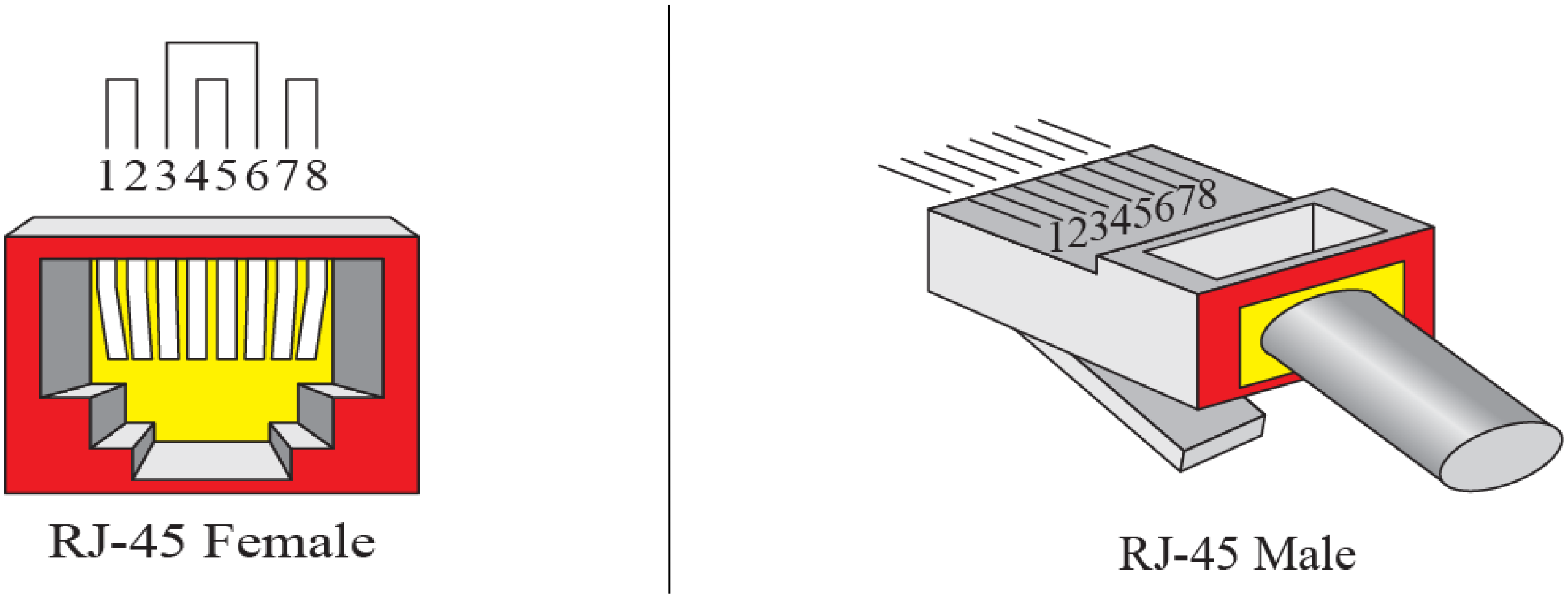
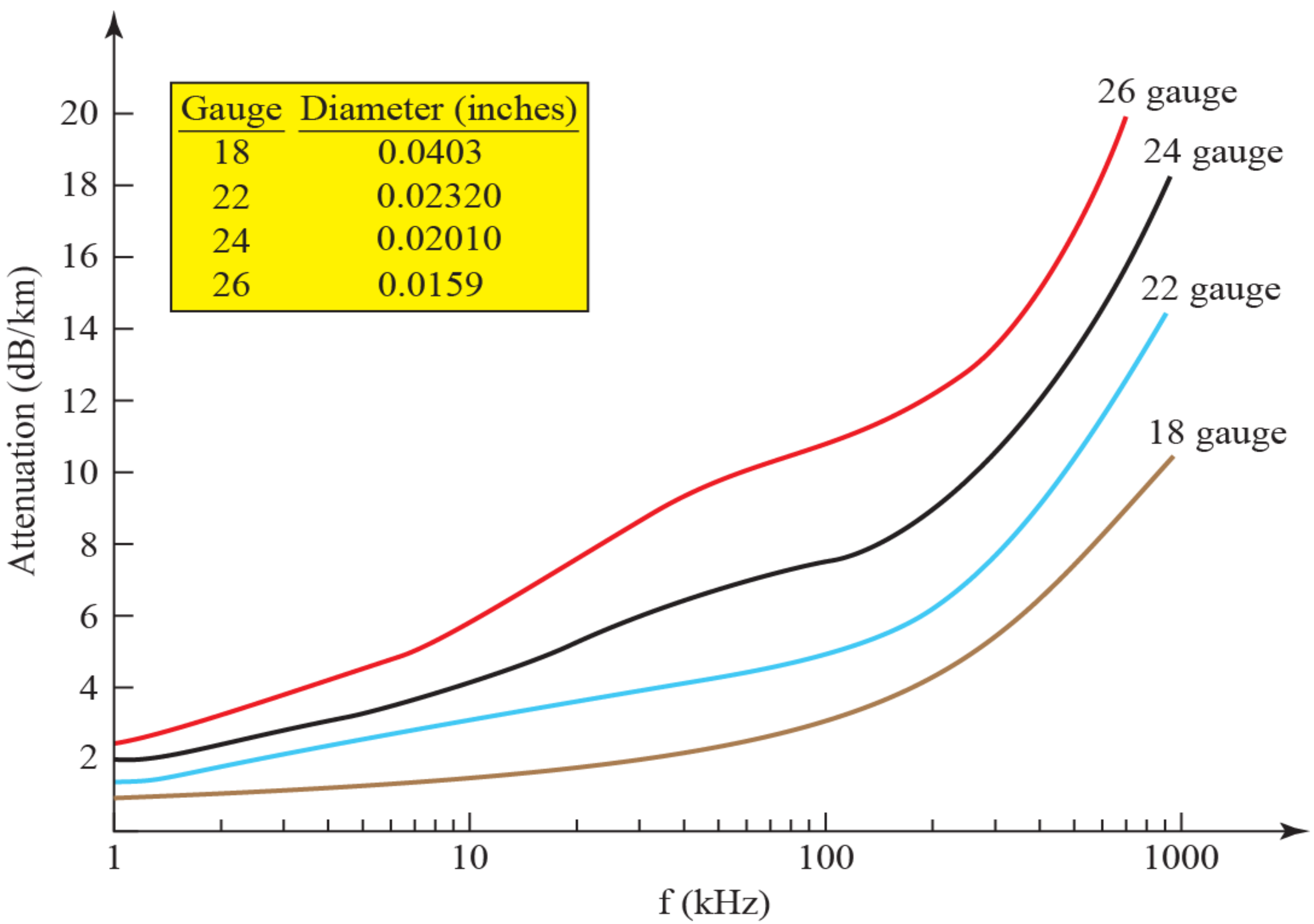


Figure 7.5: UTP Connectors

Figure 7.6: UTP Performance



gauge is a measure of the thickness of the wire.

To measure the UTP performance:

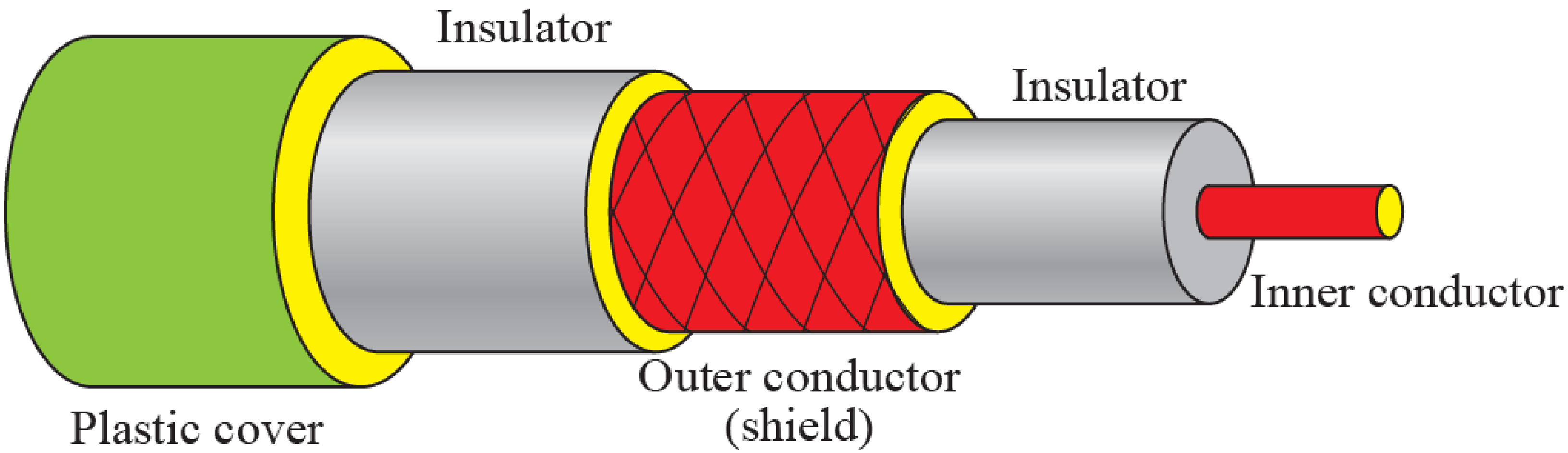
We compare attenuation with frequency and distance.

Increasing frequency make the attenuation sharply increases.

7.2.2 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.

Figure 7.7: Coaxial cable



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.

his outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.

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

Each RG number denotes a unique set of physical specification and adapted for a specialized function.

Coaxial Cable Connectors

To connect coaxial cable to devices, we need coaxial connectors Such as Bayonet Neill-Concelman (BNC) connector.

BNC connector is used to connect the end of the cable to a device.

There are three popular types of these connectors:

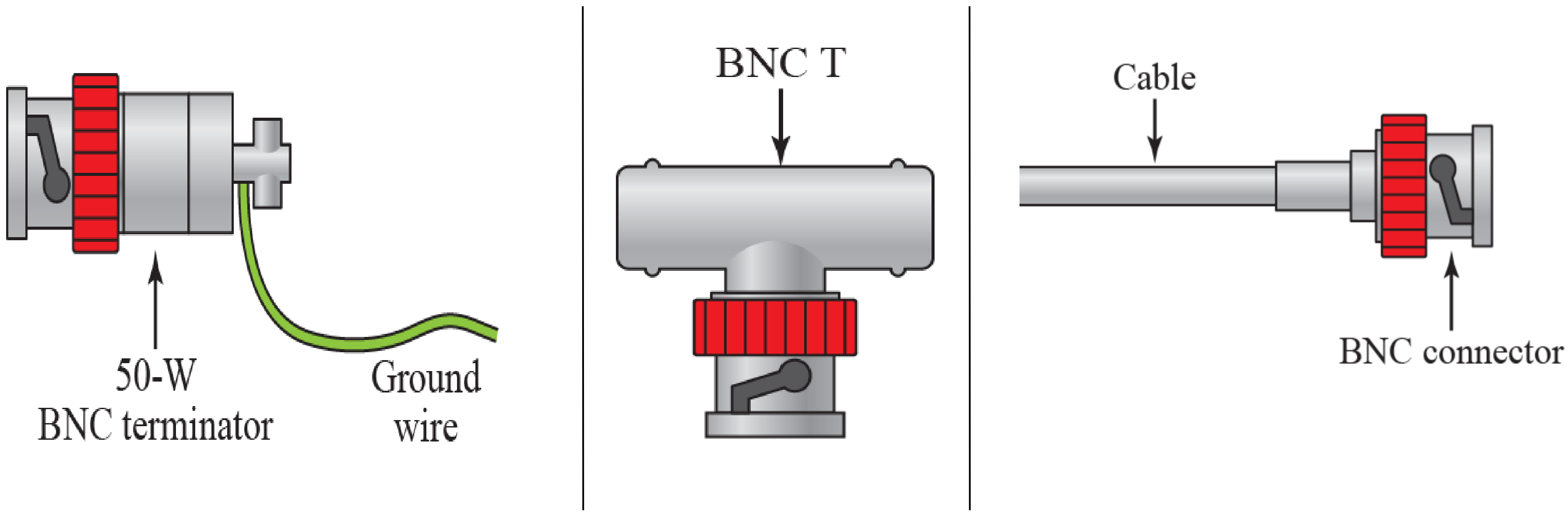
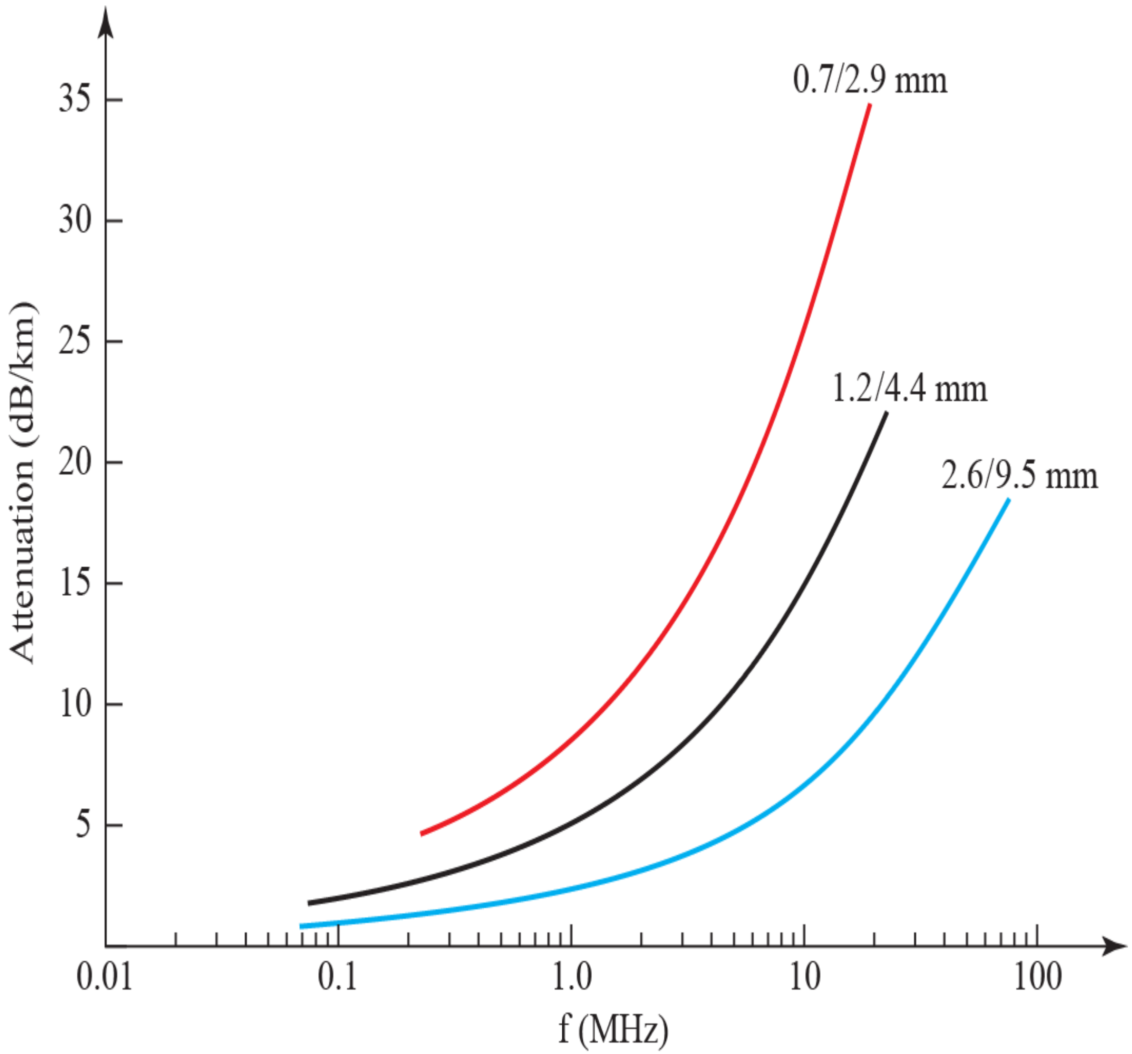


Figure 7.8: BNC connectors

Figure 7.9: Coaxial cable performance



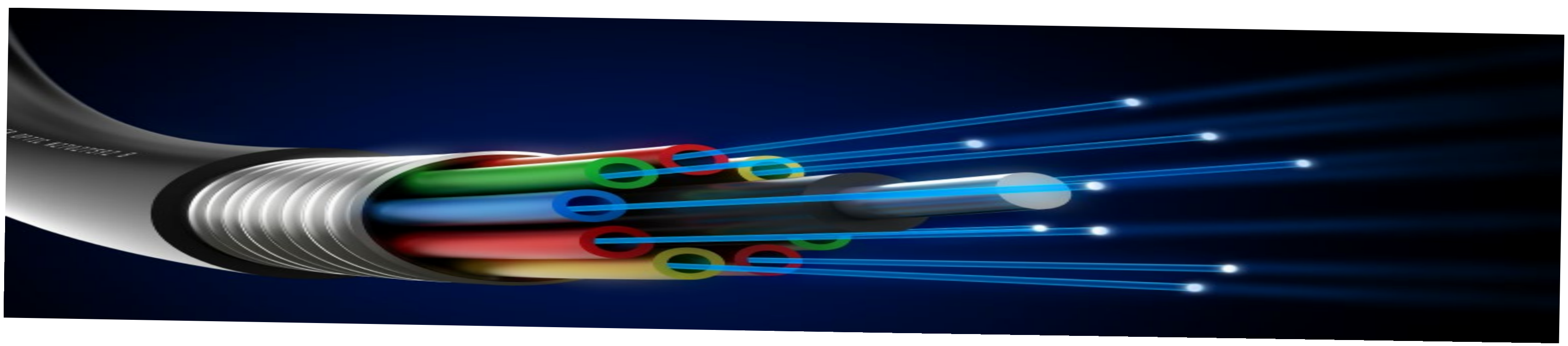
Attenuation is much higher in coaxial cable than in twisted-pair cable.

In other words, although coaxial cable has a much higher bandwidth, the signal weakens rapidly.

We need to use repeaters frequently.

7.2.3 Fiber-Optic Cable

A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.



7.2.3 Fiber-Optic Cable

To understand optical fiber, we first need to explore several aspects of the nature 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.

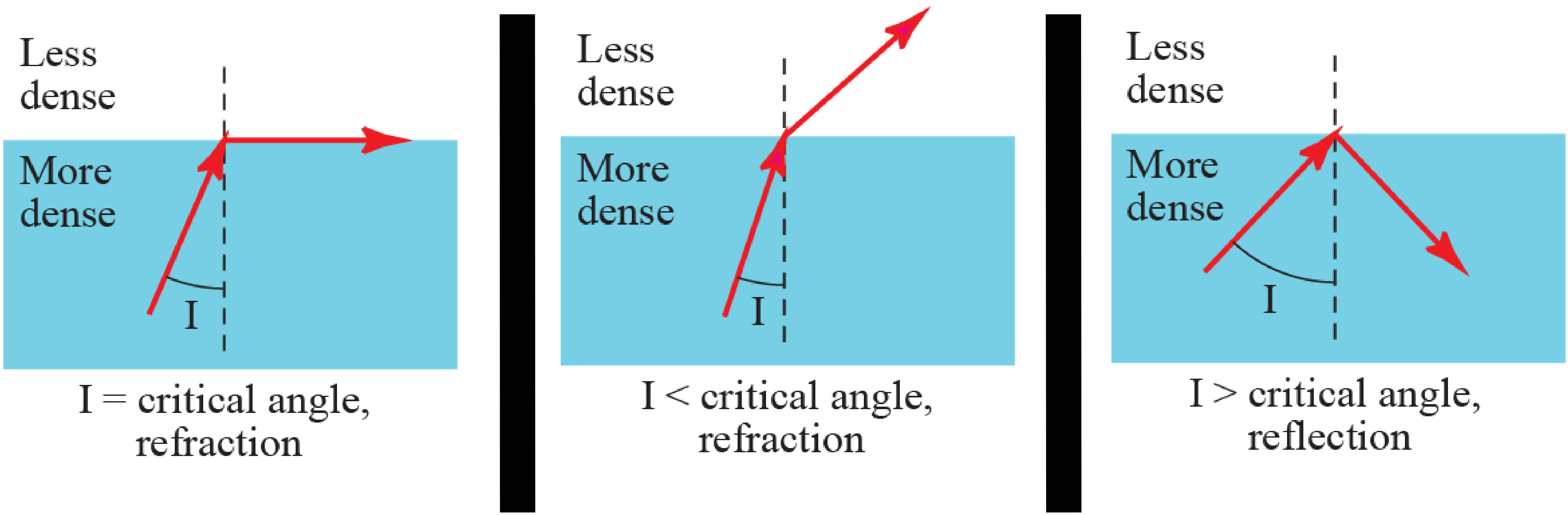
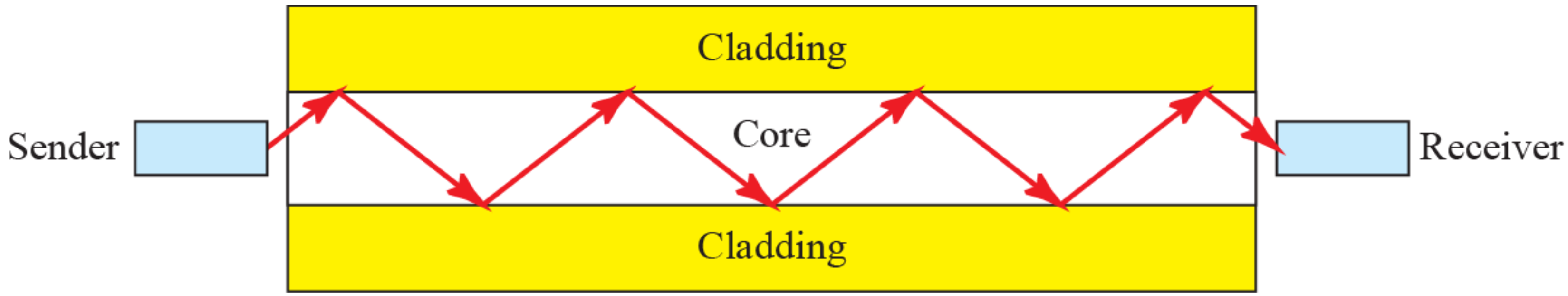


Figure 7.10 Bending of light ray when going from a more dense to a less dense substance.

Figure 7.11: Optical fiber



Optical fibers use *reflection* ***to guide light through a channel.***

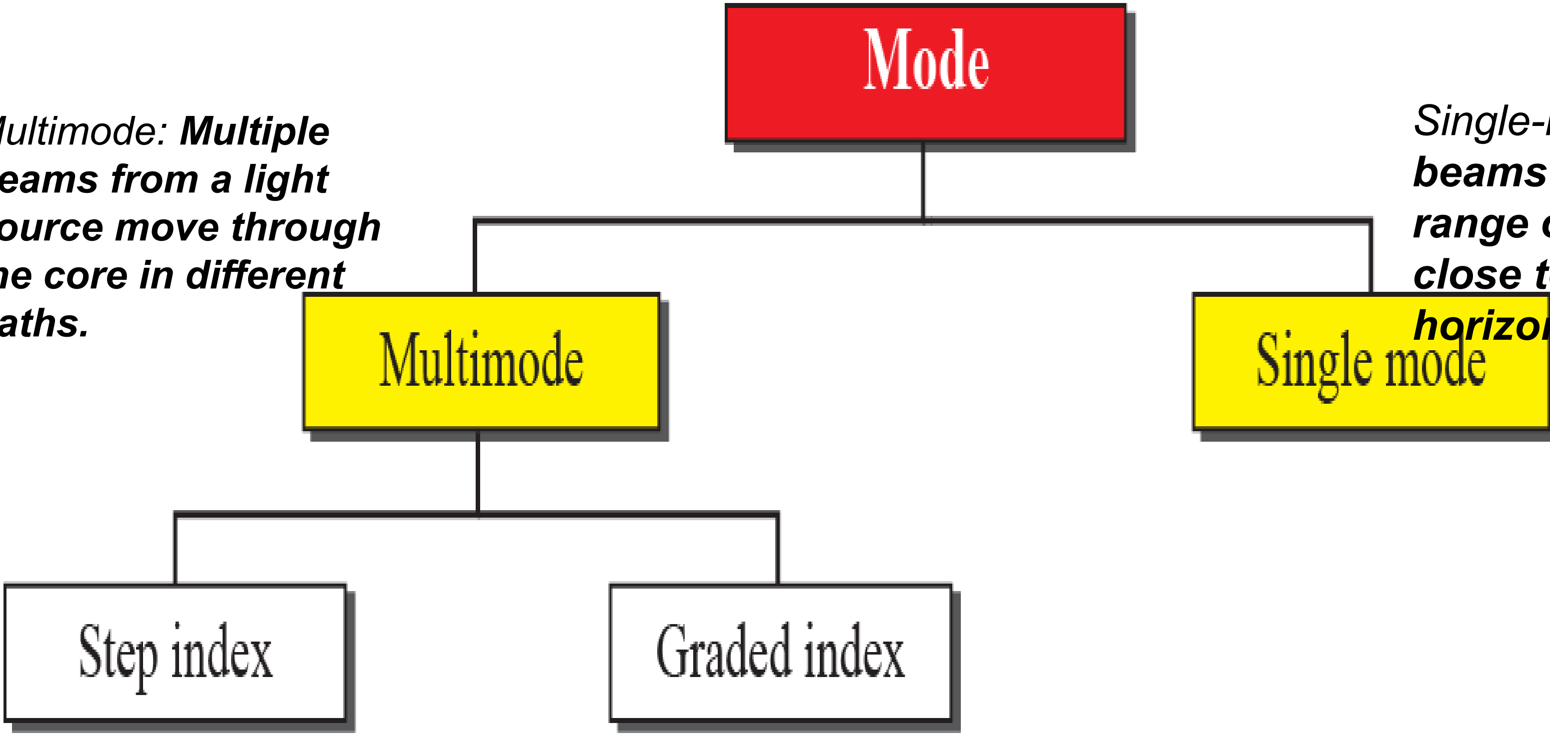
A glass or plastic core is surrounded by a *cladding* ***of less dense glass or plastic.***

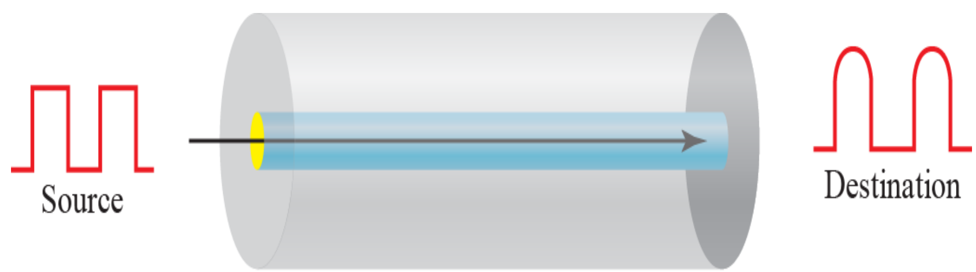
The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it.

Figure 7.12: light Propagation modes along optical channels

Multimode: ***Multiple beams from a light source move through the core in different paths.***

Single-mode ***limits beams to a small range of angles, all close to the horizontal.***

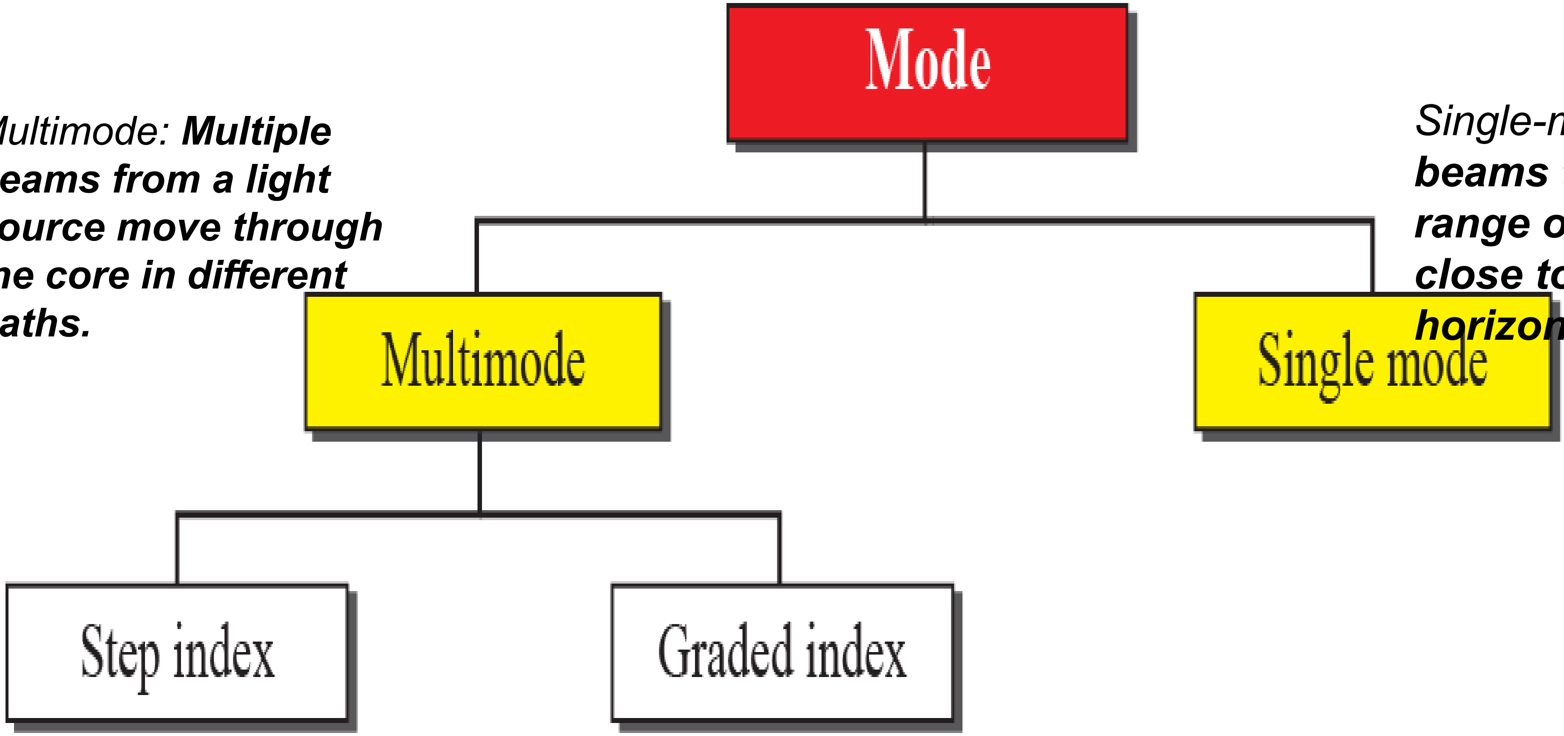




c. Single mode

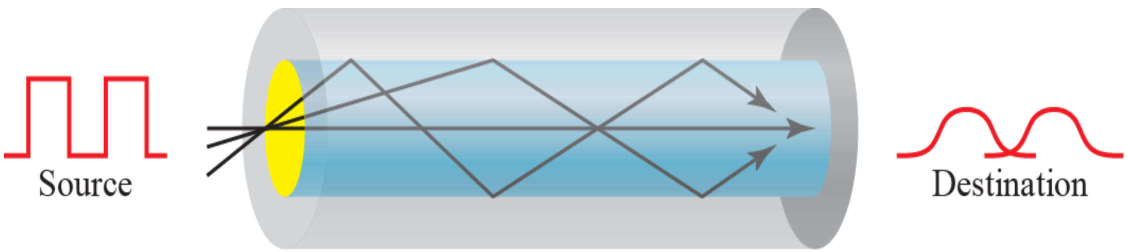
Figure 7.12: light Propagation modes along optical channels

Multimode: ***Multiple beams from a light source move through the core in different paths.***



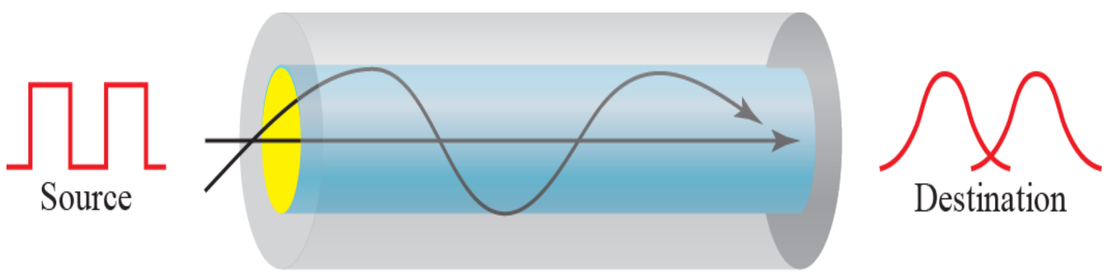
Single-mode ***limits beams to a small range of angles, all close to the horizontal.***

Figure 7.13: Modes



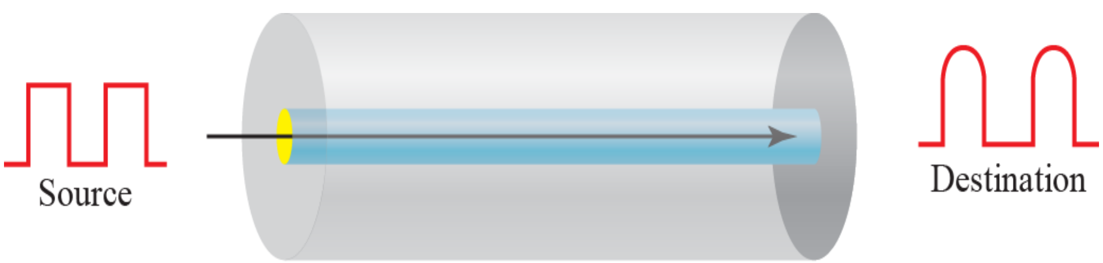
a. Multimode, step index

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(lower density); this alters the angle of the beam's motion. The term step-index refers to the suddenness of this change.



b. Multimode, graded index

Density is highest at the center of the core and decreases gradually to its lowest at the edge. This variable density impact the propagation of light beams.



c. Single mode

It has smaller diameter and lower density than multimode fiber. The decrease in density results in a critical angle that is close enough to 90° to make the propagation of beams almost horizontal.

Table 7.3: Fiber types

Optical fibers are defined by the ratio of the diameter of their core to the diameter of their cladding

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

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100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

Figure 7.14: Fiber connection

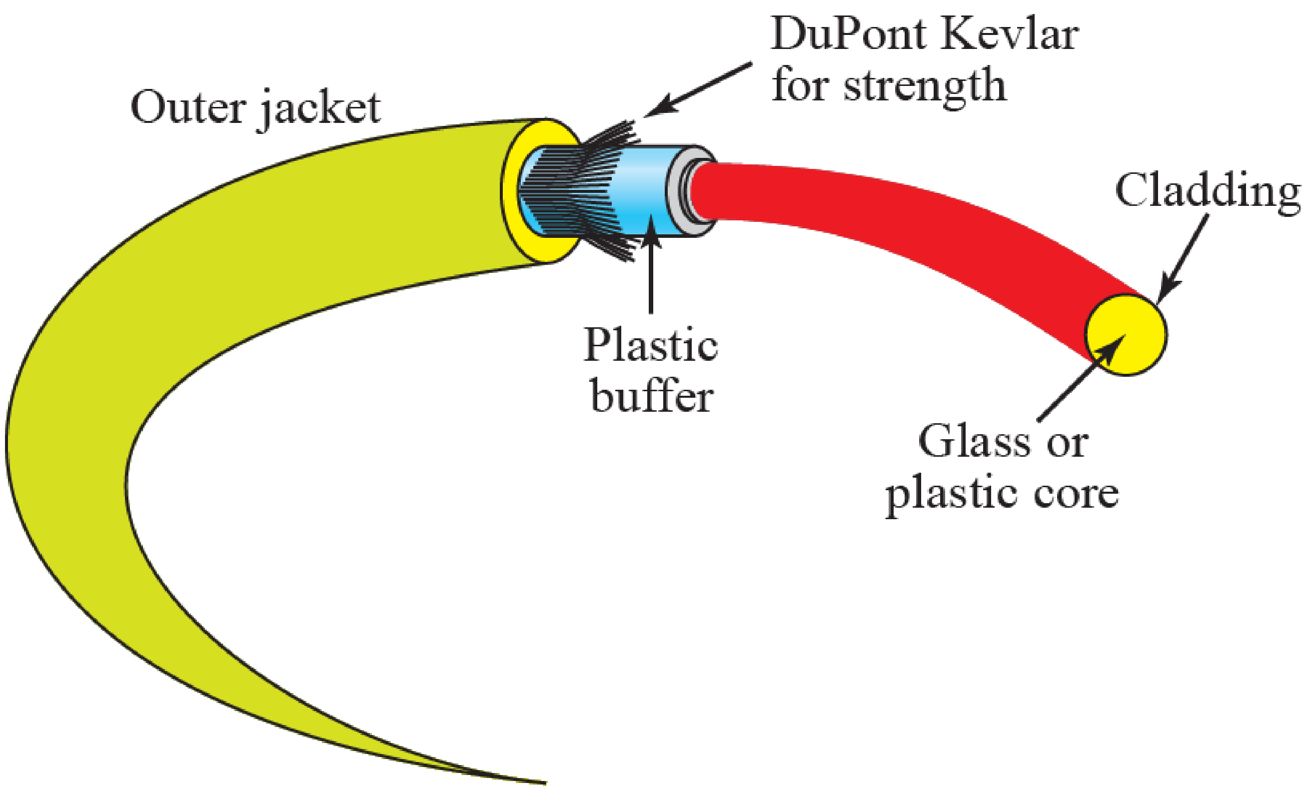
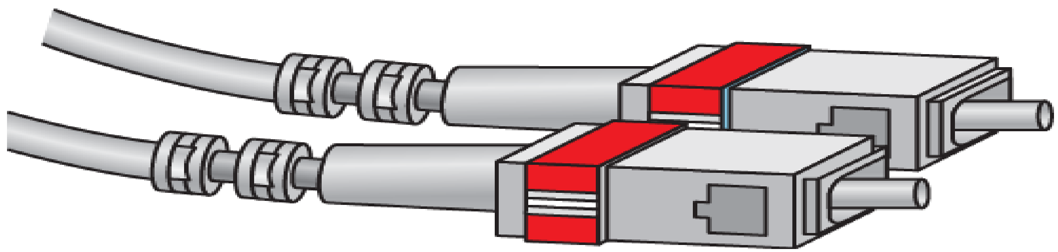
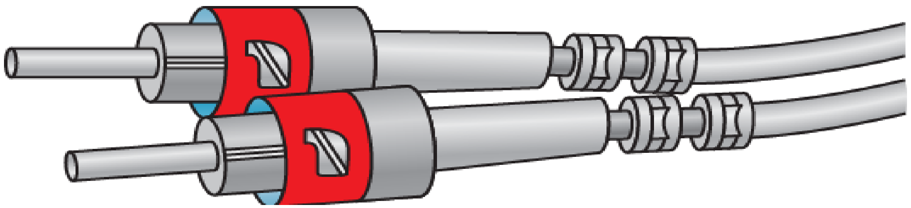


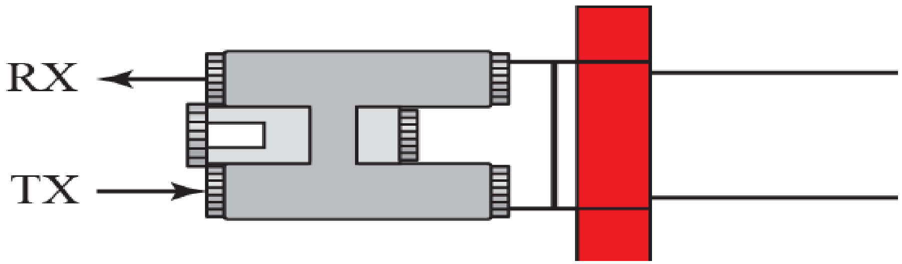
Figure 7.15: Fiber-optic cable connector



subscriber channel (SC) connector

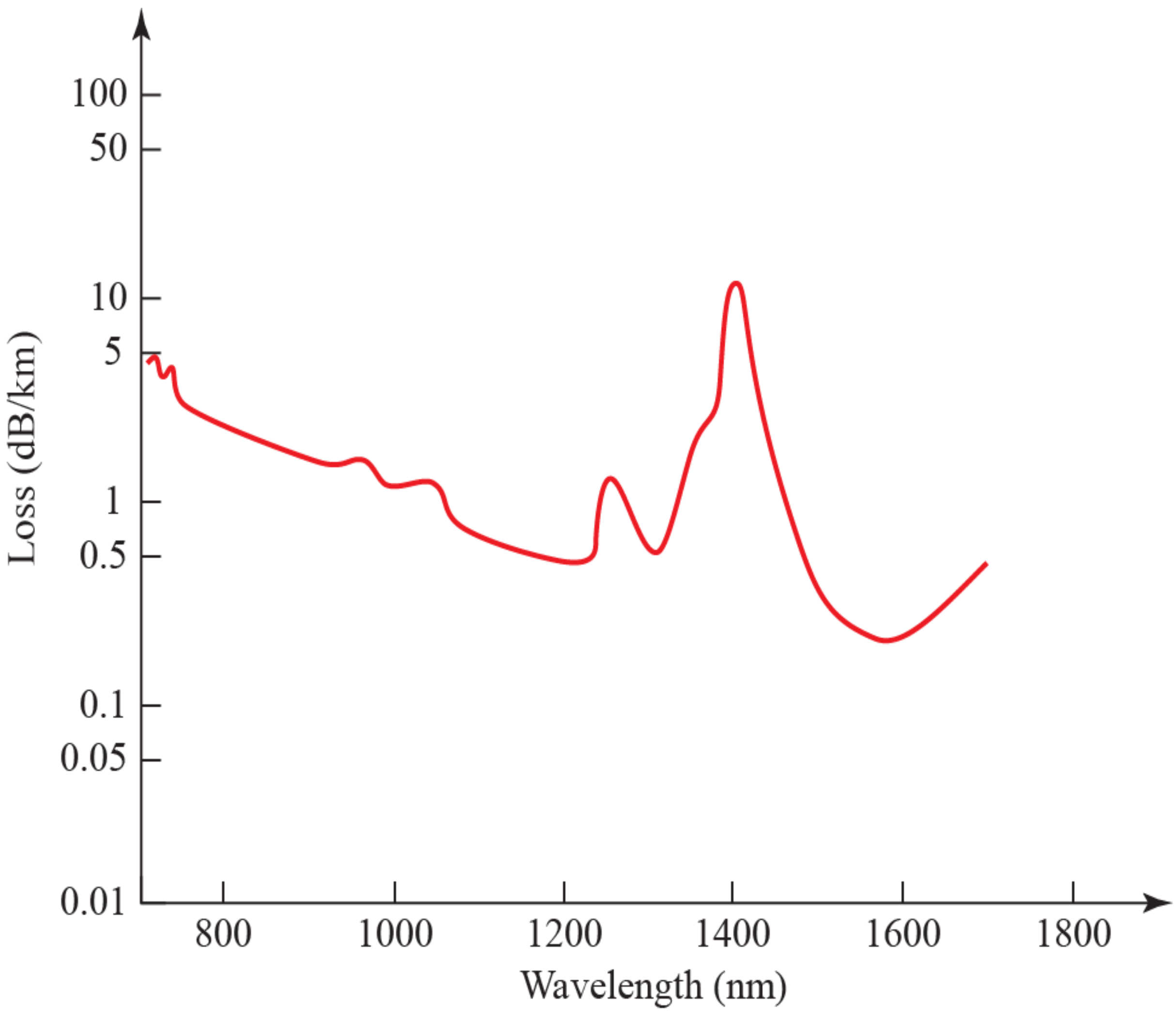


Straight-tip (ST) connector



MT-RJ
connector

Figure 7.16: Optical fiber performance



Attenuation is flatter than twisted-pair cable and coaxial cable.

So we need fewer repeaters than twisted-pair cable and coaxial cable.

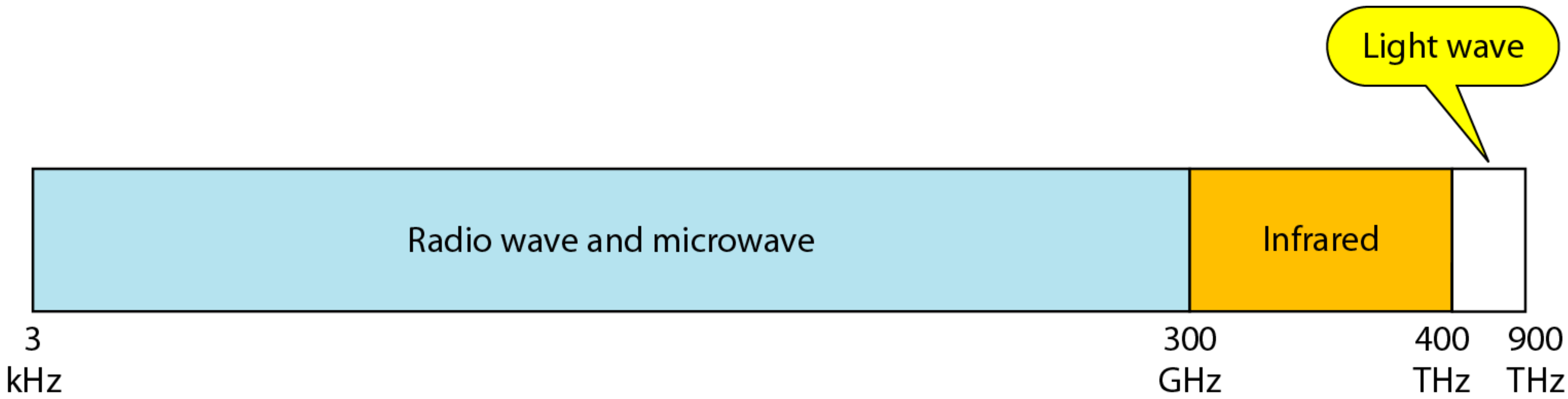
7-3 UNGUIDED MEDIA

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.

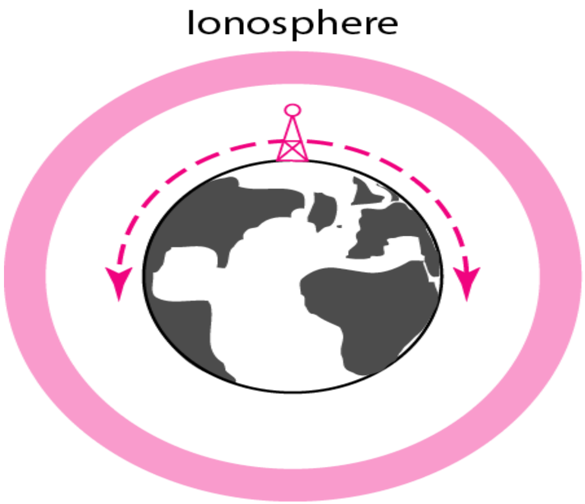
Figure 7.17: Electromagnetic spectrum for wireless communication



the electromagnetic spectrum, ranging from 3 kHz to 900 THz, are used for wireless communication.

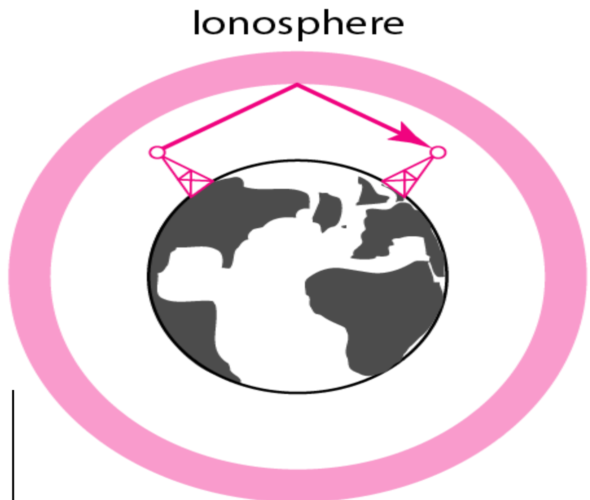
Figure 7.18: Propagation methods

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



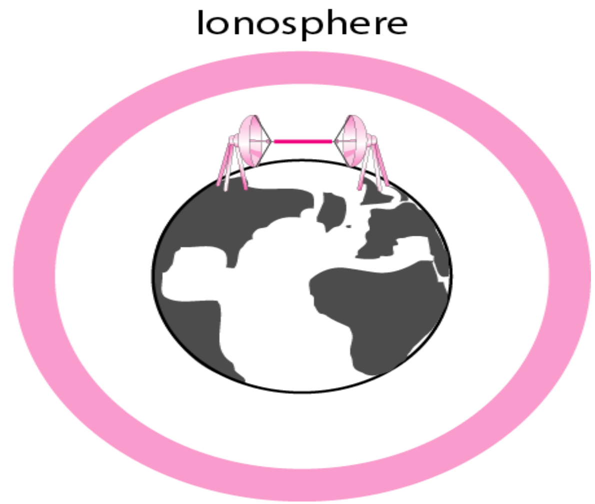
Ground propagation
(below 2 MHz)

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.



Sky propagation
(2–30 MHz)

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
(above 30 MHz)

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

Table 7.4: Bands

The section of the electromagnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called bands

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
superhigh frequency (SF)	3–30 GHz	Line-of-sight	Satellite
extremely high frequency (EHF)	30–300 GHz	Line-of-sight	Radar, satellite

7.3.1 Radio Waves

Although there is no clear-cut demarcation between radio waves and microwaves,

electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves;

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

However, the behavior of the waves, rather than the frequencies, is a better standard for classification.

7.3.1 Radio Waves

Radio waves are omnidirectional: When an antenna transmits radio waves, they are propagated in all directions, based on the wavelength, strength, and the purpose of transmission,

This means that the sending and receiving antennas do not have to be aligned. A sending antenna sends waves that can be received by any receiving antenna.

Therefore, radio waves are useful for multicasting, in which there is one sender but many receivers such as AM and FM radio and television.

Radio waves can penetrate walls.

The radio wave band is relatively narrow, just under 1 GHz, compared to the microwave band.

Using any part of the band requires permission from the authorities.

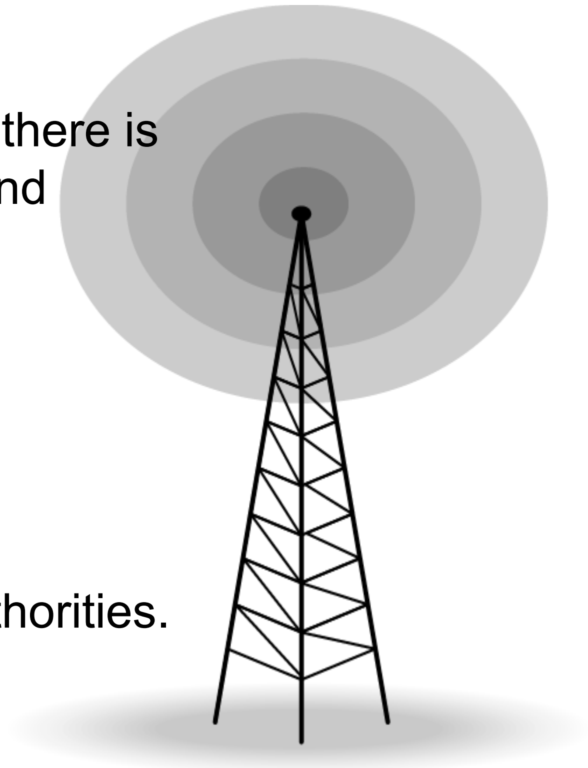


Figure 7.19: Omnidirectional antenna

7.3.2 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.

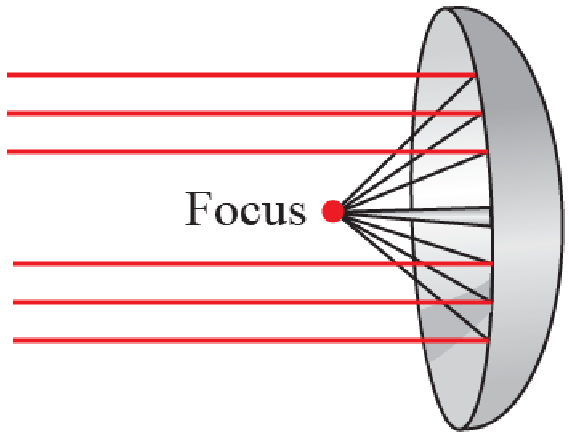
This means that the sending and receiving antennas need to be aligned.

The unidirectional property has an obvious advantage: A pair of antennas can be aligned without interfering with another pair of aligned antennas.

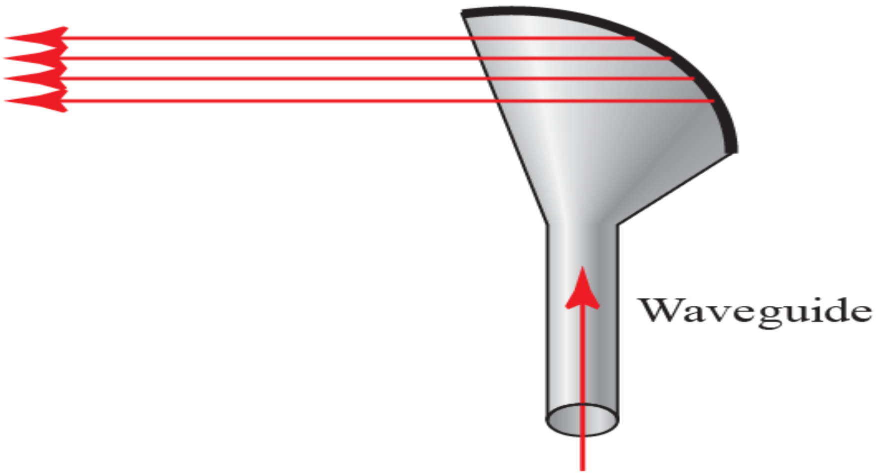
Ex: microwaves Used in cellular phones and wireless

Figure 7.20: Unidirectional antenna

Microwaves need unidirectional antennas that send out signals in one direction. Two types of antennas are used for microwave communications



a. Parabolic dish antenna



b. Horn antenna

Every line parallel to the line of symmetry reflects off the curve at angles such that all the lines intersect in a common point called the focus. In this way, more of the signal is recovered than would be possible with a single-point receiver.

Outgoing transmissions are broadcast up a stem, 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.

7.3.3 Infrared

Infrared waves characteristic:

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.

For example: ***When we use our infrared remote control, we do not interfere with the use of the remote by our neighbors.***

WiFi

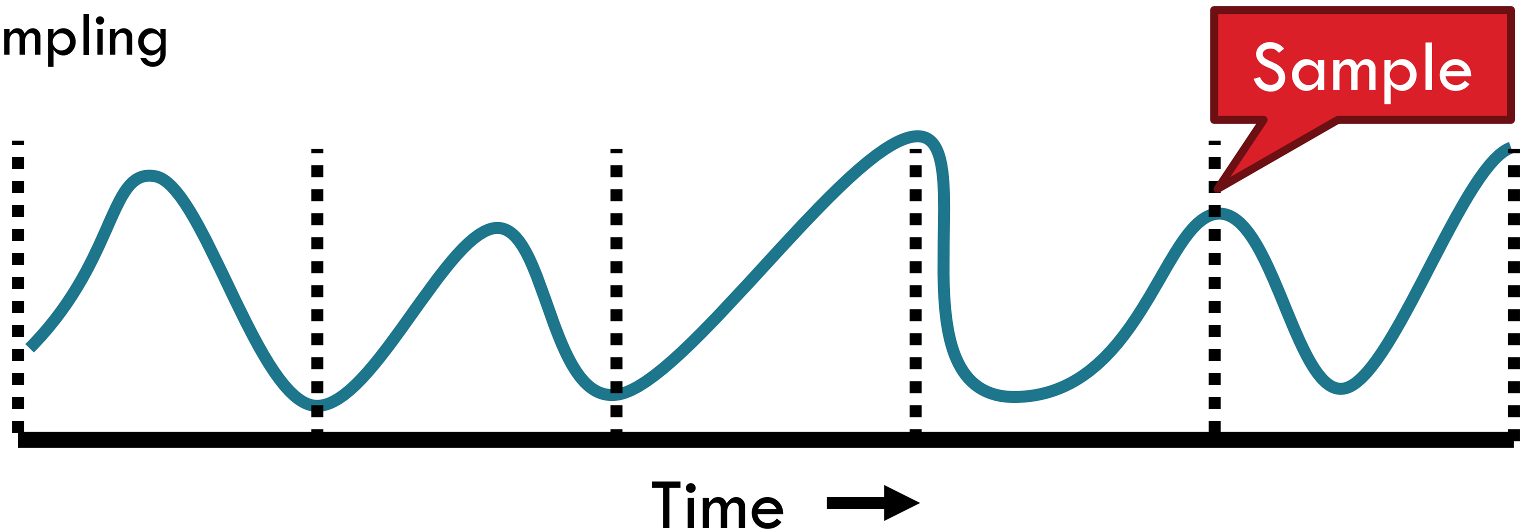
Buat 5-6 slides tentang teknologi WiFi a/b/c/g/n .....

Key challenge

- Digital computers
  - 0s and 1s
- Analog world
  - Amplitudes and frequencies

Assumptions

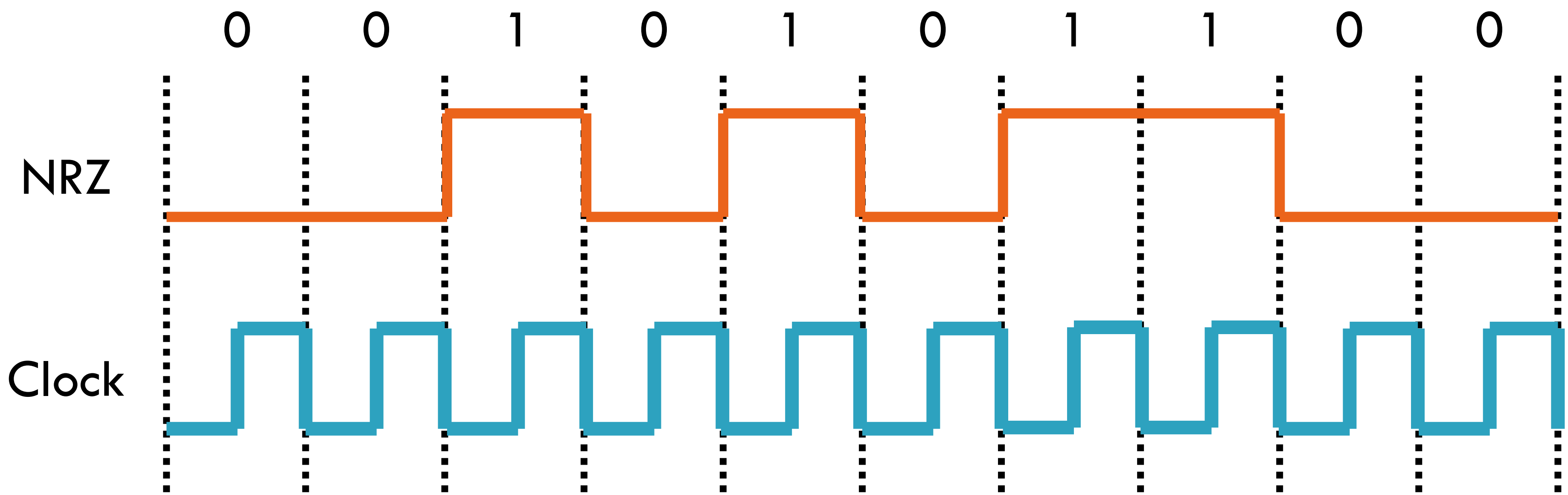
- We have two discrete signals, high and low, to encode 1 and 0
- Transmission is synchronous, i.e. there is a clock that controls signal sampling



- Amplitude and duration of signal must be significant

Non-Return to Zero (NRZ)

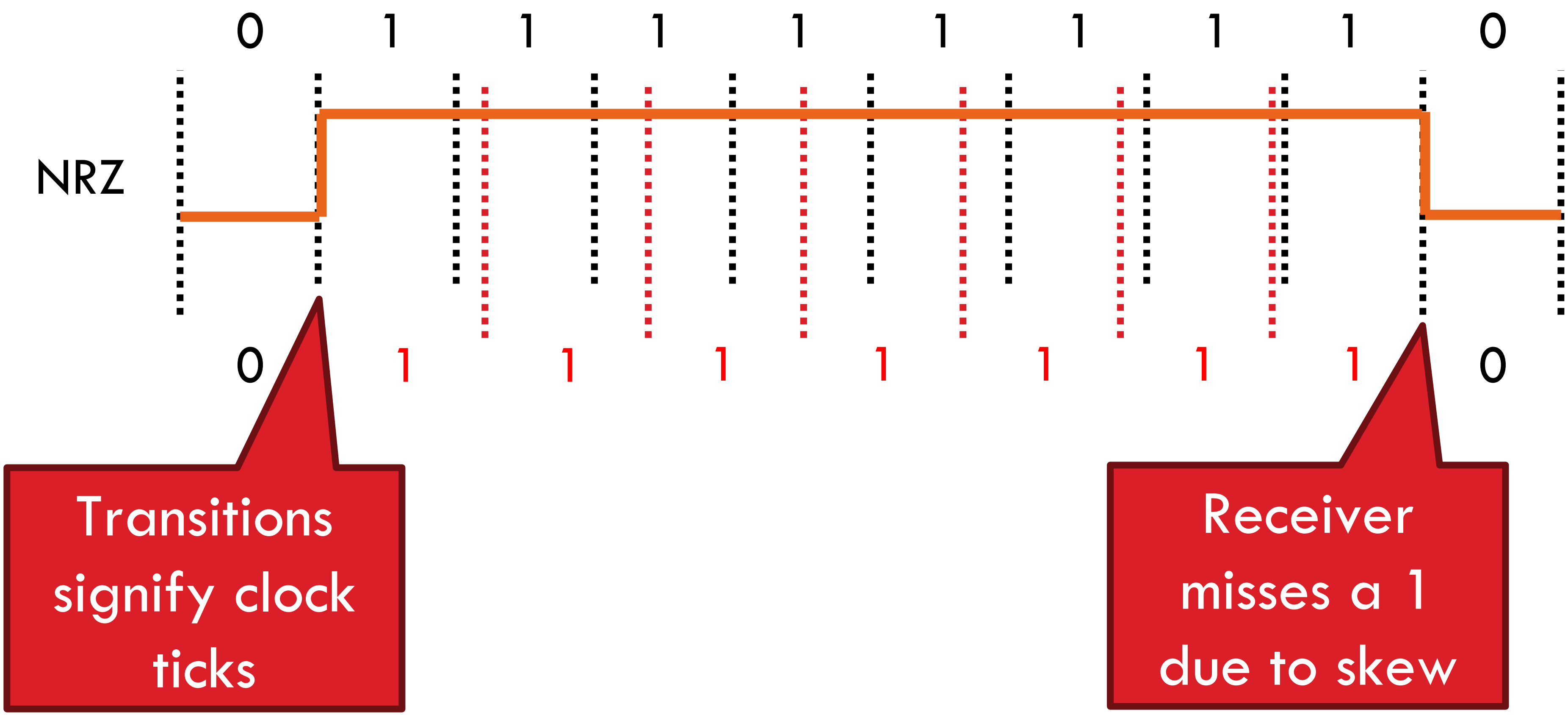
- 1 → high signal, 0 → low signal



- Problem: long strings of 0 or 1 cause desynchronization
  - How to distinguish lots of 0s from no signal?
  - How to recover the clock during lots of 1s?

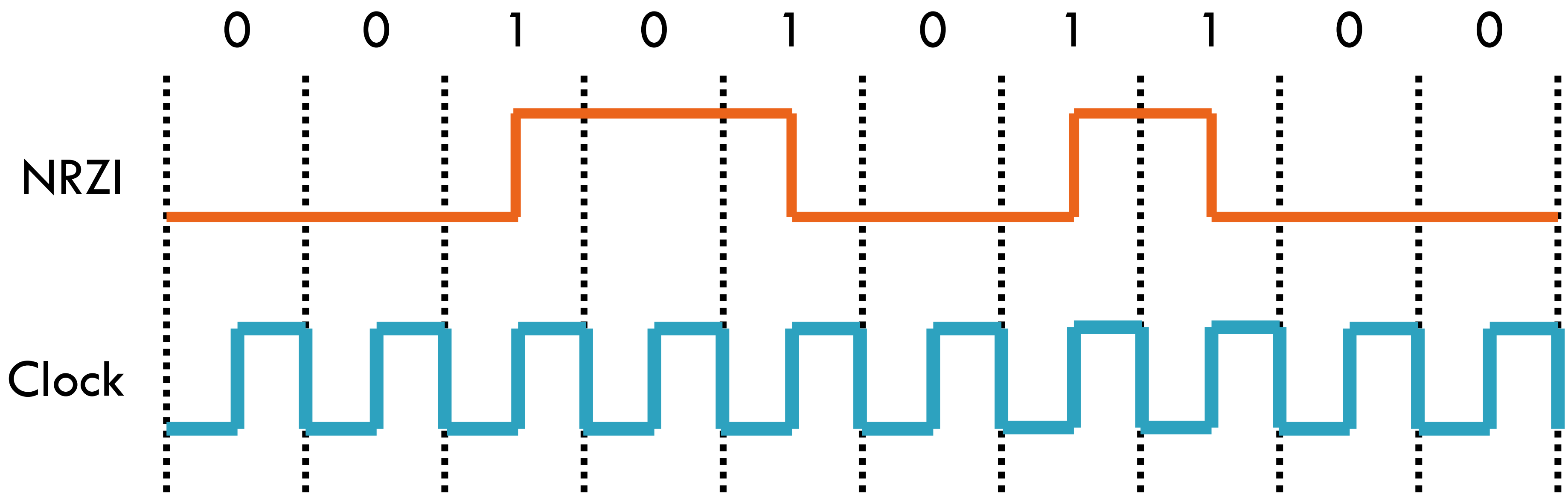
Desynchronization

- Problem: how to recover the clock during sequences of 0's or 1's?



Non-Return to Zero Inverted (NRZI)

- 1 → make transition, 0 → remain the same



- Solves the problem for sequences of 1s, but not 0s

4-bit/5-bit (100 Mbps Ethernet)

8-bit / 10-bit used in Gigabit Ethernet

- Observat… works as long as no sequences of 0
- I… ences with no more than one leading 0 and two trailing 0

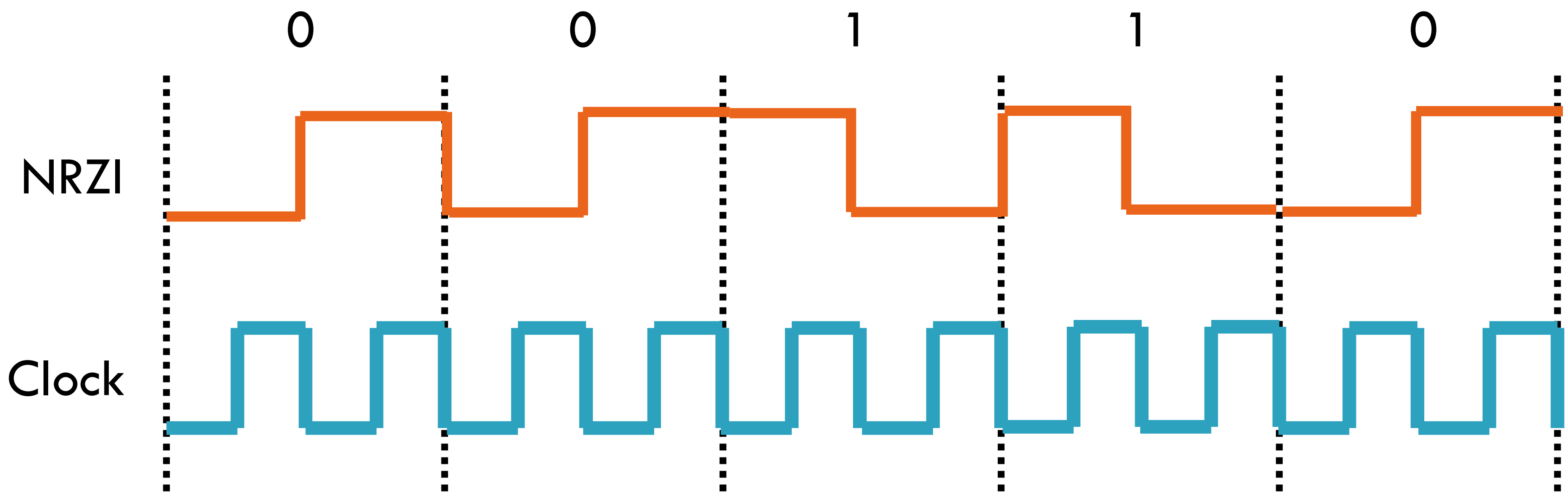
4-bit	5-bit
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111

4-bit	5-bit
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

- Tradeoff: efficiency drops to 80%

Manchester

- 1 → high-to-low, 0 → low-to-high



- Good: Solves clock skew (every bit is a transition)
- Bad: Halves throughput (two clock cycles per bit)

General comment

- Physical layer is the lowest, so…
  - We tend not to worry about where to place functionality
  - There aren't other layers that could interfere
  - We tend to care about it only when things go wrong
    - http://blog.level3.com/level-3-network/the-10-most-bizarre-and-annoying-causes-of-fiber-cuts/
- Physical layer characteristics are still fundamentally important to building reliable Internet systems
  - Insulated media vs wireless
  - Packet vs. circuit switched media