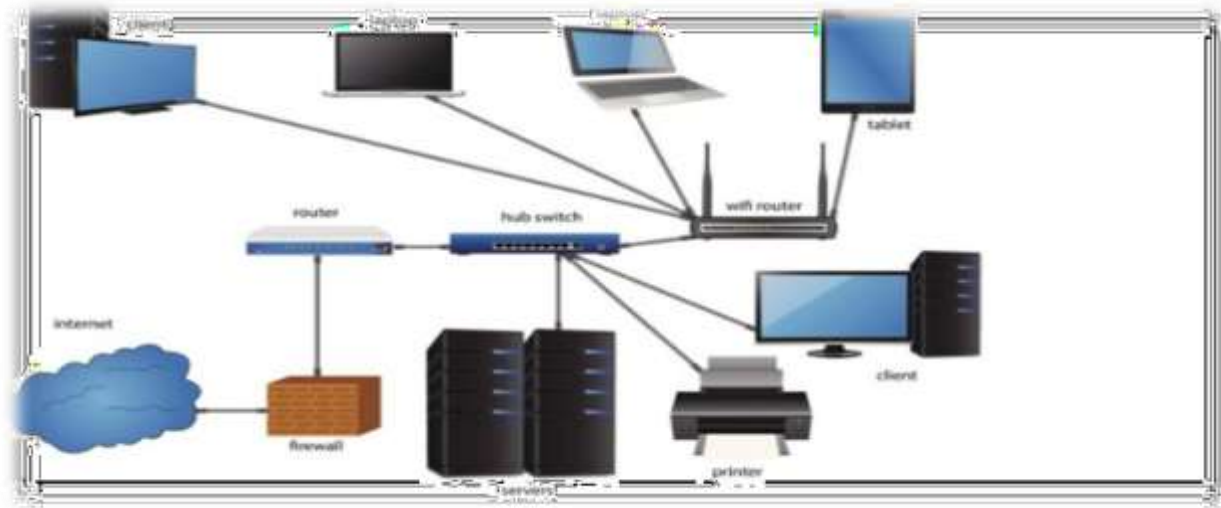


COMPUTER NETWORKS



Syllabus

UNIT – I

Physical Layer – Fourier Analysis – Bandwidth Limited Signals – The Maximum Data Rate of a Channel – Guided Transmission Media, Digital Modulation and Multiplexing: Frequency Division Multiplexing, Time Division Multiplexing, Code Division Multiplexing

UNIT-I

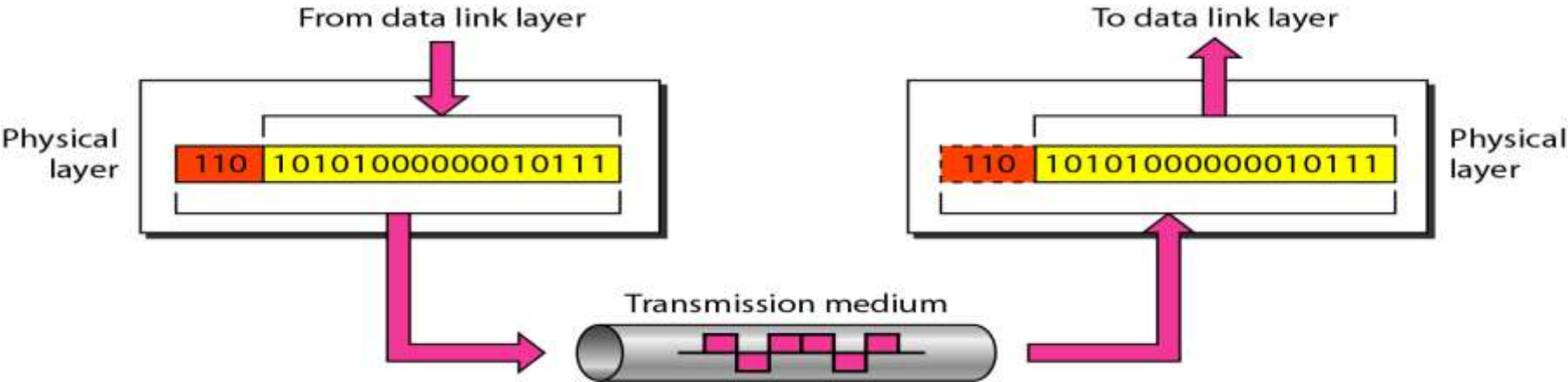
Physical Layer

Functions of physical layer

Transport data using electrical, mechanical or procedural interfaces

- **Signalling**-Transmission of bits in the suitable form over different types of physical media i.e. Light, Voltage or EM waves
- **Data encoding** – Base Band, Band pass transmission
- **Multiplexing** – Allows information from different sources on the same transmission medium without interference

Figure 2.1 *Physical layer*



Theoretical Basis for Data Communication

- Fourier analysis
- Bandwidth-limited signals
- Maximum data rate of a channel

Fourier Analysis

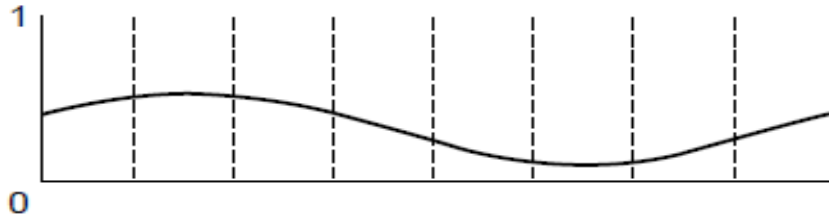
- We model the behavior of variation of voltage or current with mathematical functions

- $$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

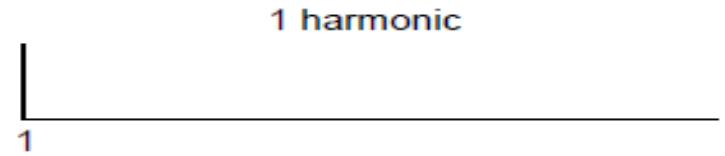
$$a_n = \frac{2}{T} \int_0^T g(t) \sin(2\pi nft) dt \quad b_n = \frac{2}{T} \int_0^T g(t) \cos(2\pi nft) dt \quad c = \frac{2}{T} \int_0^T g(t) dt$$



Contd..

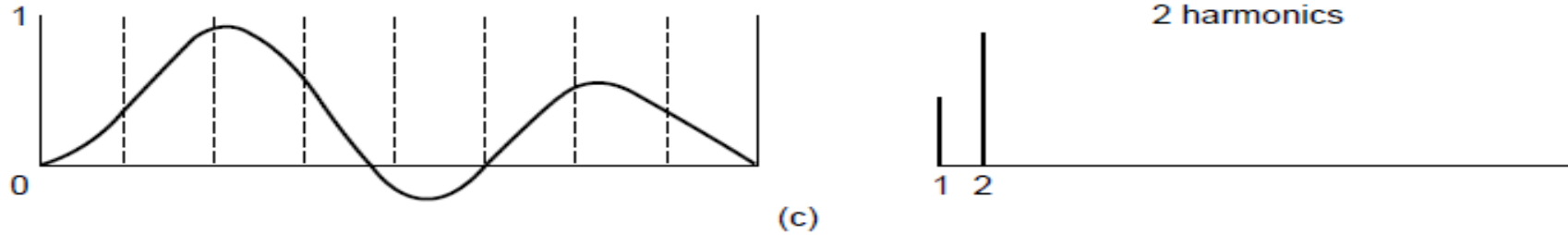


(b)



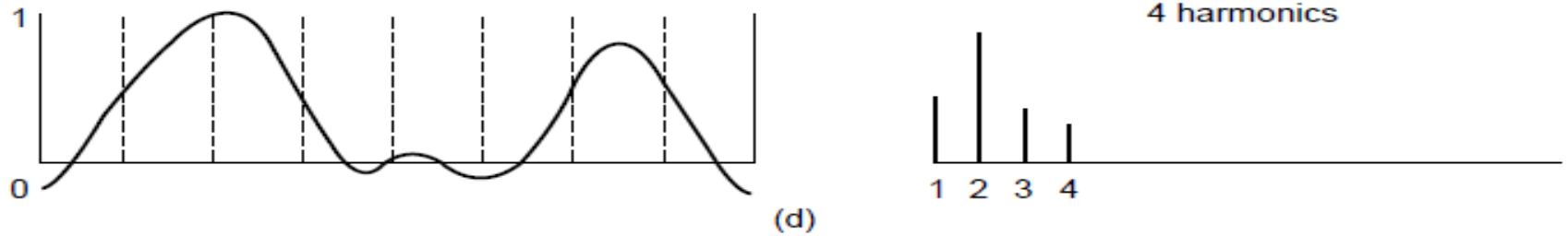
(b)-(e) Successive approximations to the original signal.

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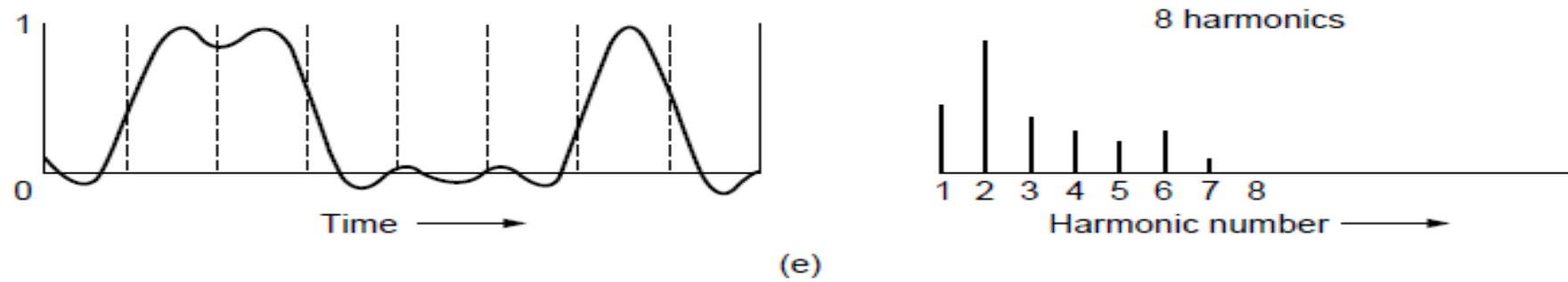
(b)-(e) Successive approximations to the original signal.

Contd..



(b)-(e) Successive approximations to the original signal.

Contd..



(b)-(e) Successive approximations to the original signal.

The Maximum Data Rate of a Channel

- Nyquist's theorem (For Noiseless channel)

maximum data rate = $2 B \log_2 V$ bits / sec

- Shannon's formula for capacity of a noisy channel

maximum number of bits / sec = $B \log_2 (1 + S / N)$

s/n---signal to noise ratio

Transmission Media

Figure 2.2 *Transmission medium and physical layer*

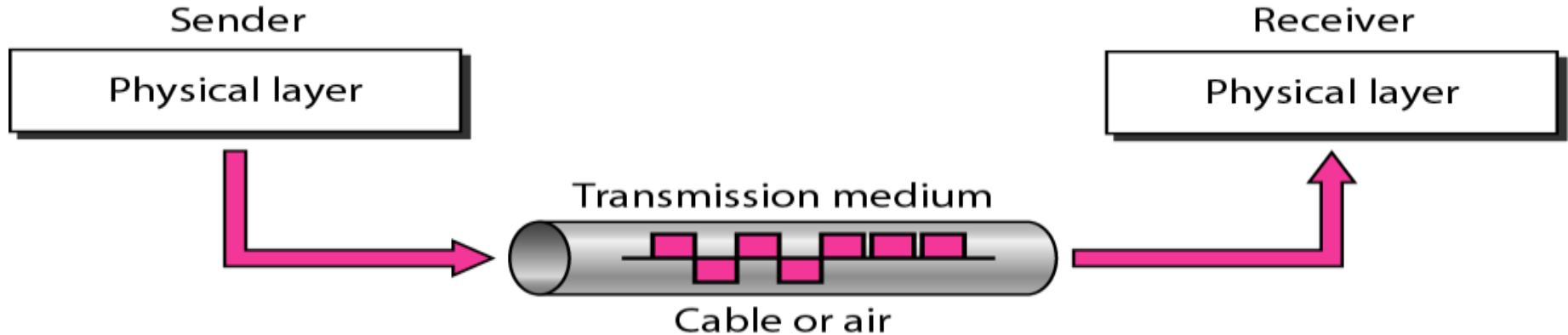
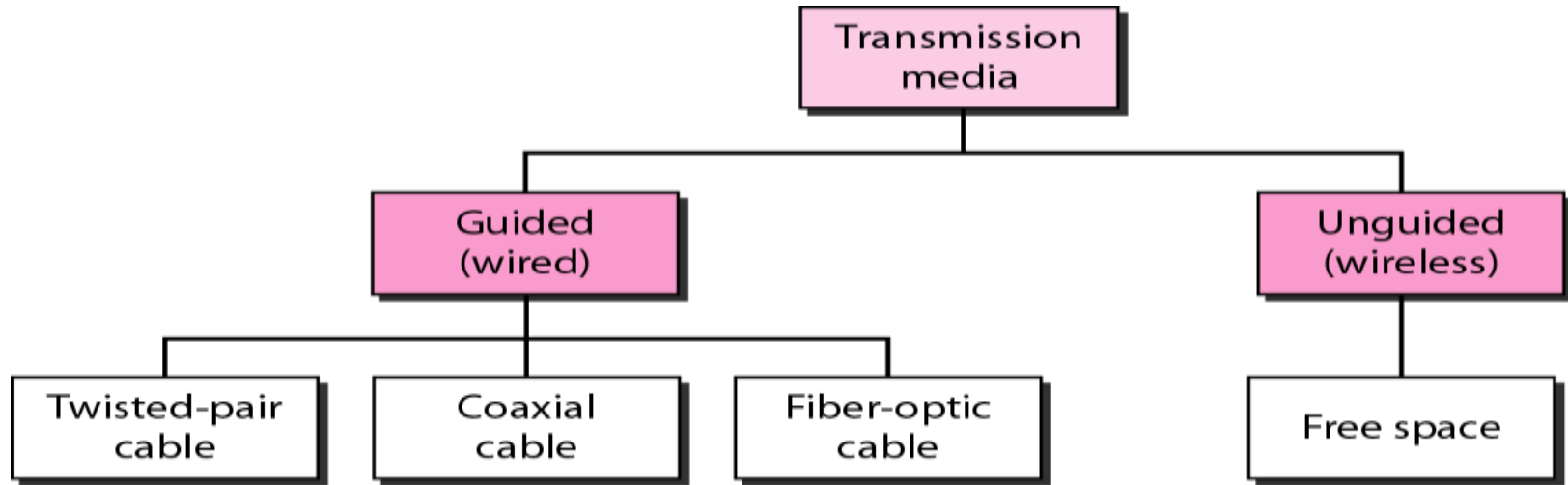


Figure 2.3 *Classes of transmission media*



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.

Topics discussed in this section:

1. Twisted-Pair Cable
2. Coaxial Cable
3. Fiber-Optic Cable

Figure 2.4 *Twisted-pair cable*

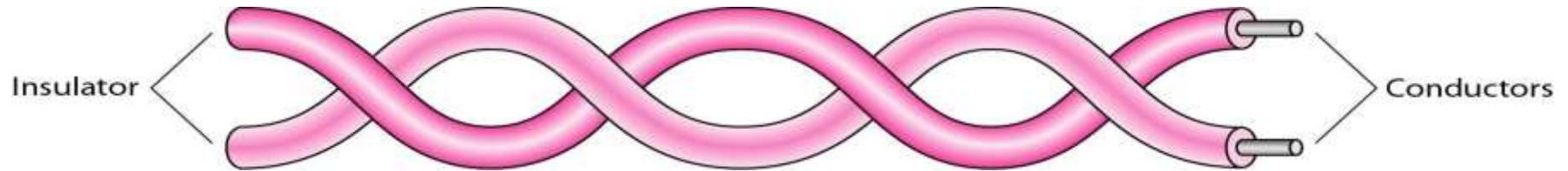
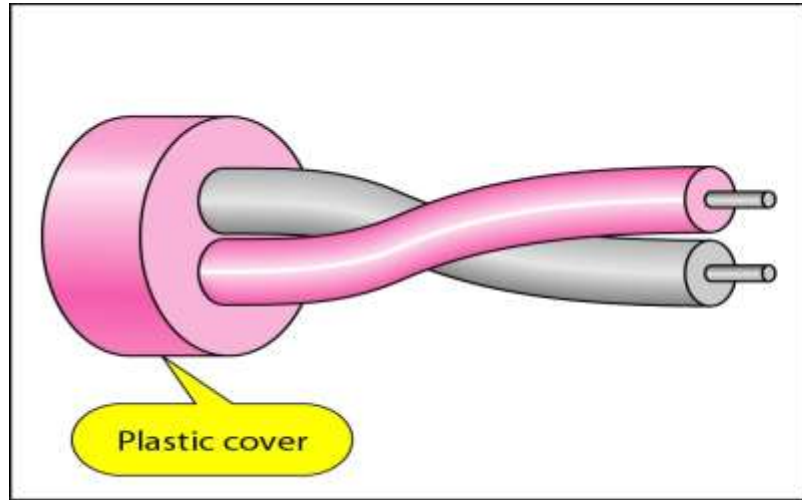
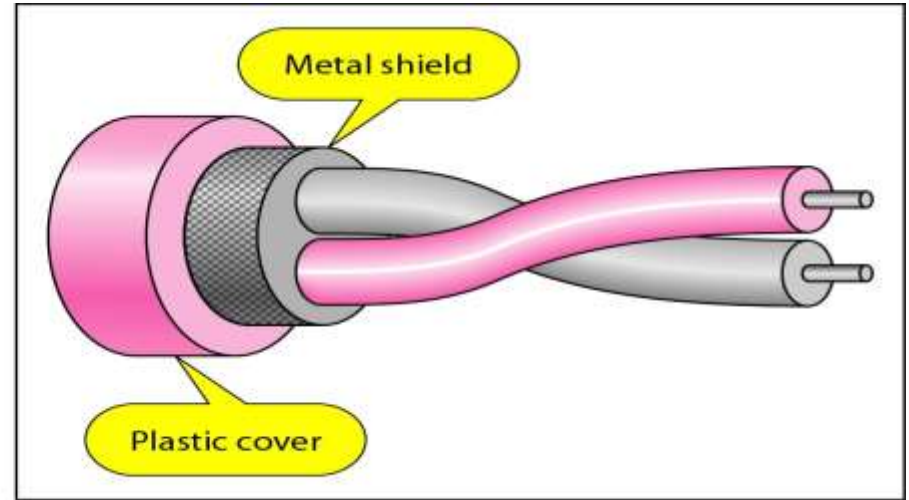


Figure 2.5 *UTP and STP cables*



a. UTP

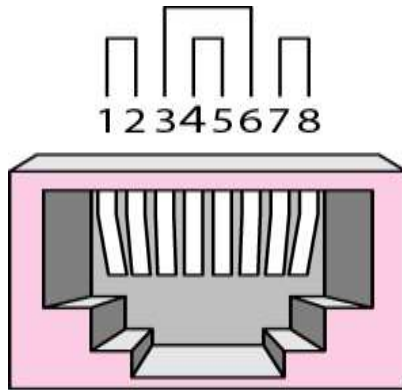


b. STP

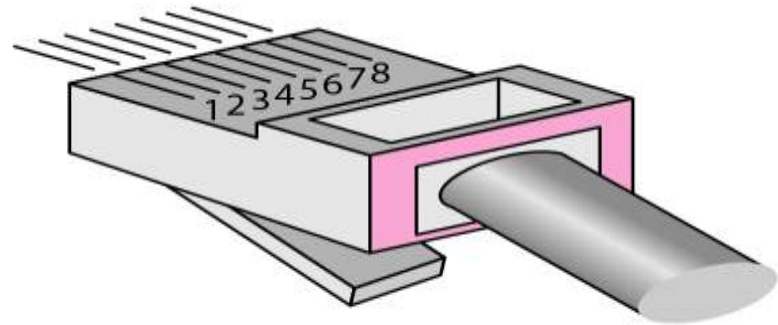
Table 2.1 *Categories of unshielded twisted-pair cables*

<i>Category</i>	<i>Specification</i>	<i>Data Rate (Mbps)</i>	<i>Use</i>
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 2.6 *UTP connector*



RJ-45 Female



RJ-45 Male

RJ- Registered Jack

Figure 2.7 *UTP performance*

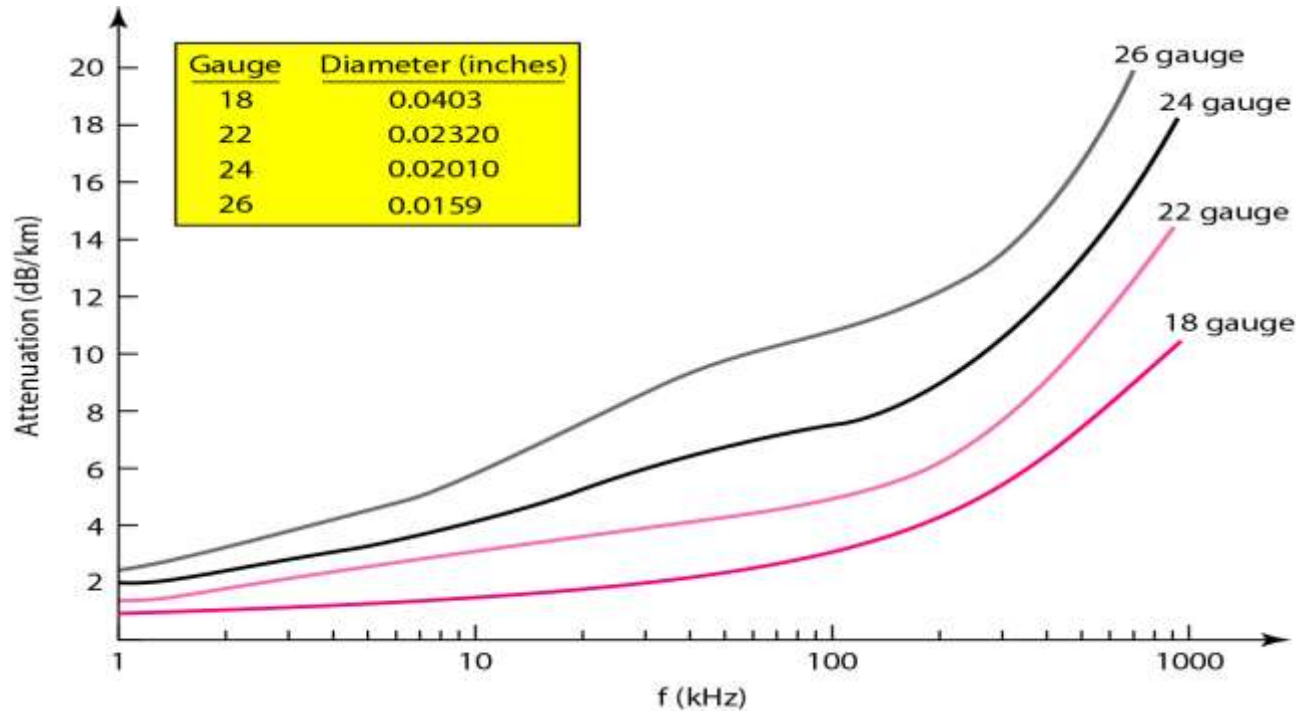


Figure 2.8 *Coaxial cable*

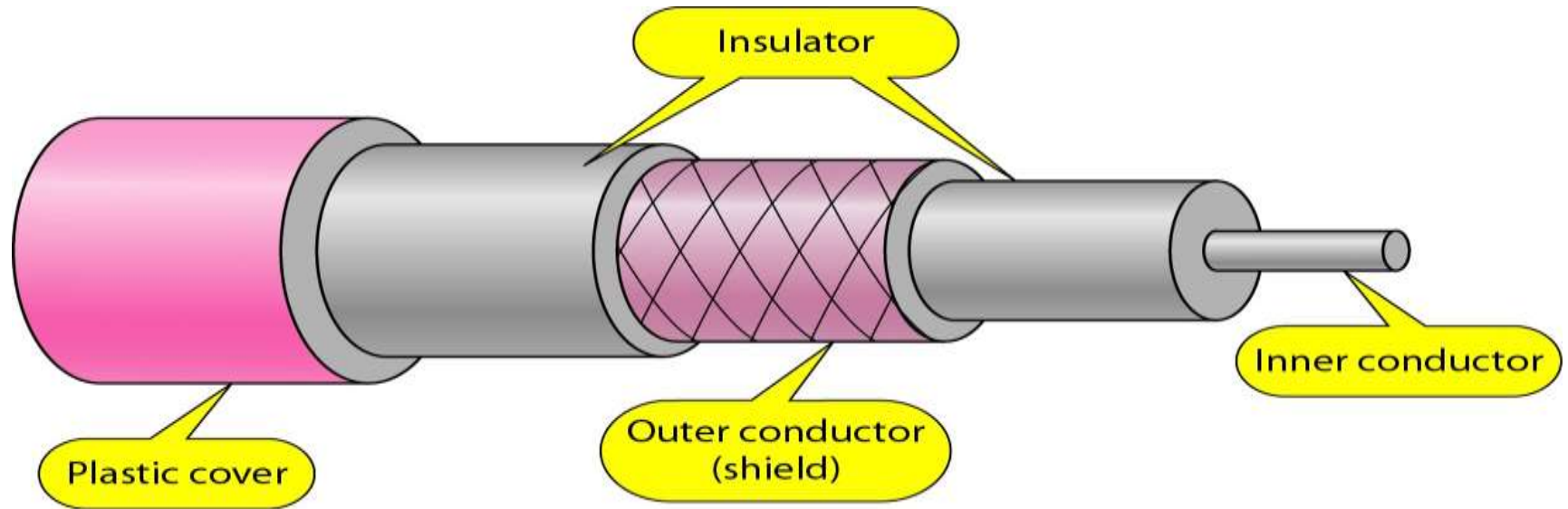
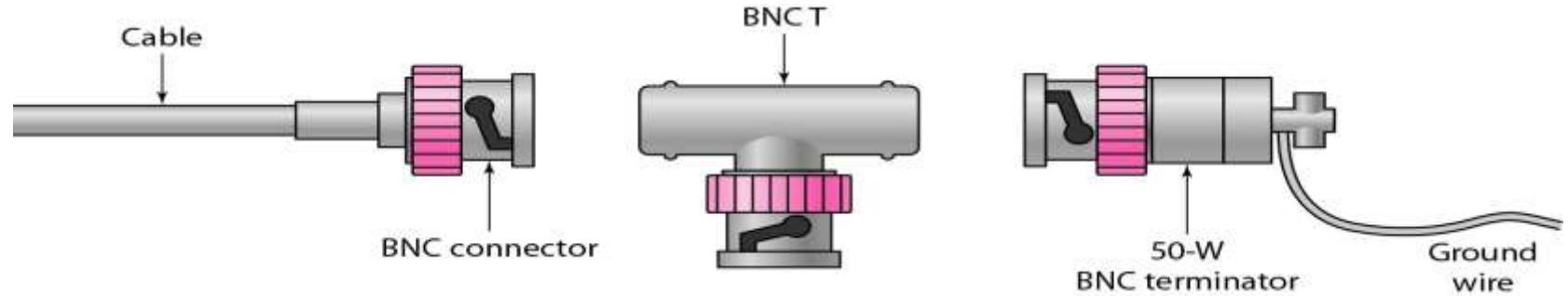


Table 2.2 *Categories of coaxial cables*

<i>Category</i>	<i>Impedance</i>	<i>Use</i>
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

RG- Radio Guide

Figure 2.9 *BNC connectors*



Bayonet Neill–Concelman

Figure 2.10 *Coaxial cable performance*

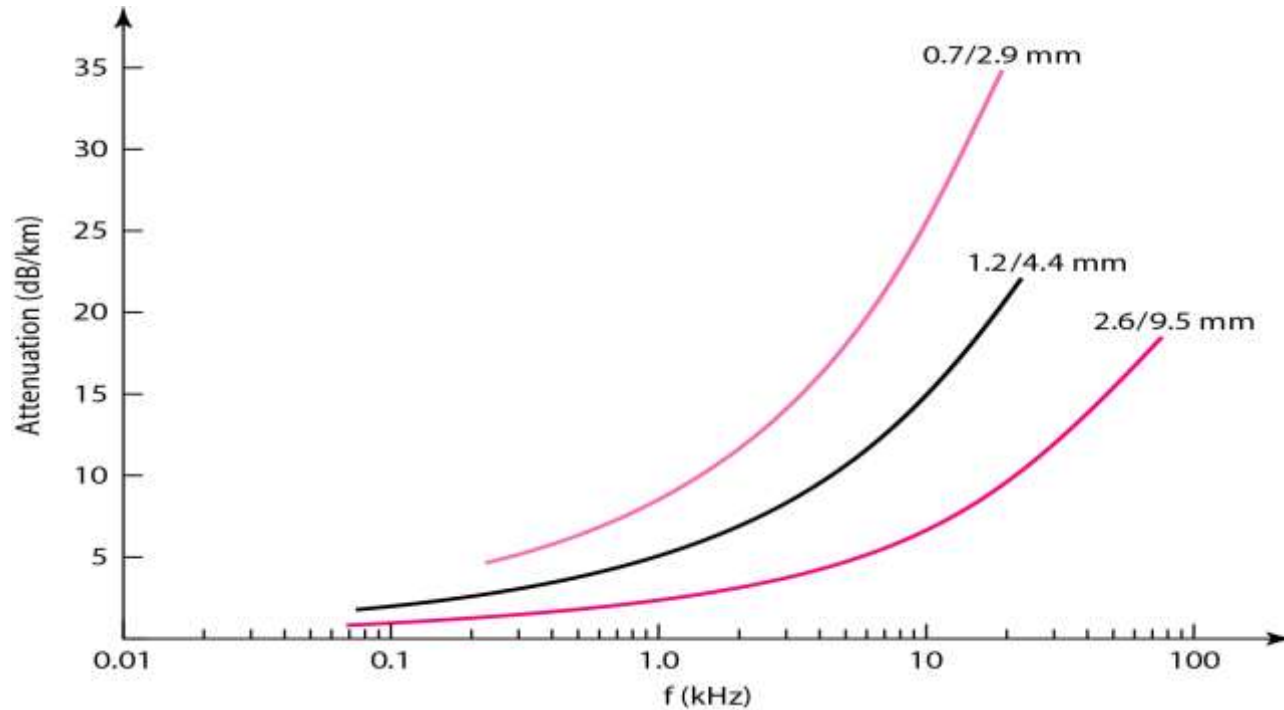


Figure 2.11 Fiber optics: *Bending of light ray*

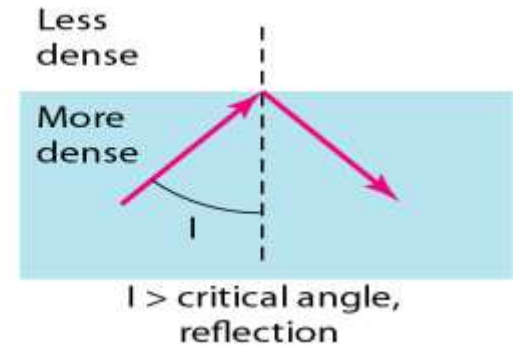
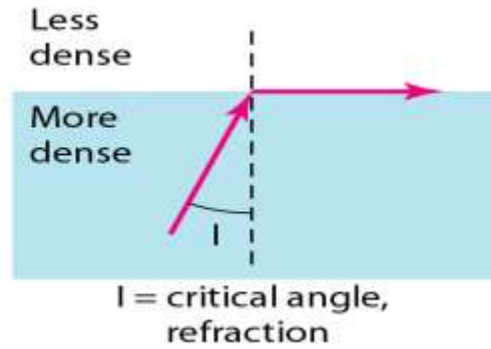
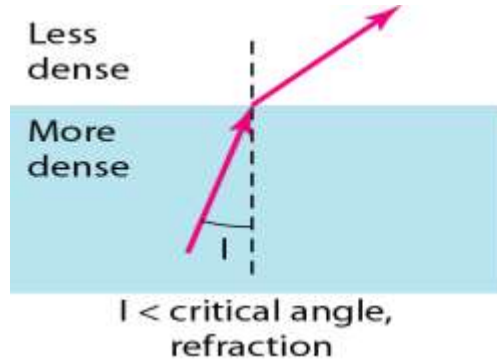


Figure 2.12 *Optical fiber*

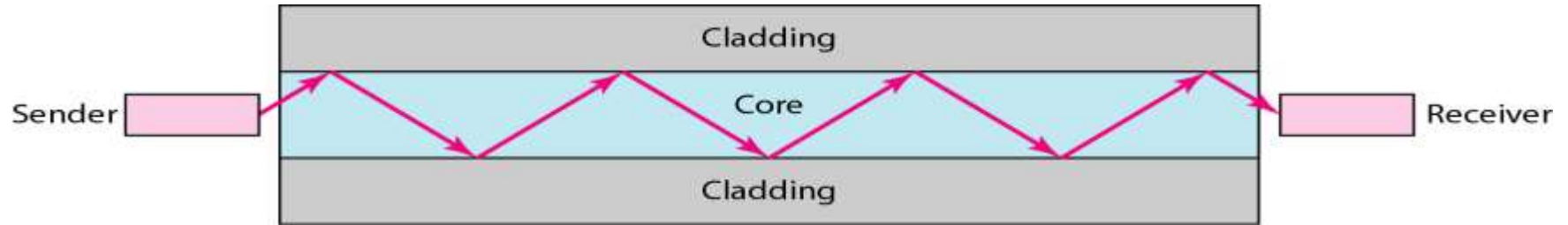


Figure 2.13 *Propagation modes*

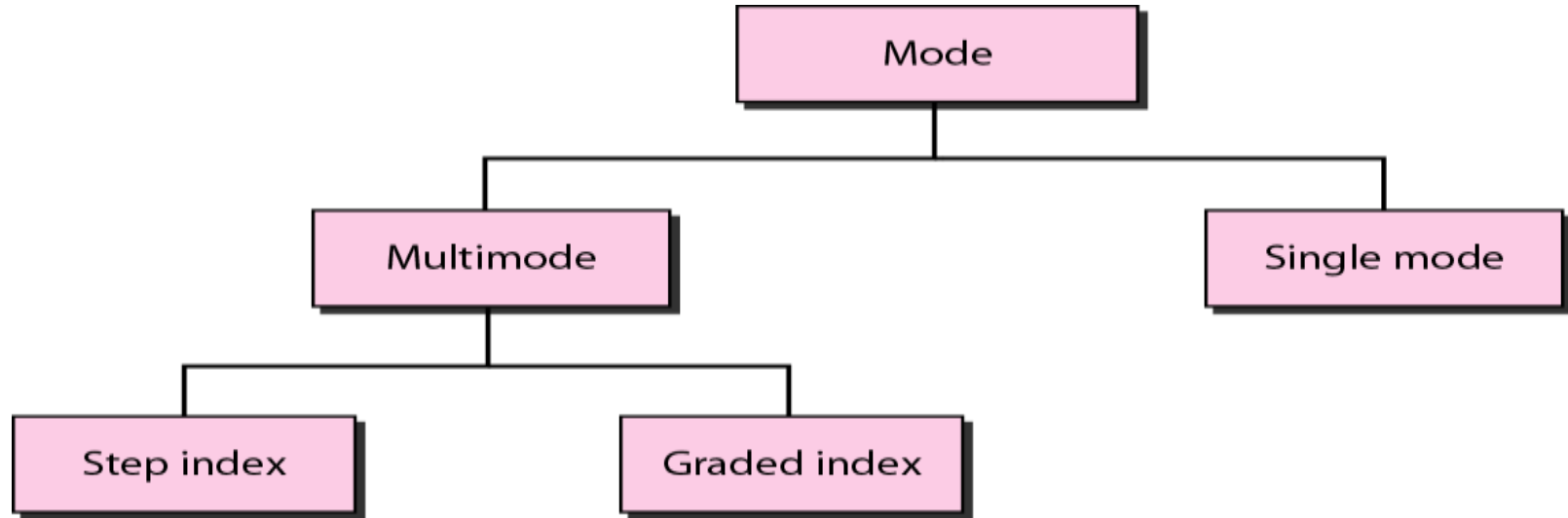


Figure 2.14 *Modes*

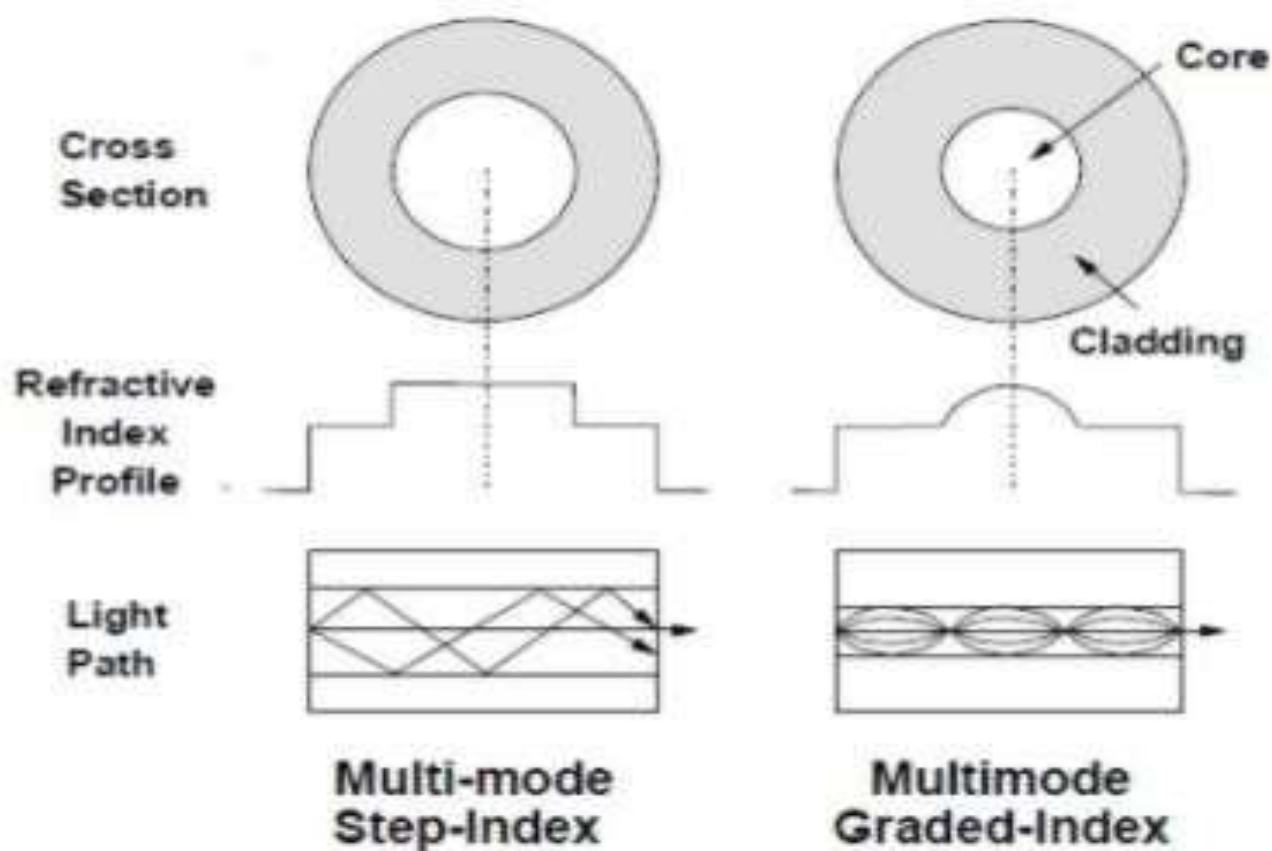
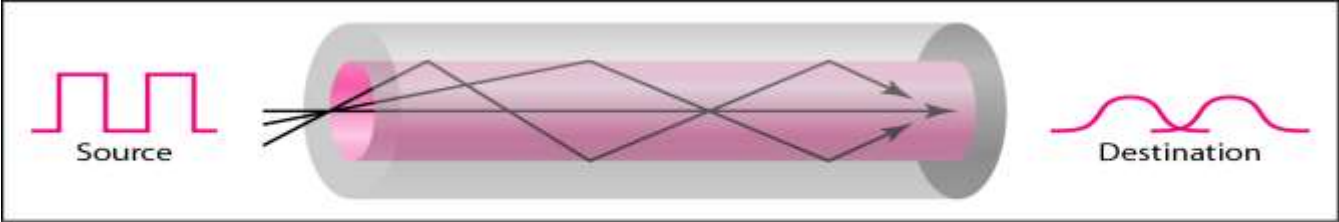
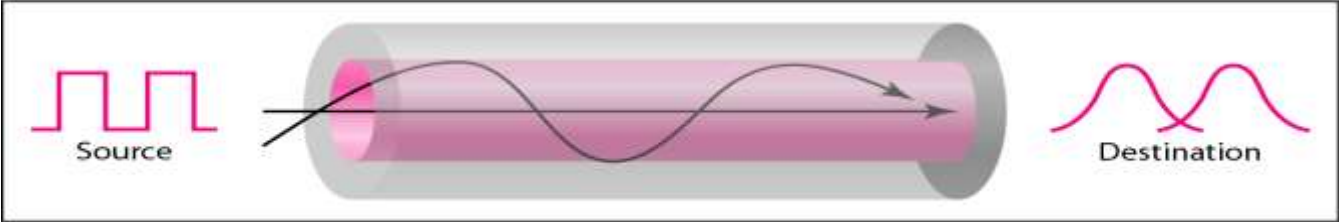


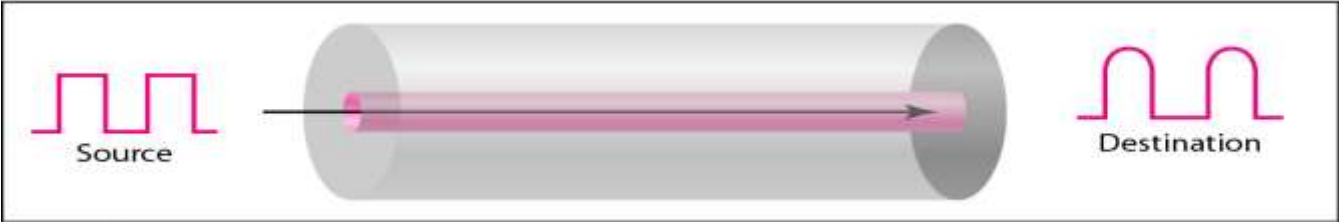
Figure 2.15 *Modes*



a. Multimode, step index



b. Multimode, graded index



c. Single mode

Table 2.3 *Fiber types*

<i>Type</i>	<i>Core (μm)</i>	<i>Cladding (μm)</i>	<i>Mode</i>
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 2.16 *Fiber construction*

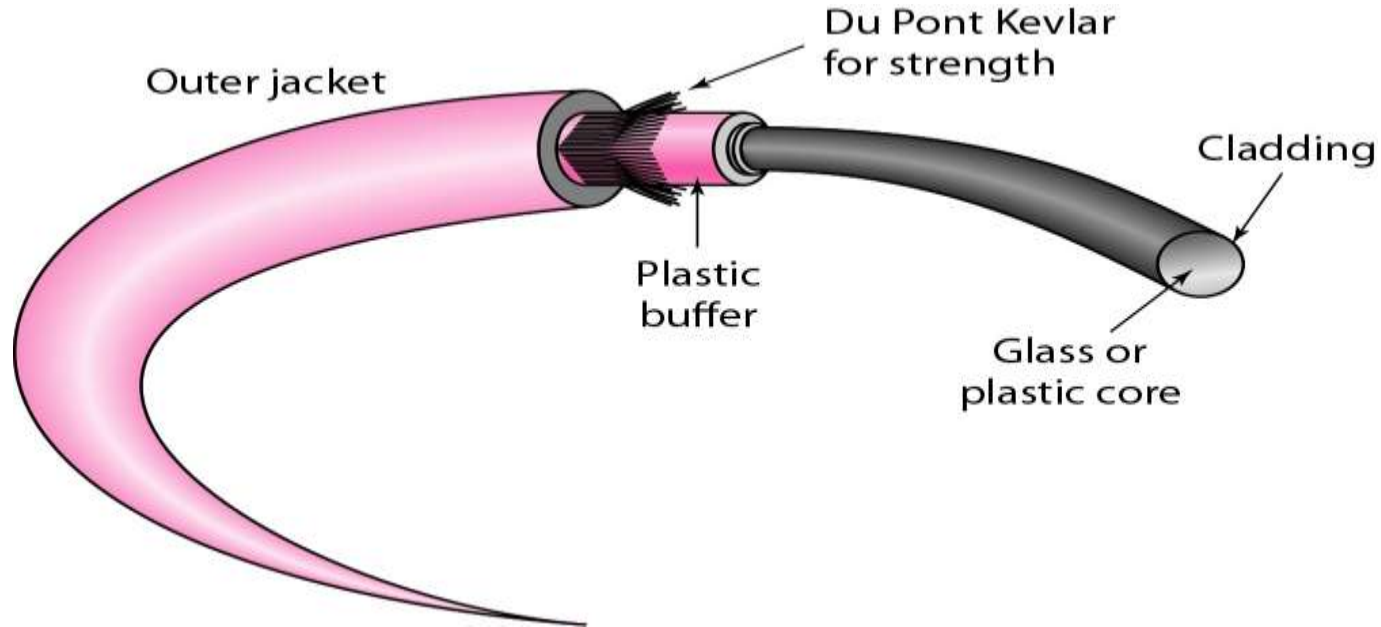
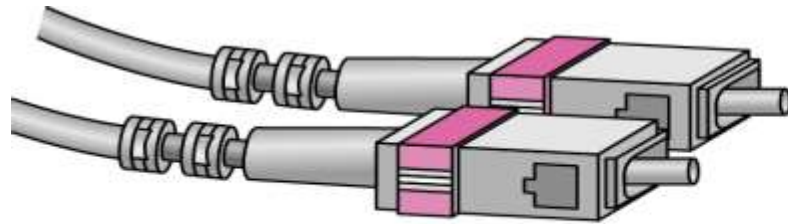
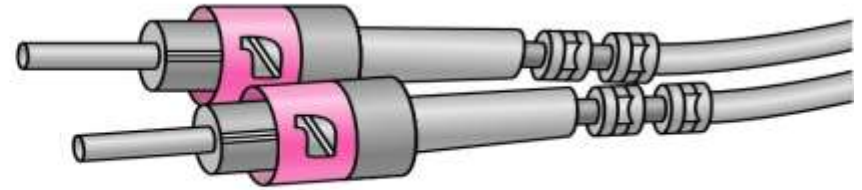


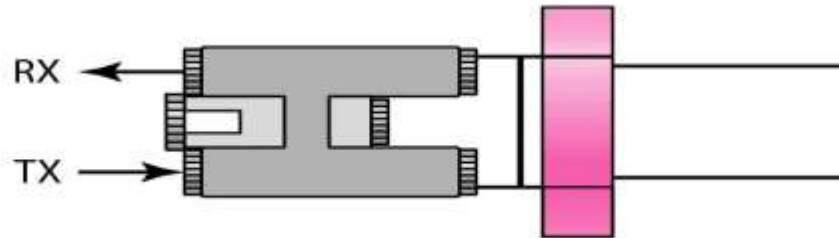
Figure 2.17 *Fiber-optic cable connectors*



SC connector

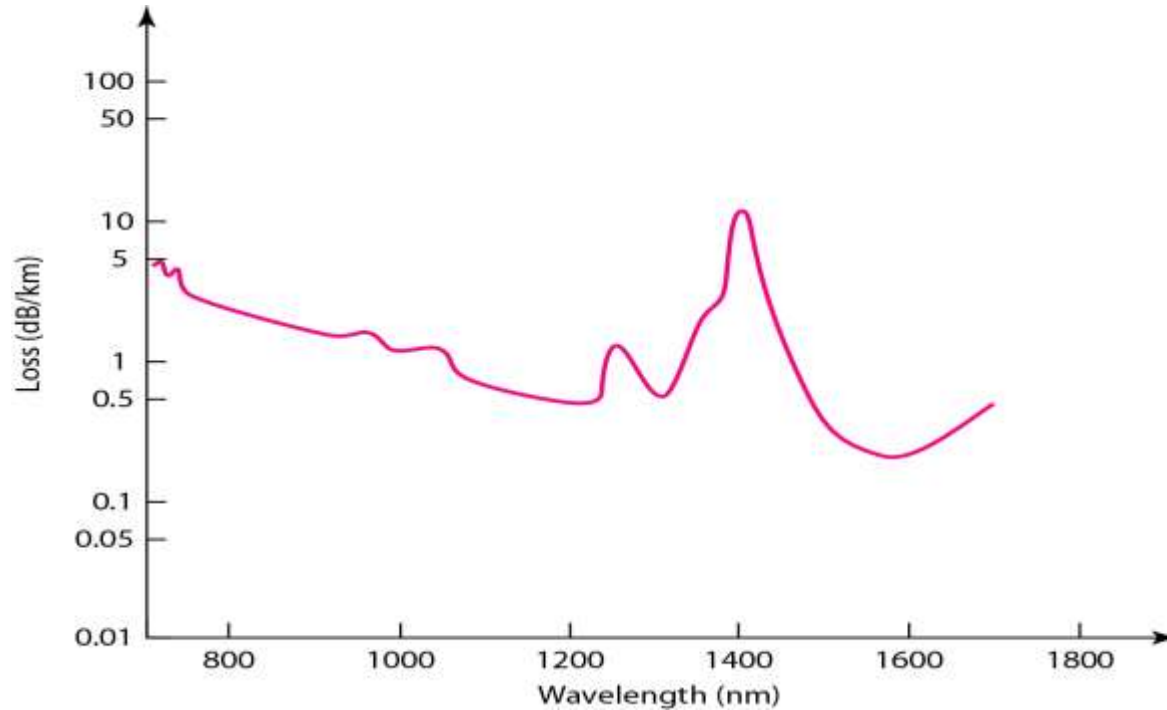


ST connector



MT-RJ connector

Figure 2.18 *Optical fiber performance*



Differences

Characteristics	UTP	STP	Coaxial Cables	Fiber Optic Cables
Bandwidth	10 Mbps - 100 Mbps	10 Mbps - 100 Mbps	10 Mbps	100 Mbps - 1 Gbps
Maximum cable segment	100 meters	100 meters	200 - 500 meters	2 k.m. - 100 k.m.
Interference rating	Poor	Better than UTP	Better than Twisted Pair Cable	Very good as compared to any other cable
Installation cost	Cheap	Costly than UTP	Costlier than twisted pair wires	Costliest to install
Bend radius	360 degrees / feet	360 degrees / feet	360 degrees / feet or 30 degrees / feet	30 degrees / feet
Security	Low	Low	Low	High

Coaxial Cable



- transmission of signals happens in the electrical form over the inner conductor of the cable
- higher noise immunity than twisted-pair cable
- moderate cost
- moderately high bandwidth
- low attenuation
- easy to install
- get disturbed by external magnetic field

Twisted-Pair Cable



- transmission of signals happens in the electrical form over the metallic conducting wires
- low noise immunity
- cheapest
- low bandwidth
- very high attenuation
- easy to install
- get disturbed by external magnetic field

Fiber-Optic Cable



- signal transmission happens in optical forms over a glass fiber
- highest noise immunity
- expensive
- very high bandwidth
- very low attenuation
- difficult to install
- not affected by the external magnetic field
- most efficient
- glass fiber

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:

1. Radio Waves
2. Microwaves
3. Infrared

Figure 2.19 *Electromagnetic spectrum for wireless communication*

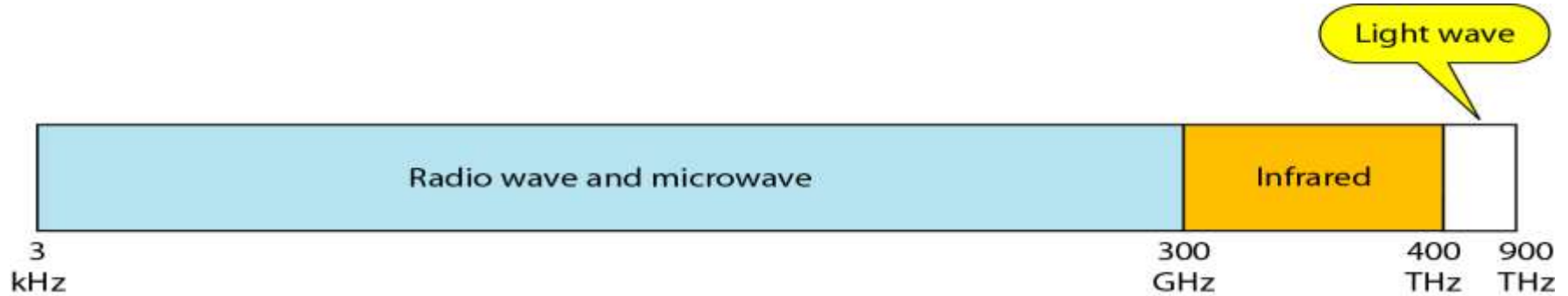


Figure 2.20 *Propagation methods*

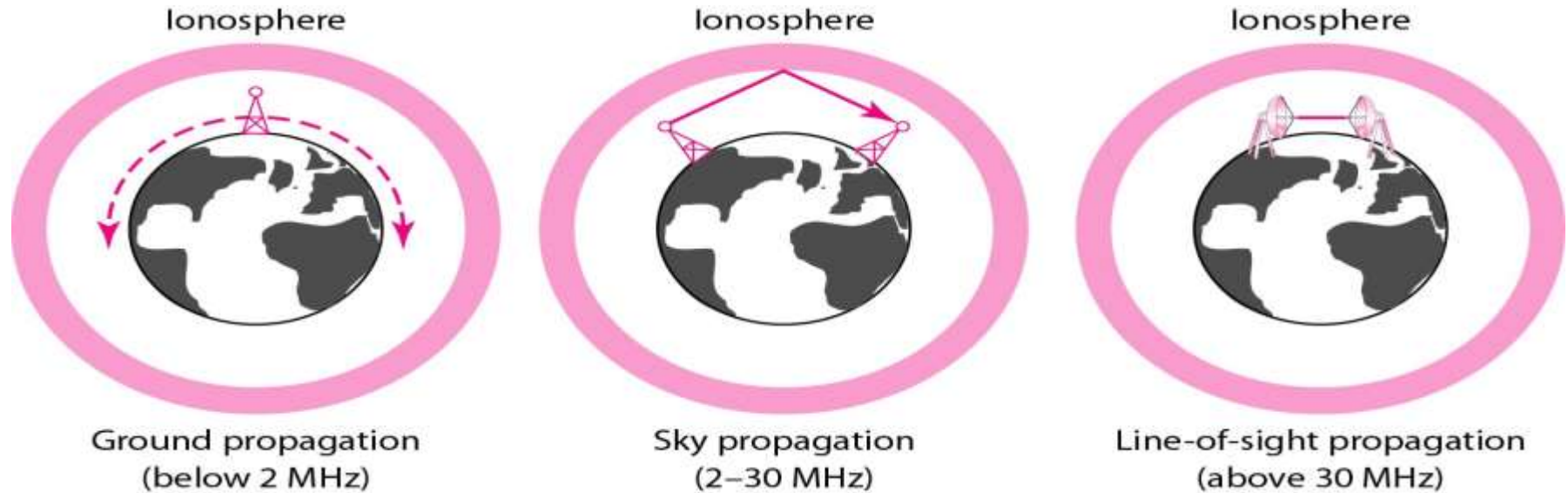
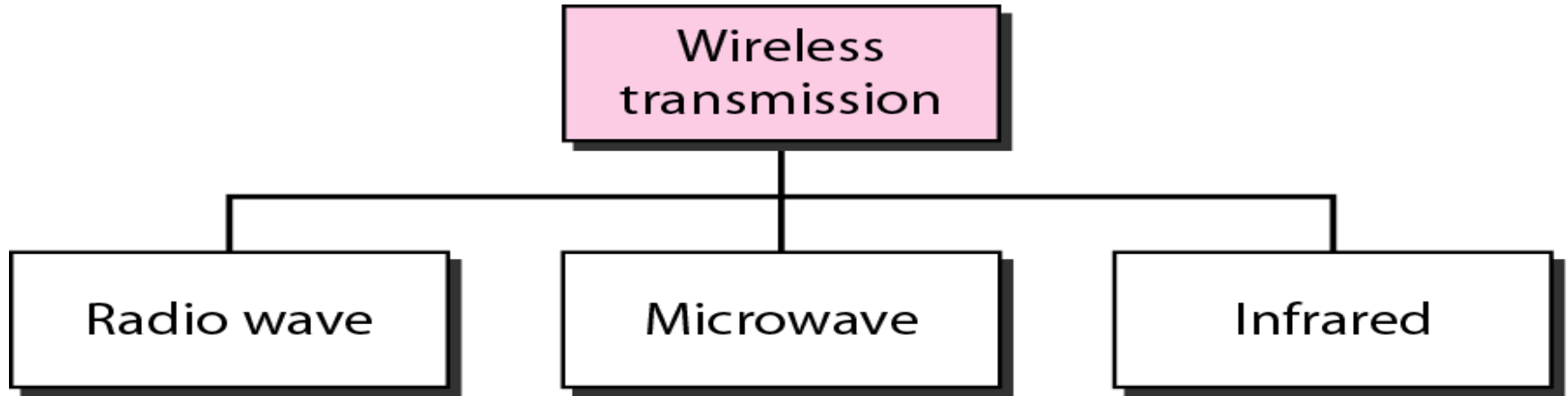




Table 2.4 *Bands*

<i>Band</i>	<i>Range</i>	<i>Propagation</i>	<i>Application</i>
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 2.21 *Wireless transmission waves*



Note

Radio waves are used for multicast communications, such as radio and television, and paging systems. They can penetrate through walls.

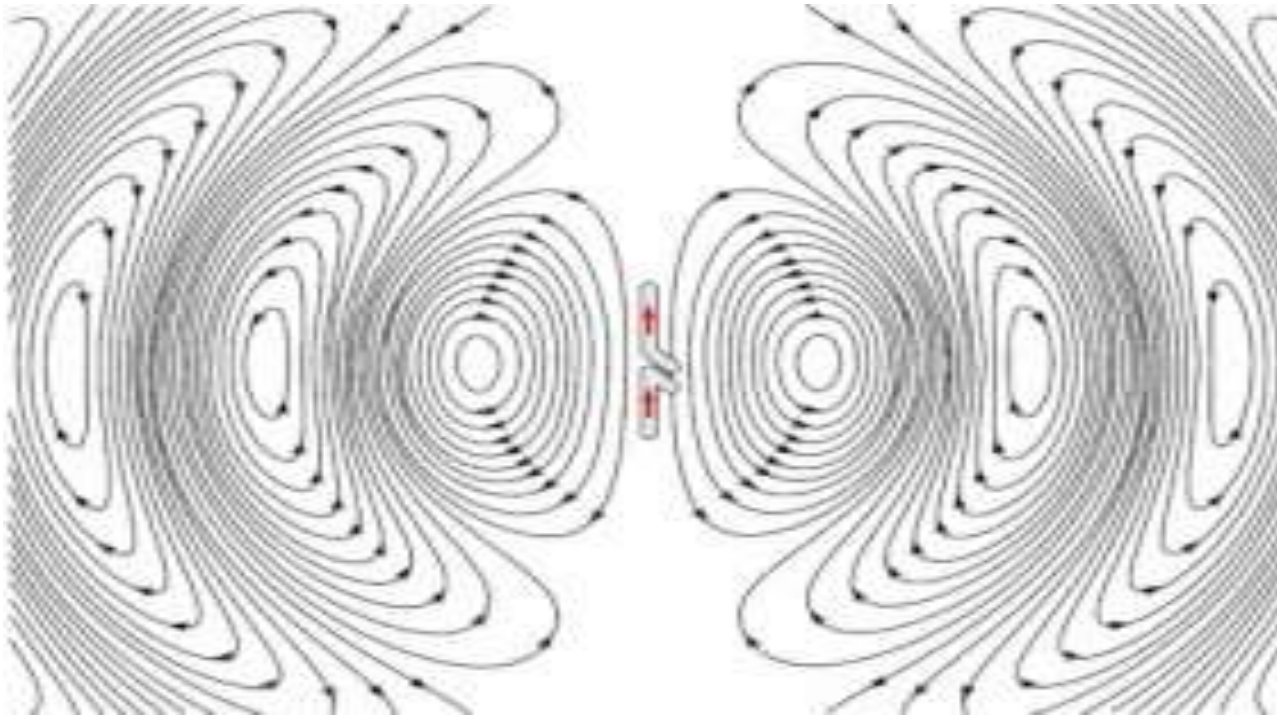
Highly regulated. Use Omni directional antennas

Figure 2.22 *Omni directional antenna*



Transmitting/receiving signals in all directions horizontally

Figure 2.23 *Radiation pattern of Omnidirectional antenna*

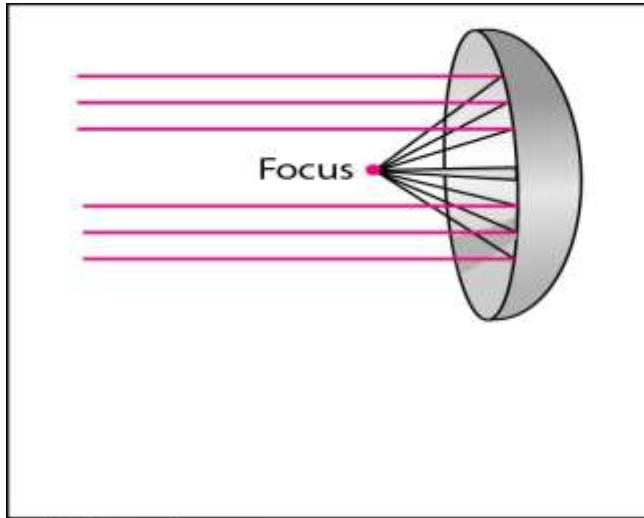


Note

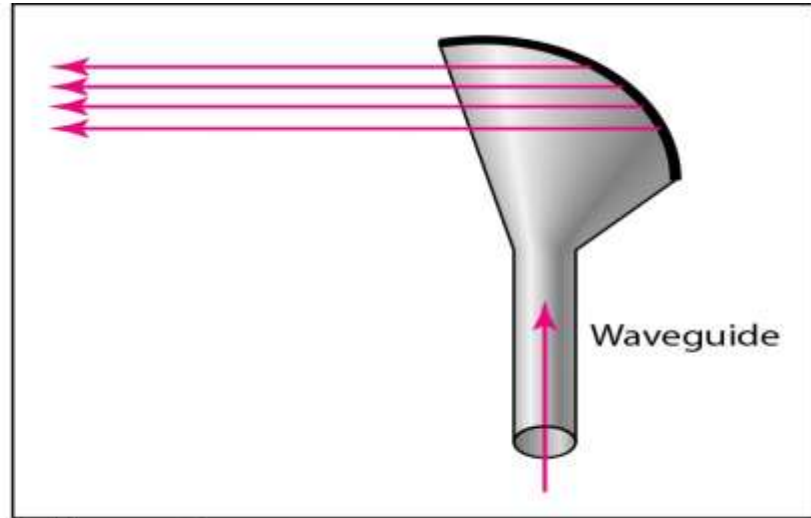
Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Higher frequency ranges cannot penetrate walls.
Use directional antennas - point to point line of sight communications.

Figure 2.24 *Unidirectional antennas*



a. Dish antenna

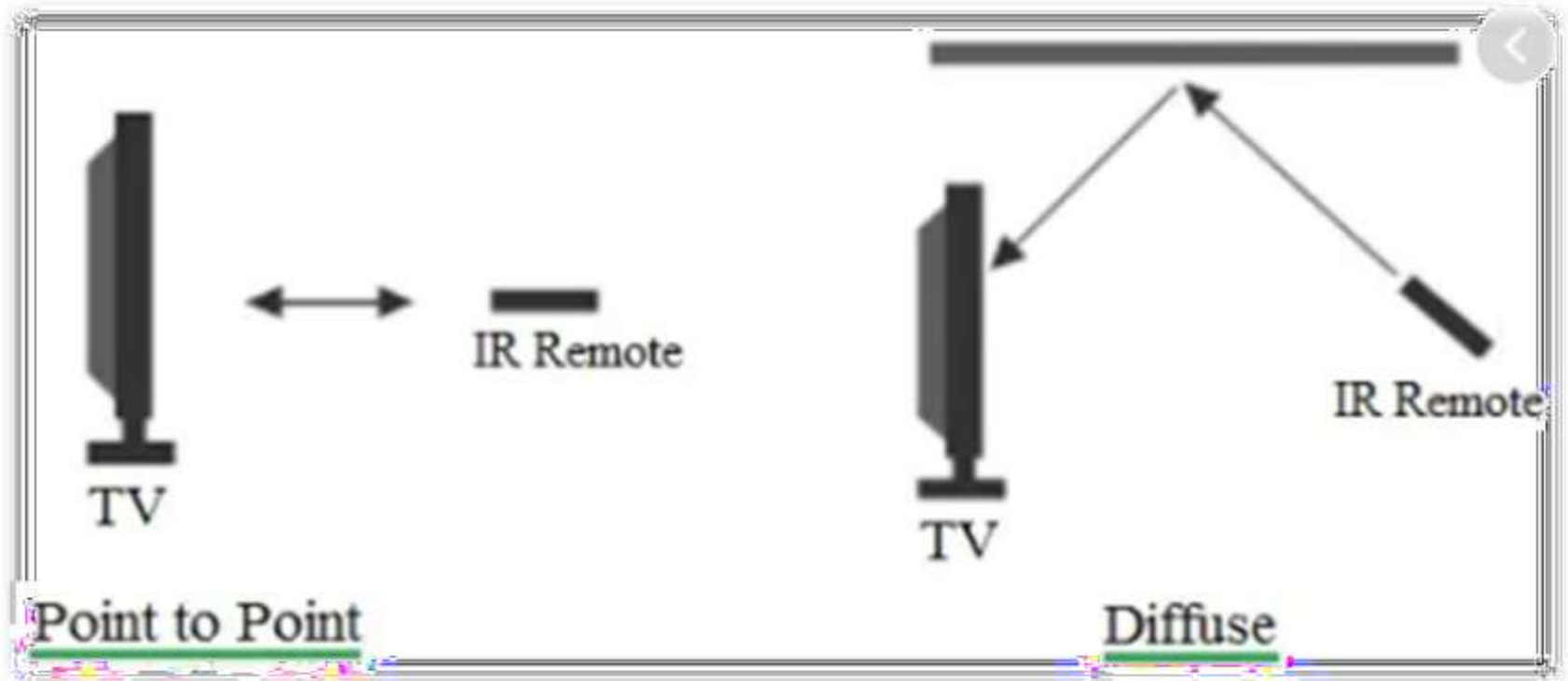


b. Horn antenna

Infrared Transmission

- Infrared waves lie in between visible light spectrum and microwaves. It has wavelength of 700 nm to 1 mm and frequency ranges from 300 GHz to 430 THz.
- Infrared waves are used for very short range communication purposes such as television and its remote.
- Infrared travels in a straight line so they are directional by nature.
- Because of high frequency range, Infrared do not cross wall like obstacles.

Contd..



Note

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

Wireless Vs. Wired Communication

Wireless Networks	Fixed Networks
1) No physical configuration is required.	1) Physical configuration is required.
2) Data loss rate is high.	2) Since a perfect link is established, data loss rate is very low.
3) Low data transmission rate which results in less speed.	3) High rate of data transmission and hence high speed.
4) More delays.	4) Less delays.
5) Low on security.	5) Highly secured.

Digital Modulation and Multiplexing

- Baseband Transmission
- Pass band Transmission
- Frequency Division Multiplexing
- Time Division Multiplexing
- Code Division Multiplexing

Baseband Transmission

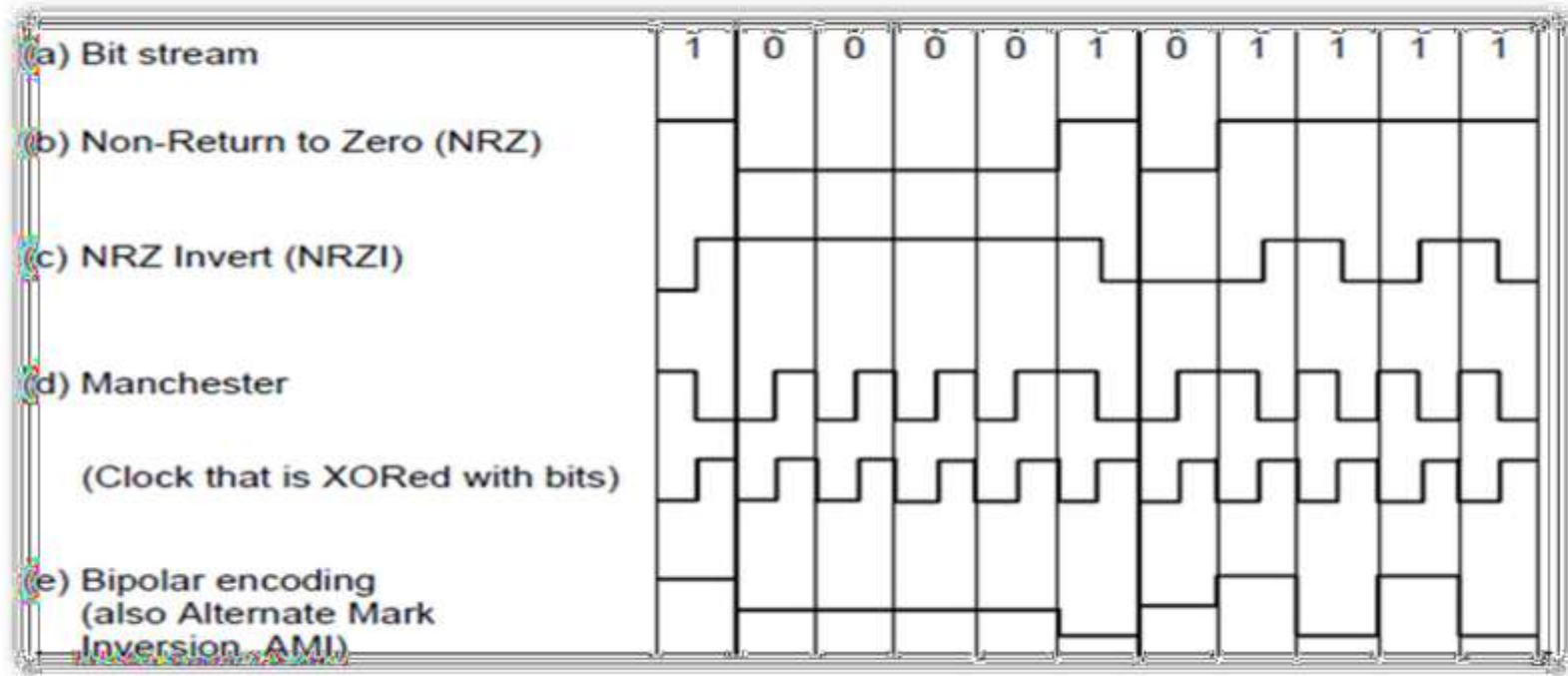
- Wires and wireless channels carry **analog signals** such as continuously varying voltage, light intensity, or sound intensity.
- To send digital information, we must plan analog signals to represent bits. The process of converting between bits and signals that represent them is called **digital modulation**.



Contd..

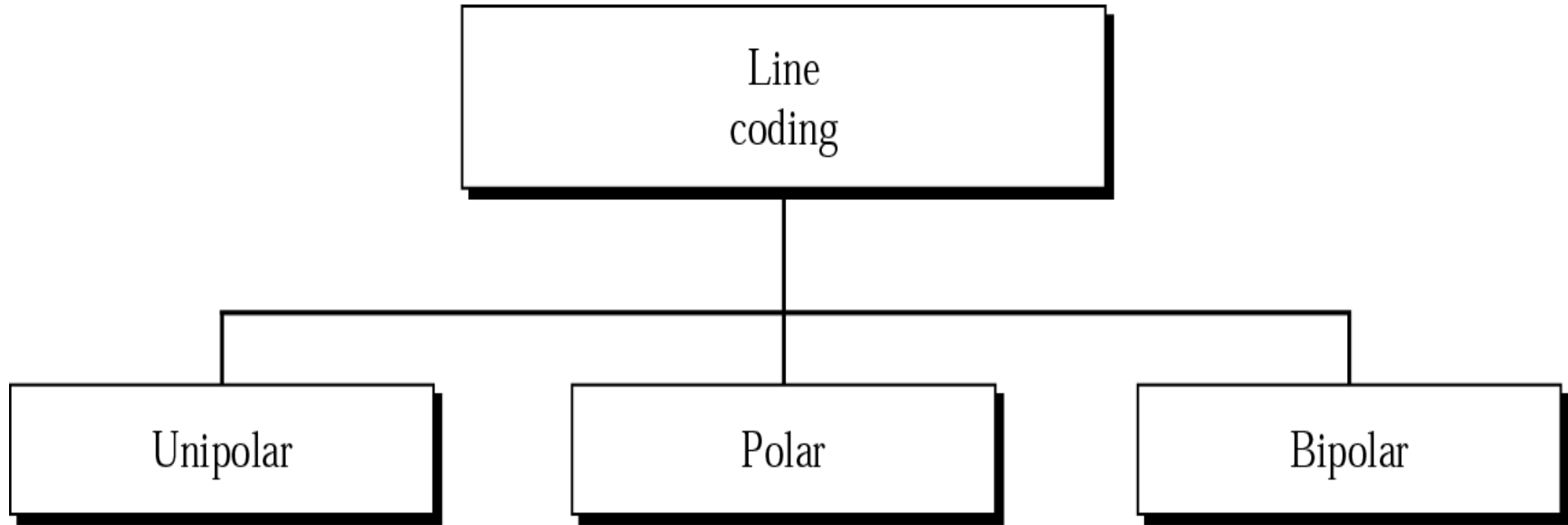
- Schemes that directly convert bits into a signal results in **baseband transmission**, in which the signal occupies frequencies from **zero up to a maximum** that depends on the signaling rate.

Baseband Transmission or Line Coding



Line codes: (a) Bits, (b) NRZ, (c) NRZI, (d) Manchester, (e) Bipolar or AMI.

Types of Line Coding



Unipolar Signaling

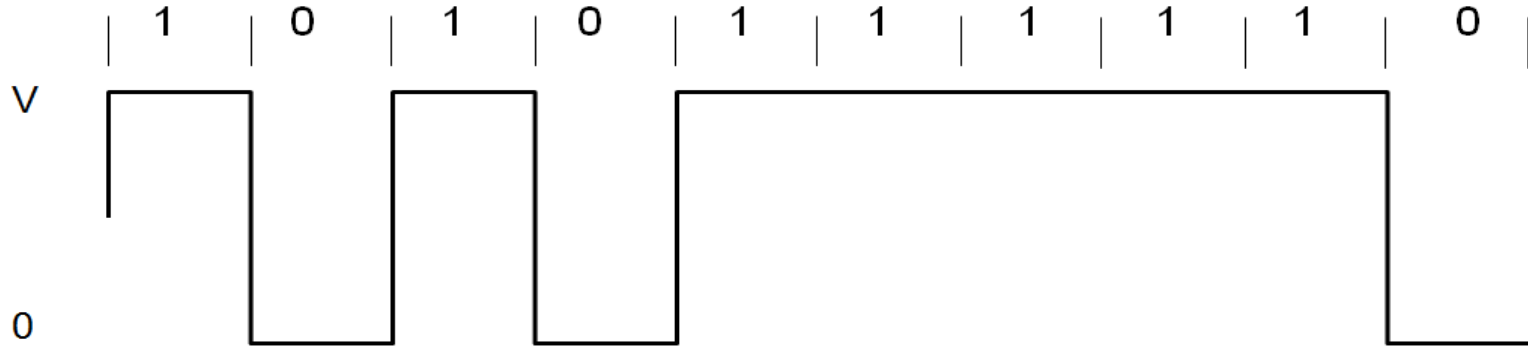
- On-Off keying ie OOK
- Pulse 0: Absence of pulse
- Pulse1 : Presence of pulse

There are two common variations of unipolar signalling:

1. Non-Return to Zero (NRZ)
2. Return to Zero (RZ)

Unipolar Non-Return to Zero (NRZ)

- Duration of the MARK pulse (T) is equal to the duration (T_o) of the symbol slot.



Advantages:

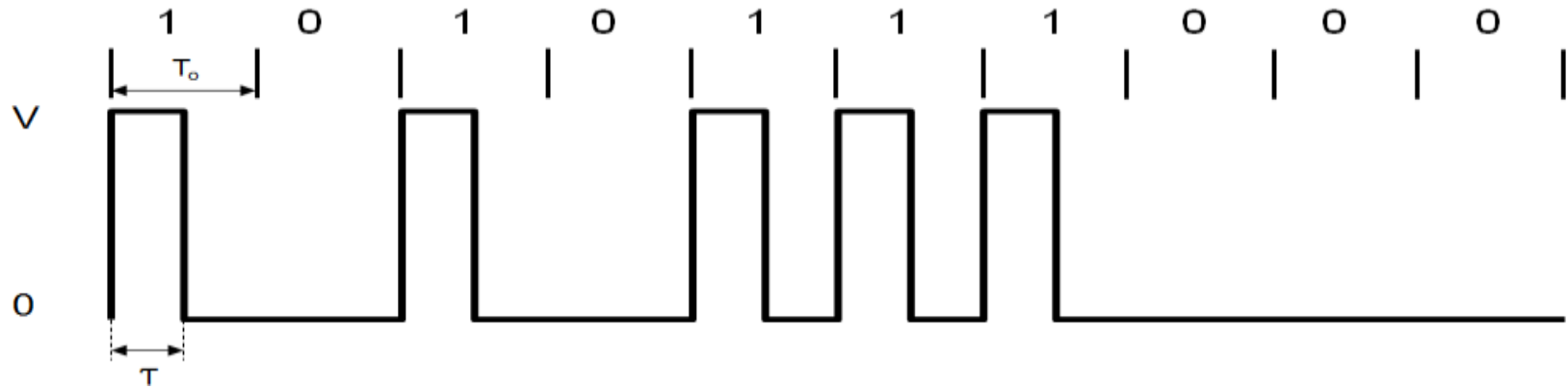
- Simplicity in implementation
- Doesn't require a lot of bandwidth for transmission.

Disadvantages:

- Presence of DC level (indicated by spectral line at 0 Hz).
- Contains low frequency components. Causes "Signal Droop"
- Does not have any error correction capability.
- Does not possess any clocking component for ease of synchronization

Unipolar Return to Zero (RZ)

- MARK pulse (T) is **less** than the duration (T_o) of the symbol slot.
- Fills only the first half of the time slot, returning to zero for the second half.



Advantages:

- Simplicity in implementation.
- Presence of a spectral line at symbol rate which can be used as symbol timing clock signal.

Disadvantages:

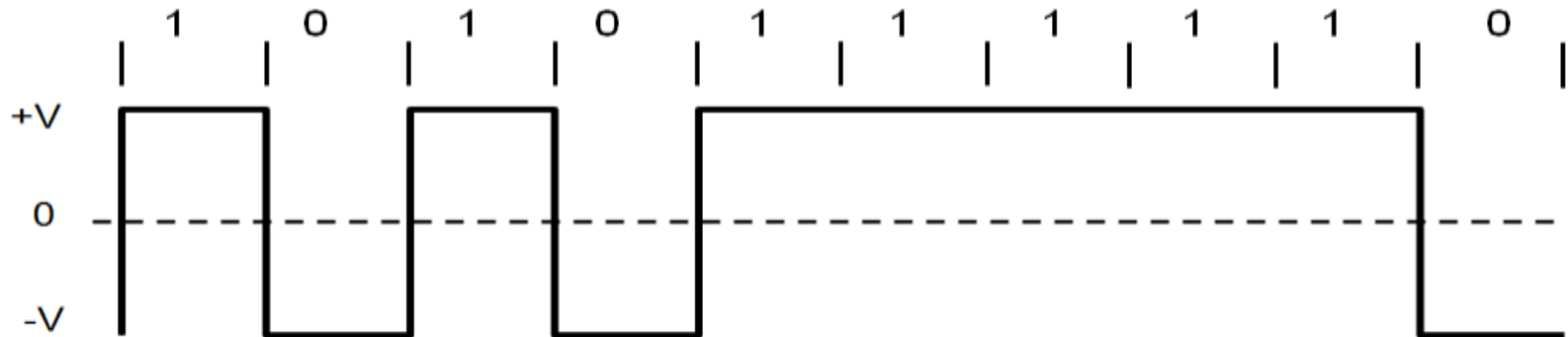
- Presence of DC level (indicated by spectral line at 0 Hz).
- Continuous part is non-zero at 0 Hz. Causes “Signal Droop”.
- Does not have any error correction capability.
- Occupies twice as much bandwidth as Unipolar NRZ.
- Is not Transparent

Polar Signalling

- Polar RZ
- Polar NRZ

Polar NRZ:

- A binary 1 is represented by a pulse $g_1(t)$
- A binary 0 by the opposite (or antipodal) pulse $g_0(t) = -g_1(t)$.



Advantages:

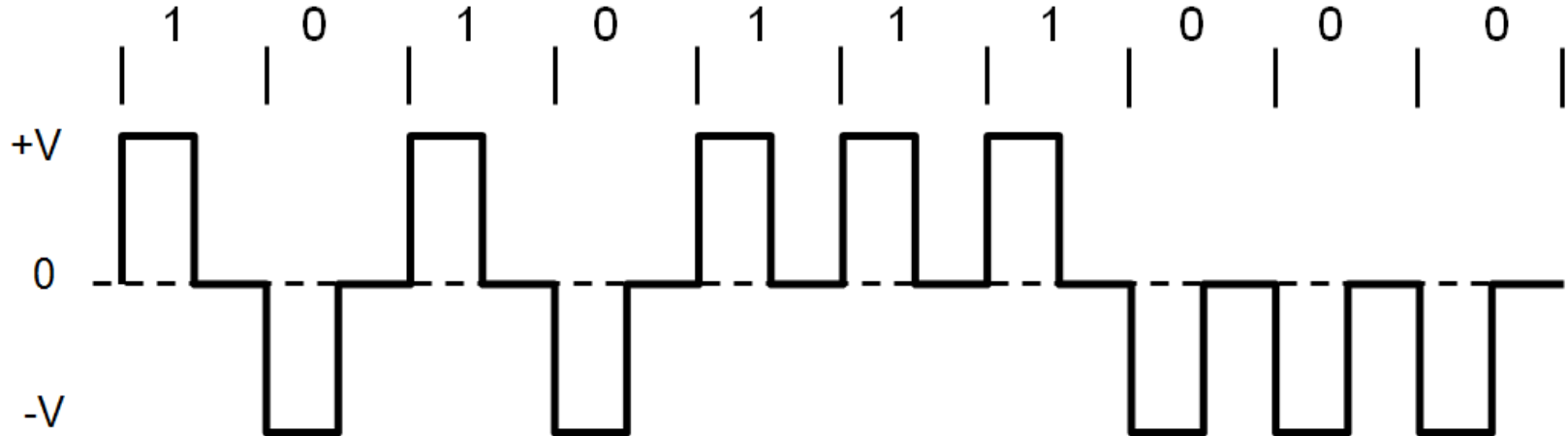
- Simplicity in implementation.
- No DC component.

Disadvantages:

- Continuous part is non-zero at 0 Hz. Causes “Signal Droop”.
- Does not have any error correction capability.
- Does not possess any clocking component for ease of synchronisation.
- Is not transparent.

Polar RZ

- A binary 1: A pulse $g_1(t)$
- A binary 0: The opposite (or antipodal) pulse $g_0(t) = -g_1(t)$.
- Fills only the first half of the time slot, returning to zero for the second half.



Advantages:

- Simplicity in implementation.
- No DC component.

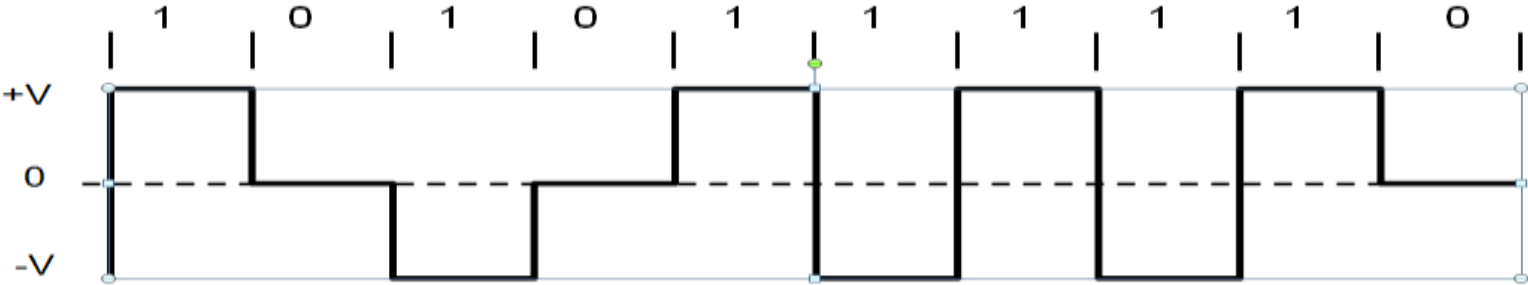
Disadvantages:

- Continuous part is non-zero at 0 Hz. Causes “Signal Droop”.
- Does not have any error correction capability.
- Occupies twice as much bandwidth as Polar NRZ.

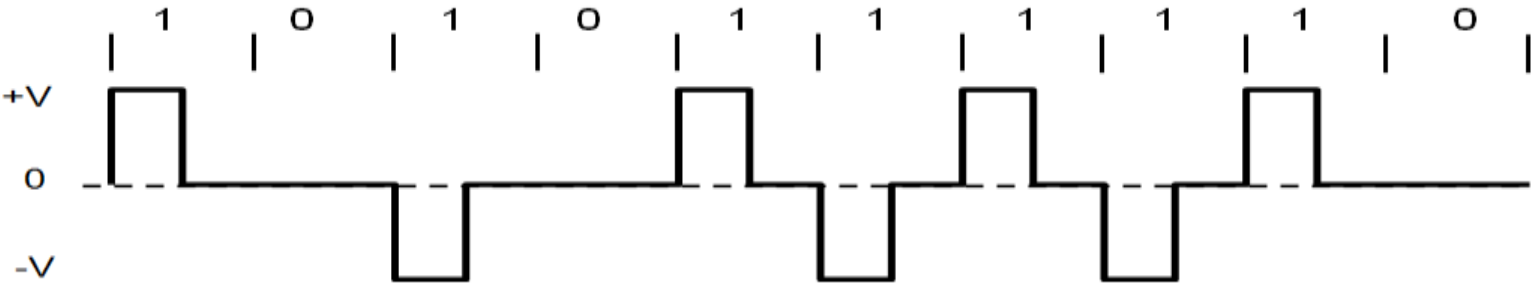
Bipolar Signalling

- Alternate mark inversion (AMI)
- Uses three voltage levels ($+V$, 0 , $-V$)
- 0 : Absence of a pulse
- 1 : Alternating voltage levels of $+V$ and $-V$

Bipolar NRZ:



Bipolar RZ:



Advantages:

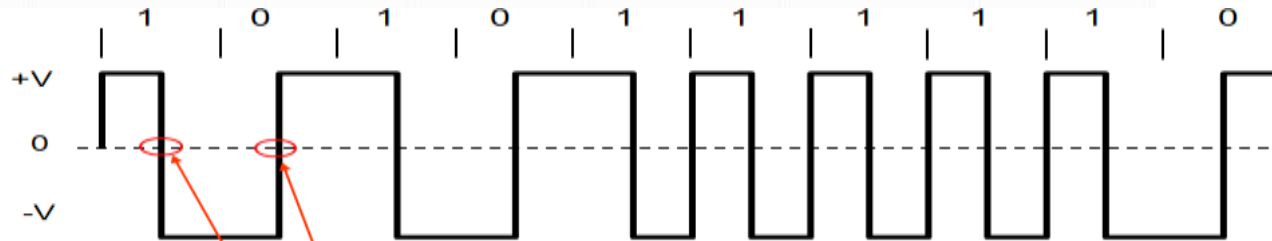
- No DC component.
- Occupies less bandwidth than unipolar and polar NRZ schemes.
- Does not suffer from signal droop (suitable for transmission over AC coupled lines).
- Possesses single error detection capability.

Disadvantages:

- Does not possess any clocking component for ease of synchronisation.
- Is not Transparent.

Manchester Signalling

- The duration of the bit is divided into two halves
- A One is +ve in 1st half and -ve in 2nd half.
- A Zero is -ve in 1st half and +ve in 2nd half.



Note: There is always a transition at the centre of bit duration.

Advantages:

- No DC component.
- Does not suffer from signal droop (suitable for transmission over AC coupled lines).
- Easy to synchronise.
- Is Transparent.

Disadvantages:

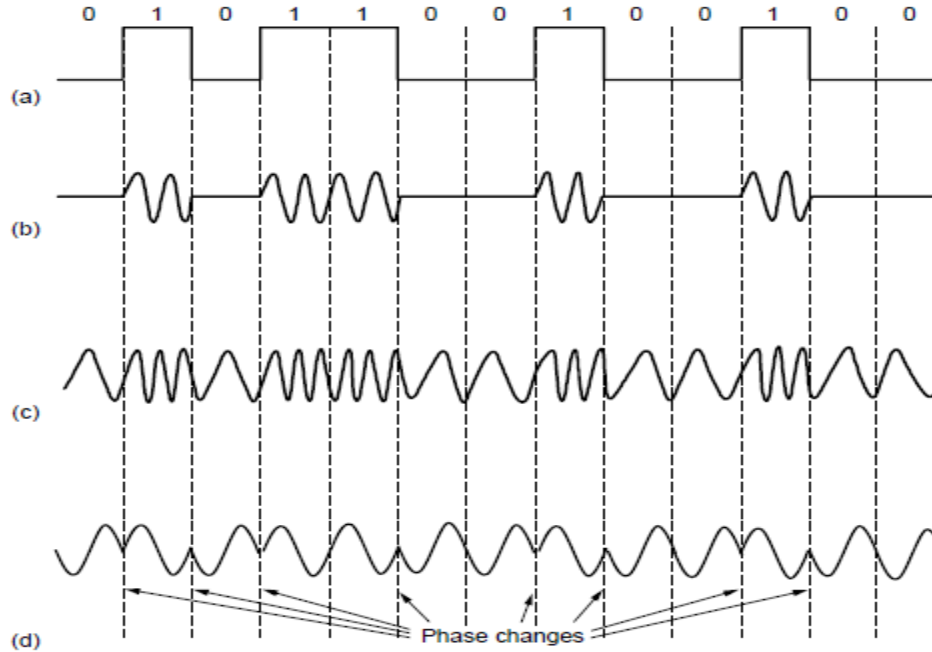
- Because of the greater number of transitions it occupies a significantly large bandwidth.
- Does not have error detection capability.

Comparison of Line Codes

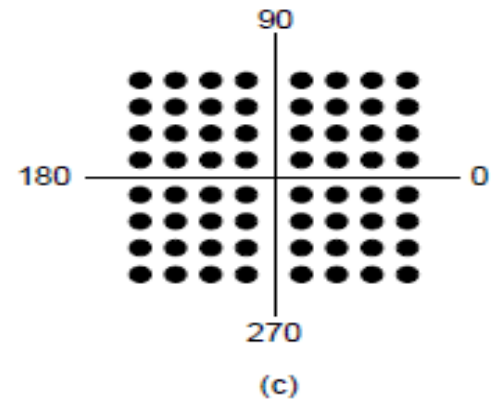
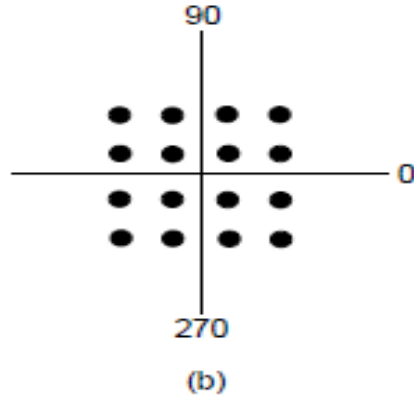
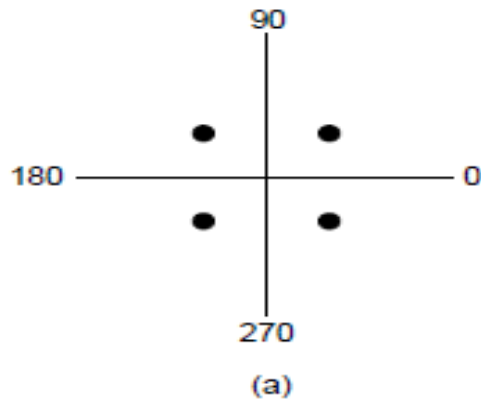
Sr. No.	Parameters	Polar RZ	Polar NRZ	AMI	Manchester
1	Transmission of DC component	YES	YES	NO	NO
2	Signaling Rate	1/Tb	1/Tb	1/Tb	1/Tb
3	Noise Immunity	LOW	LOW	HIGH	HIGH
4	Synchronizing Capability	Poor	Poor	Very Good	Very Good
5	Bandwidth Required	1/Tb	1/2Tb	1/2Tb	1/Tb
6	Crosstalk	HIGH	HIGH	LOW	LOW

Pass band Transmission

- Schemes that regulate the amplitude, phase, or frequency of a carrier signal to convey bits results in **pass band transmission**, in which the signal occupies a band of frequencies around the frequency of the carrier signal.
- We can modulate the amplitude, frequency, or phase of the carrier signal according to the digital data named as ASK,FSK,PSK respectively.



- (a) A binary signal. (b) Amplitude shift keying.
(c) Frequency shift keying. (d) Phase shift keying.



(a) QPSK. (b) QAM-16. (c) QAM-64.

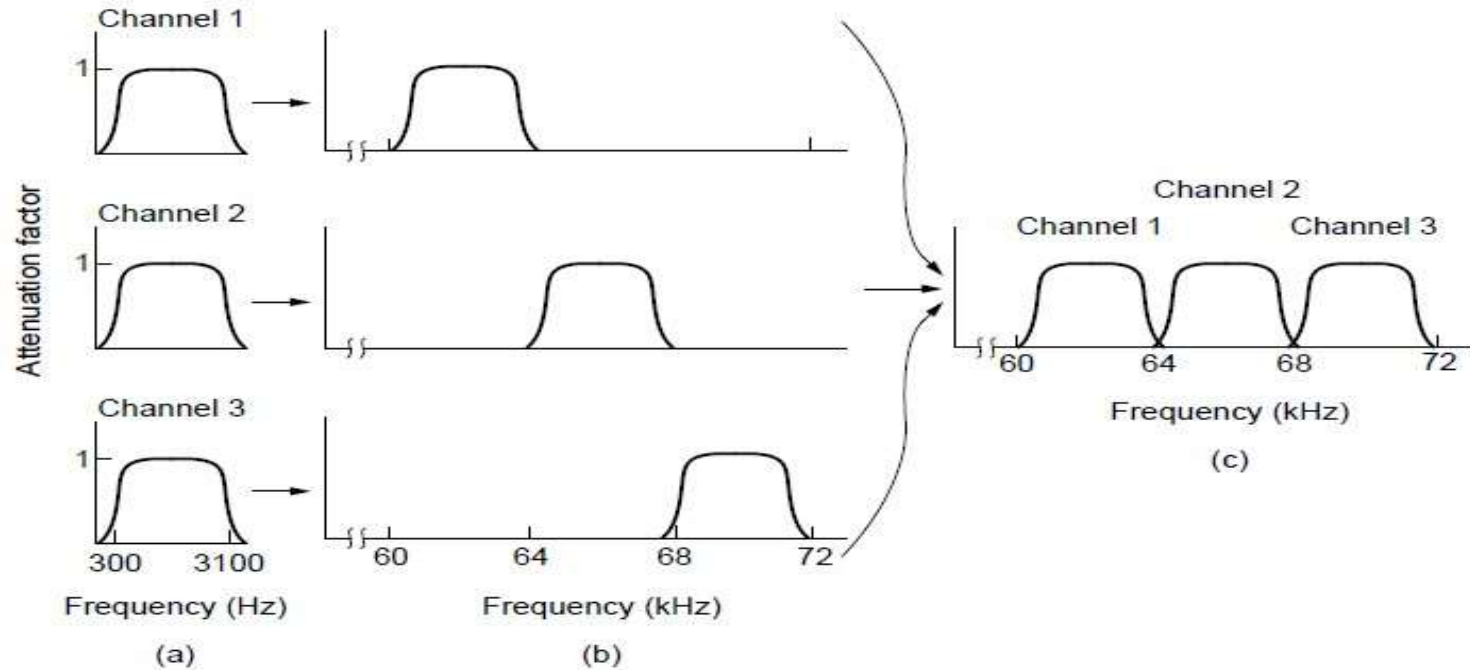
Multiplexing

- Channels are often shared by multiple signals. After all, it is much more convenient to use a single wire to carry several signals than to install a wire for every signal. This kind of sharing is called **multiplexing**.
- It can be accomplished in several different ways. We will present methods for time, frequency, and code division multiplexing.

Multiplexing techniques

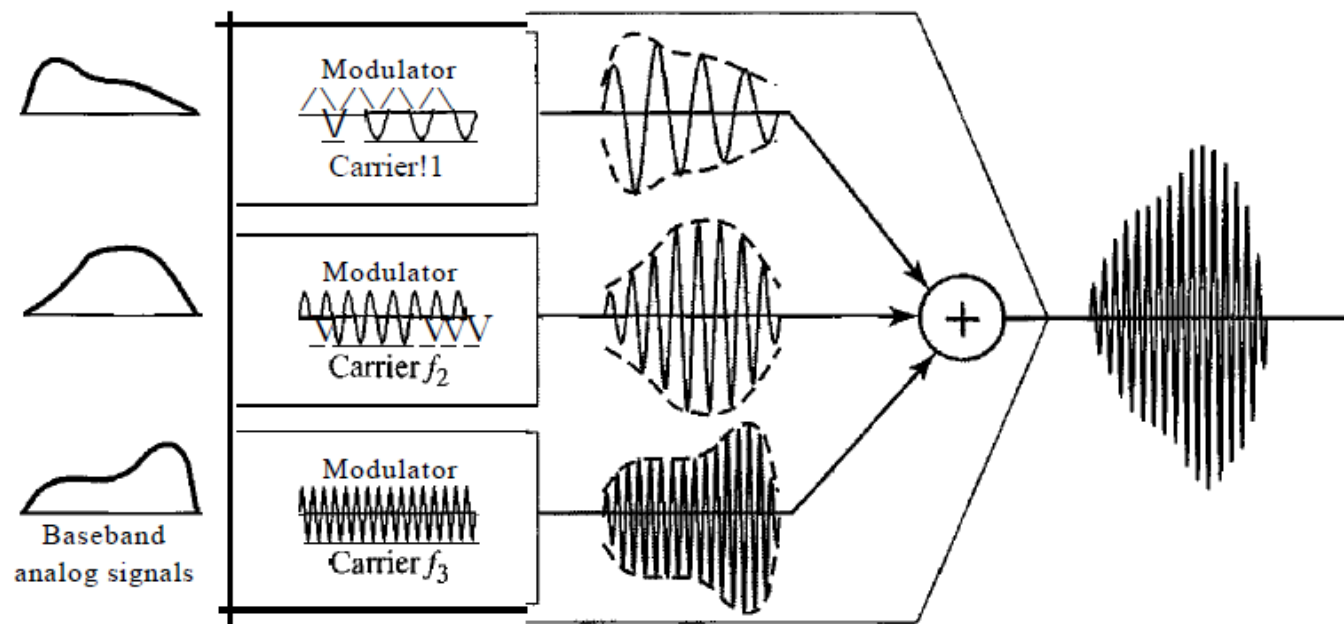
- Frequency division multiplexing
- Wavelength division multiplexing
- Time division multiplexing
- Code division multiplexing

Frequency Division Multiplexing

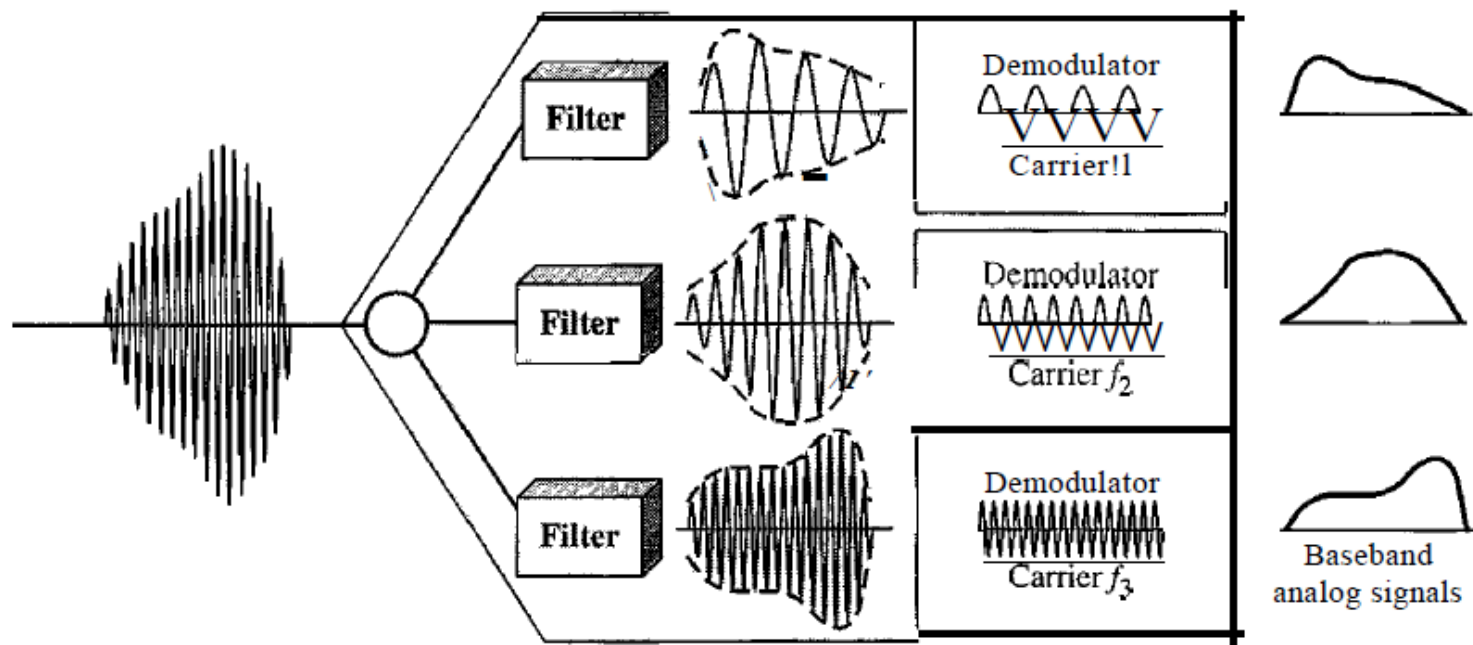


Frequency division multiplexing. (a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.

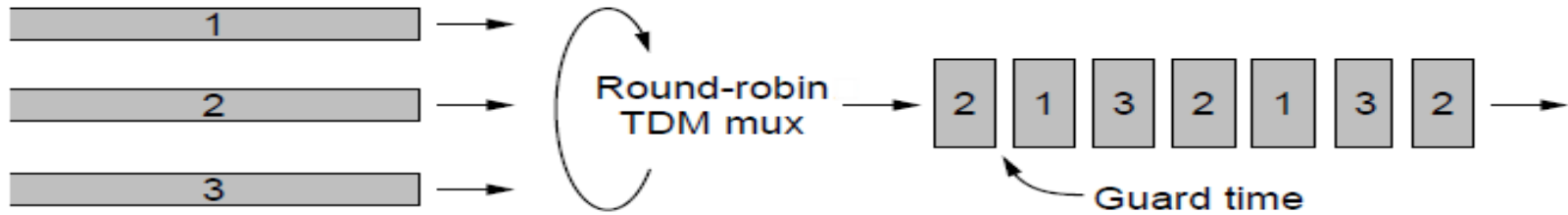
FDM process



FDM demultiplexing example



Time Division Multiplexing



Time Division Multiplexing (TDM).

Code Division Multiplexing

- CDM allows each station to transmit over the entire frequency spectrum all the time.
- Multiple simultaneous transmissions are separated using coding theory.

Walsh codes(orthogonal)

$$\mathbf{S} \bullet \mathbf{T} \equiv \frac{1}{m} \sum_{i=1}^m S_i T_i = 0$$

$$\mathbf{S} \bullet \mathbf{S} = \frac{1}{m} \sum_{i=1}^m S_i S_i = \frac{1}{m} \sum_{i=1}^m S_i^2 = \frac{1}{m} \sum_{i=1}^m (\pm 1)^2 = 1$$

$$\mathbf{S} \bullet \bar{\mathbf{S}} = -1.$$

Contd..

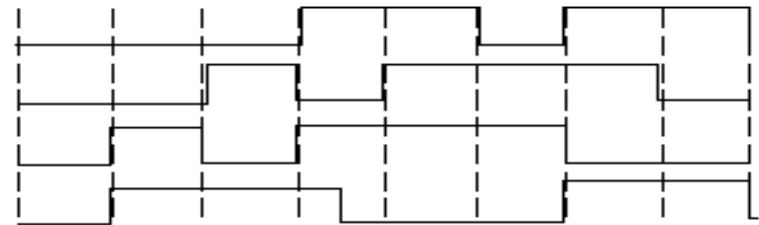
$$A = (-1 -1 -1 +1 +1 -1 +1 +1)$$

$$B = (-1 -1 +1 -1 +1 +1 +1 -1)$$

$$C = (-1 +1 -1 +1 +1 +1 -1 -1)$$

$$D = (-1 +1 -1 -1 -1 -1 +1 -1)$$

(a)



(b)

(a) Chip sequences for four stations.

(b) Signals the sequences represent

$$\begin{aligned}
 S_1 &= C &= (-1 \ +1 \ -1 \ +1 \ +1 \ +1 \ -1 \ -1) \\
 S_2 &= B + \overline{C} &= (-2 \ 0 \ 0 \ 0 \ +2 \ +2 \ 0 \ -2) \\
 S_3 &= A + \overline{B} &= (0 \ 0 \ -2 \ +2 \ 0 \ -2 \ 0 \ +2) \\
 S_4 &= A + \overline{B} + C &= (-1 \ +1 \ -3 \ +3 \ +1 \ -1 \ -1 \ +1) \\
 S_5 &= A + B + \overline{C} + D &= (-4 \ 0 \ -2 \ 0 \ +2 \ 0 \ +2 \ -2) \\
 S_6 &= A + B + \overline{C} + D &= (-2 \ -2 \ 0 \ -2 \ 0 \ -2 \ +4 \ 0)
 \end{aligned}$$

(c)

$$\begin{aligned}
 S_1 \bullet C &= [1+1-1+1+1+1-1-1]/8 = 1 \\
 S_2 \bullet C &= [2+0+0+0+2+2+0+2]/8 = 1 \\
 S_3 \bullet C &= [0+0+2+2+0-2+0-2]/8 = 0 \\
 S_4 \bullet C &= [1+1+3+3+1-1+1-1]/8 = 1 \\
 S_5 \bullet C &= [4+0+2+0+2+0-2+2]/8 = 1 \\
 S_6 \bullet C &= [2-2+0-2+0-2-4+0]/8 = -1
 \end{aligned}$$

(d)

(a) Six examples of transmissions.

(b) Recovery of station C's

FDM Vs. TDM Vs. CDM

