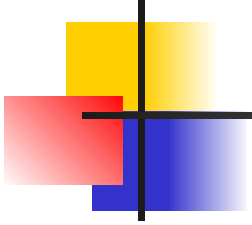
Lecture 5
Multiplexing And Transmission Media



Bandwidth utilization is the wise use of available bandwidth to achieve specific goals.

Efficiency can be achieved by multiplexing

6-1 MULTIPLEXING

Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared. Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link. As data and telecommunications use increases, so does traffic.

Frequency-Division Multiplexing
Wavelength-Division Multiplexing
Synchronous Time-Division Multiplexing
Statistical Time-Division Multiplexing

Figure 6.1 *Dividing a link into channels*

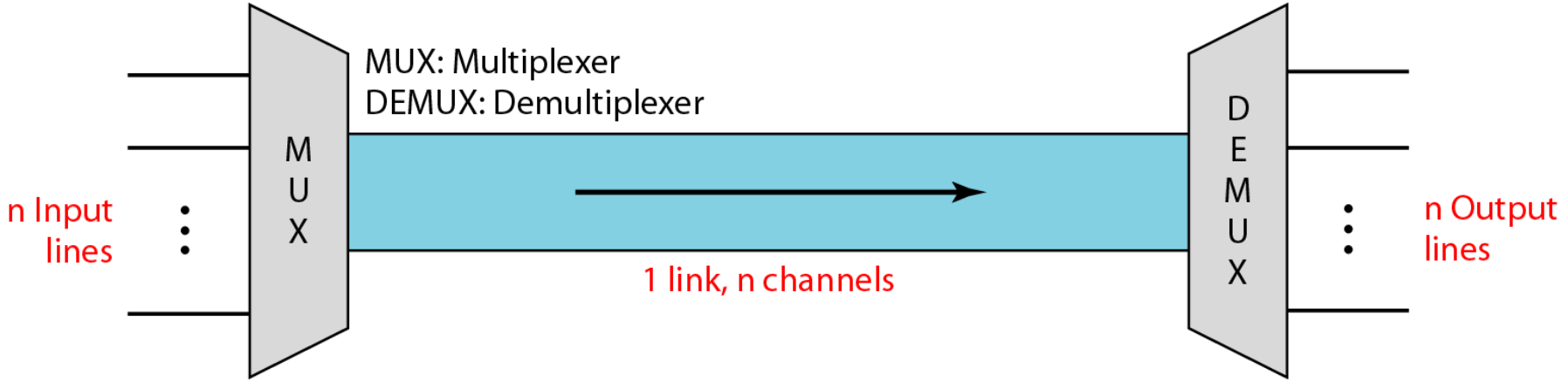


Figure 6.2 *Categories of multiplexing*

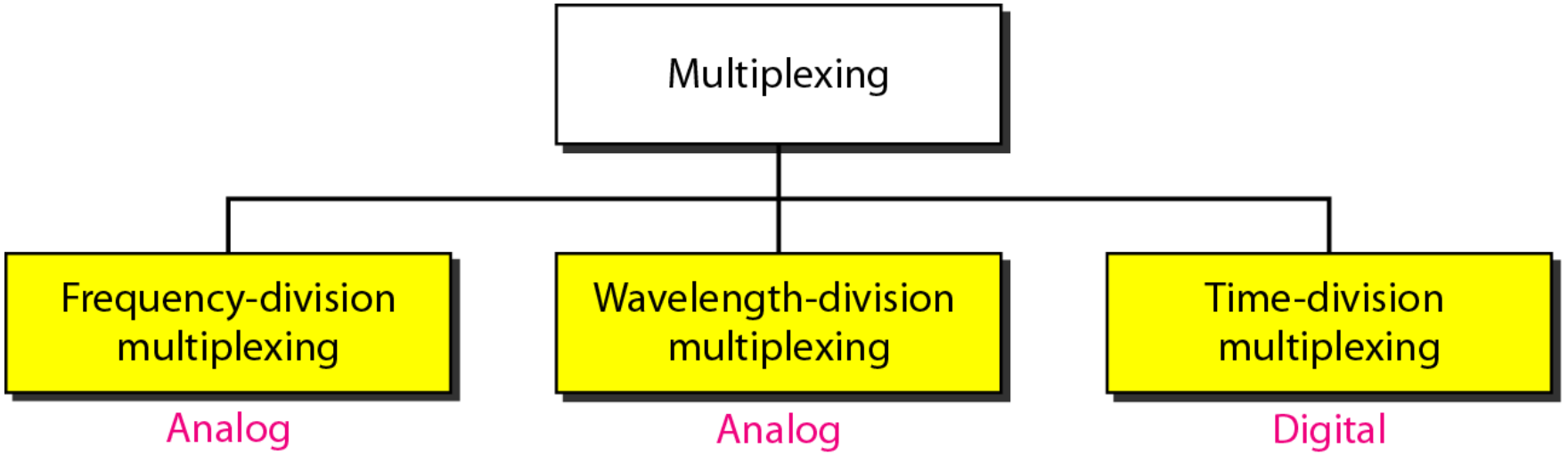


Figure 6.3 *Frequency-division multiplexing*

Figure 6.4 *FDM process*

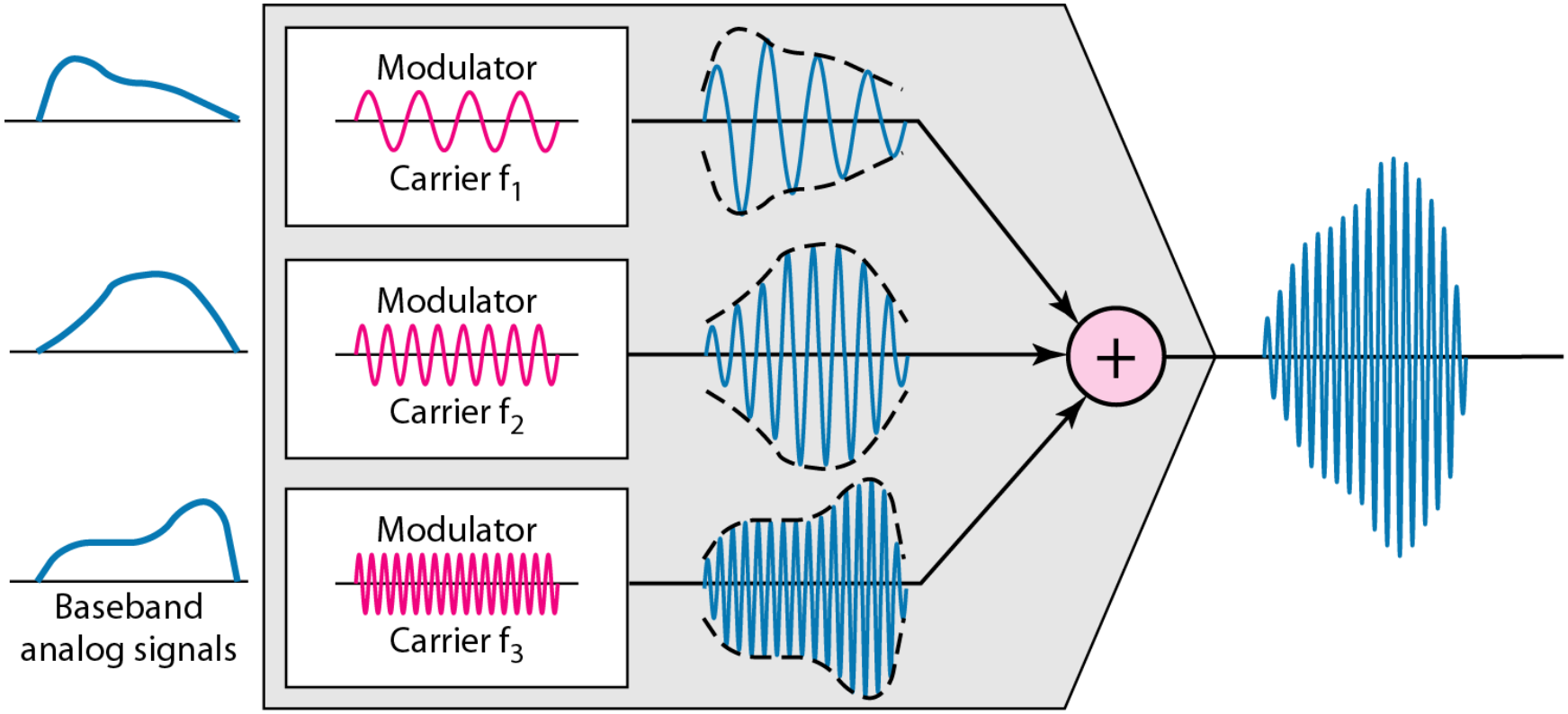
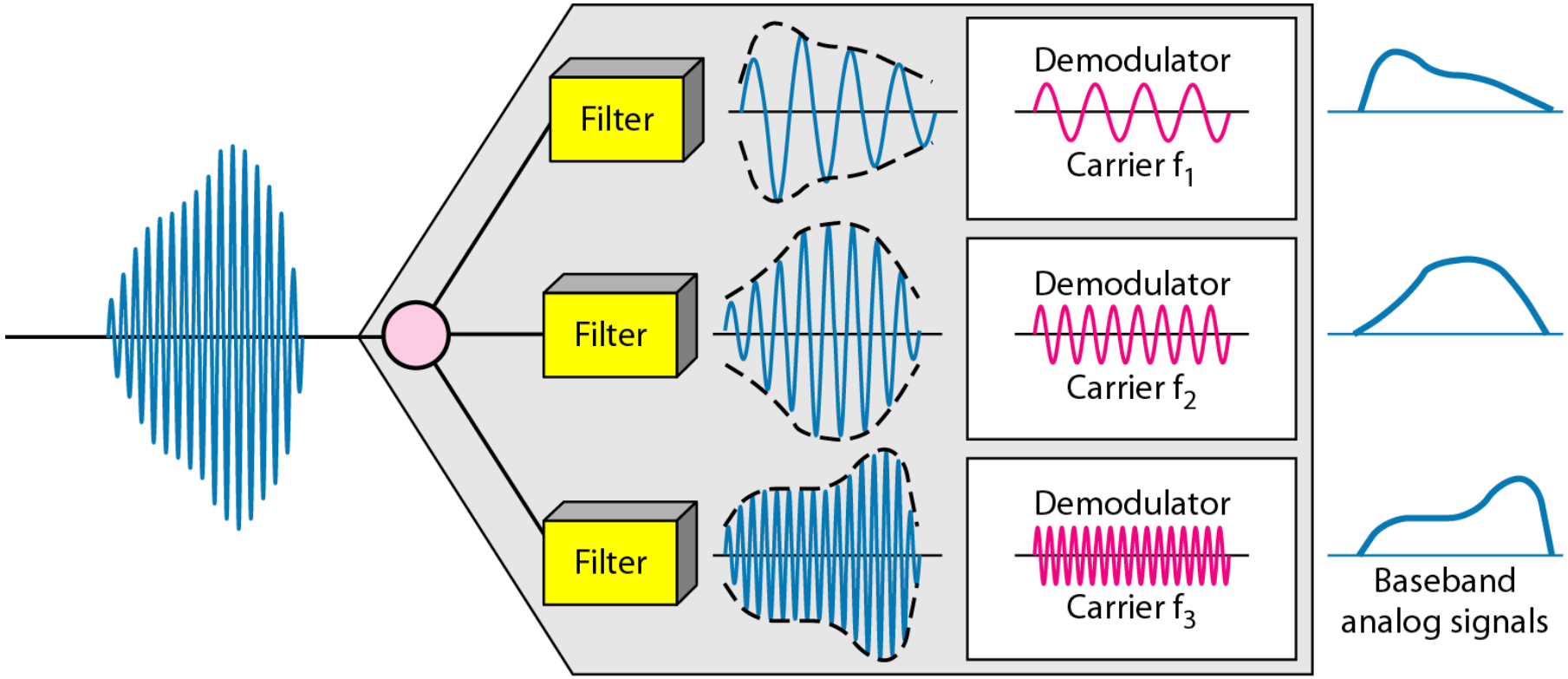


Figure 6.5 *FDM demultiplexing example*



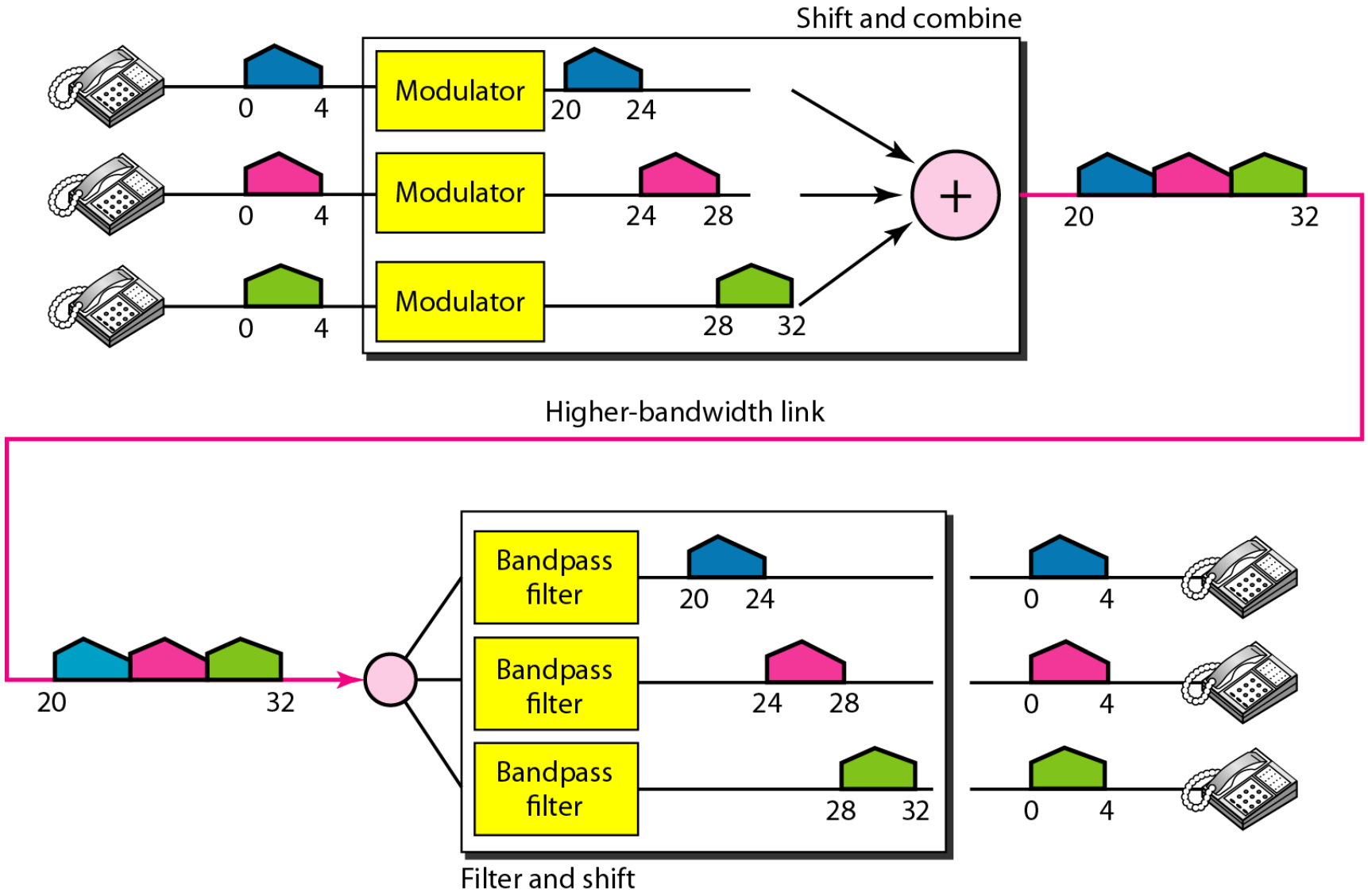
Example 6.1

Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine three voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show the configuration, using the frequency domain. Assume there are no guard bands.

Solution

We shift (modulate) each of the three voice channels to a different bandwidth, as shown in Figure 6.6. We use the 20- to 24-kHz bandwidth for the first channel, the 24- to 28-kHz bandwidth for the second channel, and the 28- to 32-kHz bandwidth for the third one. Then we combine them as shown in Figure 6.6.

Figure 6.6 *Example 6.1*



Example 6.2

Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?

Solution

For five channels, we need at least four guard bands. This means that the required bandwidth is at least

$$5 \times 100 + 4 \times 10 = 540 \text{ kHz},$$

as shown in Figure 6.7.

Figure 6.7 *Example 6.2*

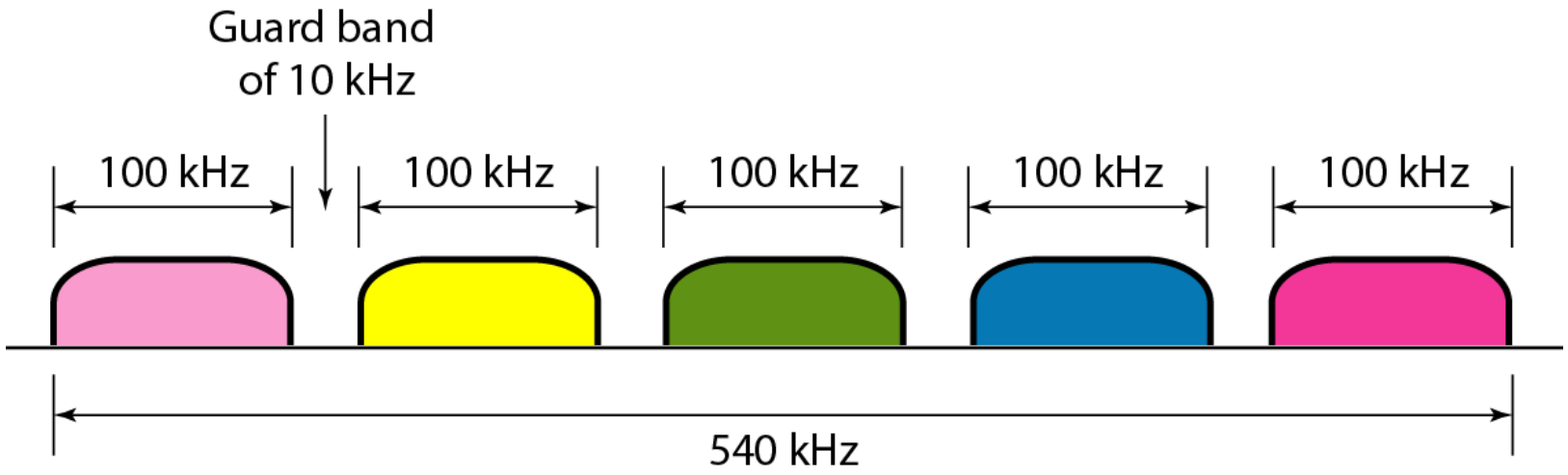


Figure 6.9 *Analog hierarchy*

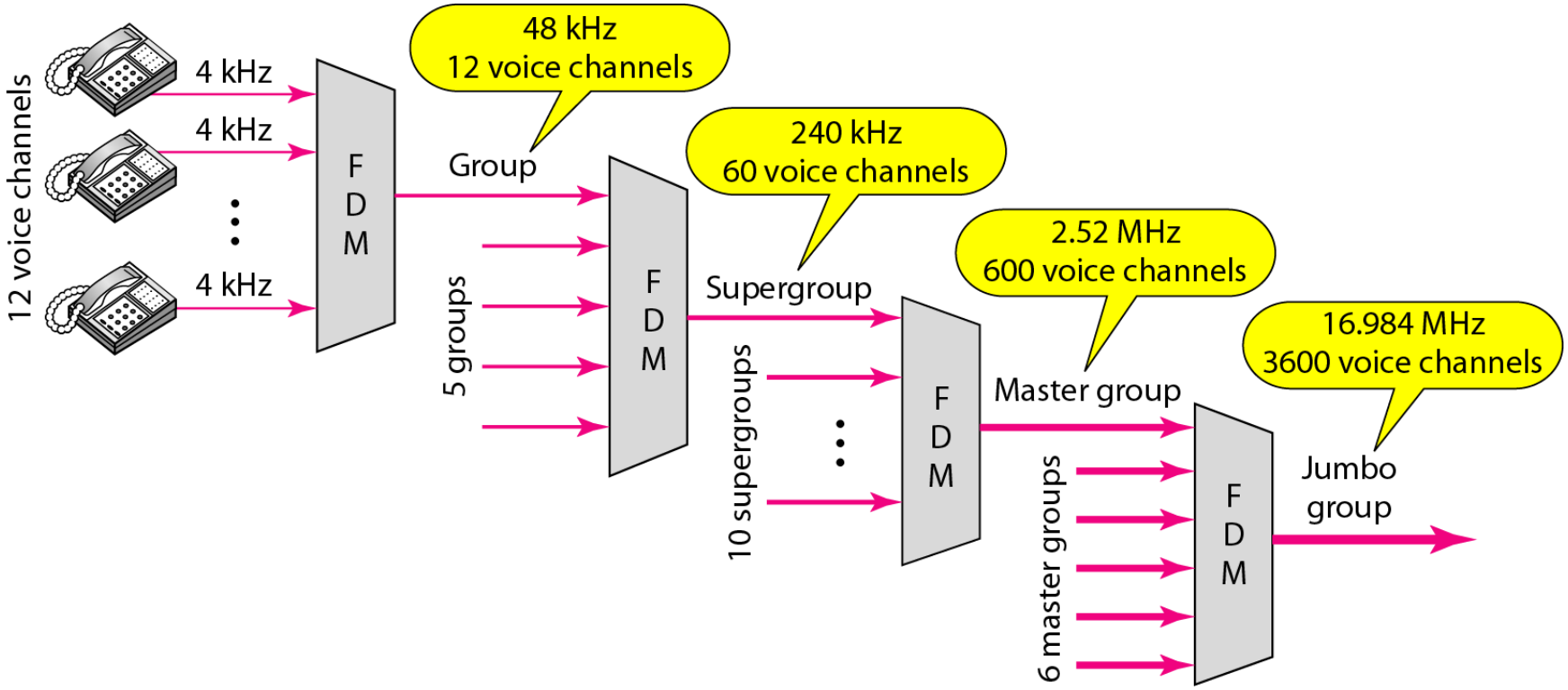
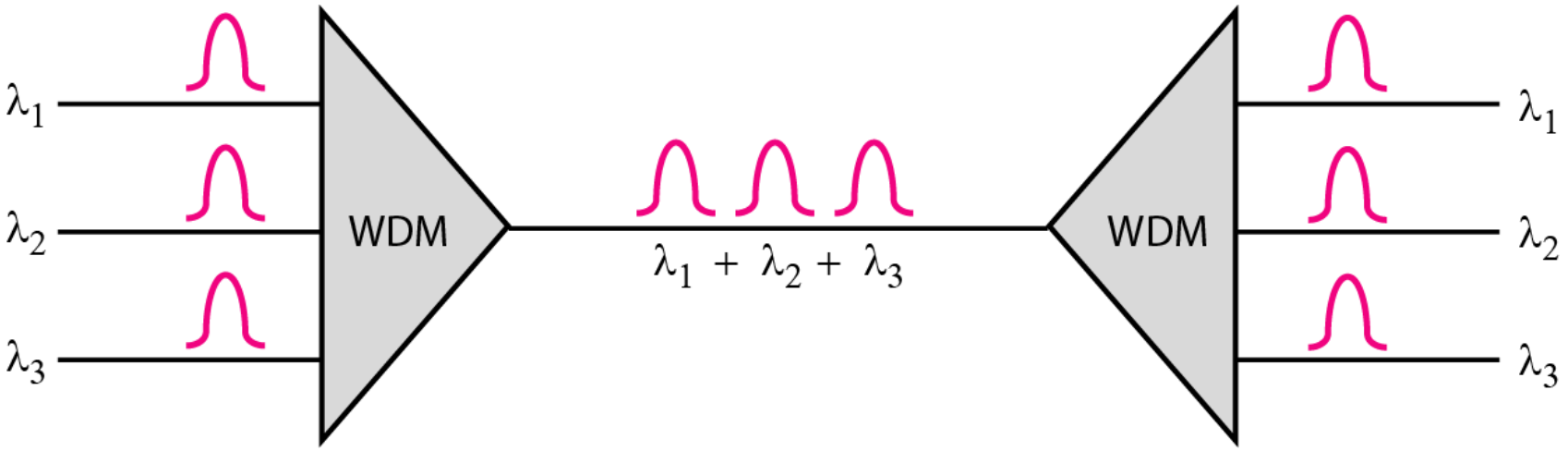
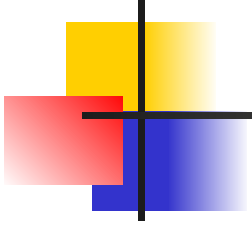


Figure 6.10 *Wavelength-division multiplexing (optical signals)*





WDM is an analog multiplexing technique to combine optical signals.

Figure 6.11 *Prisms in wavelength-division multiplexing and demultiplexing*

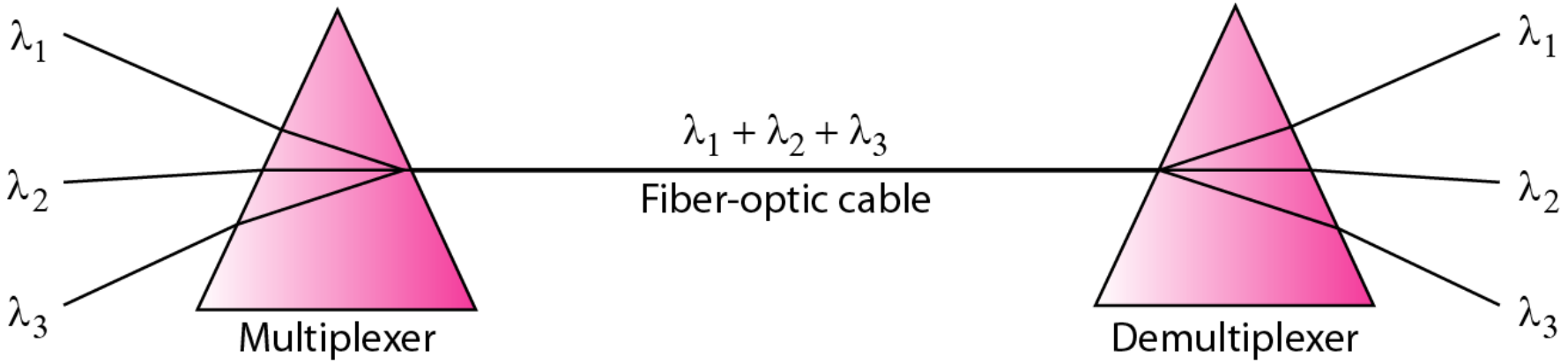
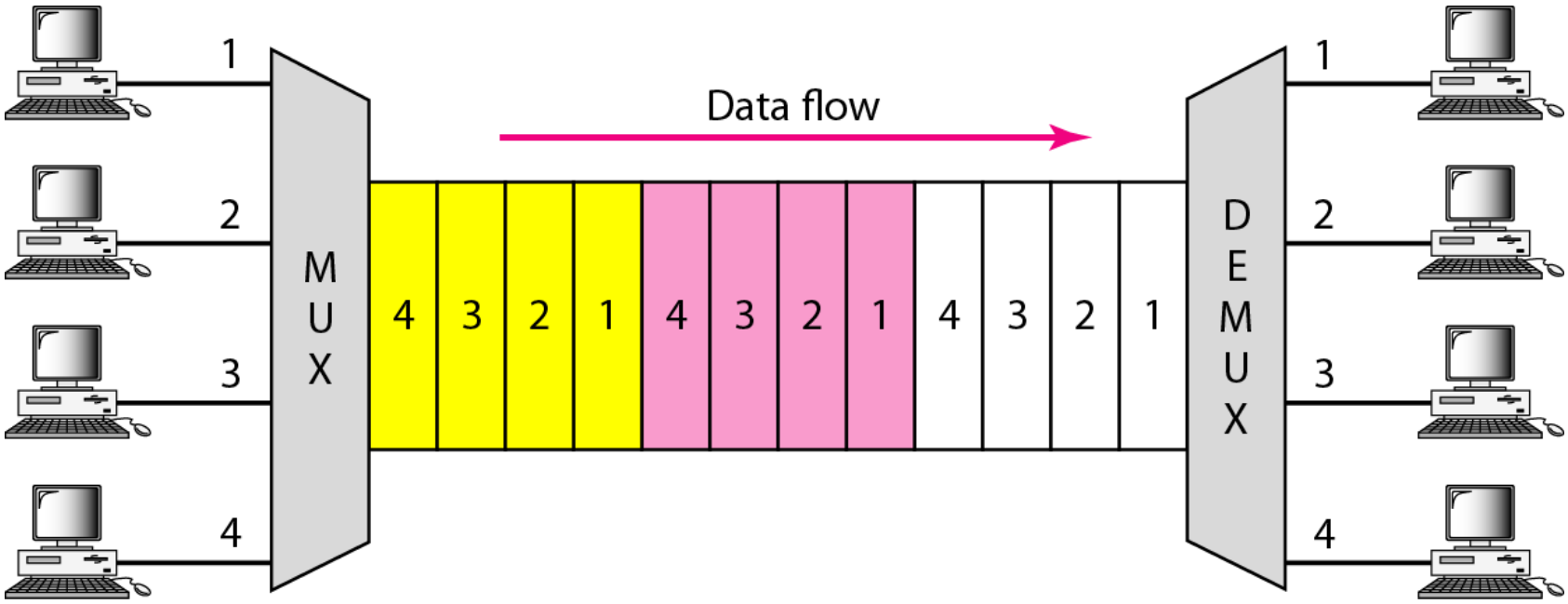
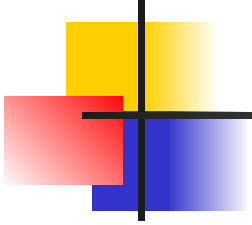


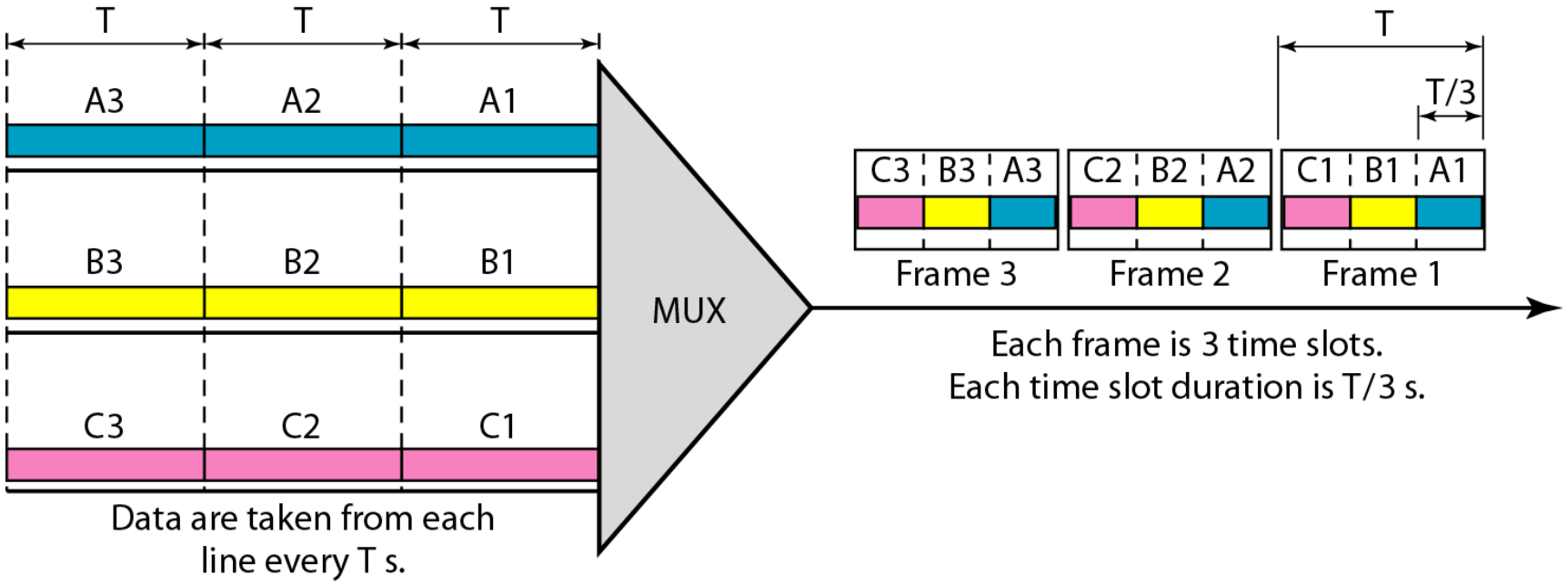
Figure 6.12 *TDM*

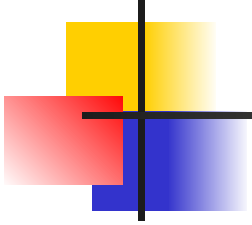




TDM is a digital multiplexing technique for combining several low-rate channels into one high-rate one.

Figure 6.13 *Synchronous time-division multiplexing*





In synchronous TDM, the data rate of the link is *n* times faster, and the unit duration is *n* times shorter.

Figure 6.15 *Interleaving*

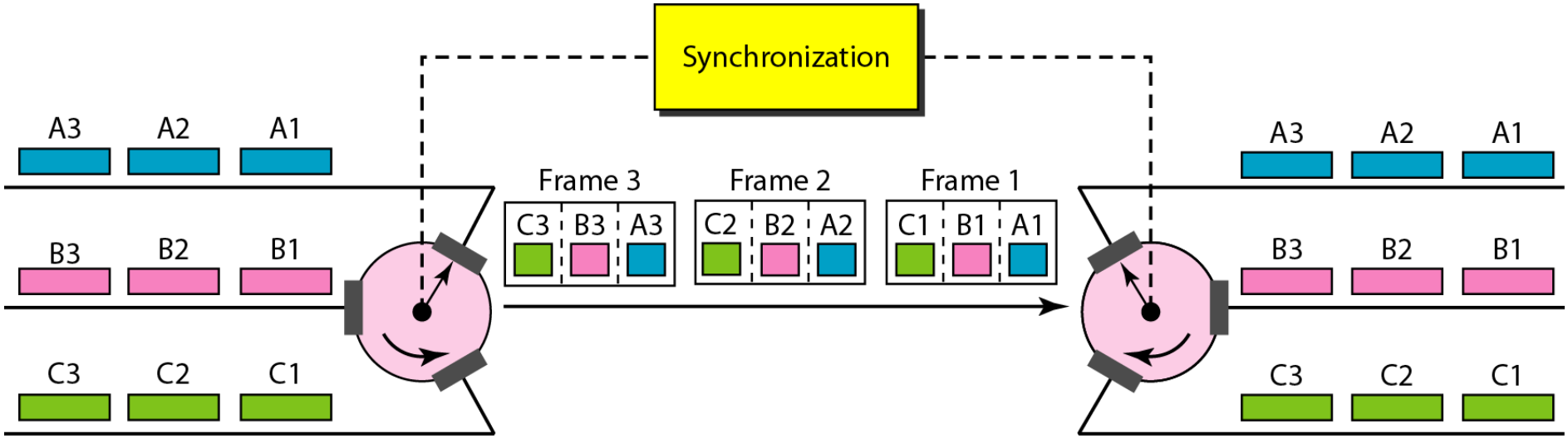


Figure 6.18 *Empty slots*

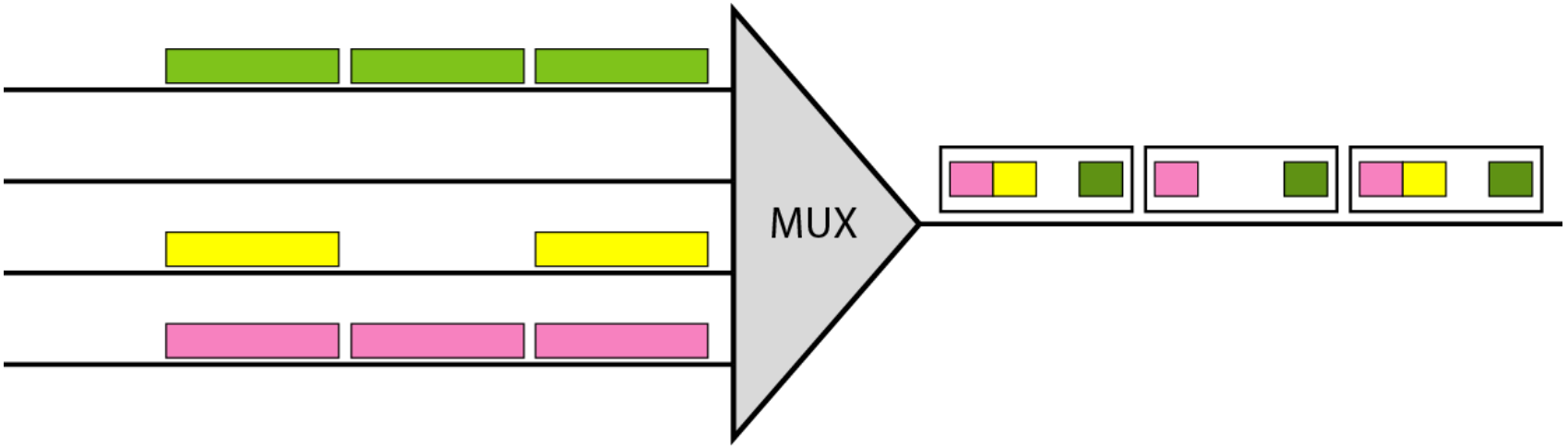


Figure 6.19 *Multilevel multiplexing (data rate management)*

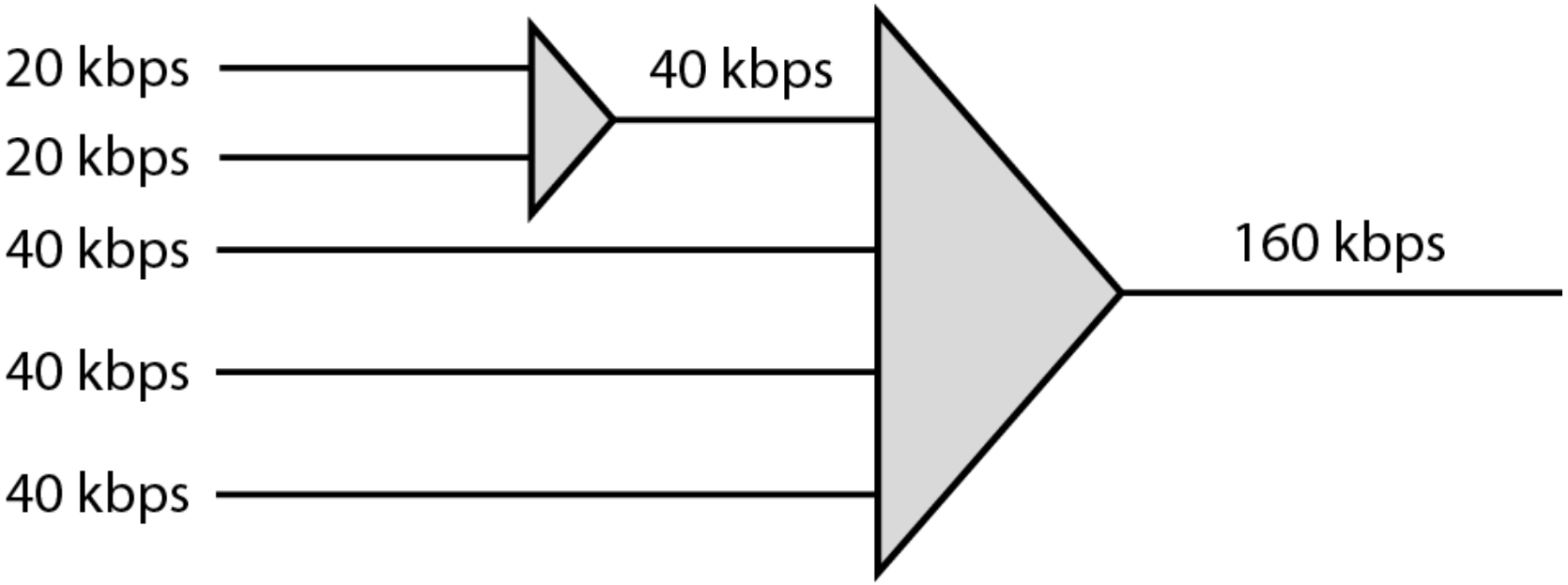


Figure 6.20 *Multiple-slot multiplexing*

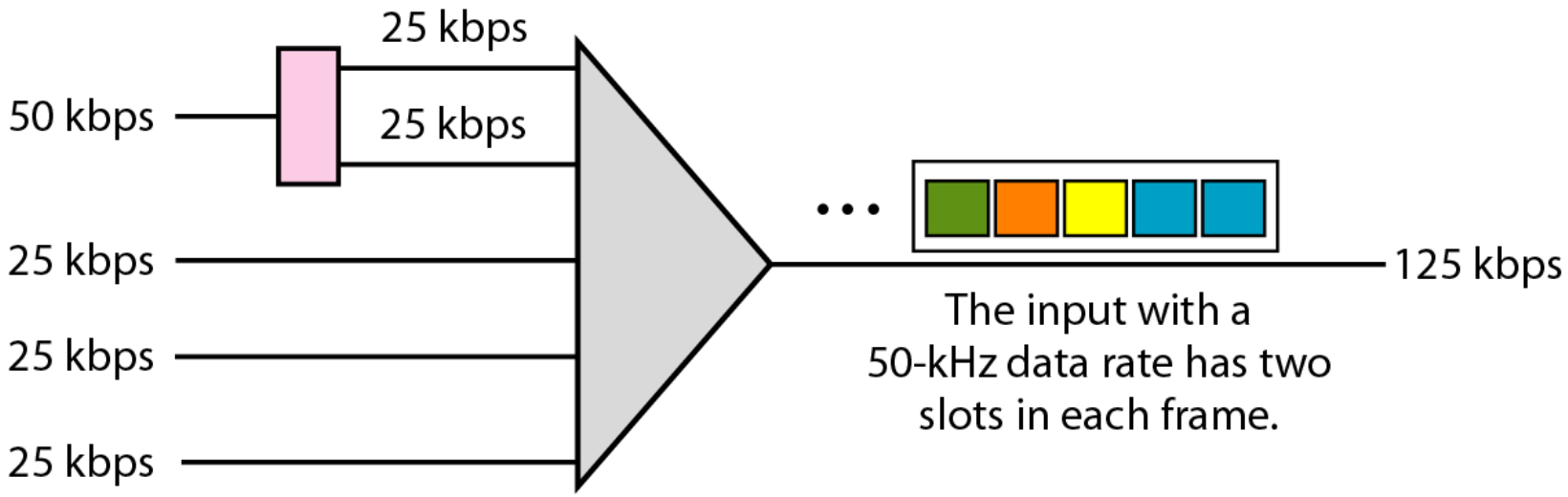


Figure 6.21 *Pulse stuffing (data rate management)*

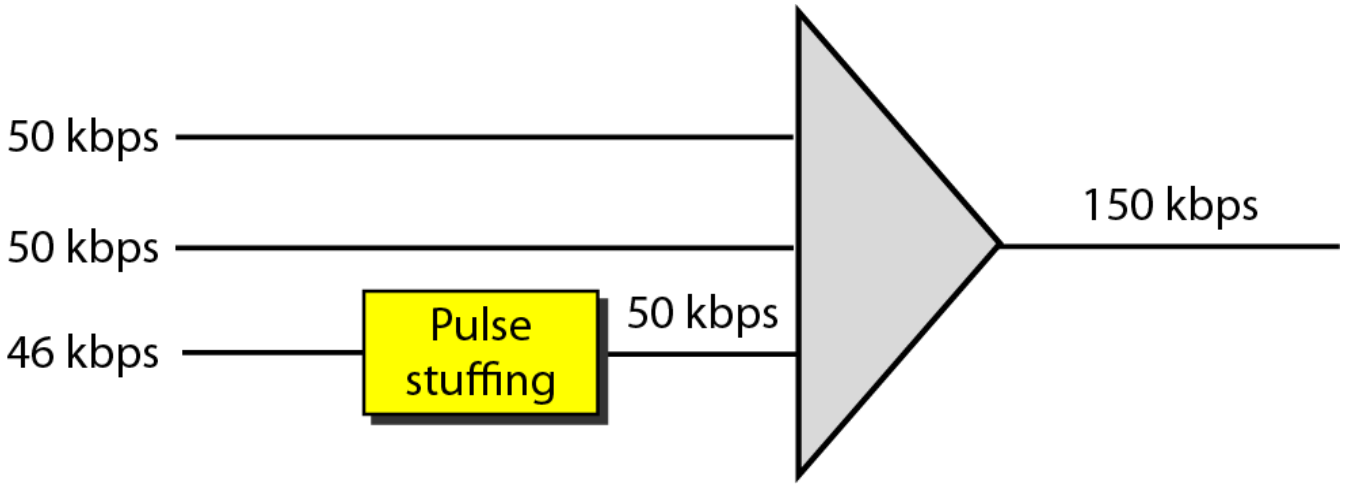


Figure 6.22 *Framing bits (frame synchronization)*

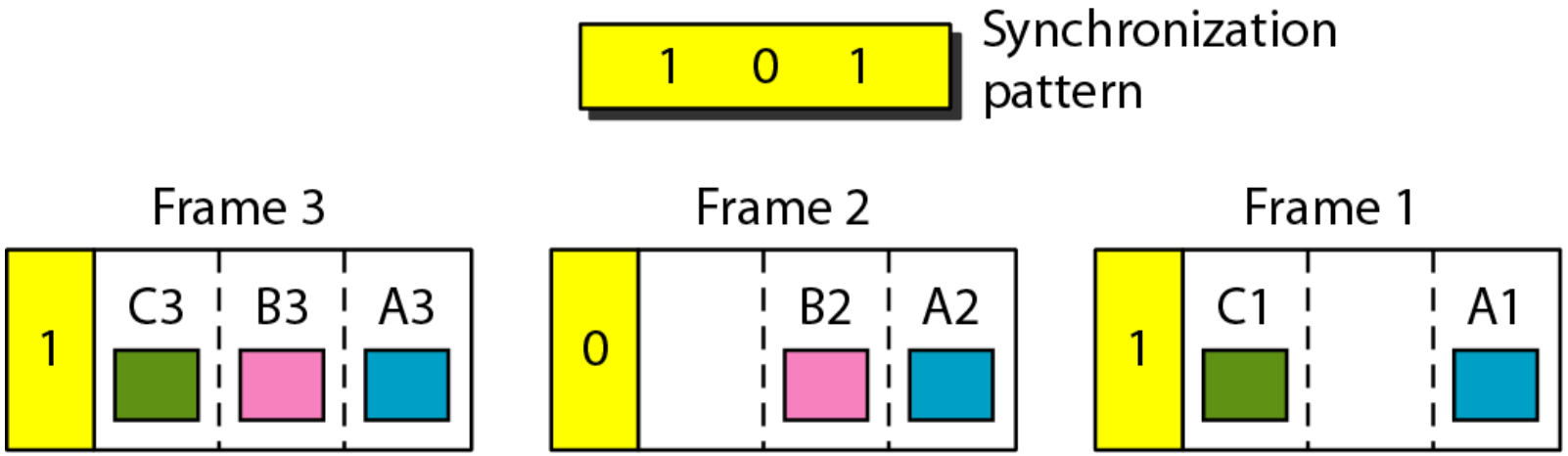
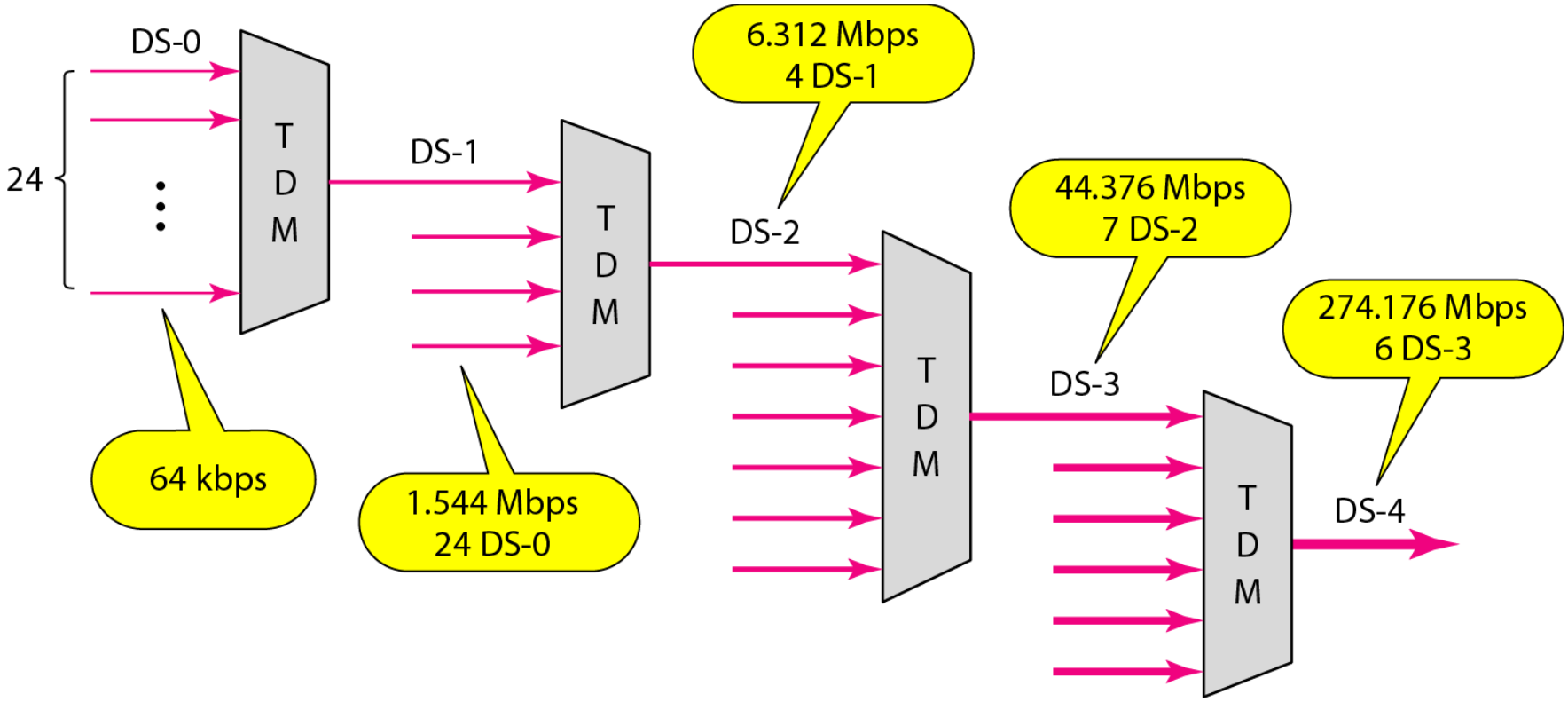


Figure 6.23 *Digital hierarchy*



Transmission Media

Figure 7.1 *Transmission medium and physical layer*

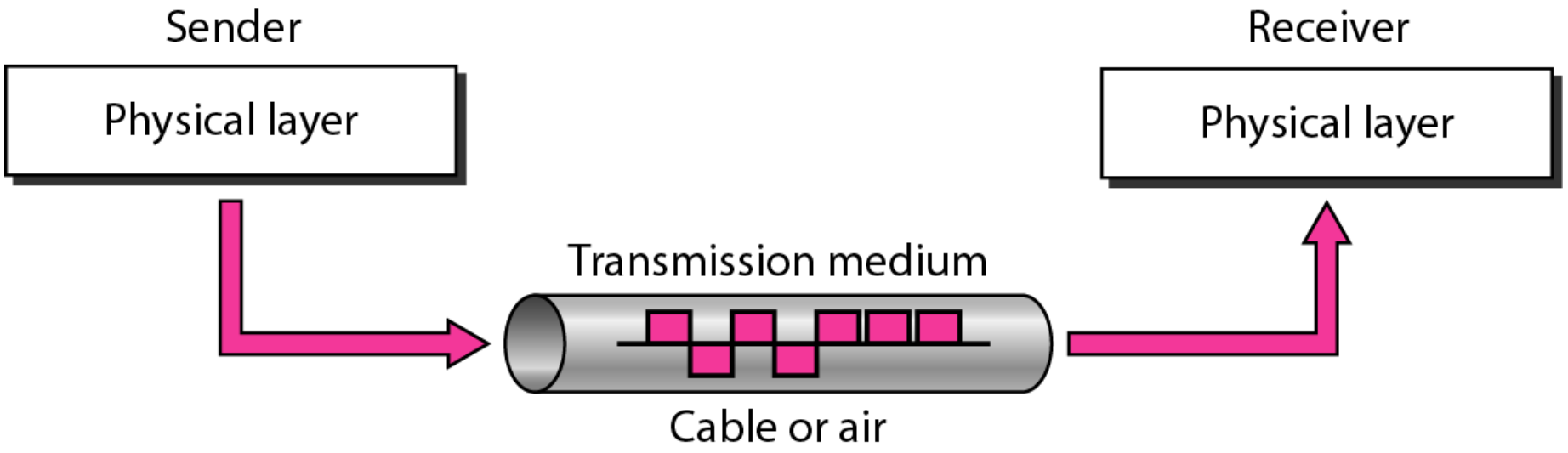
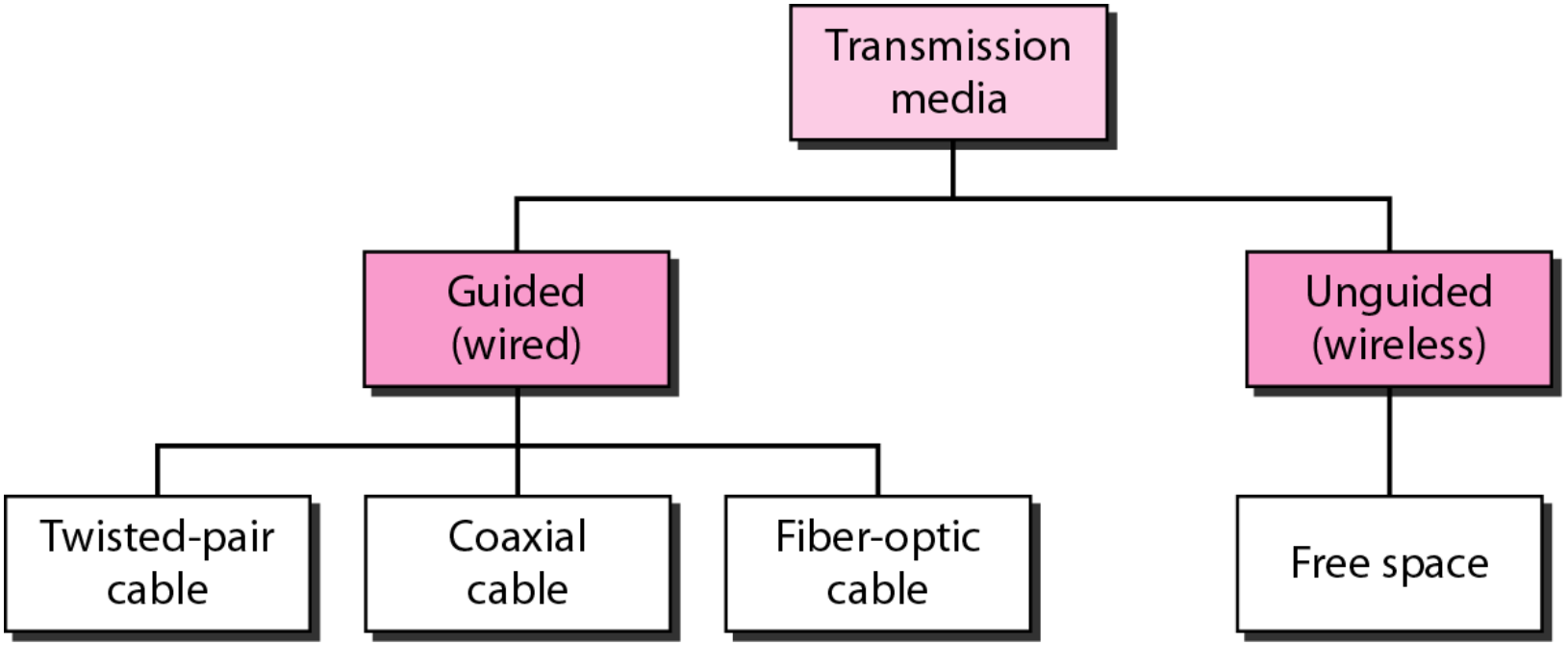


Figure 7.2 *Classes of transmission media*



7-1 GUIDED MEDIA

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

Twisted-Pair Cable
Coaxial Cable
Fiber-Optic Cable

Figure 7.3 *Twisted-pair cable*

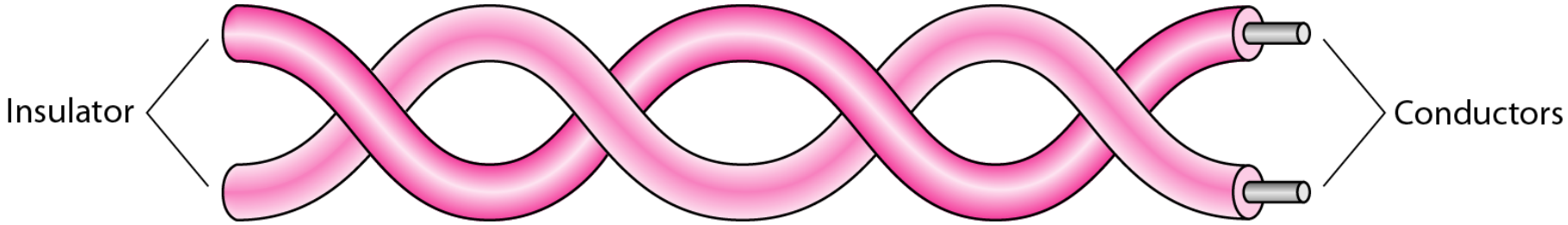
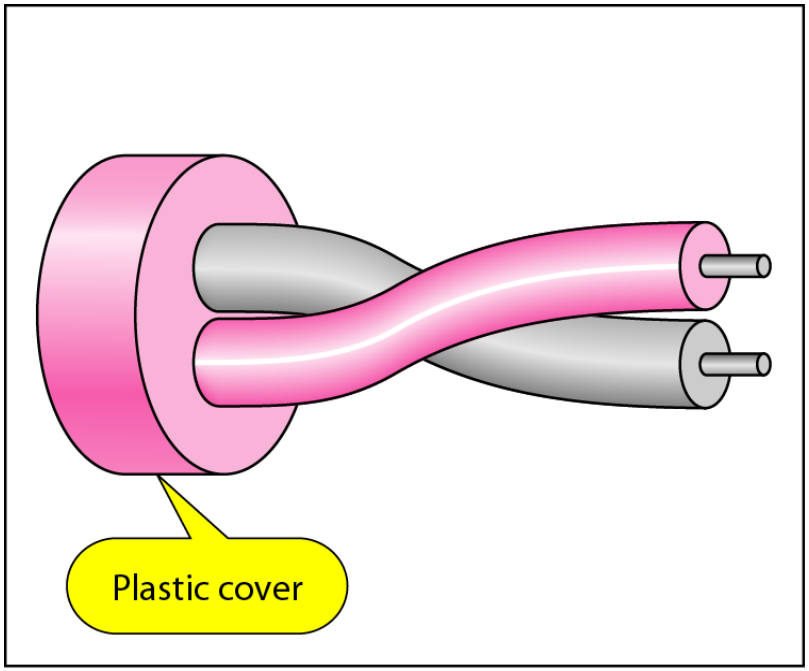
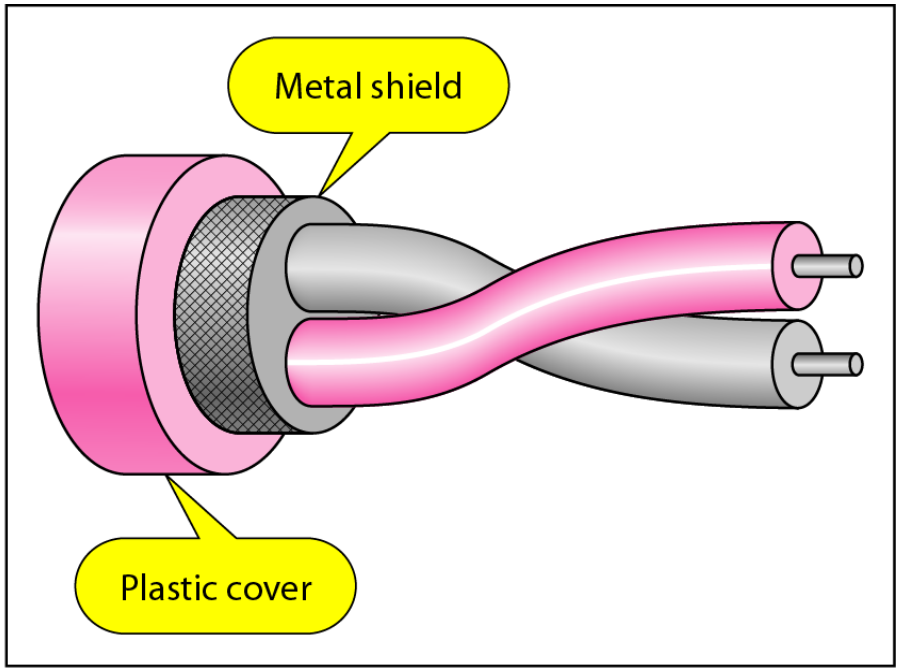


Figure 7.4 *UTP and STP cables*



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*

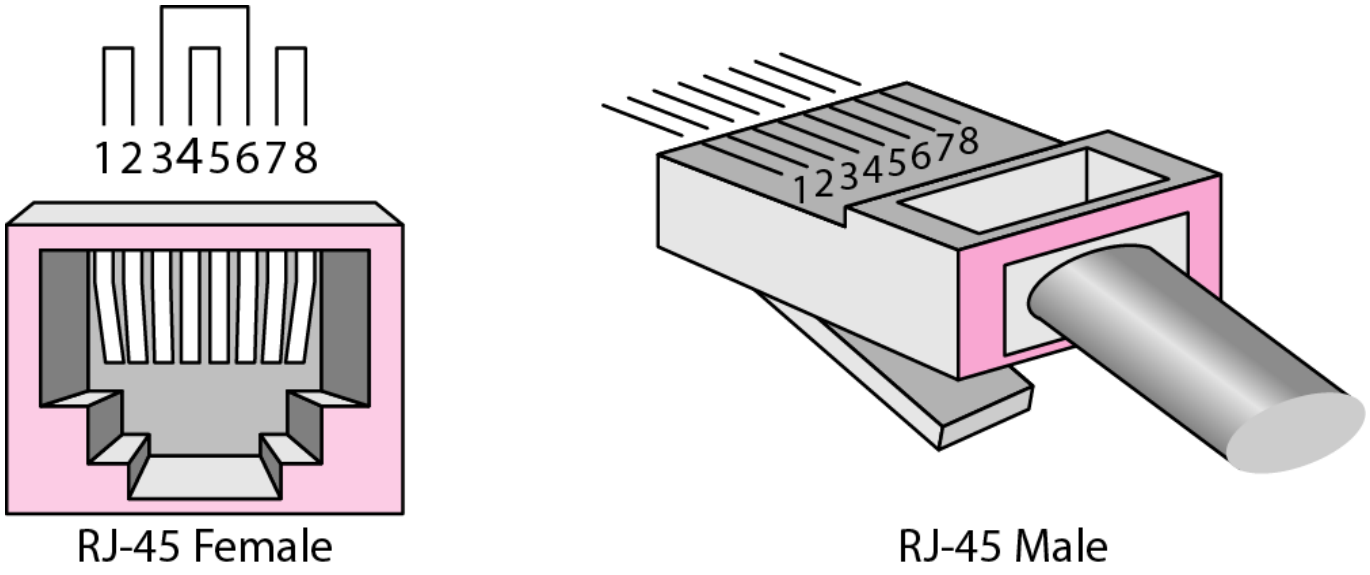


Figure 7.6 *UTP performance*

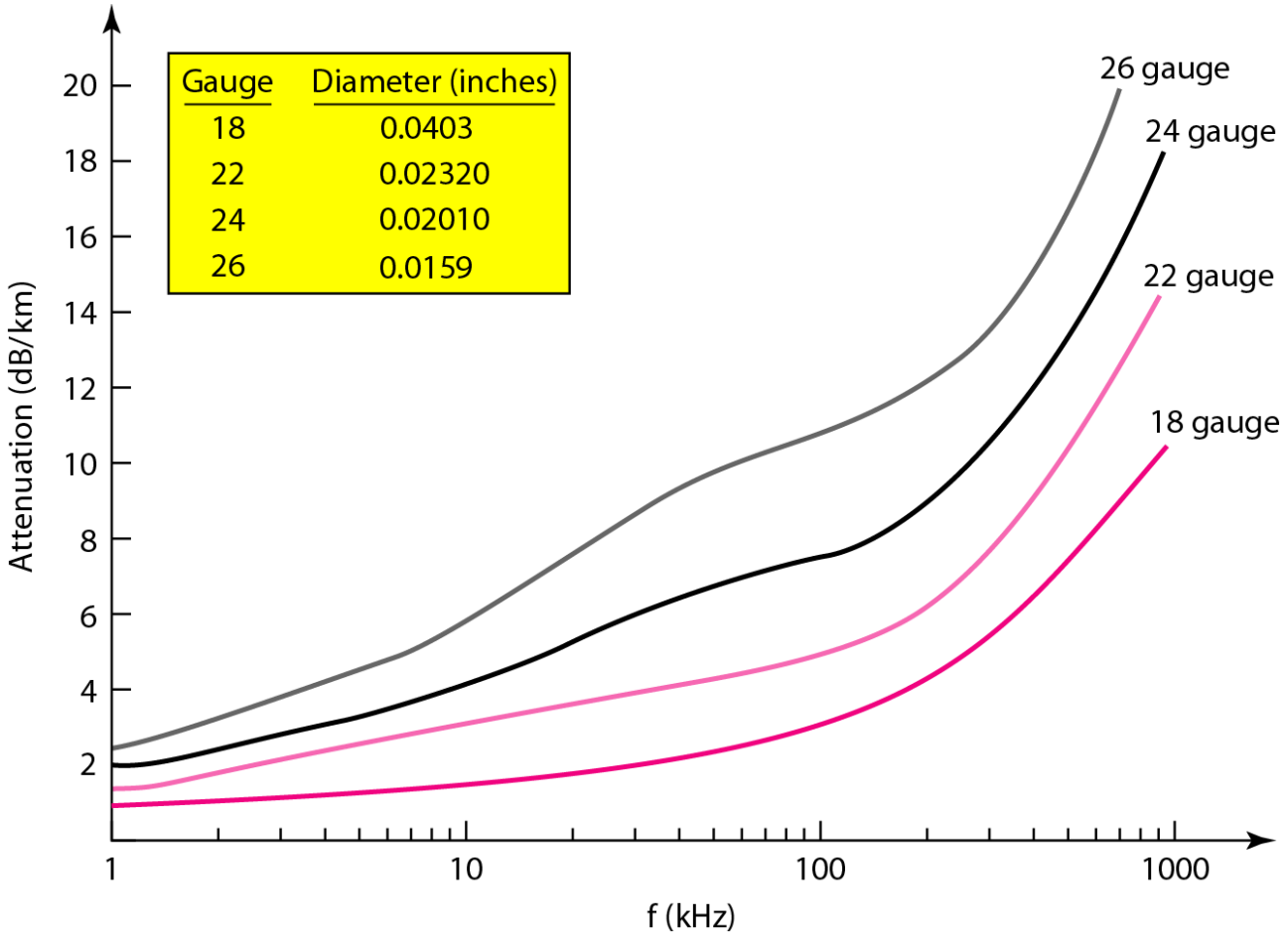


Figure 7.7 *Coaxial cable*

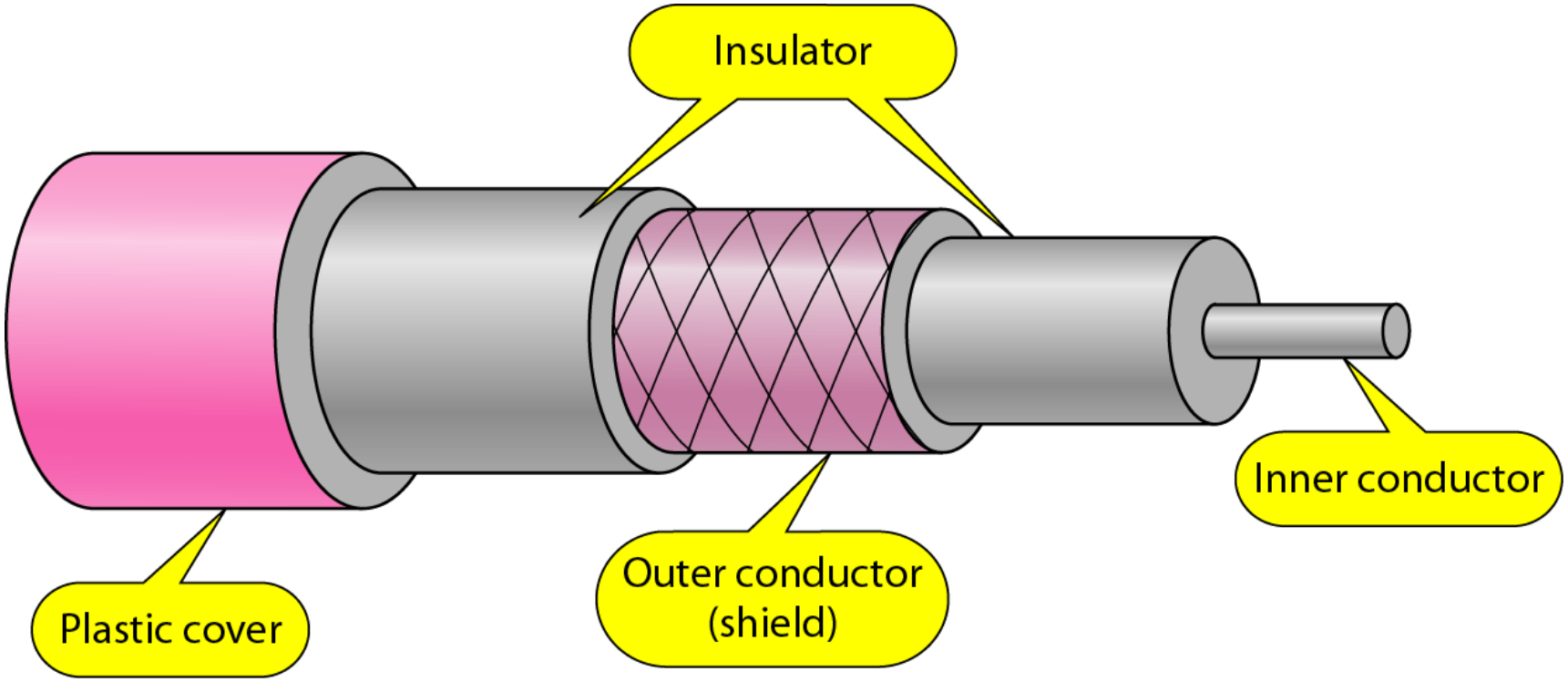


Table 7.2 ***Categories of coaxial cables***

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*

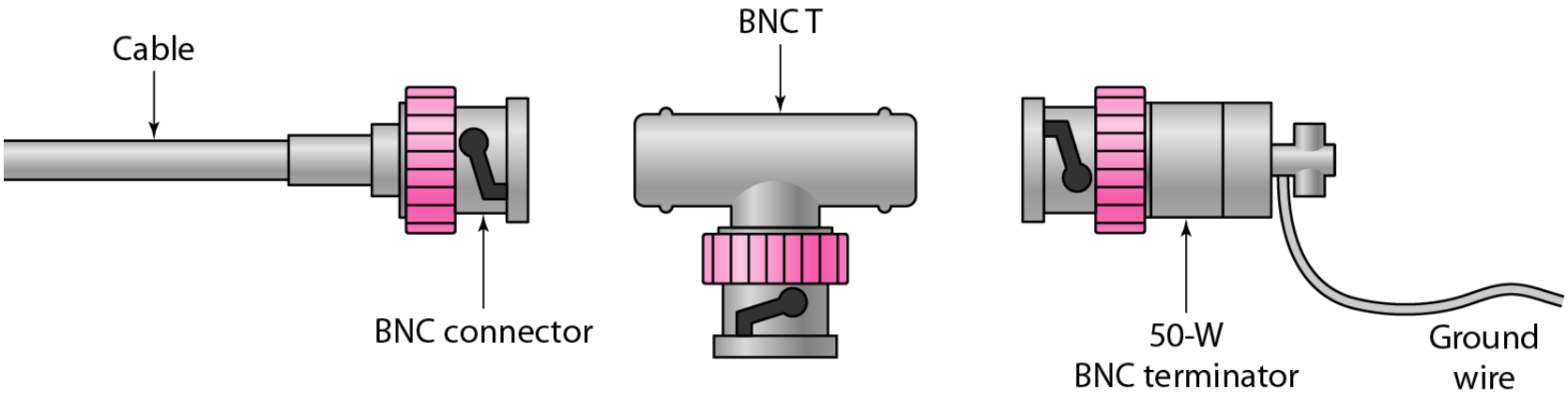


Figure 7.9 *Coaxial cable performance*

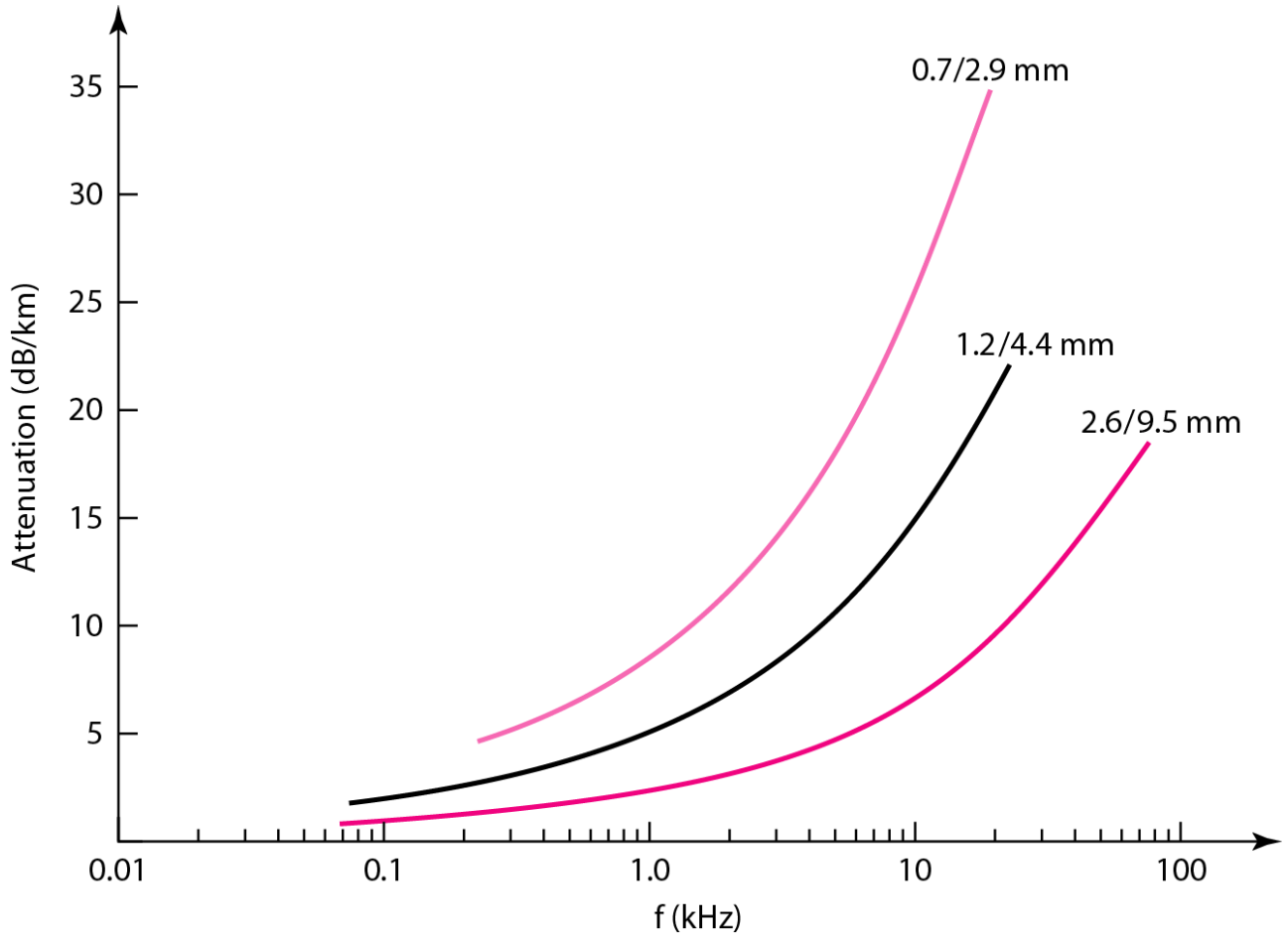


Figure 7.10 *Bending of light ray*

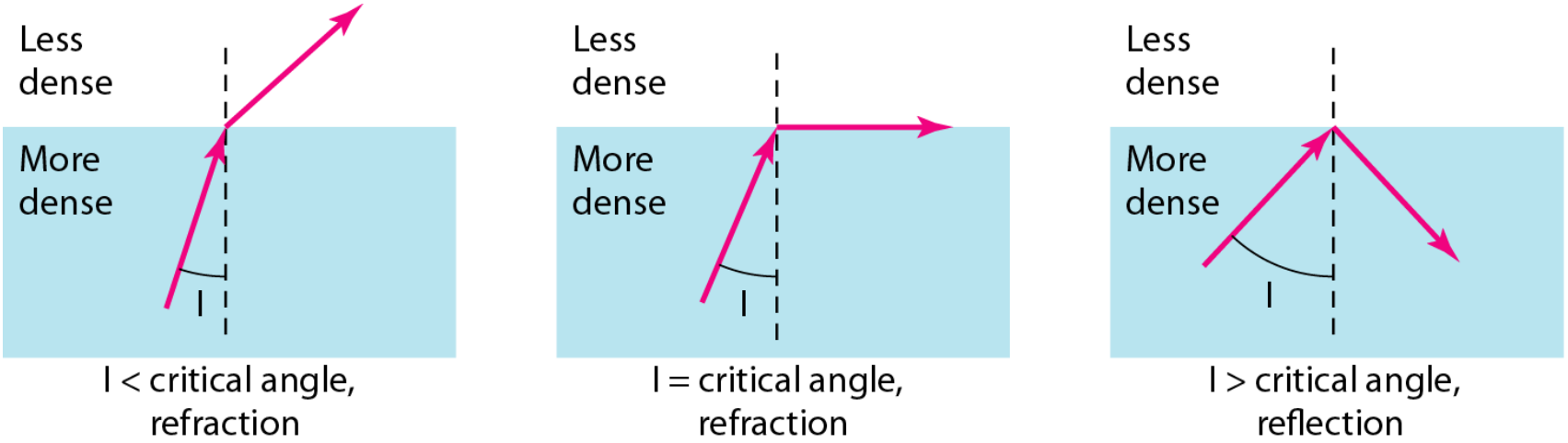


Figure 7.11 *Optical fiber*

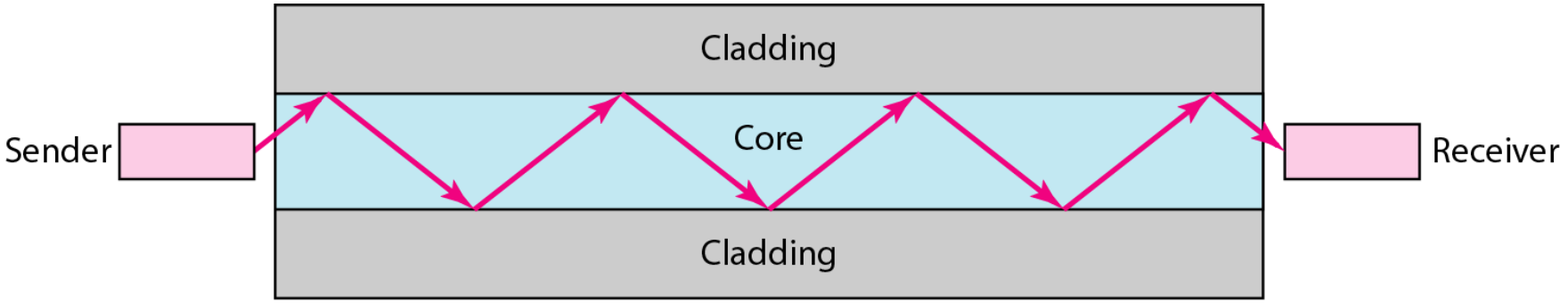
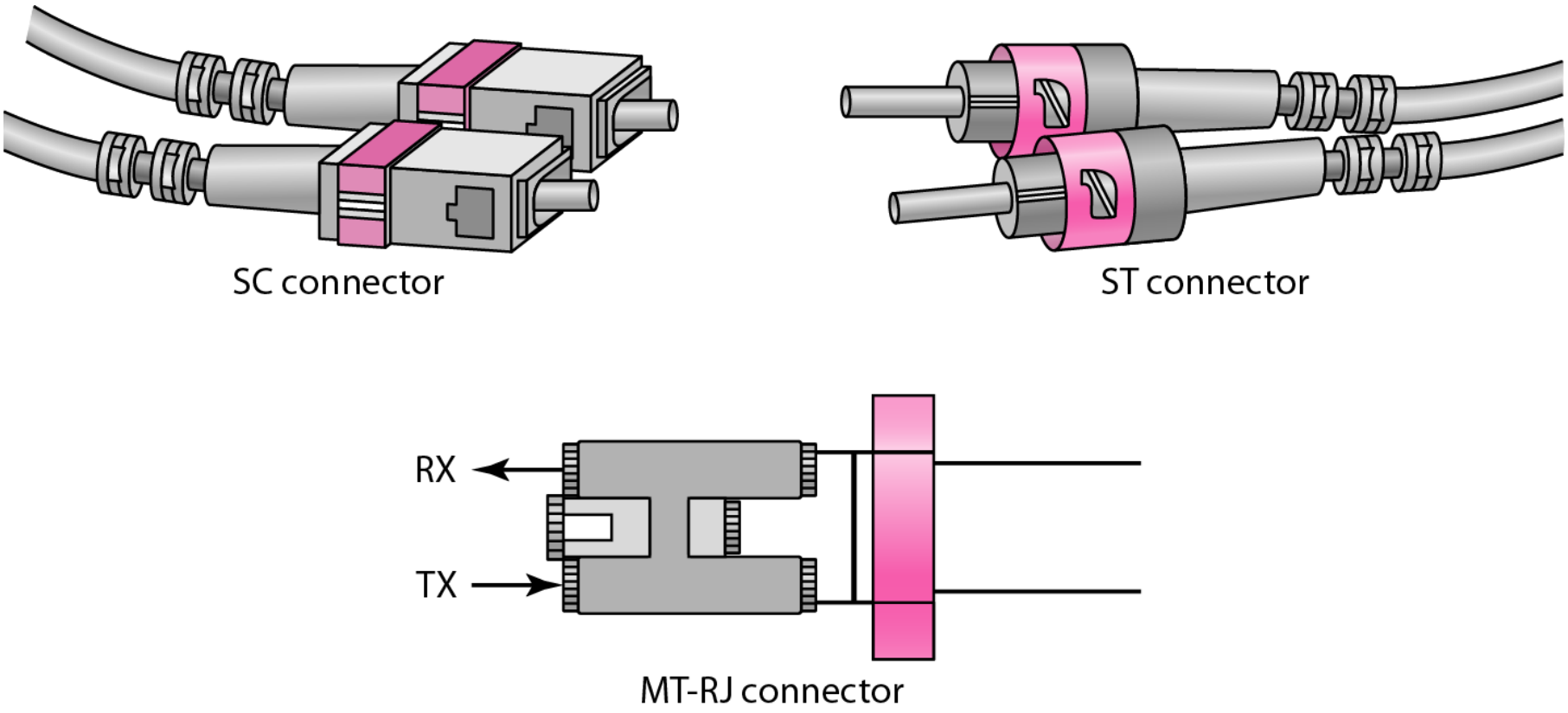


Figure 7.15 *Fiber-optic cable connectors*



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.

Radio Waves
Microwaves
Infrared

Figure 7.17 *Electromagnetic spectrum for wireless communication*

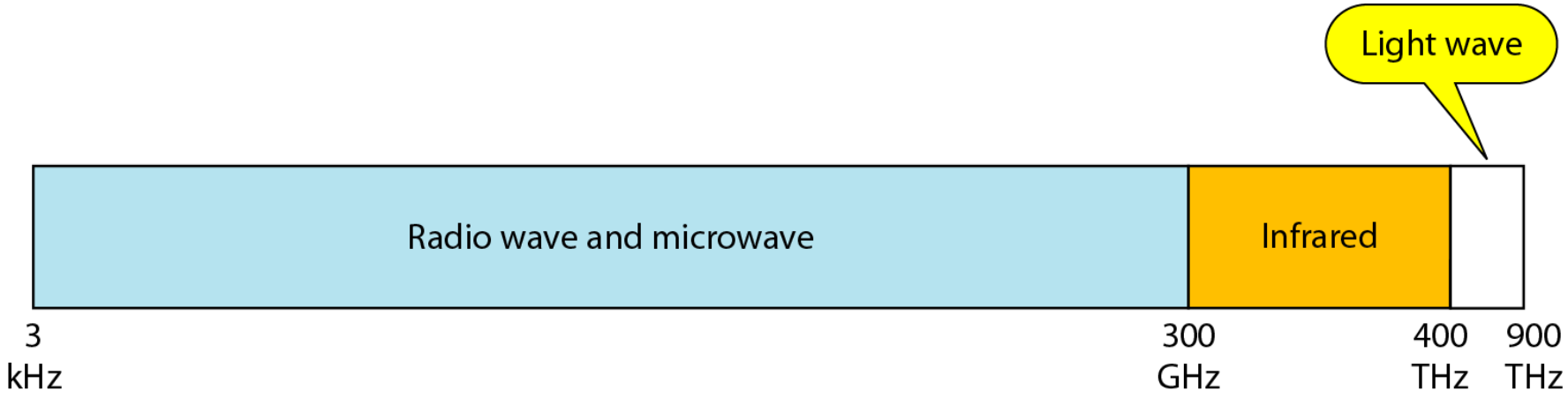


Figure 7.18 *Propagation methods*

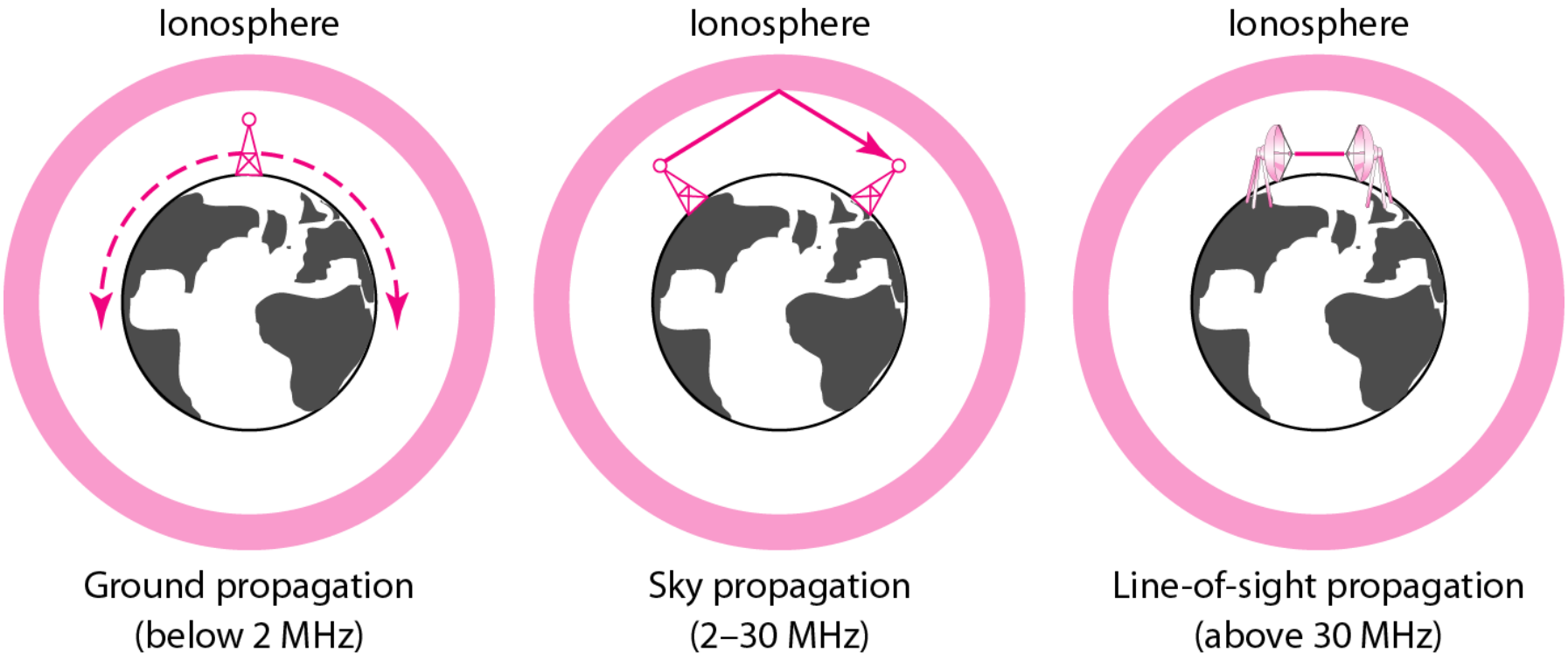


Table 7.4 *Bands*

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*

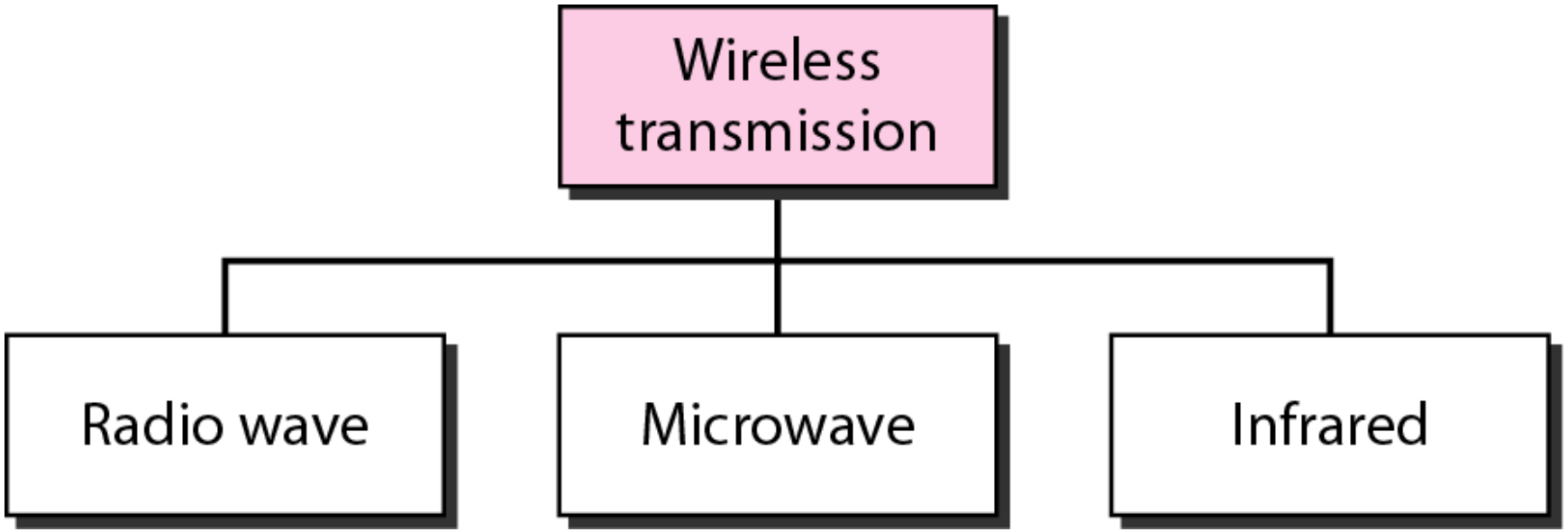
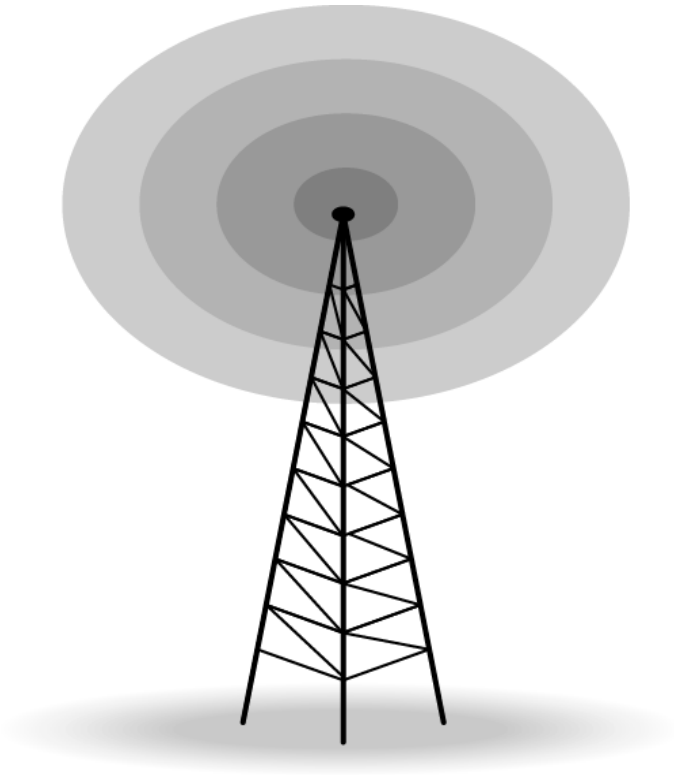
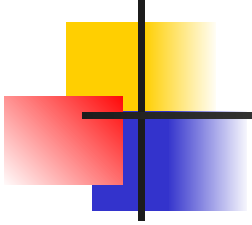


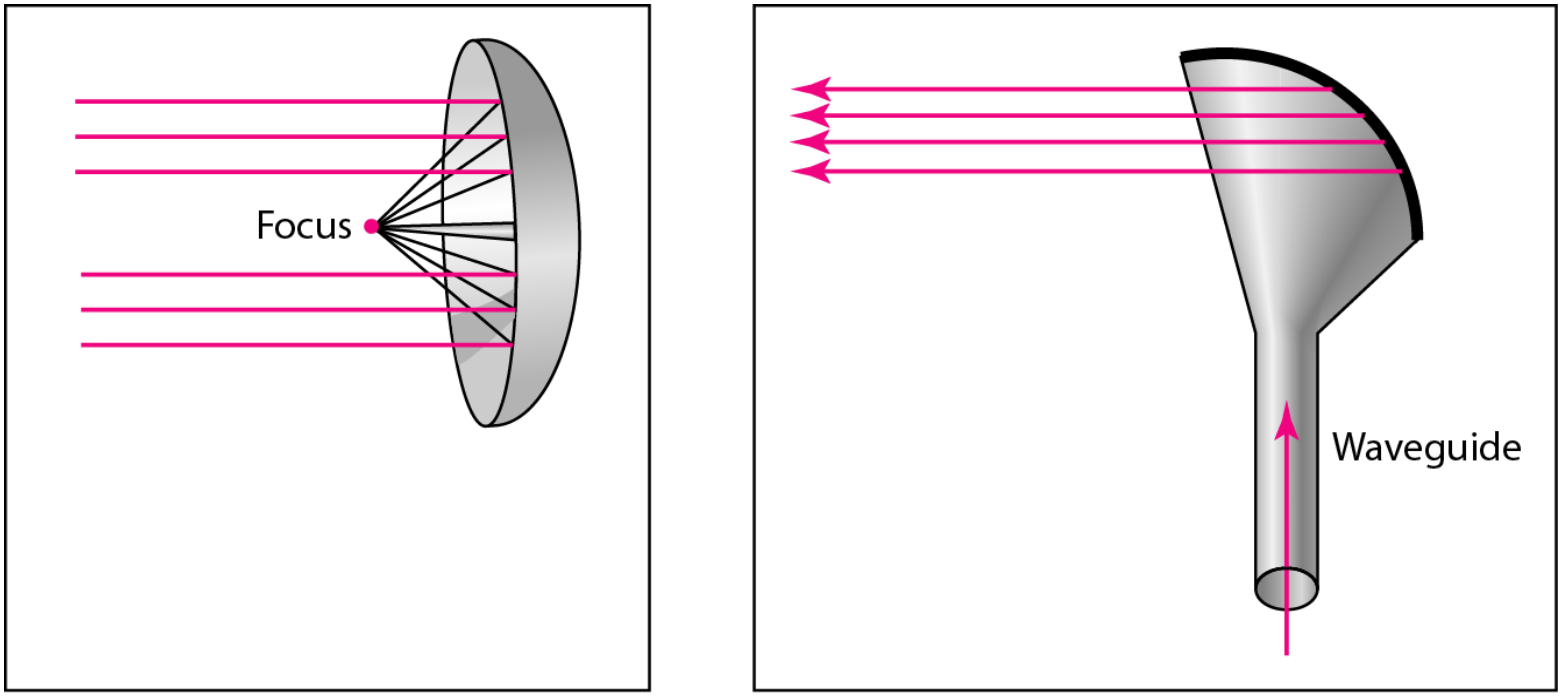
Figure 7.20 *Omnidirectional antenna*





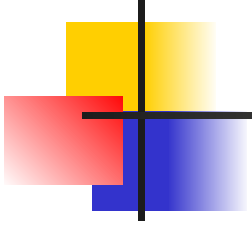
Radio waves are used for multicast communications, such as radio and television, and paging systems.

Figure 7.21 *Unidirectional antennas*

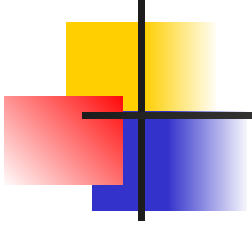


a. Dish antenna

b. Horn antenna



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



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