Computer Network and Data Communication

UNIT 3
Data Transmission Fundamentals and the Physical Layer

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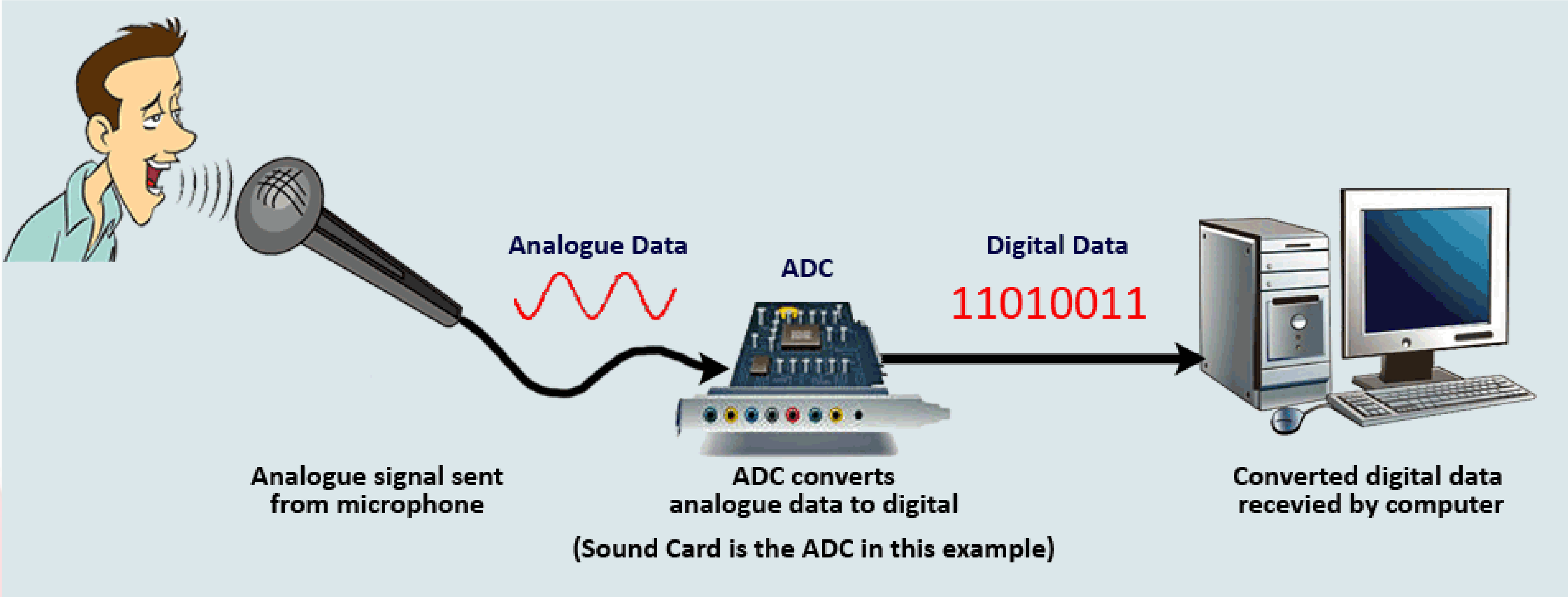
Course Outline

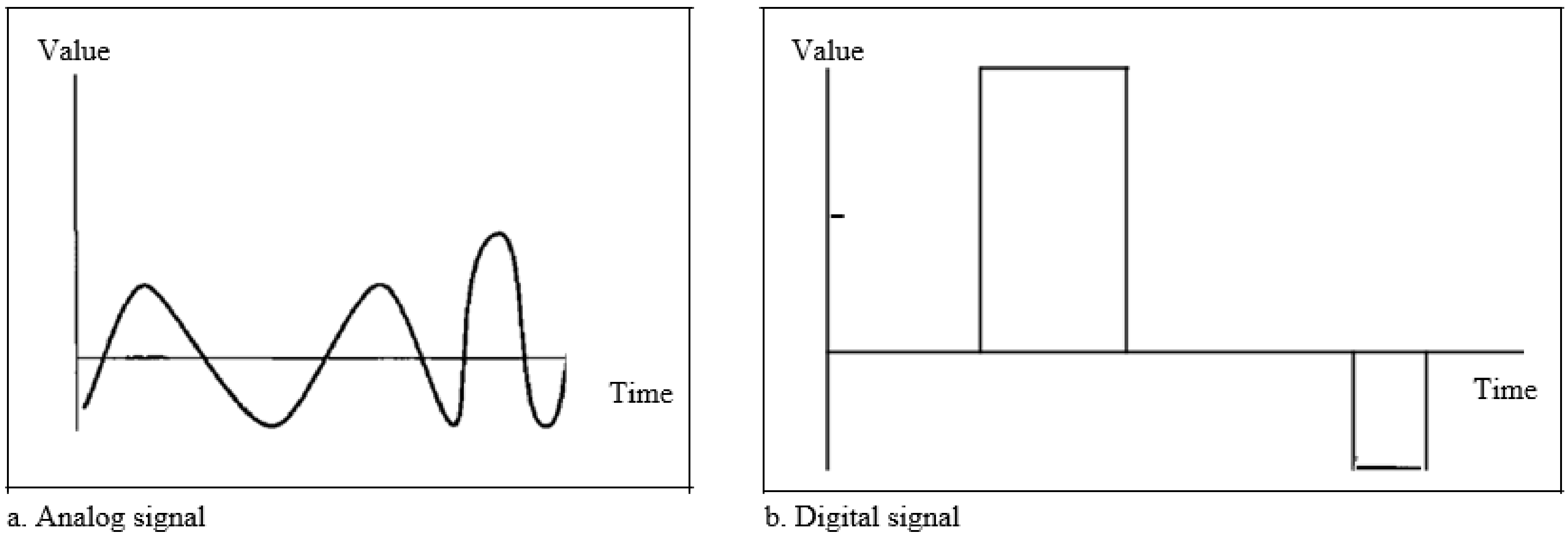
3. **Data Transmission Fundamentals & The Physical Layer** **[6 Hrs]**
   - 3.1. Signals for Conveying Information
   - 3.2. Analog & Digital Transmission
   - 3.3. Types of Transmission Medium: Guided & Unguided
   - 3.4. Bandwidth, Channel Capacity, Latency, Throughput, Transmission Impairments
   - 3.5. Transmission Modes: Simplex, Half-Duplex and Full-Duplex
   - 3.6. Circuit Switching, Packet Switching
   - 3.7. Serial Data Transmission: Synchronous and Asynchronous Transmission
   - 3.8. Multiplexing and Demultiplexing: FDM, WDM, TDM
   - 3.9. Introduction to Data Encoding and Modulation
   - 3.10. Analog Modulation: Amplitude, Frequency and Phase Modulation
   - 3.11. Digital Modulation: ASK, PSK, FSK

Analog and Digital Data



- Analog data, such as the sounds made by a human voice, take on continuous values
- Digital data take on discrete values. For example, data are stored in computer memory in the form of Os and 1s.

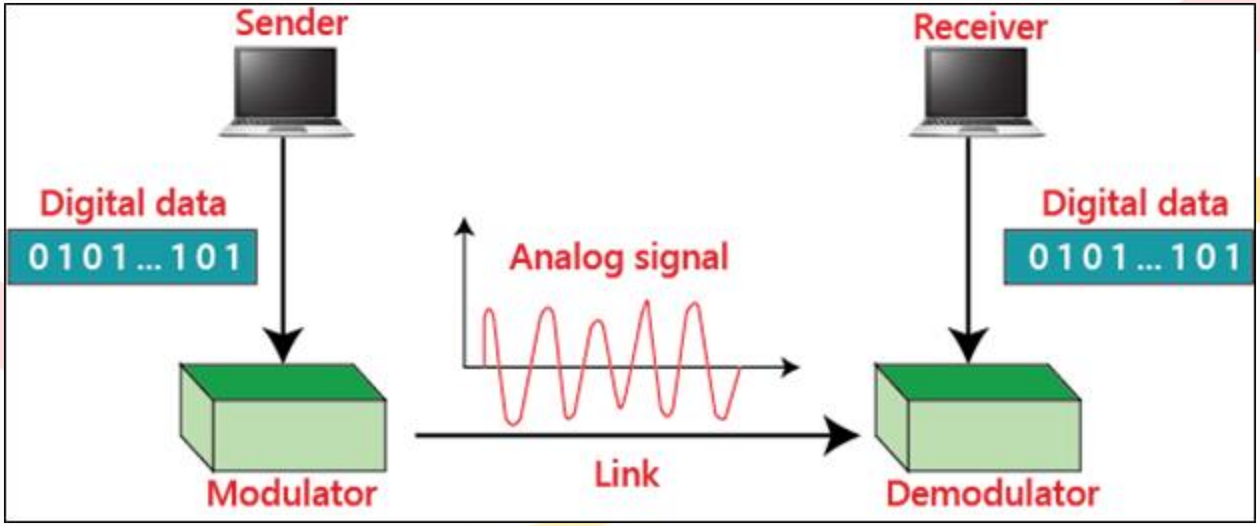
Analog and Digital Signals



- An analog signal has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path.
- A digital signal, on the other hand, can have only a limited number of defined values. Although each value can be any number, it is often as simple as 1 and O.

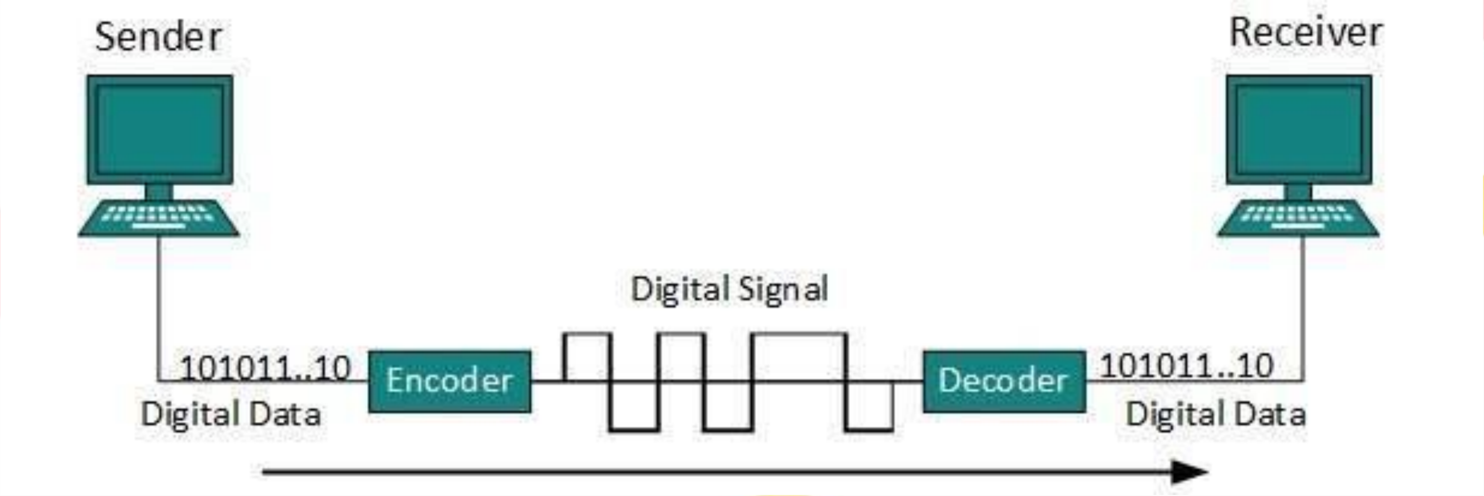
Analog Transmisssion

- Continuous transmission of data in the form of analog signals.
- In analog transmission, the original data is encoded into analog signals, which are then transmitted over a communication medium.



Digital Transmisssion

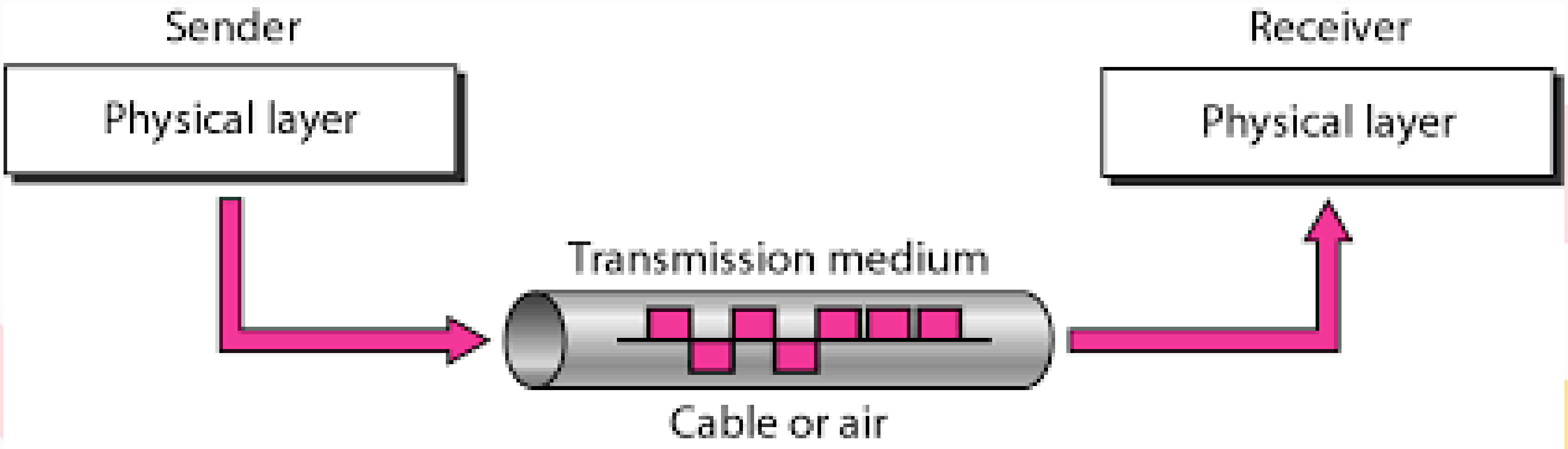
- In digital transmission, data is encoded into digital signals
- More efficient and reliable transmission over communication channels.



Analog and Digital Transmission

- Analog
  - Legacy Telephony
  - Audio Broadcasting
  - Video Broadcasting
- Digital
  - Data Communication
  - Mobile Communication
  - Multimedia Streaming
  - Data Storage

Transmission Medium

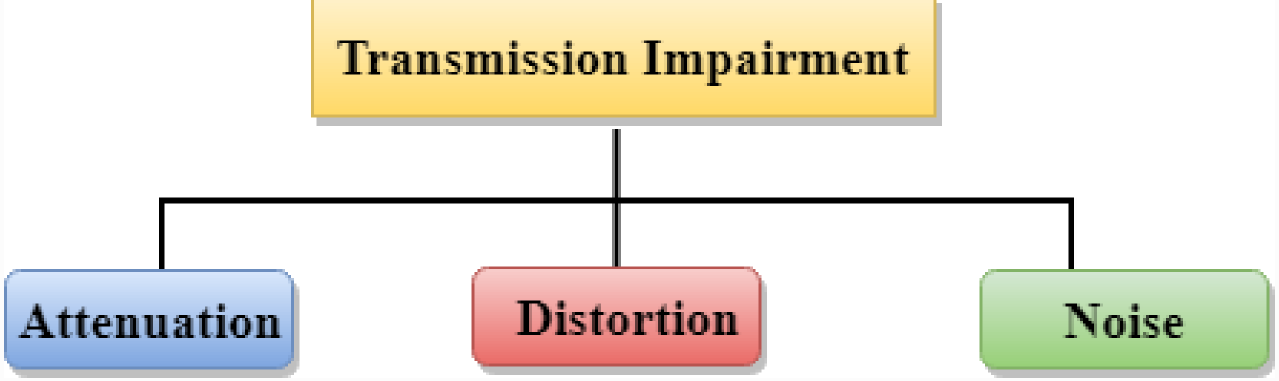


Transmission Medium

- Anything that can carry information from a source to a destination.
- Also known as communication channels,
- physical pathways or mediums through which signals, data, or information are transmitted from one point to another in a communication system.

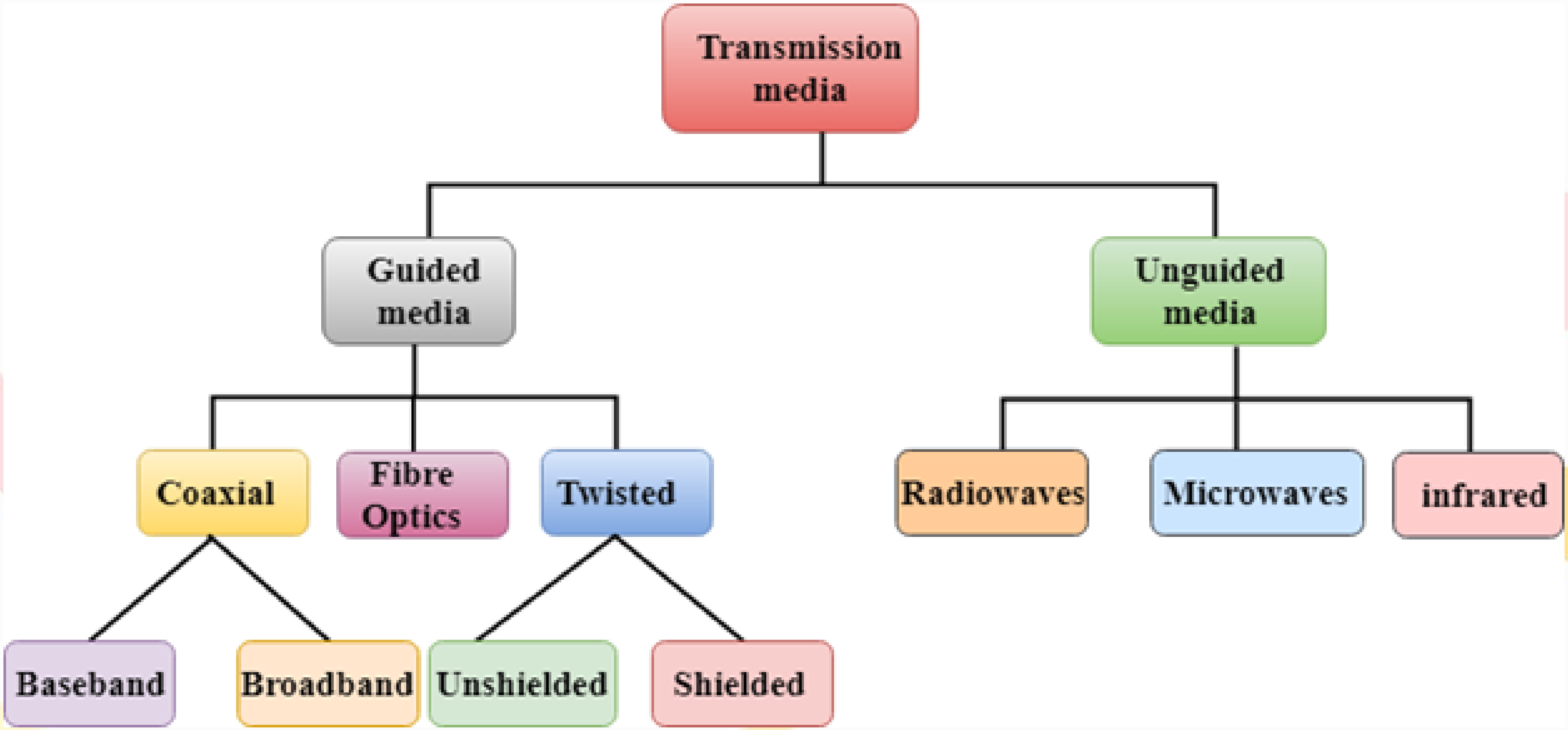
Factors that need to be considered for designing the transmission media:

- Bandwidth:
- Transmission impairment:
- Interference



- **Attenuation**: Attenuation means the loss of energy, i.e., the strength of the signal decreases with increasing the distance which causes the loss of energy.
- **Distortion**: Distortion occurs when there is a change in the shape of the signal. This type of distortion is examined from different signals having different frequencies.
- **Noise**: When data is travelled over a transmission medium, some unwanted signal is added to it which creates the noise.

Classification Of Transmission Media:

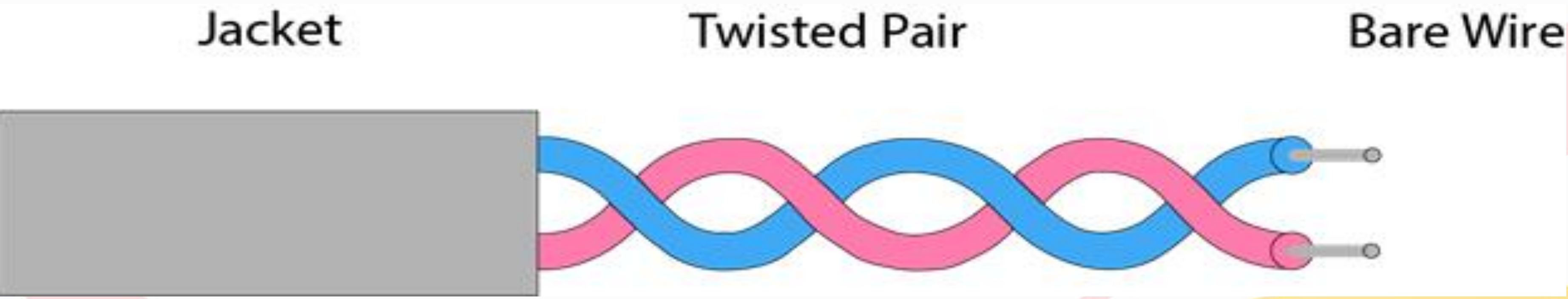


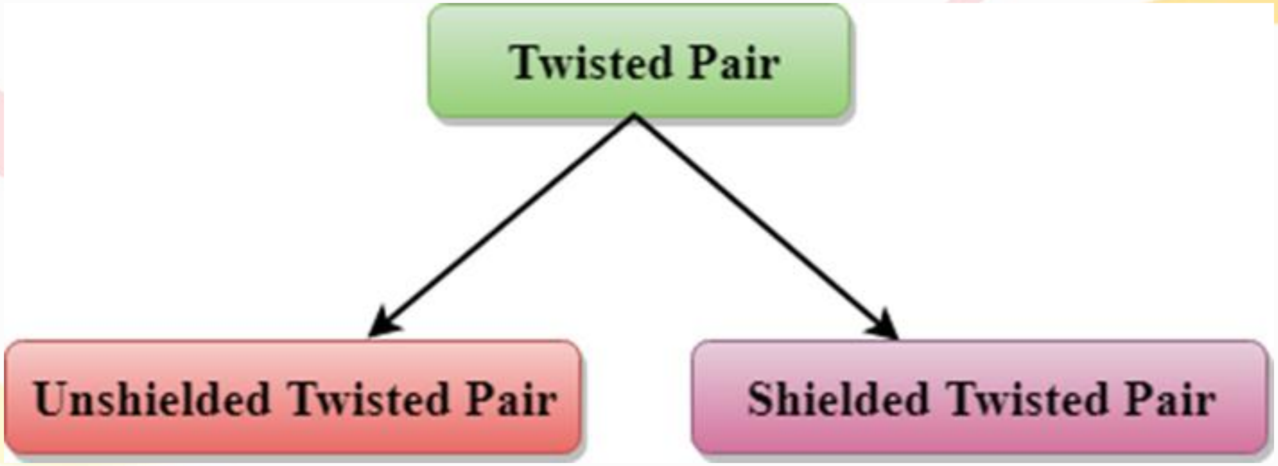
Guided Vs Unguided Transmission Media

- Guided Transmission Media:
  - Guided transmission media are physical mediums that provide a guided path for the propagation of signals.
  - These mediums confine and direct the signals along their path,
- Unguided Transmission Media:
  - Also known as wireless or unbounded media, propagate signals through free space
  - These mediums allow for wireless communication between devices over varying distances.

Twisted Pair

- It consists of 2 separately insulated conductor wires wound about each other.
- Generally, several such pairs are bundled together in a protective sheath.
- They are the most widely used Transmission Media.



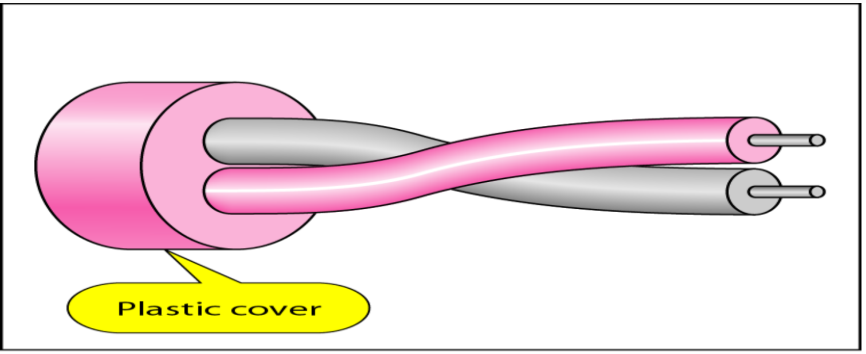


Unshielded Twisted Pair (UTP):

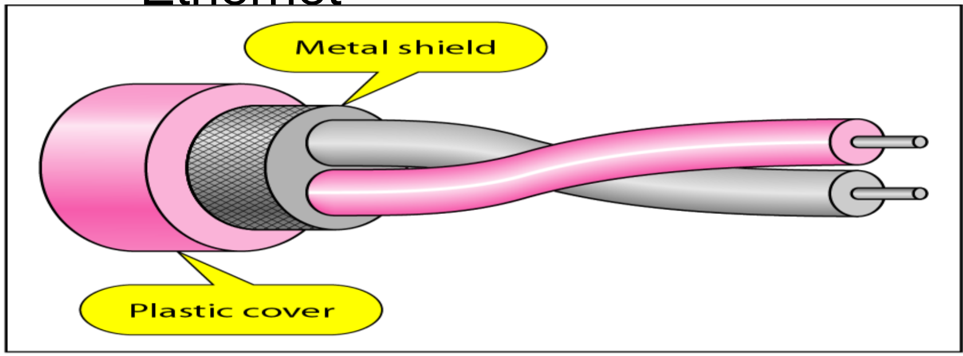
- UTP consists of two insulated copper wires twisted around one another.
- Doesn’t consist shielded foil
- It is used for telephonic applications.

Shielded Twisted Pair (STP):

- This type of cable consists of a special jacket (a copper braid covering or a foil shield) to block external interference.
- It is used in fast-data-rate Ethernet



a. UTP



b. STP

- **Category 1**: Category 1 is used for telephone lines that have low-speed data.
- **Category 2**: It can support upto 4Mbps.
- **Category 3**: It can support upto 16Mbps.
- **Category 4**: It can support upto 20Mbps. Therefore, it can be used for long-distance communication.
- **Category 5**: It can support upto 200Mbps.

Unshielded Twisted Pair (UTP):

- **Advantages:**
  - ⇢ Least expensive
  - ⇢ Easy to install
  - ⇢ High-speed capacity
- **Disadvantages:**
  - ⇢ Susceptible to external interference
  - ⇢ Lower capacity and performance in comparison to STP
  - ⇢Short distance transmission due to attenuation
- **Applications:**
  - – Used in telephone connections

Shielded Twisted Pair (STP):

Advantages:

⇢ Better performance

⇢ Eliminates crosstalk

⇢ Comparatively faster

Disadvantages:

⇢ difficult to install and manufacture

⇢ More expensive

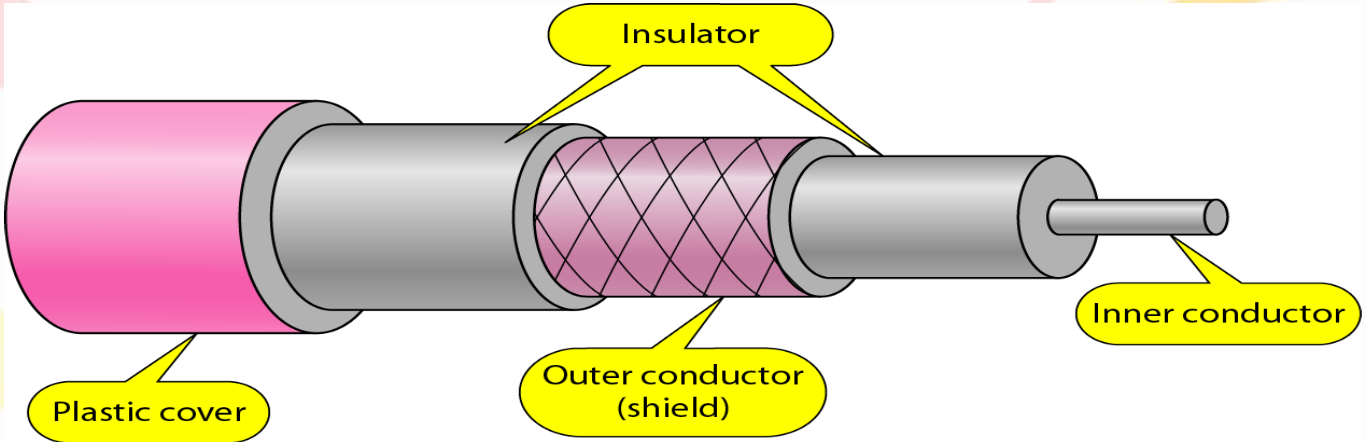
⇢ Bulky

Applications:

- In Extreme Environment to protect the inner layers

Coaxial Cable

- It has an outer plastic covering containing an insulation layer made of PVC or Teflon and 2 parallel conductors each having a separate insulated protection cover.
- The coaxial cable transmits information in two modes:
  - **Baseband mode**(dedicated cable bandwidth) and
  - **Broadband mode**(cable bandwidth is split into separate ranges).
- Cable TVs and analog television networks widely use Coaxial cables.

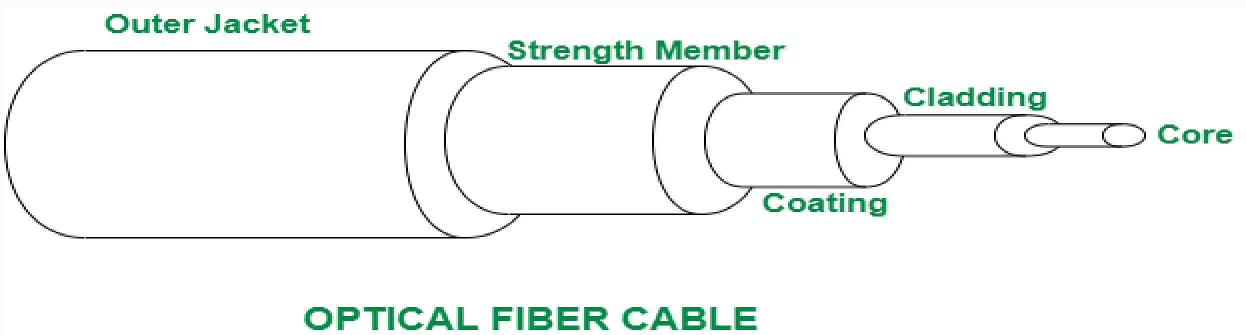


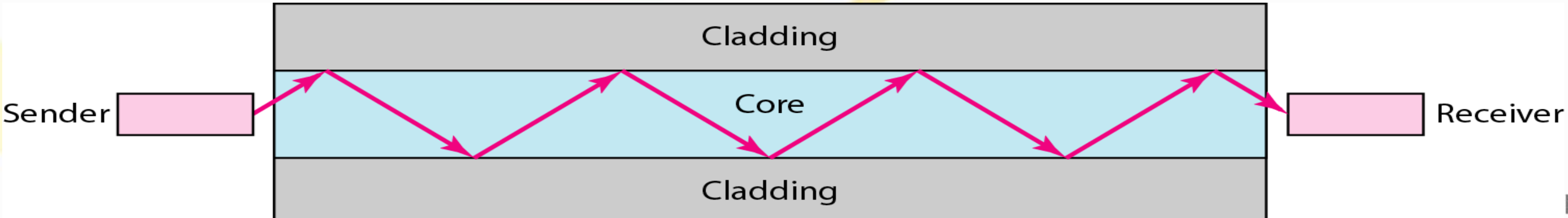
Coaxial Cable

- Advantages:
  - High Bandwidth
  - Better noise Immunity
  - Easy to install and expand
- Disadvantages:
  - More expensive as compared to Twisted pair cable

Optical Fiber Cable

- It uses the concept of Total Internal Reflection of light through a core made up of glass or plastic.
- The core is surrounded by a less dense glass or plastic covering called the cladding.
- Use WDM (Wavelength Division Multiplexer)





Optical Fiber: Advantages

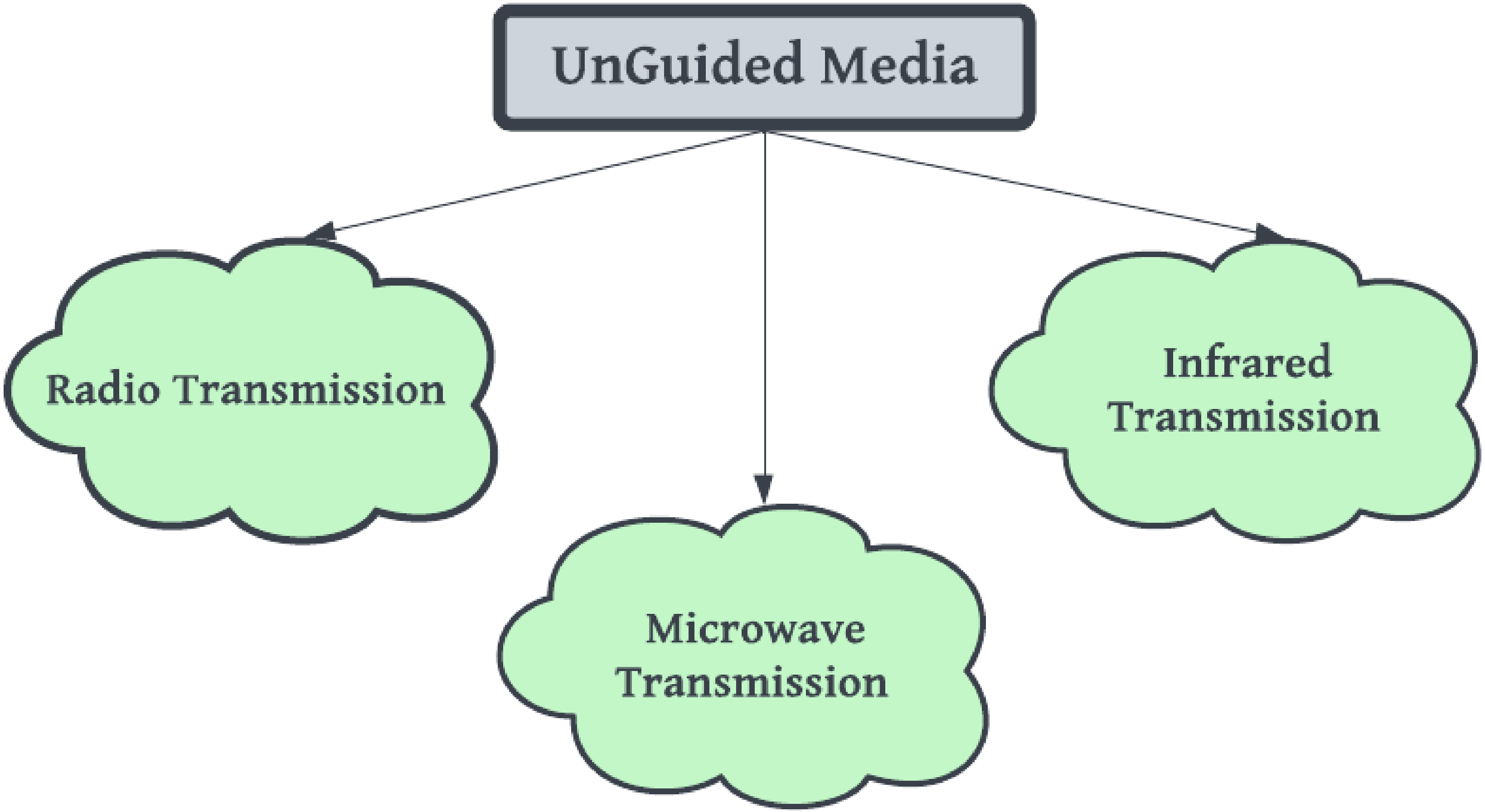
- High bandwidth and High Capacity
- Low signal loss:
- Immunity to electromagnetic interference
  - Useful in power lines and industrial Equipments
- Secure transmission:
  - difficult to tap into, enhancing the security of transmitted data.
- Lightweight and small size:
- Low maintenance:
  - less susceptible to damage from environmental factors like moisture and temperature fluctuations.

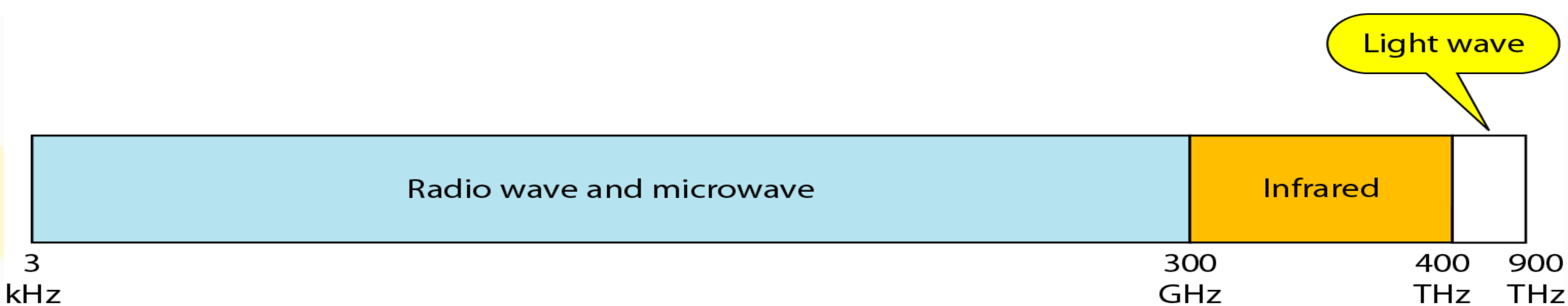
Optical Fiber: Disadvantages

- High initial cost:
- Fragility
  - more fragile than copper cables and can be damaged
- Limited flexibility:
  - Optical fibers have limited flexibility compared to copper cables, .
- Specialized expertise required:
- Compatibility issues:
  - Optical fiber networks may not be compatible with existing copper-based infrastructure,

Unguided Media

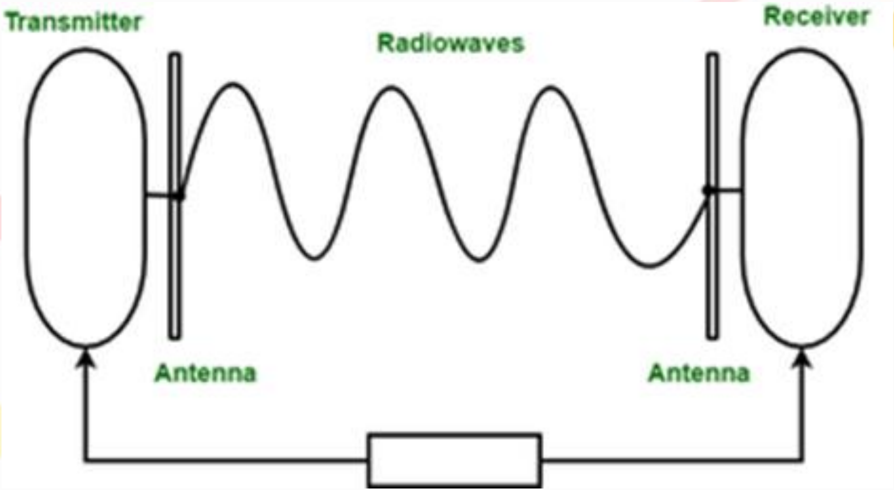
- Wireless or Unbounded transmission media.
- No physical medium is required for the transmission of electromagnetic signals.
- propagate signals through free space without the need for physical conductors.
- allow for wireless communication between devices over varying distances, enabling mobility and flexibility in communication networks.
- utilize electromagnetic waves to carry signals, with different frequencies and modulation techniques


UnGuided Media
Radio Transmission
Microwave Transmission
Infrared Transmission


Light wave
Radio wave and microwave
Infrared
3 kHz
300 GHz
400 THz
900 THz

Radio Waves

- Radio waves are a type of electromagnetic radiation with frequency ranging from 3kHZ to 1 GHZ
- Commonly used for wireless communication in radio broadcasting, cellular networks, Wi-Fi, Bluetooth, and satellite communication.
- Radio waves propagate through the atmosphere and can penetrate obstacles such as buildings and foliage, making them suitable for long-distance communication and indoor coverage.



Microwave

- Microwaves are electromagnetic waves with frequencies ranging from 1 gigahertz (GHz) to 300 gigahertz (GHz).
- They are employed in point-to-point communication links, microwave radio relay systems, satellite communication, and radar systems.
- Microwaves travel in straight lines and require line-of-sight propagation between transmitting and receiving antennas,

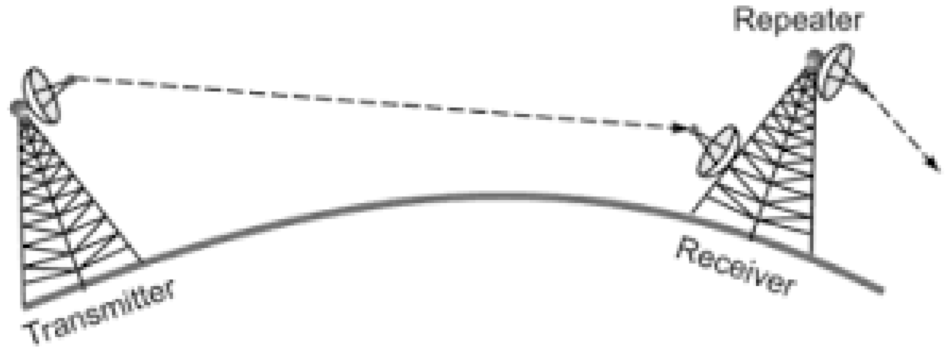
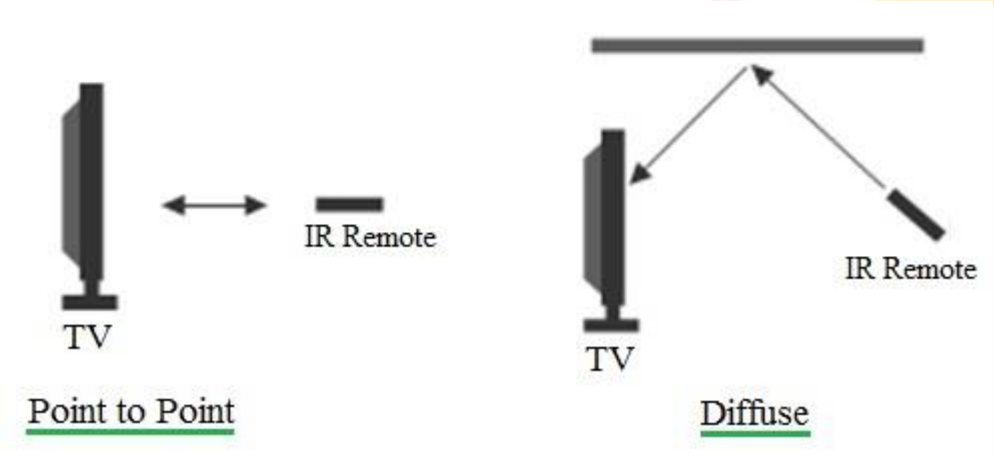


Fig: Microwave Transmission

Infrared

- Consists of electromagnetic waves with wavelengths longer than those of visible light but shorter than microwaves. Frequency Range:300GHz – 400THz.
- typically used for line-of-sight communication within a confined area, such as a room or building.
- Infrared waves are used for very short distance communication.
- They cannot penetrate through obstacles.
- It is used in TV remotes, wireless mouse, keyboard, printer, etc.



Transmission Modes

- Simplex
- Half Duplex
- Full Duplex

- Already discussed in unit 1

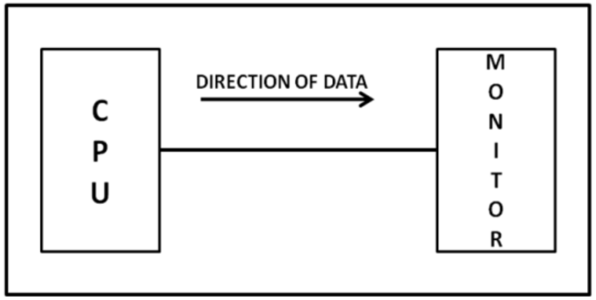


Figure: Simplex mode of communication

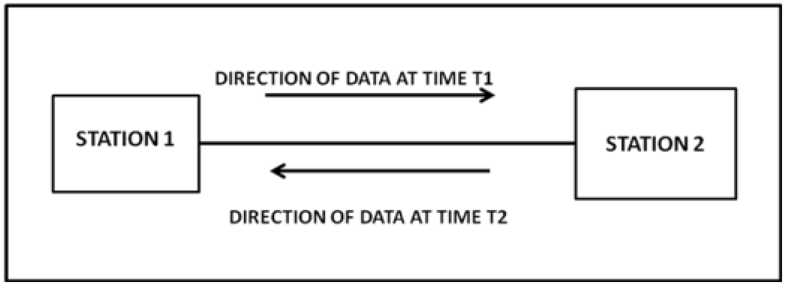


Figure: Half Duplex Mode of Communication

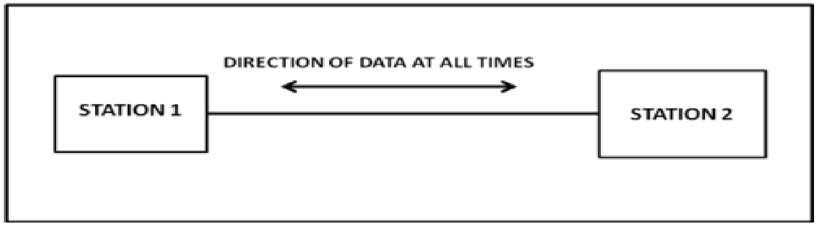


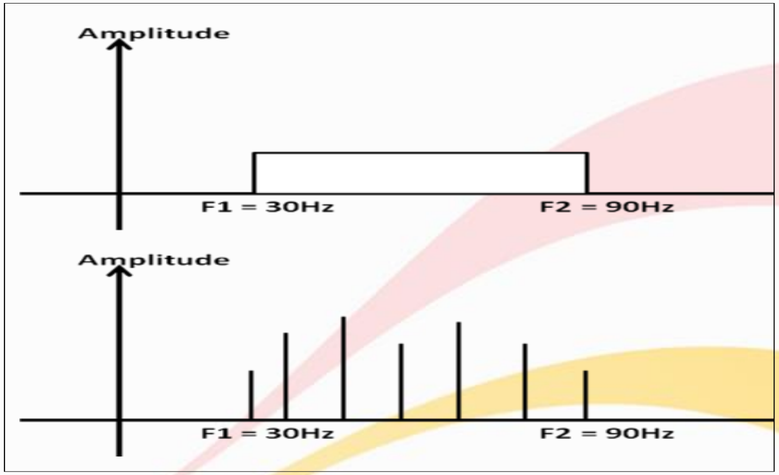
Figure: Full Duplex Mode of Communication

Bandwidth

- Range of frequencies within a signal or a channel that can carry information.
- Ddifference between the highest and lowest frequencies of a signal or channel.
- In communication systems, bandwidth indicates the capacity of the system to transmit data or information.
- A broader bandwidth allows for the transmission of a greater amount of data, while a narrower bandwidth restricts the amount of data that can be transmitted.

Bandwidth of Signal

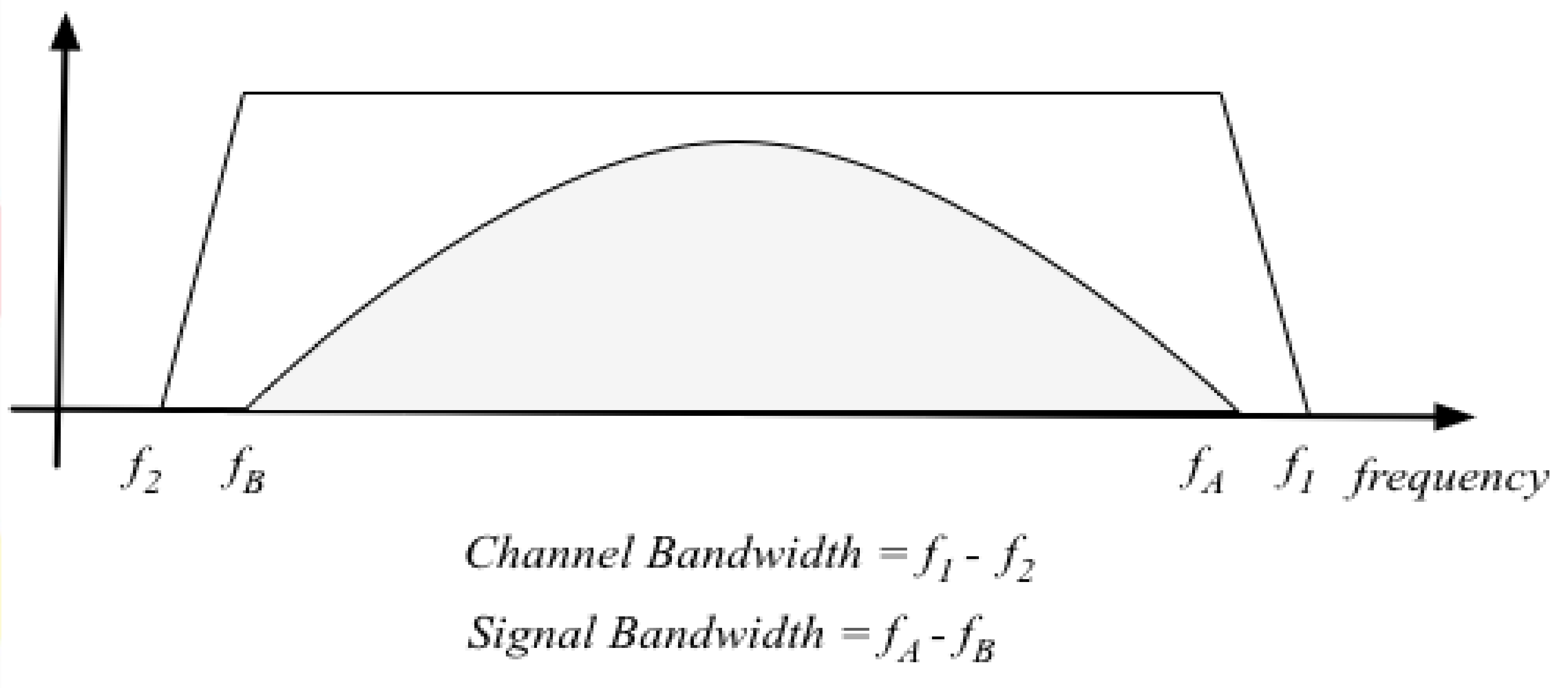
- The bandwidth of a signal refers to the range of frequencies occupied by the signal.
- Eg: For audible frequencies (typically 20 Hz to 20 kHz).
- **For Analog Signal**
  - **It is calculated by the difference between the maximum frequency and the minimum frequency.**



- **For Digital Signal**
  - bandwidth of a signal determines the data rate or the maximum rate at which data can be transmitted using the signal.
  - It is defined as the maximum bit rate of the signal to be transmitted.
  - It is measured in bits per second.

Bandwidth of Channel

- The bandwidth of a channel refers to the range of frequencies over which the channel can effectively transmit signals without significant attenuation or distortion.
- Channel bandwidth sets the upper limit on the data rate that can be transmitted through the channel.



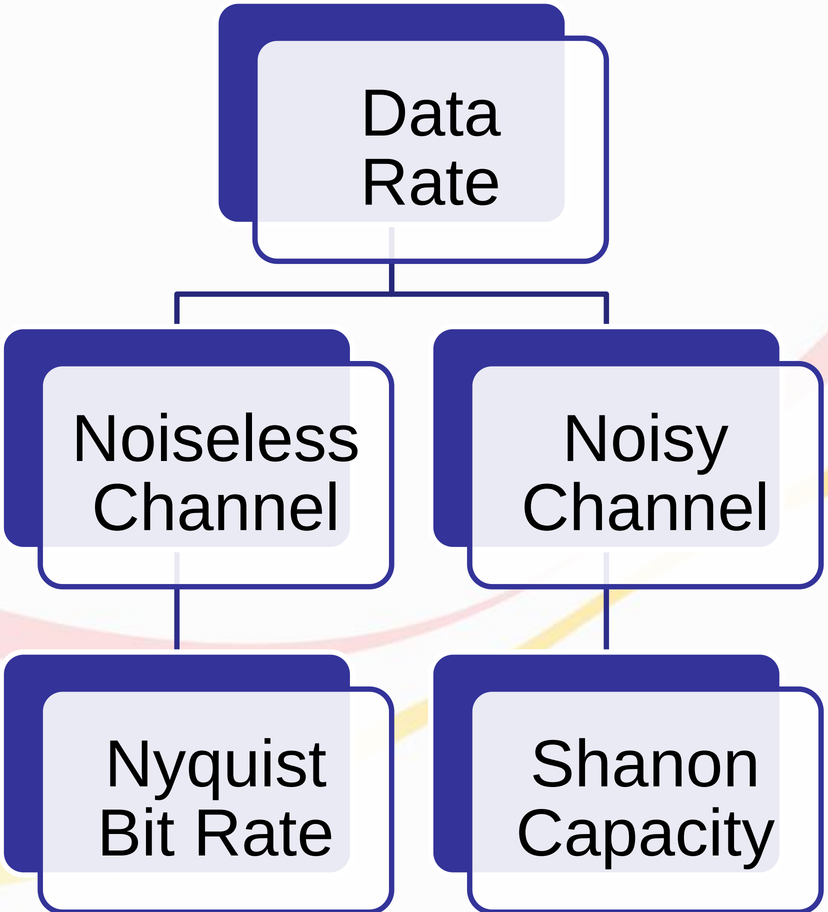
Channel Bandwidth

- In terms of analog signal, bandwidth of the channel is the range of frequencies that the channel can carry.
- **In terms of digital signal**, bandwidth of the channel is the maximum bit rate supported by the channel.

- The bandwidth of the medium should always be greater than the bandwidth of the signal to be transmitted

Data Rate of a channel

- Data rate depends on three factors:
  1. The bandwidth available
  2. The level of the signals we use
  3. The quality of the channel (the level of noise)



Nyquist Bit Rate

$$\text{Bitrate} = 2 \times \text{Bandwidth} \times \log_2 L$$

- Where,
  - Bitrate is the bitrate of the channel in bits per second
  - Bandwidth is the bandwidth of the channel
  - L is the number of signal levels.

Example

- What is the maximum bit rate of a noiseless channel with a bandwidth of 5000 Hz transmitting a signal with two signal levels.

Example

The bit rate for a noiseless channel according to Nyquist Bit rate can be calculated as follows:

$$BitRate = 2 \times Bandwidth \times Log_2 L$$

$$= 2 \times 5000 \times \log_2 2$$

$$= \mathbf{10000\ bps}$$

Shannon Capacity

$$\text{Capacity}=\text{bandwidth X } \log_2 (1 + \text{SNR})$$

Capacity is the capacity of the channel in bits per second Bandwidth is the bandwidth of the channel SNR is the Signal to Noise Ratio

Example

- **Calculate the bit rate for a noisy channel with SNR 300 and bandwidth of 3000Hz**

Example

- The bit rate for a noisy channel according to Shannon Capacity can be calculated as follows:

- Capacity=bandwidth X $\log_2$ (1 +SNR)

= 3000 x $\log_2 (1 + 300)$

= 3000 x $\log_2 (301)$

= 3000 x 8.23

= **24,690bps**

$$\log_2 x = \frac{\log_{10} x}{\log_{10} 2}$$

Example 3.37

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

Example 3.38

We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000 Hz (300 to 3300 Hz) assigned for data communications. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

Example 3.37

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

$$C = B \log2 (1 + \text{SNR}) = B \log_2 (1 + 0) = B \log2\ 1 = B \times 0 = 0$$

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

Example 3.38

We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000 Hz (300 to 3300 Hz) assigned for data communications. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

$$C = B \log2 (1 + \text{SNR}) = 3000 \log2 (1 + 3162) = 3000 \log2\ 3163$$
$$= 3000 \times 11.62 = 34{,}860 \text{ bps}$$

This means that the highest bit rate for a telephone line is 34.860 kbps. If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

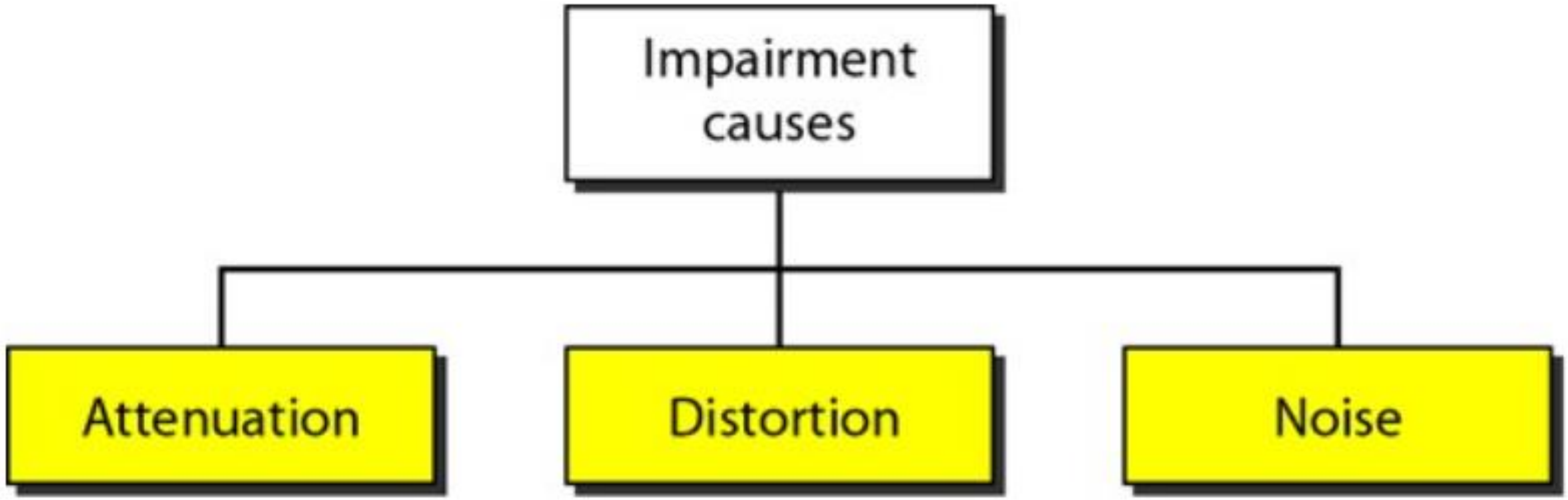
Latency

- Latency refers to the delay or time lag between the initiation of a process or action and its completion.
- In the context of communication systems or networks, latency refers to the time it takes for data to travel from its source to its destination
- Factors for Latency
  - **Propagation Delay**
  - time taken for the signal to propagate through the transmission medium
  - **Transmission Delay**
  - includes the time required for encoding, modulation, and transmission of the data.
  - **Processing Delay**
  - This includes the time required for decoding, error checking, and any other processing tasks.
  - **Queuing Delay**
  - This can occur in routers, switches, or other network devices

Throughput

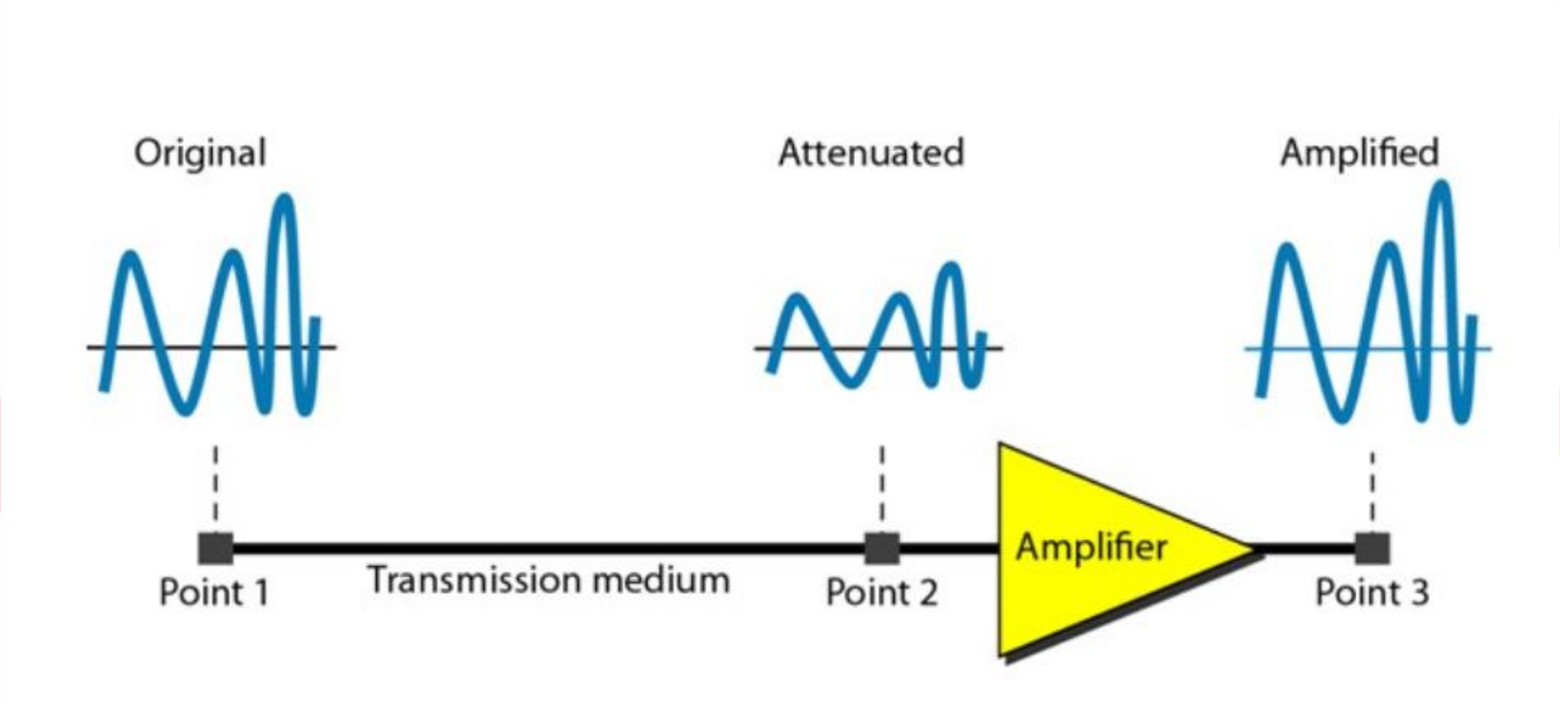
- Throughput refers to the rate at which data is successfully transmitted or processed over a communication channel or network within a given period of time.
- It is a measure of the amount of data transferred per unit time and is often expressed in bits per second (bps), kilobits per second (kbps), megabits per second (Mbps), or gigabits per second (Gbps), depending on the scale of the data being transferred.

Transmission Impairments



Attenuation

- Attenuation means a loss of energy.
- When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium.
- To compensate for this loss, amplifiers are used to amplify the signal.



Attenuation

- **Decibel**
  - To show that a signal has lost or gained strength, decibel unit is used.
  - The decibel (dB) measures the relative strengths of two signals or one signal at two different points.

Note that the decibel is negative if a signal is attenuated and positive if a signal is amplified

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

Variables PI and P2 are the powers of a signal at points 1 and 2, respectively.

Example:

Suppose a signal travels through a transmission medium and its power is reduced to one-half. Find the attenuation (loss of power).

Solution:

dB=10 log (P/2P)= -3 dB

Example:

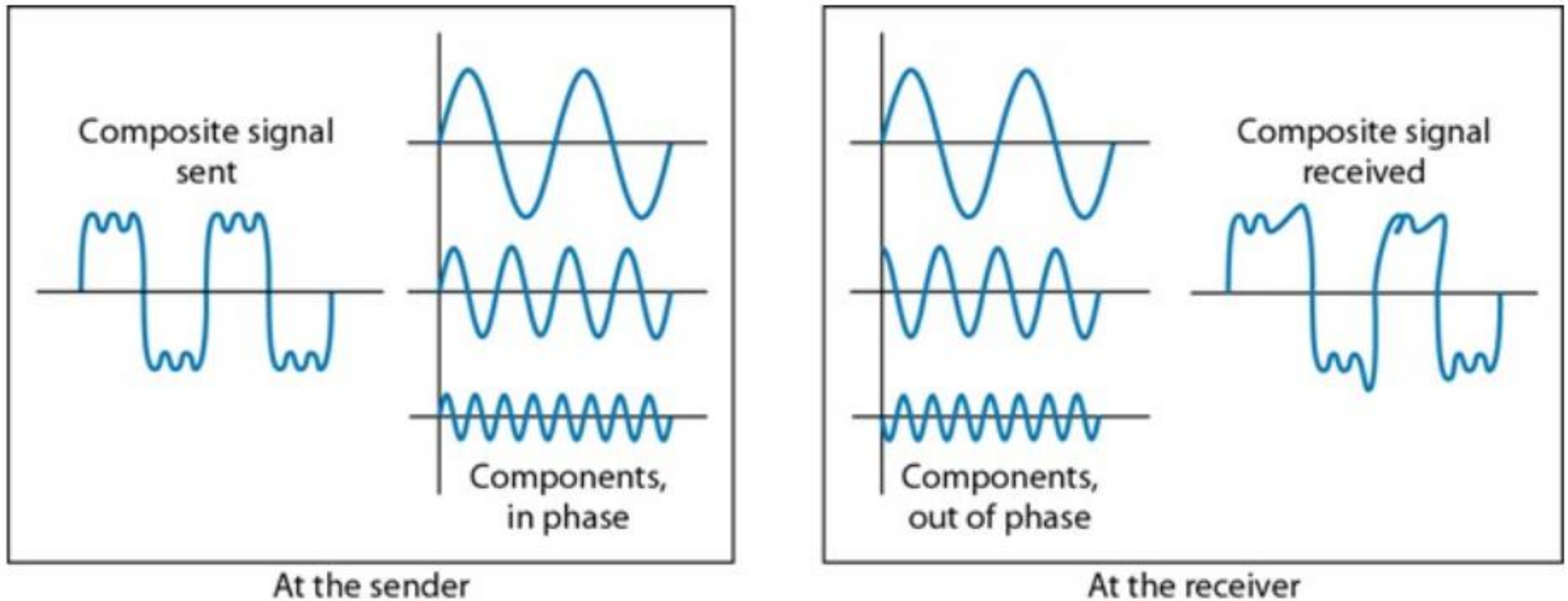
A signal travels through an amplifier, and its power is increased 10 times Find the amplification (gain of power).

Solution:

dB=10 log (10P/P)= 10 dB

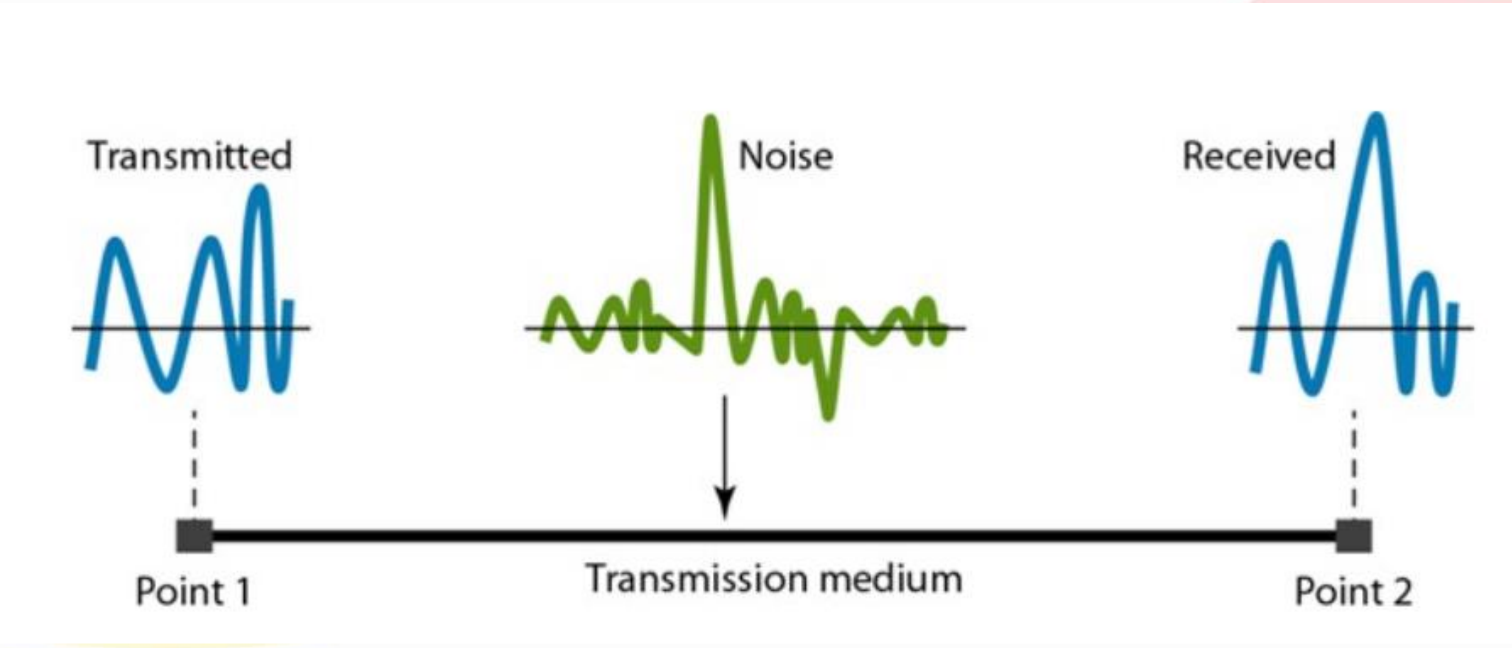
Distortion

- Distortion means that the signal changes its form or shape.
- Distortion can occur in a composite signal made of different frequencies.
- Signal components at the receiver have properties different from what they had at the sender.
- The shape of the composite signal is therefore not the same.



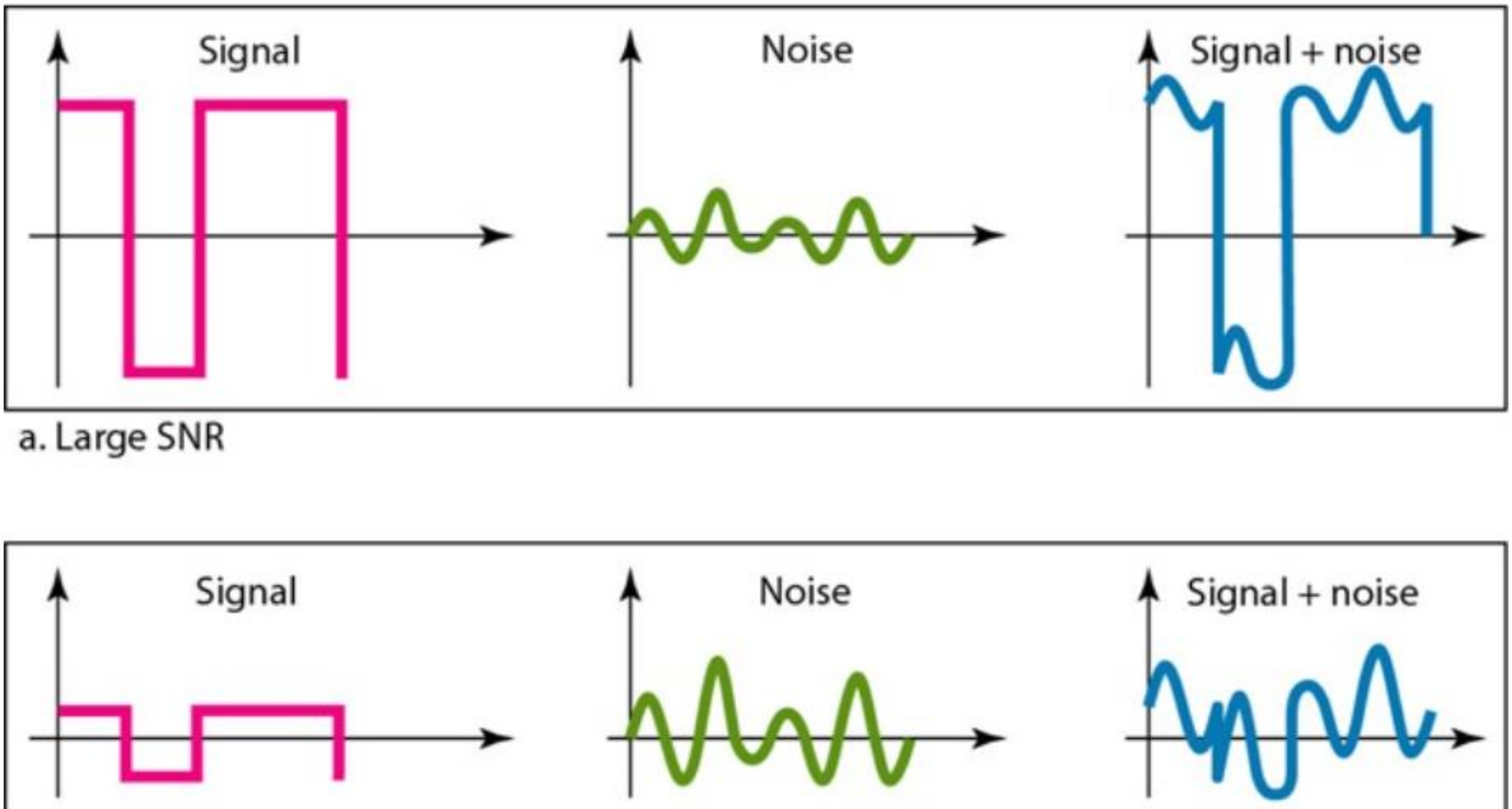
Noise

- Noise is another cause of impairment.
- Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal.
- Induced noise comes from sources such as motors and appliances.



Signal to Noise Ratio (SNR)

Figure 3.30 *Two cases of SNR: a high SNR and a low SNR*



Signal to Noise Ratio (SNR)

•The signal-to-noise ratio is defined as

$$\mathbf{SNR} = \frac{\textbf{average signal power}}{\textbf{average noise power}}$$

•A high SNR means the signal is less corrupted by noise; a low SNR means the signal is more corrupted by noise.

• Because SNR is the ratio of two powers, it is often described in decibel units, SNR_{dB}, defined as

$$\mathbf{SNR_{dB} = lO\ log\ 10\ SNR}$$

Example

Example The power of a signal is 10 mW and the power of the noise is 1 microW; what are the values of SNR and SNRdB?

Example

Example The power of a signal is 10 mW and the power of the noise is 1 microW; what are the values of SNR and SNRdB?

The values of SNR and SNR db can be calculated as follows:

$$SNR = 10*10^{-3} / 10*10^{-6}$$

$$=10000$$

$$SNRdB = 10 \log 1O\ 10{,}000 = 10 \log lO\ 10^{4} = 40$$

Analog Transmission

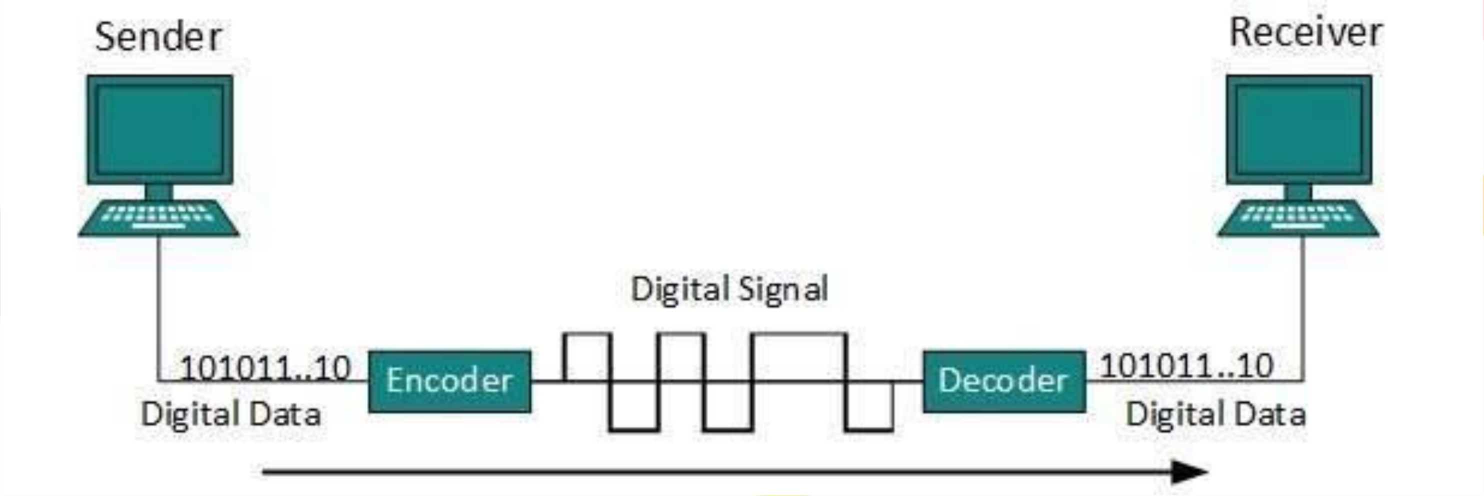
- Analog transmission is the type of transmission where information is conveyed through continuously varying signals.
- **Characteristics of Analog Transmission:**
  - Continuous Signals: Analog transmission involves the use of continuous waveforms to represent information, such as voice, audio, or video signals.
  - Variable Parameters: Information is encoded into the analog signal by varying one or more parameters, such as amplitude, frequency, or phase.
  - Susceptibility to Noise: Analog signals are susceptible to noise and interference, which can distort the signal and degrade quality.

Analog Transmission

- Examples:
  - Amplitude Modulation (AM):
  - Frequency Modulation (FM):
  - Phase Modulation (PM):
- Applications of Analog Transmission:
  - Radio Broadcasting:
  - Analog Television (TV):
  - Analog Telephone Networks: .
- Challenges and Limitations:
  - Noise and Interference:
  - Bandwidth Efficiency:
  - Quality Degradation:

Digital Transmisssion

- In digital transmission, data is encoded into digital signals
- More efficient and reliable transmission over communication channels.



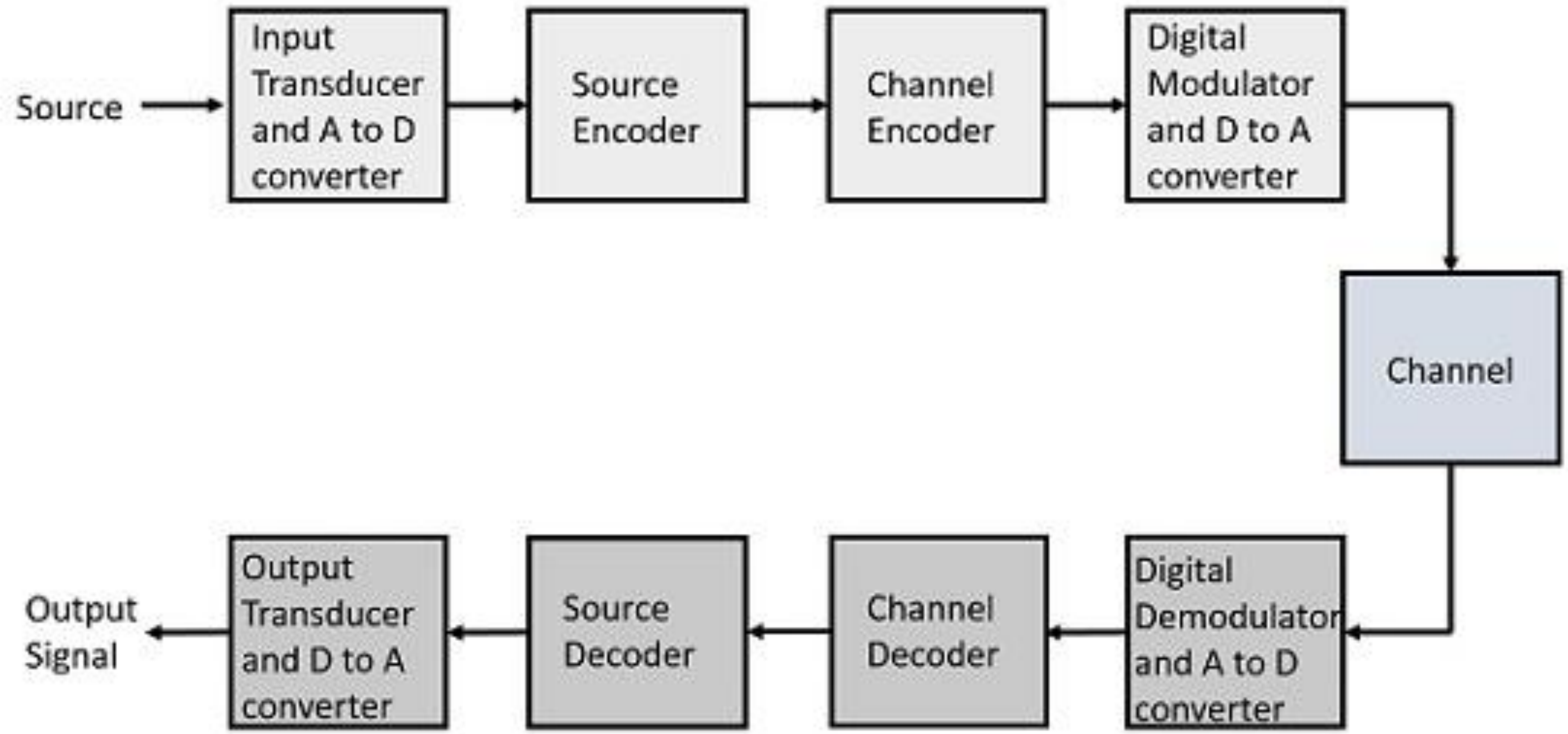
Digital Transmission: Advantages

- 1. Higher Quality:
  - less susceptible to noise and interference.
  - improved signal quality and fidelity in data transmission.
- 2. Greater Flexibility:
  - Digital transmission allows for the integration of various types of data into a single digital stream.
  - Supports multimedia communication and a wide range of applications.
- 3. Improved Efficiency:
  - Digital transmission techniques enable more efficient use of bandwidth and resources.
- 4. Enhanced Security:
  - Offers greater security and privacy
- 5. Error Detection and Correction:
  - `Techniques such as CRC, FEC, and ARQ improve reliability and accuracy, reducing data loss or corruption.

Digital Transmission: Advantages

- 6. Ease of Integration:
  - Digital transmission technologies can be easily integrated with other digital systems and devices.
- 7. Scalability:
  - Digital transmission systems are highly scalable and can accommodate increasing demands for data transmission.
- 8. Cost-Effectiveness:
  - Digital transmission offers cost-effective solutions for data communication and networking.
  - Reductions in equipment costs, improved energy efficiency, and streamlined maintenance processes lead to lower overall costs of ownership.

Elements of Digital Communication



Basic Elements of a Digital Communication System

- Source: Example: A Sound signal
- Input Transducer:
  - transducer physical input signal to an electrical signal (Eg: microphone).
  - ADC: Converts analog to digital signal
- Source Encoder:
  - Compresses the data and removes the redundant bits.
- Channel Encoder:
  - The channel encoder, does the coding for error correction. .
- Modulator:
  - The signal to be transmitted is modulated here by a carrier.
- Channel: The channel or a medium,
- Demodulator:
  - The received signal is demodulated and gets reconstructed here.
- Channel Decoder: Error Detection and correction
- Source Decoder: recreates the source output.
- Output Transducer:electrical signal - physical output (Eg: loud speaker).
- Output Signal: Example – The sound signal received

Line Coding

- Process of converting digital data to digital signals.

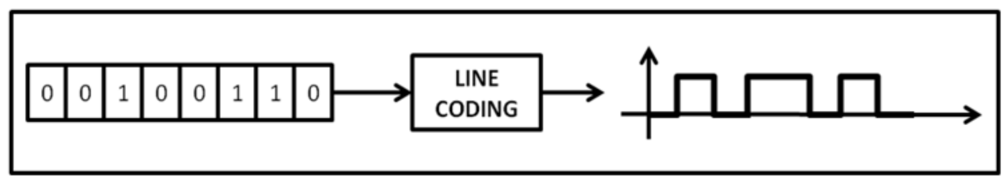
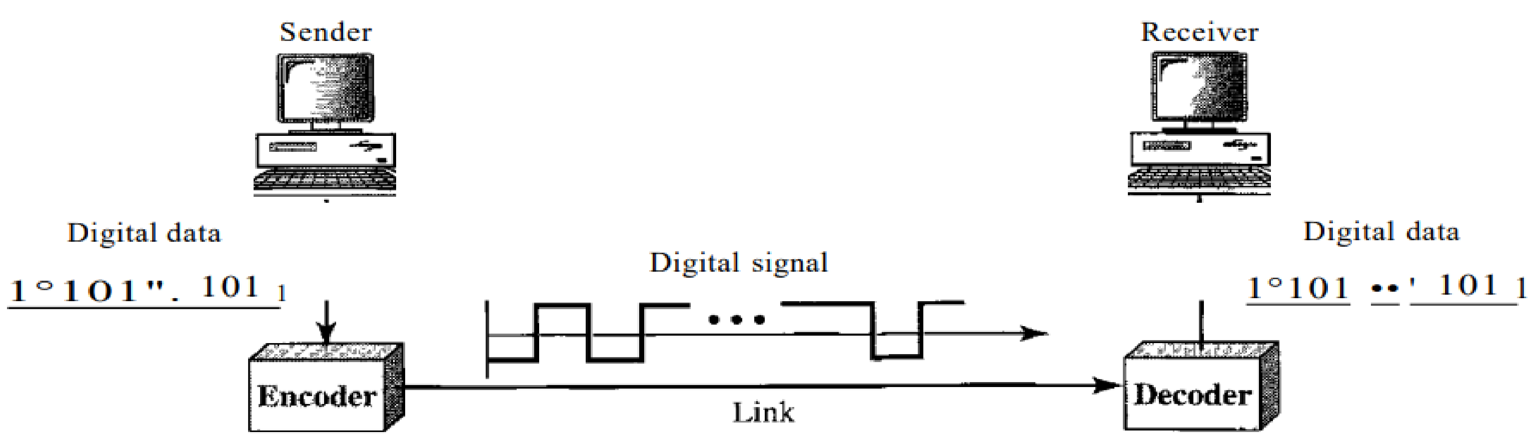
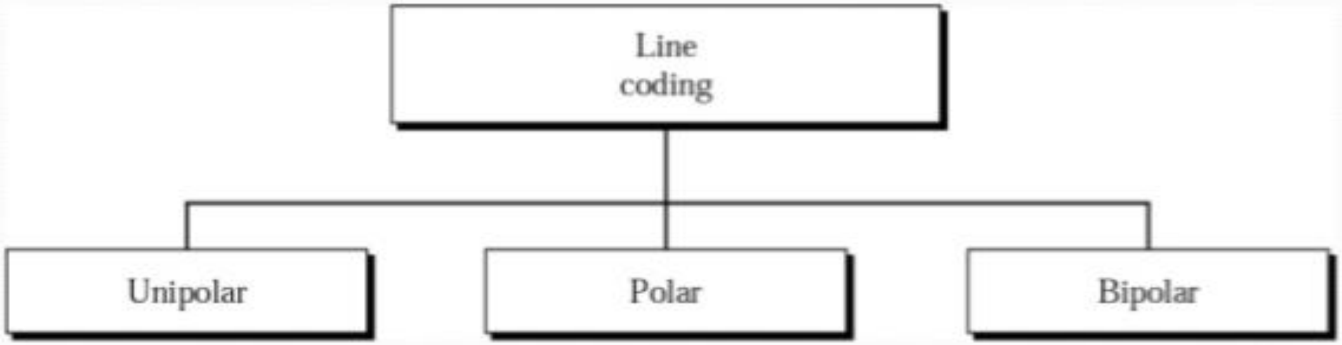


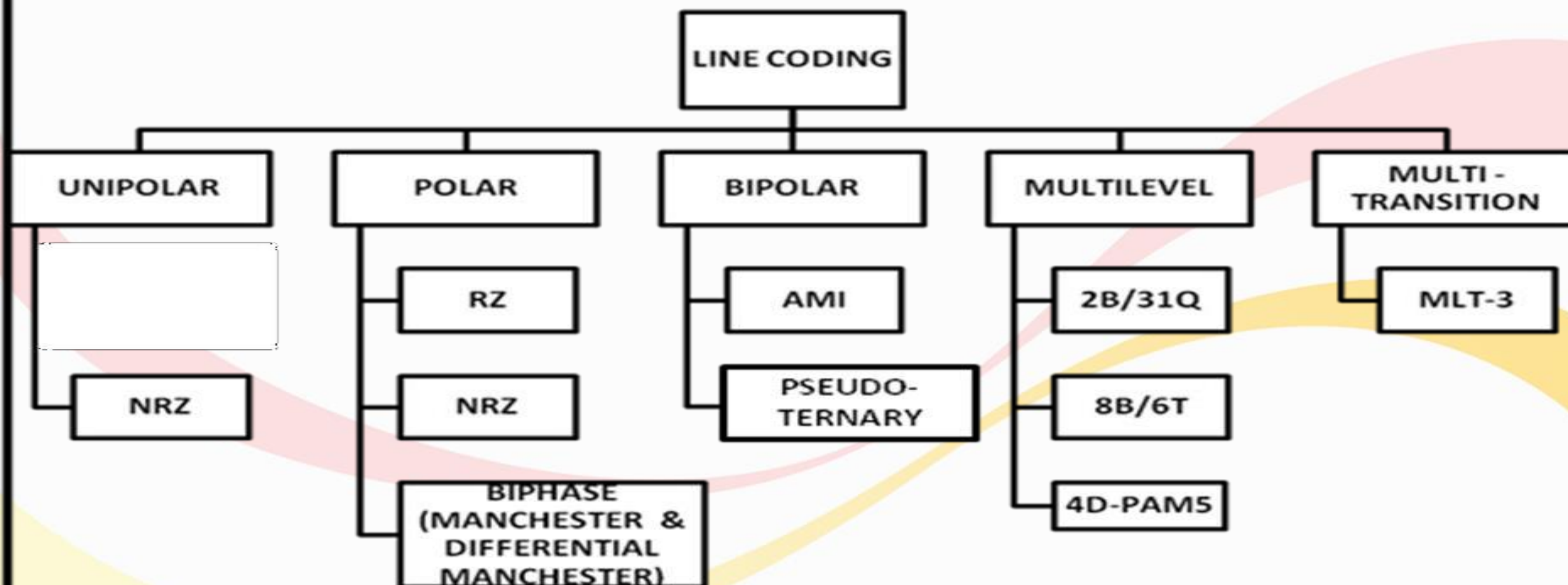
Figure: Line Coding

- Line coding converts a sequence of bits to a digital signal.
- At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal.

Figure 4.1 *Line coding and decoding*




Line coding
Unipolar
Polar
Bipolar

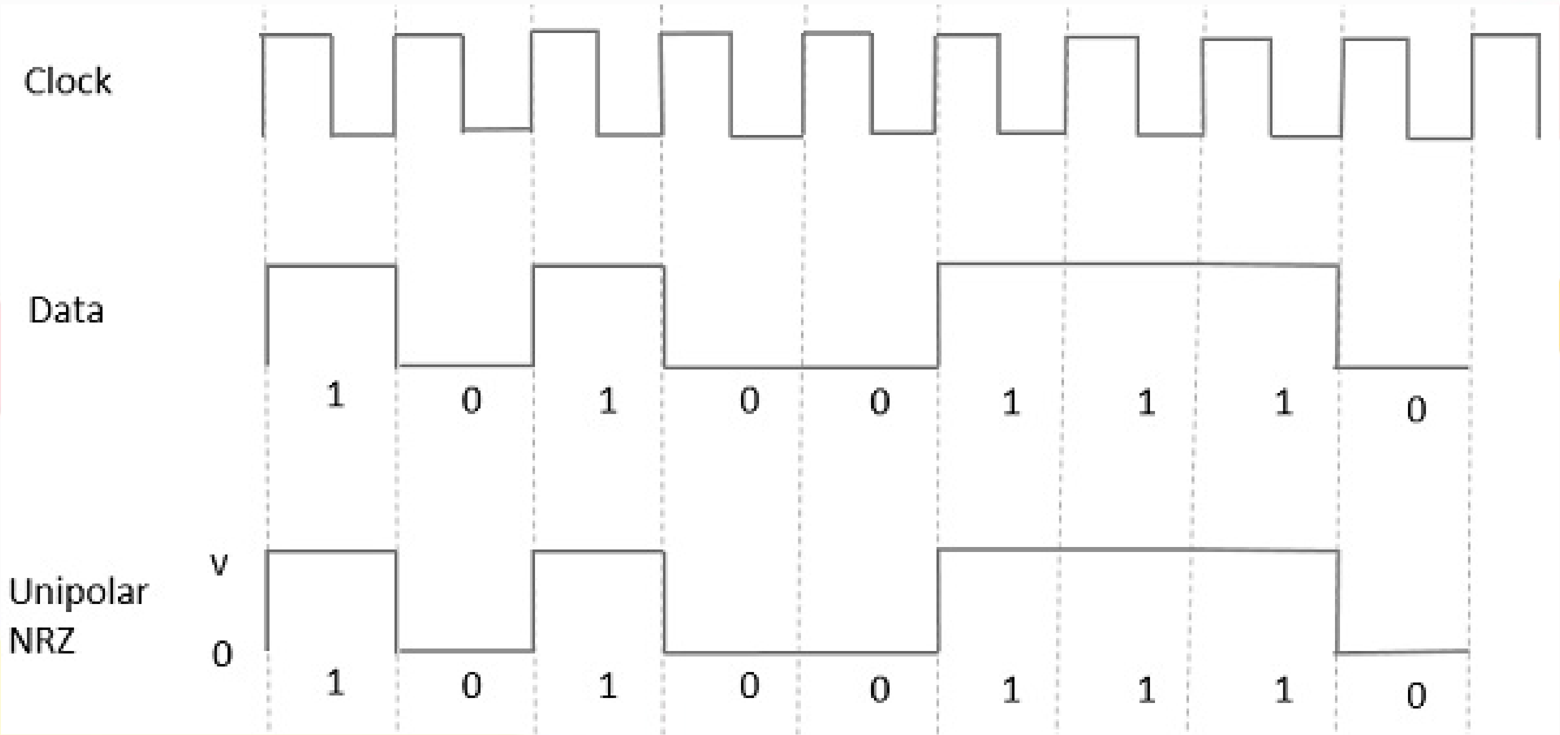

LINE CODING
UNIPOLAR
POLAR
BIPOLAR
MULTILEVEL
MULTI - TRANSITION
NRZ
RZ
NRZ
BIPHASE (MANCHESTER & DIFFERENTIAL MANCHESTER)
AMI
PSEUDO-TERNARY
2B/31Q
8B/6T
4D-PAM5
MLT-3

Unipolar

- The Unipolar signaling is also known as On-Off Keying or simply OOK.
  - ‘1’ is transmitted by a pulse and a ‘
  - 0’ is transmitted by no pulse.
- There are two common variations in Unipolar signaling :
  - Non Return to Zero (NRZ)
  - Return to Zero (RZ)

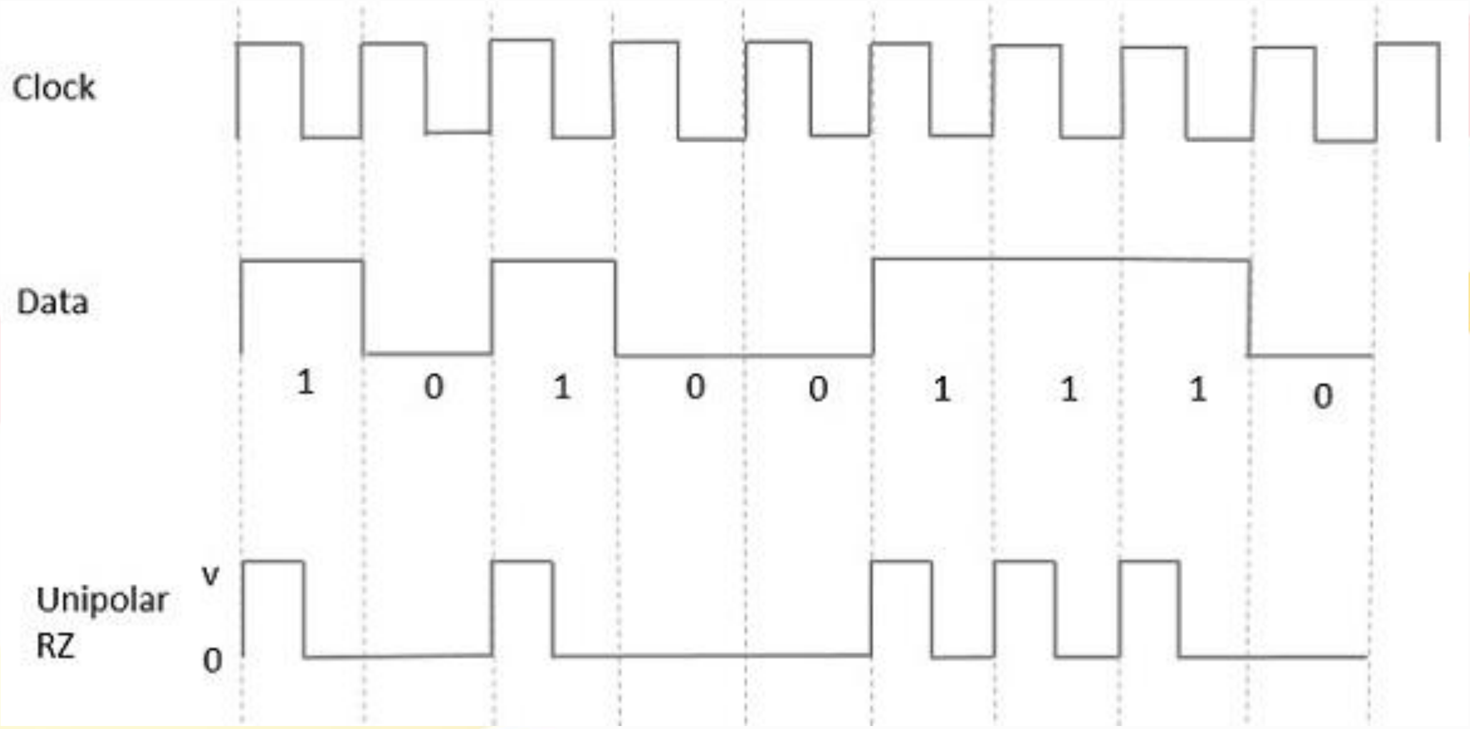
Unipolar Non Return to zero NRZ

- High (1) is represented by a positive pulse called as Mark, which has a duration T0 equal to the symbol bit duration.
- A Low(0) in data input has no pulse.



Unipolar Return to Zero (RZ)

- 1 -represented by a Mark pulse,
  - its duration T0 is less than the symbol bit duration(usually half).
- Half of the bit duration remains high but it immediately returns to zero and shows the absence of pulse during the remaining half of the bit duration.

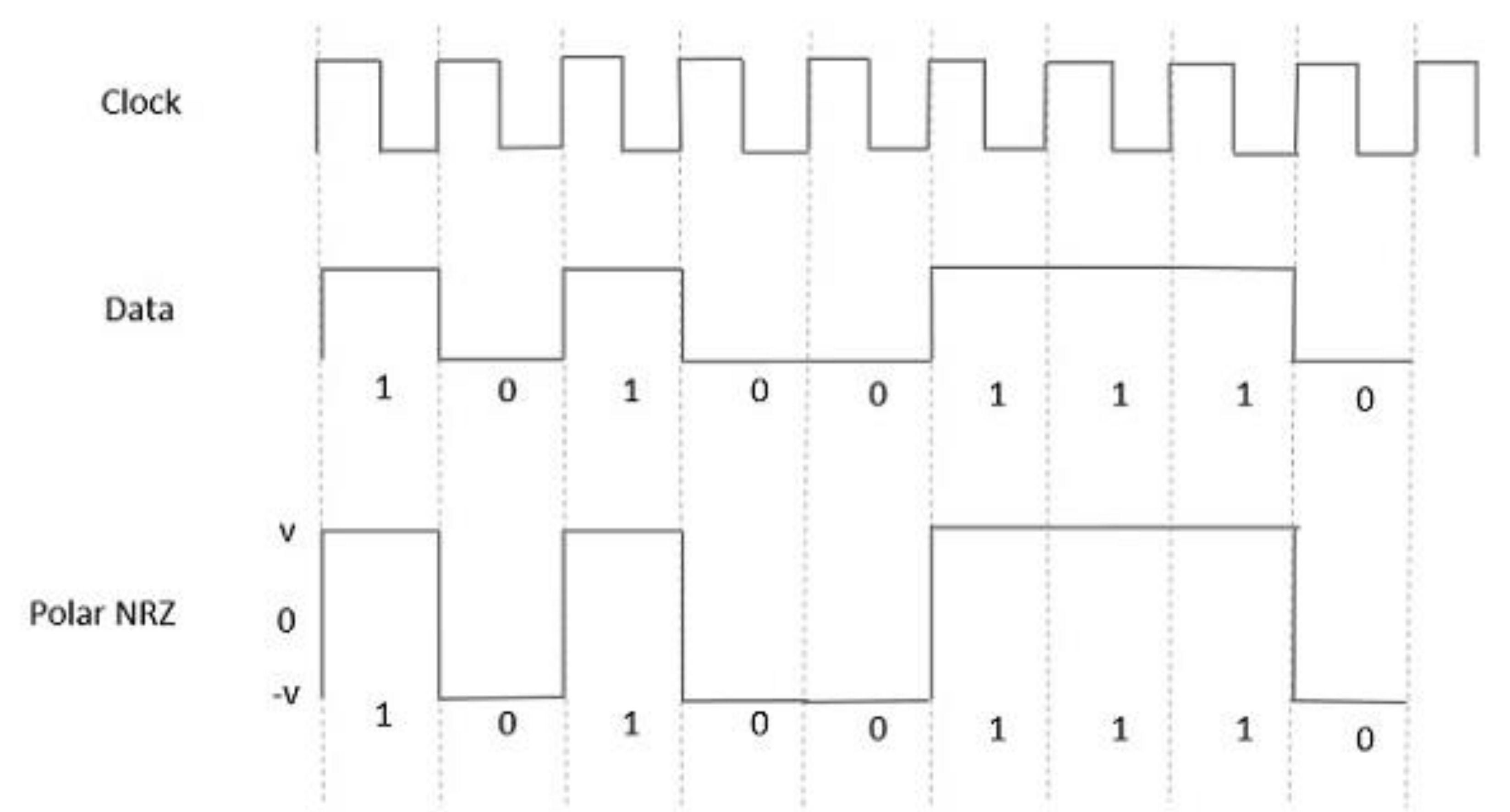


Classwork

- Draw unipolar NRZ and unipolar RZ for the data
  - 101001110
  - 010100011

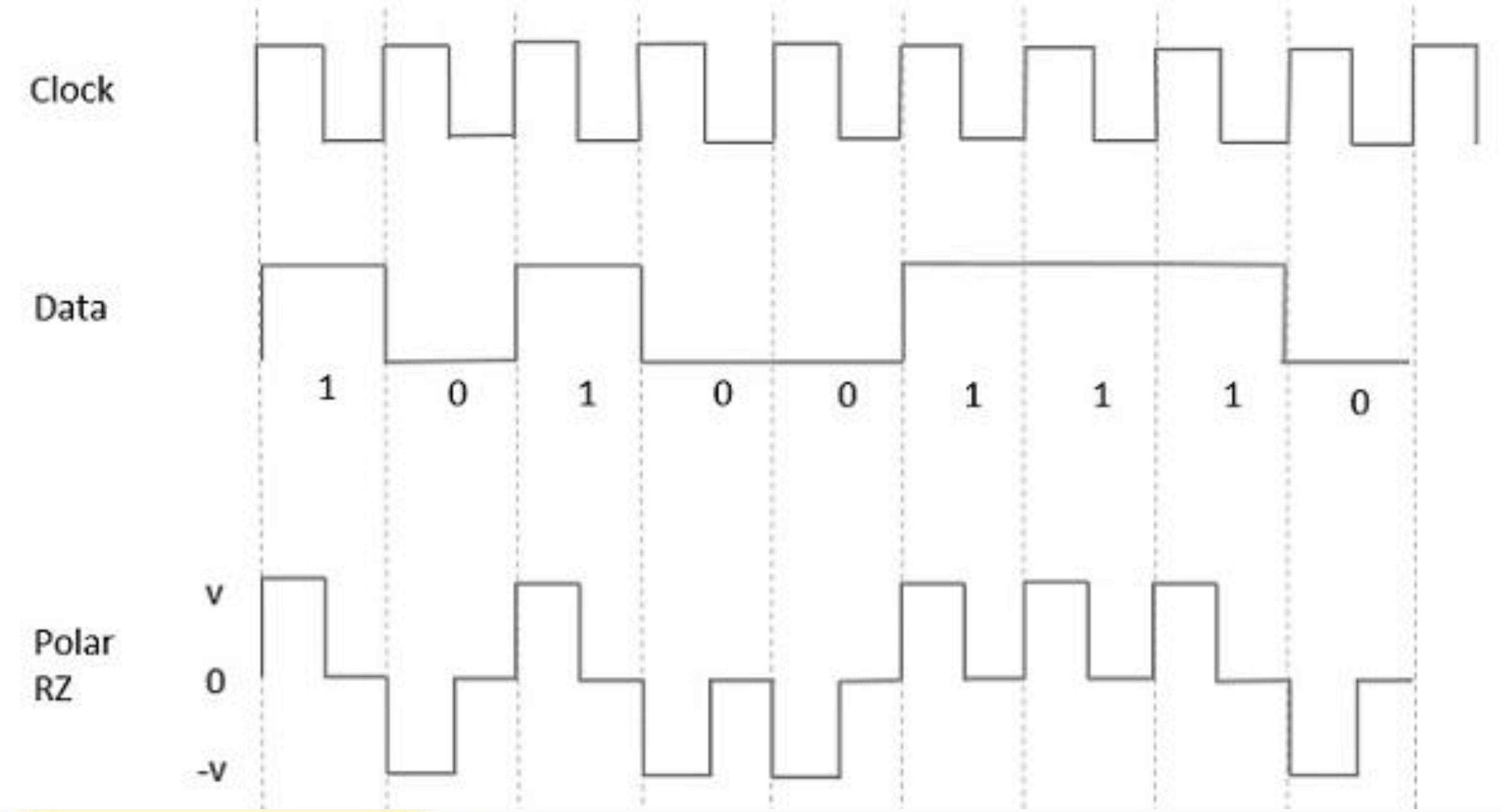
Polar NRZ

- High (1)in data is represented by a positive pulse,
- Low (0) in data is represented by a negative pulse



Polar RZ

- High (1) in data, though represented by a Mark pulse, Half of the bit duration remains high but it immediately returns to zero and shows the absence of pulse during the remaining half of the bit duration.
- Low (0) input, a negative pulse represents the data, and the zero level remains same for the other half of the bit duration.



classwork

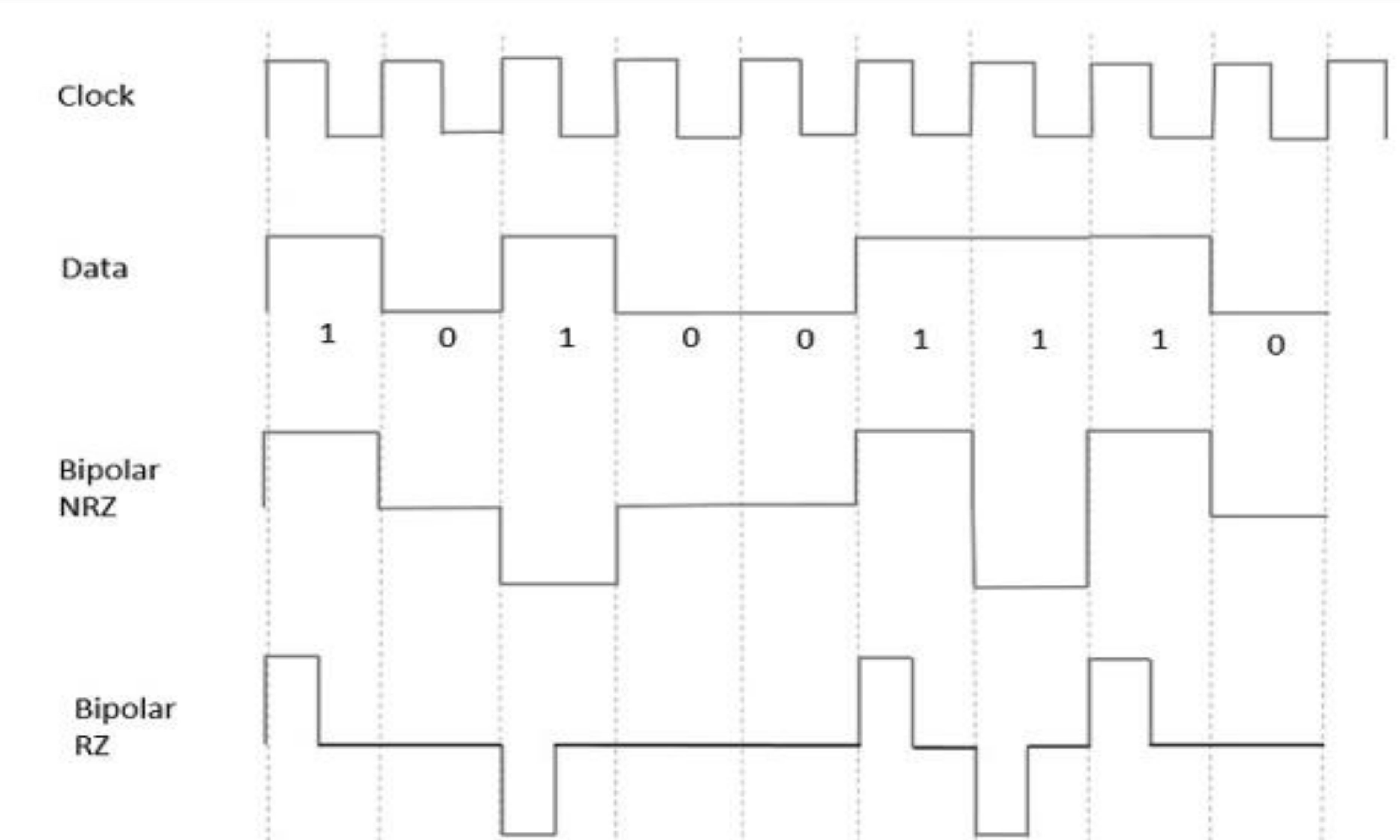
- Draw polar NRZ and Polar RZ for
  - 101001110

  - 010100011

Bipolar

- Eg: AMI (Alternate Mask Inversion)
- For a 1, the voltage level gets a transition from + to – or from – to +, having alternate 1s to be of equal polarity.
- A 0 will have a zero voltage level.

Bipolar NRZ and RZ



classwork

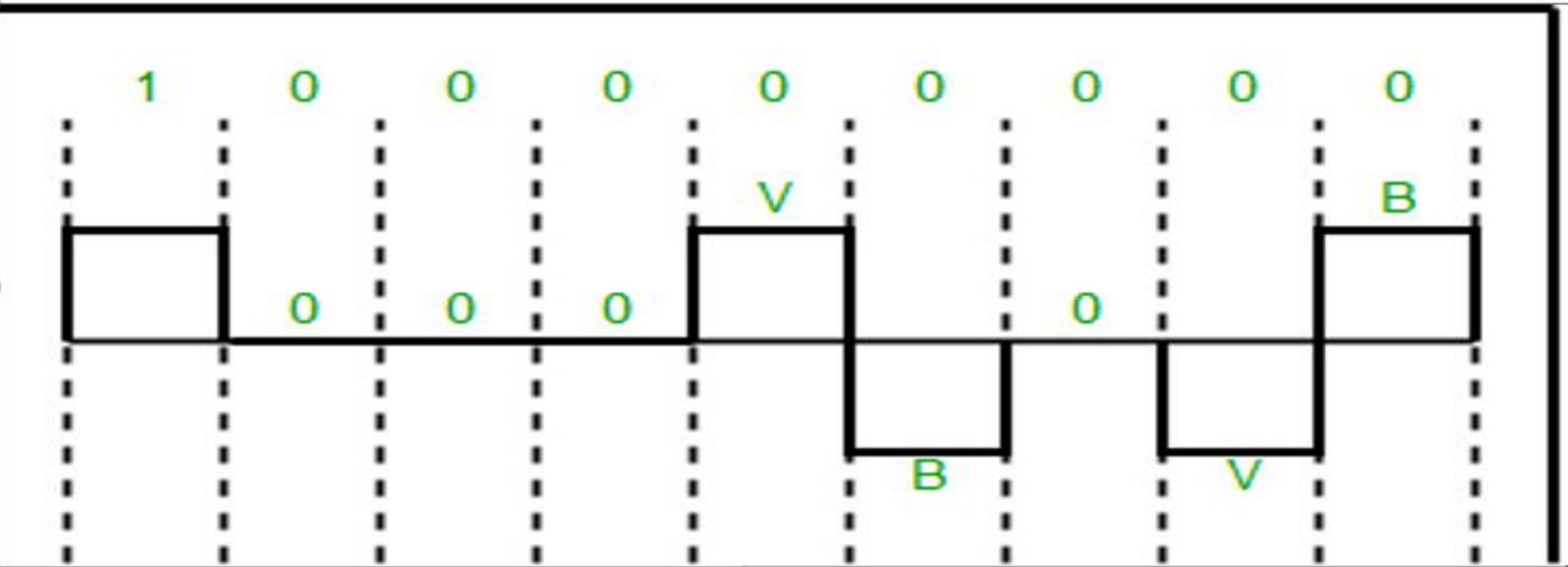
- Draw Bipolar NRZ for (Dram AMI for)
  - 101001110
  - 010100011

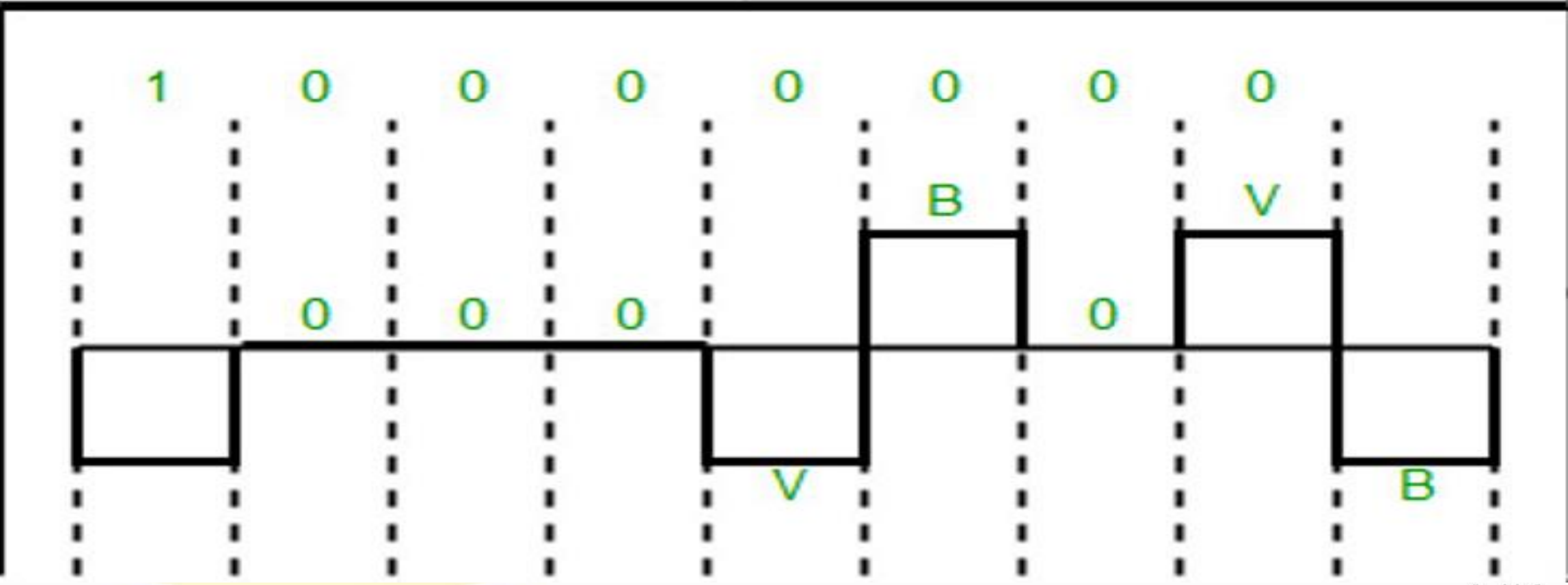
Scrambling

- Scrambling is a technique that provide synchronization without the increase in number of bits.
- The problem with techniques like Bipolar AMI (Alternate Mark Inversion) is that continuous sequence of zero’s create synchronization problems
- solution to this is Scrambling.
- There are two common scrambling techniques:
- 1. B8ZS(Bipolar with 8-zero substitution)
- 2. HDB3(High-density bipolar3-zero)

B8ZS(Bipolar with 8-zero substitution)

- similar to Bipolar AMI
- except when eight consecutive zero-level voltages are encountered they are replaced by the sequence, **“000VB0VB”.**
- V(Violation), is a non-zero voltage which means the signal has the same polarity as the previous non-zero voltage. Thus it is a violation of the general AMI technique.
- B(Bipolar), is also a non-zero voltage level that is in accordance with the AMI rule (i.e., opposite polarity from the previous non-zero voltage).


1 0 0 0 0 0 0 0 0
V
B
0 0 0
0
B
V


1 0 0 0 0 0 0 0
B
V
0 0 0
0
V
B

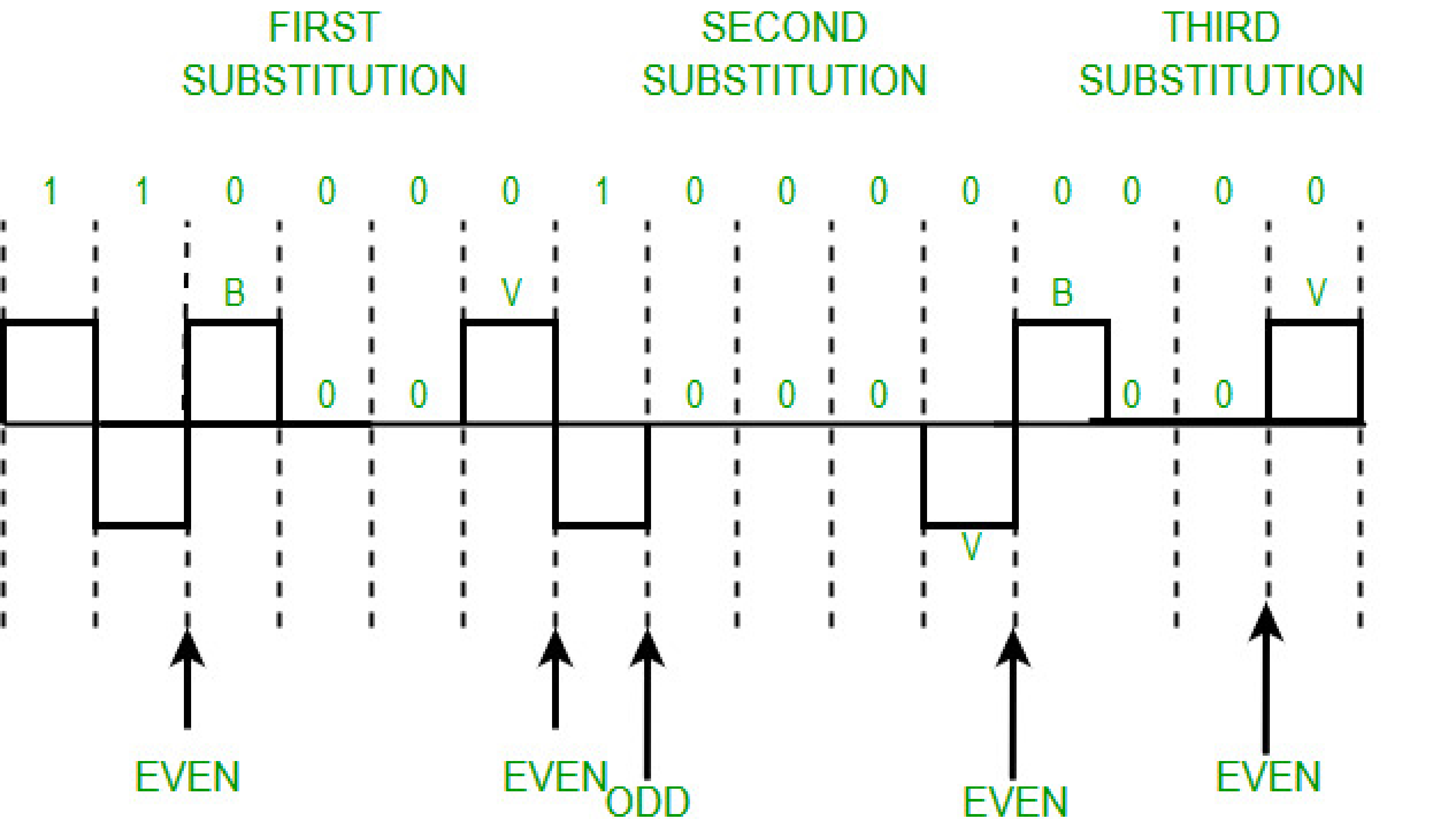
Classwork

- Draw B8ZS for
  - 101100000000
  - 100100000000

HDB3: High-density bipolar3-zero

- In this technique, four consecutive zero-level voltages are replaced with a sequence "**000V" or "B00V".**
  - If the number of nonzero pulses after the last substitution is odd, the substitution pattern will be **"000V**", this helps in maintaining a total number of nonzero pulses even.
  - If the number of nonzero pulses after the last substitution is even, the substitution pattern will be "**B00V".** Hence even the number of nonzero pulses is maintained again.

HDB3

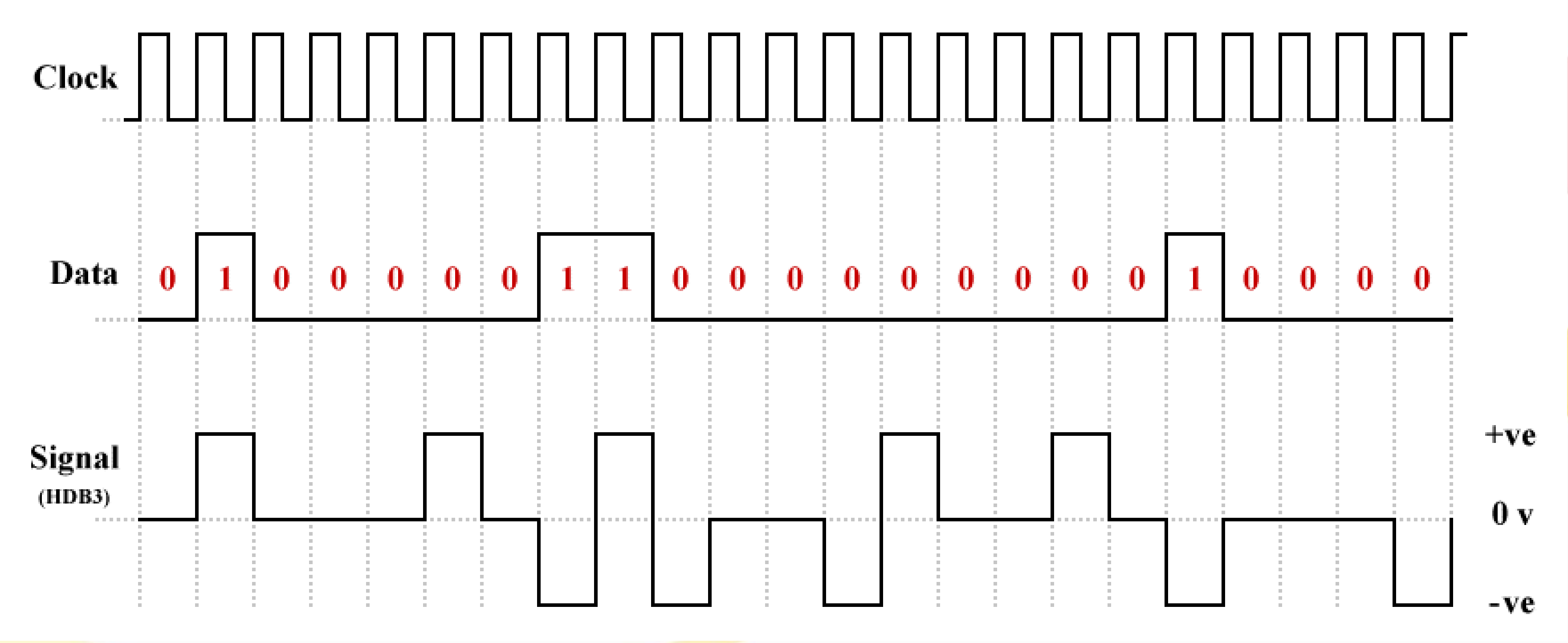

FIRST SUBSTITUTION
SECOND SUBSTITUTION
THIRD SUBSTITUTION
1 1 0 0 0 0 1 0 0 0 0 0 0 0 0
B
V
0 0
0 0 0
V
B
V
0 0
EVEN
EVEN
ODD
EVEN
EVEN

Classwork

- Draw B8ZS and HDB3 for data
  - 01000001100000000010000

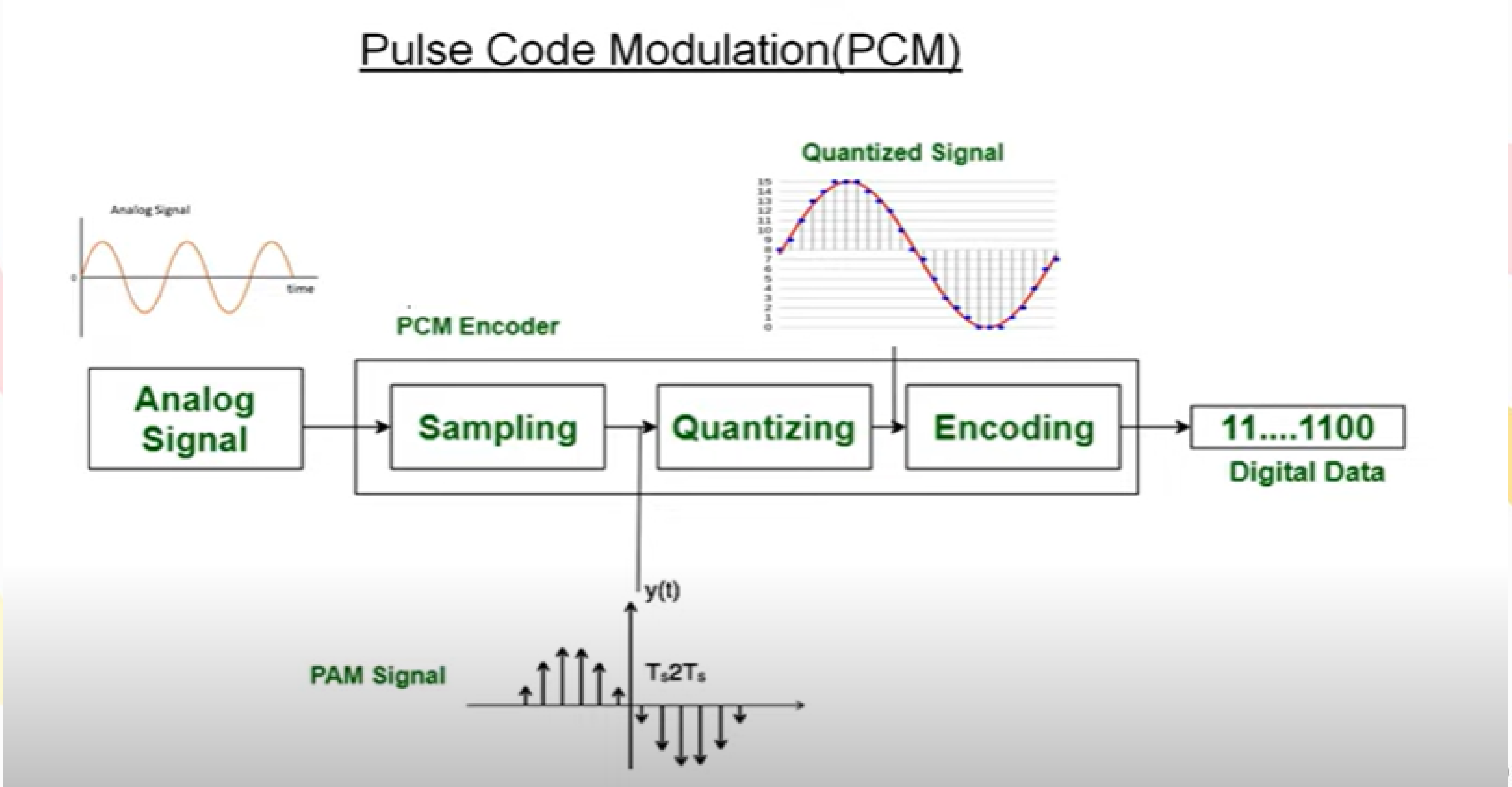
Classwork

- Draw B8ZS and HDB3 for data
  - 0100000110000000001000



PCM (Pulse Code Modulation)

- The Pulse Code Modulation (PCM) process involves several steps to convert an analog signal into a digital format for transmission over digital communication systems.



PCM

1. Sampling: Measuring Amplitude of signal at discrete point in time

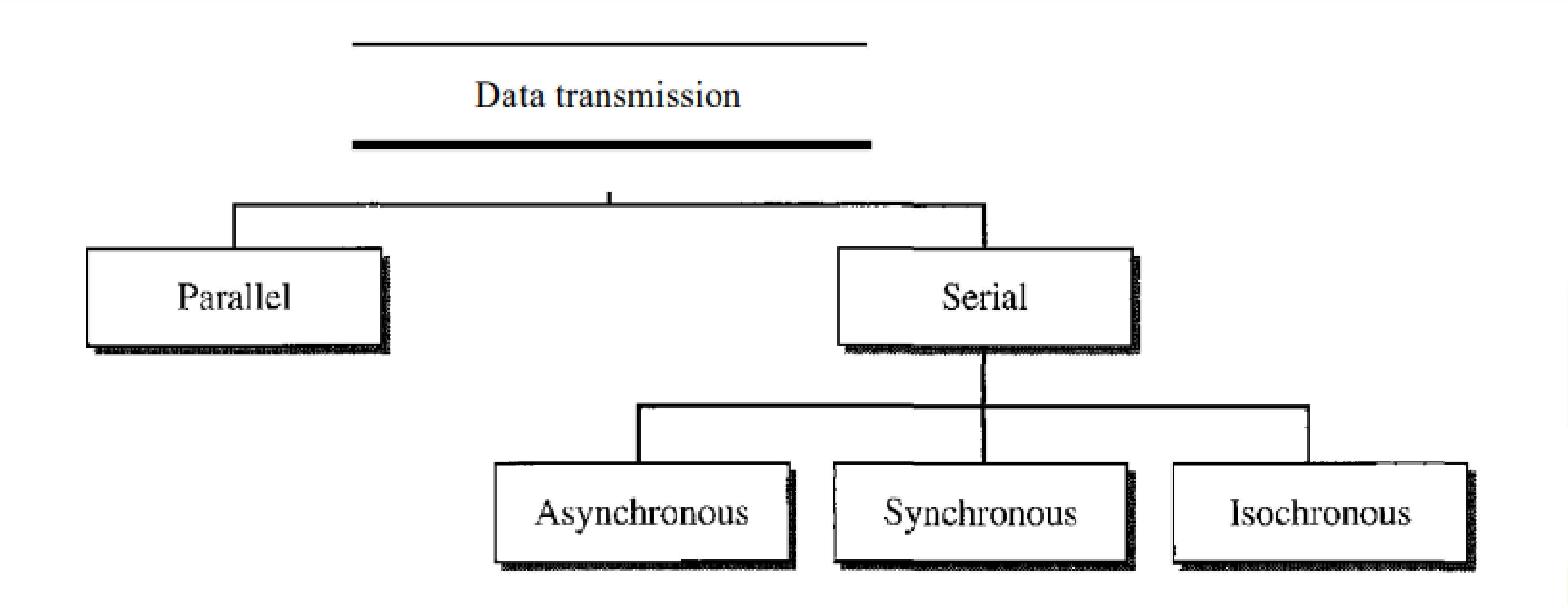
2. Quantization:

   - Each sample obtained during the sampling process is quantized into a discrete set of levels. T
   - his quantization process assigns a binary code to each sample, representing its amplitude.

3. Encoding

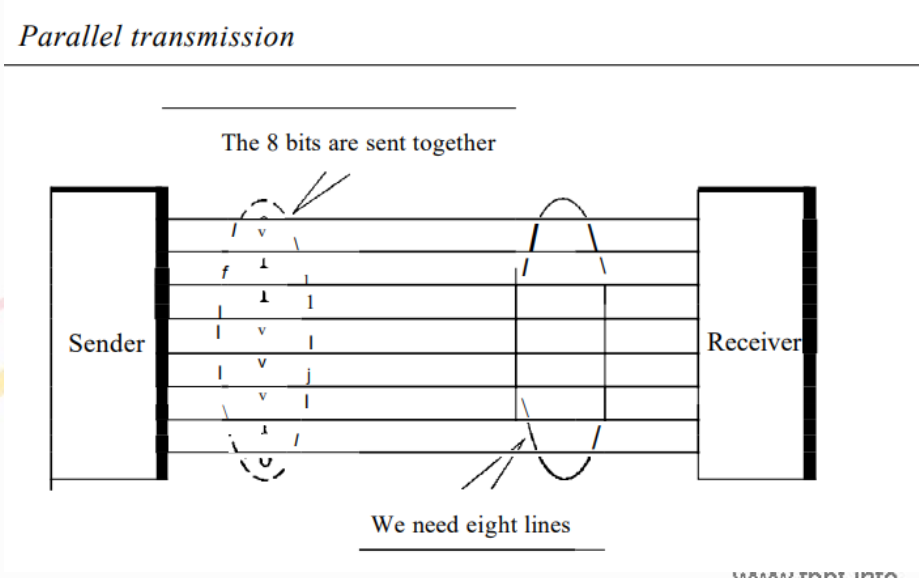
   - The quantized samples are encoded into a binary code using a binary numbering system.
   - Each sample is represented by a binary word consisting of a fixed number of bits.

DATA TRANSMISSION MODES



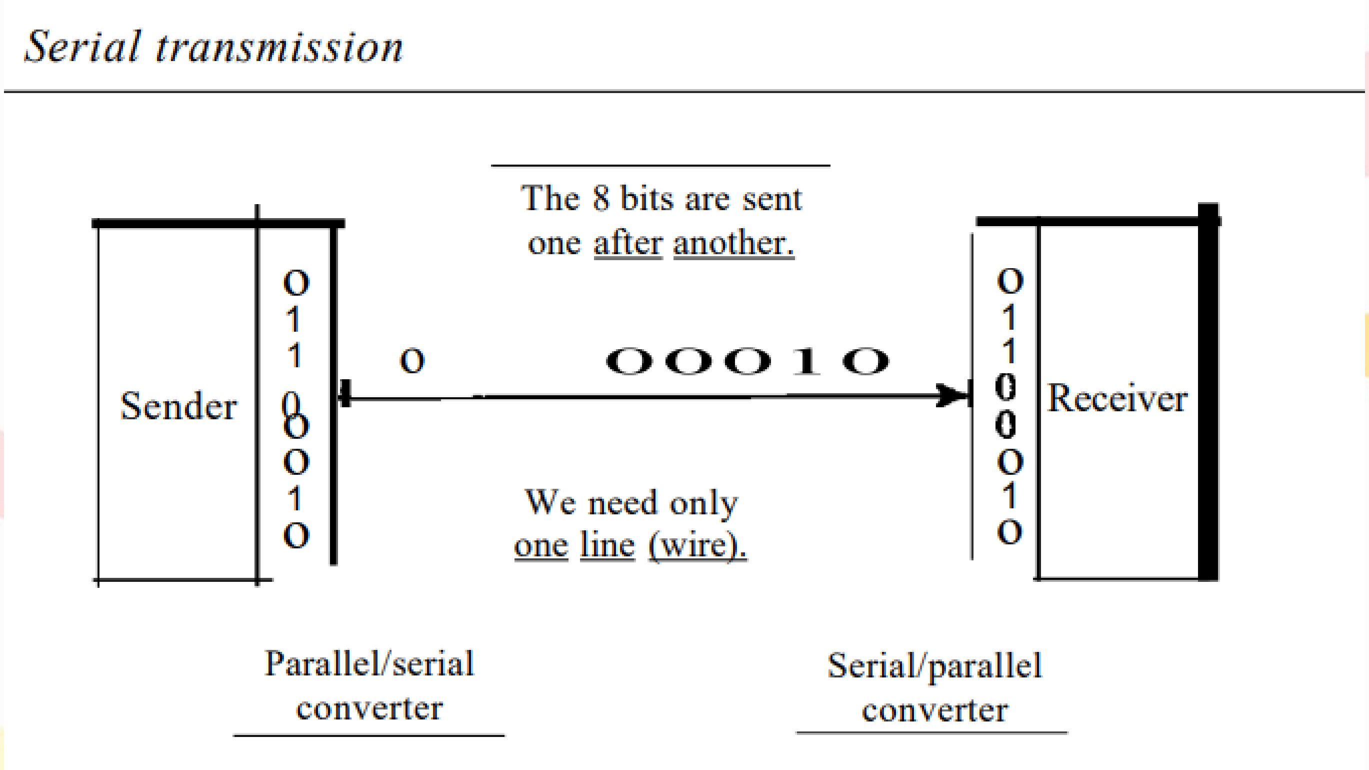
Parallel Transmission Mode:

- Multiple bits of data are transmitted simultaneously over multiple channels
- Parallel processing of the bits at the receiving end.
- Used for short-distance communication within computer systems, where high-speed data transfer is required.
- Examples parallel ATA (PATA) for connecting hard drives to motherboards and parallel ports for connecting peripherals such as printers and scanners to computers.



Serial Transmission Mode:

- Data is transmitted sequentially, one bit at a time,
- commonly used for long-distance communication over cables or wireless links
- Examples : RS-232, USB (Universal Serial Bus), Ethernet, and serial ATA (SATA)



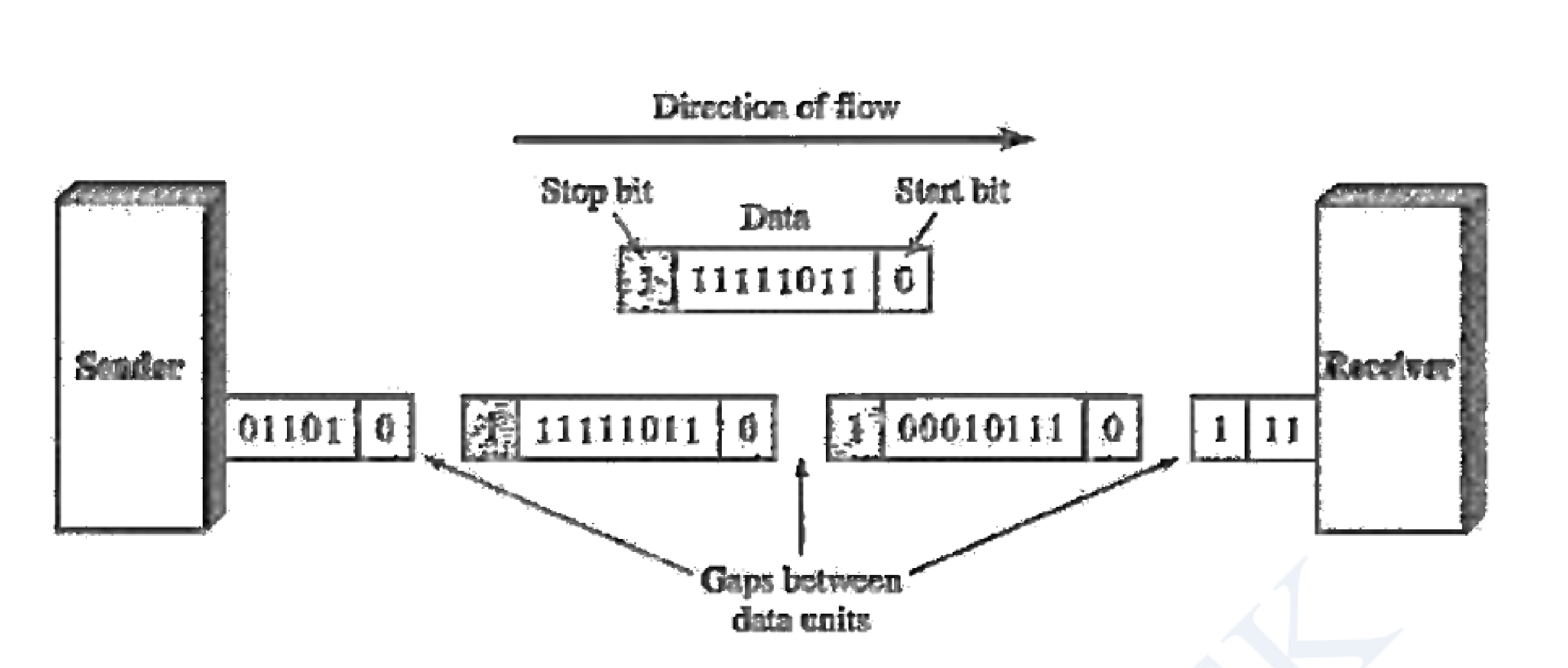
Aspect	Parallel Communication	Serial Communication
Definition	Simultaneous transmission of multiple bits over multiple wires/channels	Sequential transmission of data, one bit at a time, over a single wire/channel
Number of Wires/Channels	Requires multiple wires or channels equal to the number of bits being transmitted simultaneously	Requires only one wire or channel for data transmission
Data Transfer Rate	Can achieve higher data transfer rates, especially over short distances	Generally has lower data transfer rates compared to parallel communication
Transmission Distance	Suitable for short-distance communication within computer systems	Suitable for long-distance communication over cables or wireless links
Complexity and Cost	Requires more wires and hardware components, increasing complexity and cost	Requires fewer wires and hardware components, reducing complexity and cost
Synchronization	Requires precise timing and synchronization between multiple data lines	Relies on start and stop bits or clock signals for synchronization
Efficiency	Provides higher data transfer rates over shorter distances, ideal for high-speed internal communication	Offers greater efficiency for long-distance communication, with less susceptibility to signal degradation
Interference	More susceptible to signal interference and crosstalk due to multiple parallel data lines	Less susceptible to signal interference, as data is transmitted sequentially over a single channel
Application	Commonly used for high-speed data transfer within computer systems, such as between a CPU and memory or between peripherals and the motherboard	Widely used for communication between devices over longer distances, such as between computers, modems, routers, and storage devices

Serial transmission

- Asynchronous,
- Synchronous, and
- Isochronous.

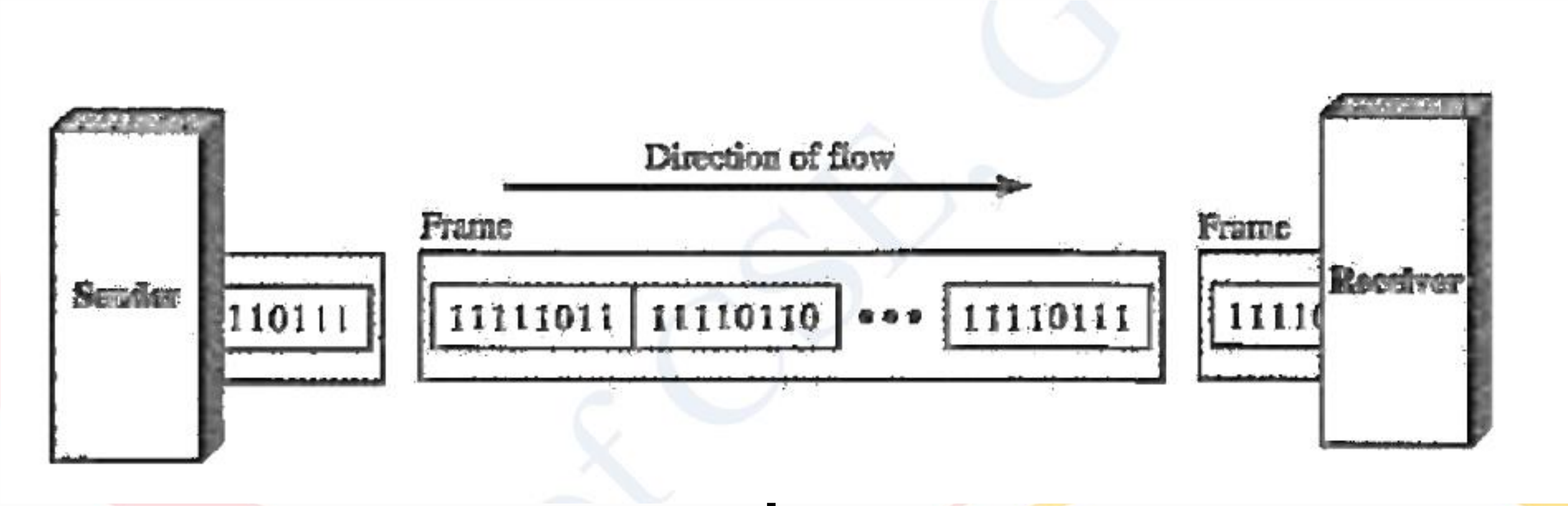
Asynchronous

- In asynchronous transmission, we send 1 start bit (0) at the beginning and 1 or more stop bits (1) at the end of each byte. There may be a gap between each byte



Synchronous

- In synchronous transmission, we send bits one after another without start or stop bits or gaps. It is the responsibility of the receiver to group the bits.



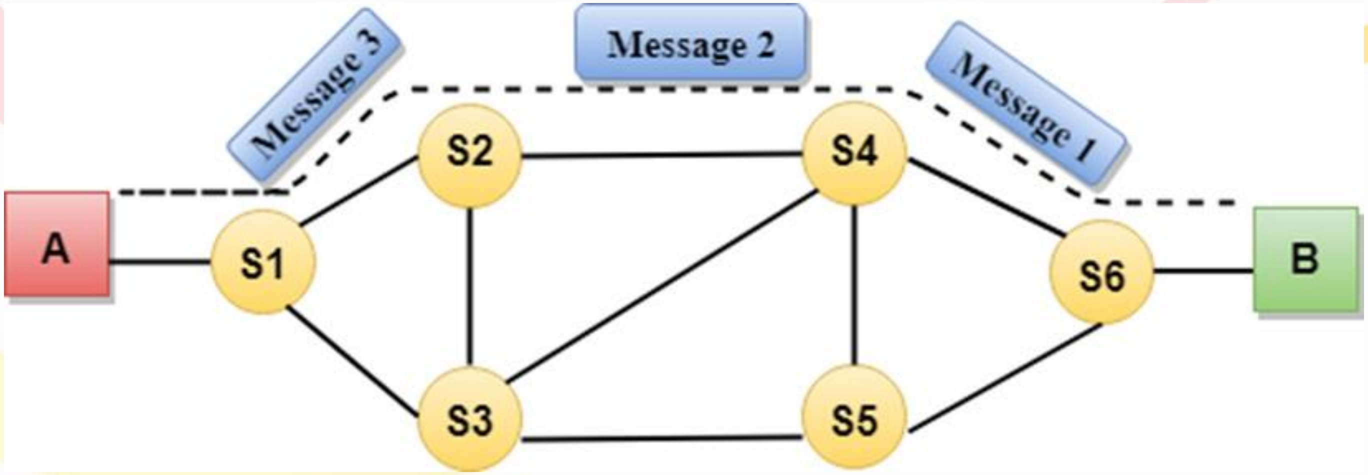
Isochronous

- The isochronous transmission guarantees that the data arrive at a fixed rate

CIRCUIT SWITCHING AND PACKET SWITCHING

- Circuit switching is a networking technique that establishes a dedicated communication path between two nodes before the actual data transfer begins.

- In circuit-switched networks, resources, such as bandwidth, are reserved along the entire path for the duration of the communication session.



Circuit Switching

- **Operation:**

1. **Connection Establishment**: Before data transfer can begin, a dedicated circuit or channel is established between the sender and receiver. This process involves reserving resources, such as bandwidth, along the entire path.
2. **Data Transfer**: Once the circuit is established, data is transmitted directly along the dedicated path without interruption until the session ends.
3. **Release**: When the communication session is complete, the dedicated circuit is released, and the reserved resources are freed up for other connections.

Circuit Switching

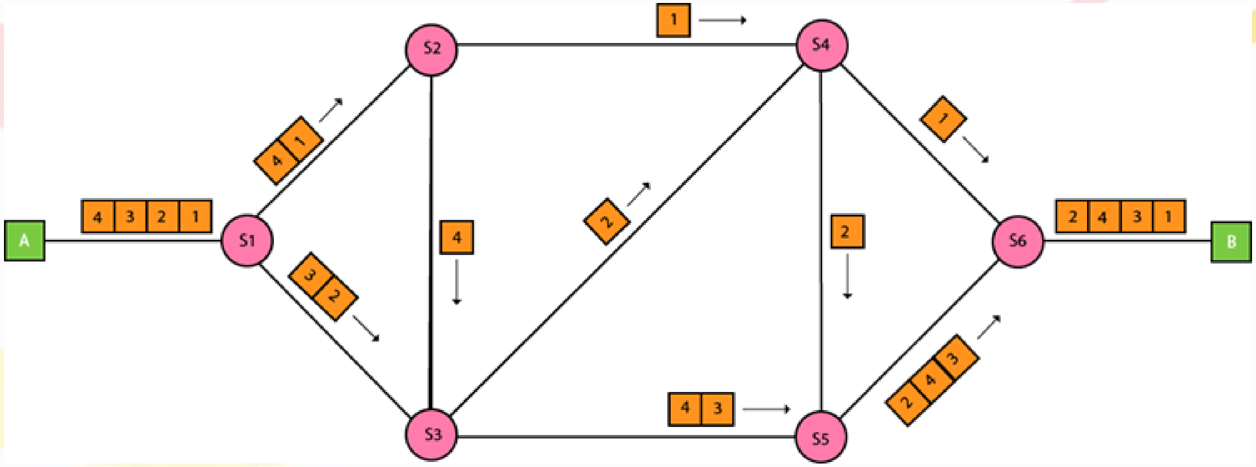
- **Characteristics:**
  - Dedicated resources: A fixed bandwidth is allocated along the entire communication path for the duration of the session.
  - Predictable performance: Circuit-switched networks offer predictable and constant transmission delay and throughput.
  - Suitable for continuous data streams: Ideal for applications that require real-time, continuous data transmission, such as voice and video calls.

Circuit Switching

- **Advantages of Circuit Switching**
  - It uses a fixed bandwidth.
  - Quality of communication.
  - Data is transmitted with a fixed data rate.
  - No waiting time at switches.
  - Suitable for long and continuous communication.
- **Disadvantages of circuit switching**
  - A dedicated connection makes it impossible to transmit other data even if the channel is free.
  - Resources are not utilized fully.
  - The time required to establish the physical link between the two stations is too long.
  - Circuit switching is more expensive.
  - Even if there is no transfer of data, the link is still maintained until it is terminated by users.

Packet Switching

- Packet switching is a networking technique that breaks data into smaller packets for transmission over a shared network.
- Each packet contains routing information, allowing them to be independently routed from the sender to the receiver.
- Packet switching networks do not establish dedicated paths; instead, packets are forwarded dynamically based on network conditions.



Packet Switching Operation

1. **Packetization:**

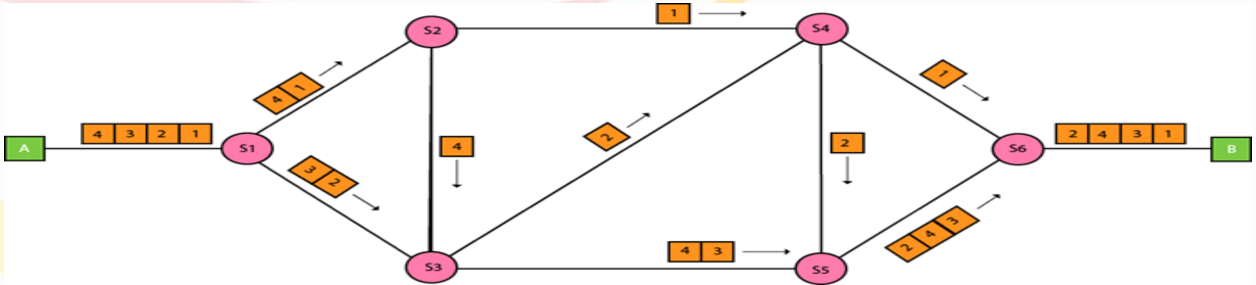
 Data is divided into smaller packets, each containing a portion of the original message along with header information, including source and destination addresses.

2. **Routing:**

Each packet is independently routed through the network based on the destination address in its header. Packets may take different paths and arrive out of order at the destination.

3. **Reassembly:**

Upon reaching the destination, packets are reassembled in the correct order to reconstruct the original message.



Characteristics:

- **Shared resources:** Bandwidth is dynamically allocated based on demand, allowing for efficient use of network resources.
- **Variable performance**: Packet-switched networks offer variable transmission delay and throughput, depending on network congestion and packet routing.
- **Suitable for bursty data**: Ideal for applications that generate bursty or intermittent traffic, such as web browsing and file transfers.

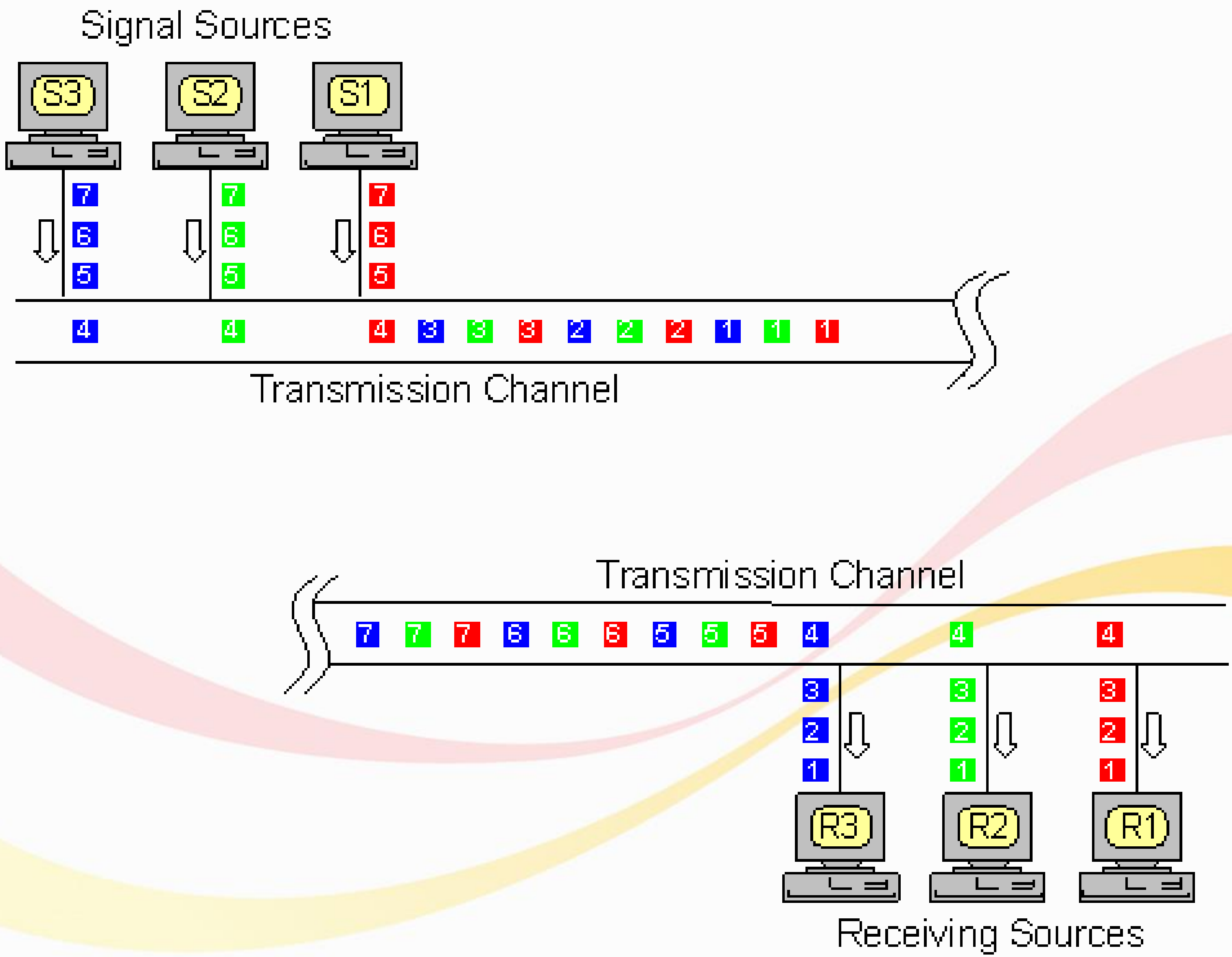
- **Advantages of Packet switching**
  - It reduces access delay.
  - Costs are minimized to great extent.
  - Packets are rerouted in case of any problems. This ensures reliable communication.
  - It is more efficient for data transmission
  - Efficient use of Bandwidth: Several users can share the same channel simultaneously.

  Disadvantages of Packet switching
  - Compromise on quality and delay.
  - Protocols used in the packet switching are complex.
  - If the network becomes overloaded, packets are delayed or discarded, or dropped. This leads to the retransmission of lost packets by the sender.
  - It is not secured if security protocols are not used during packet transmission.

Difference Between Circuit Switching and Packet Switching

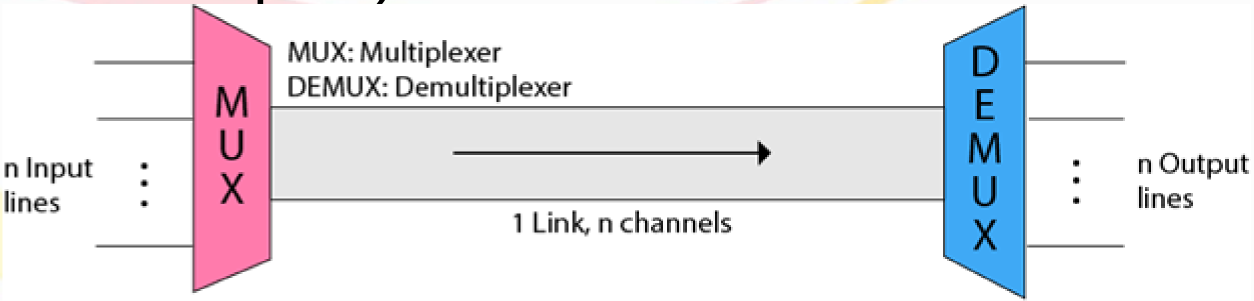
- Assignment

Multiplexing and Demultiplexing

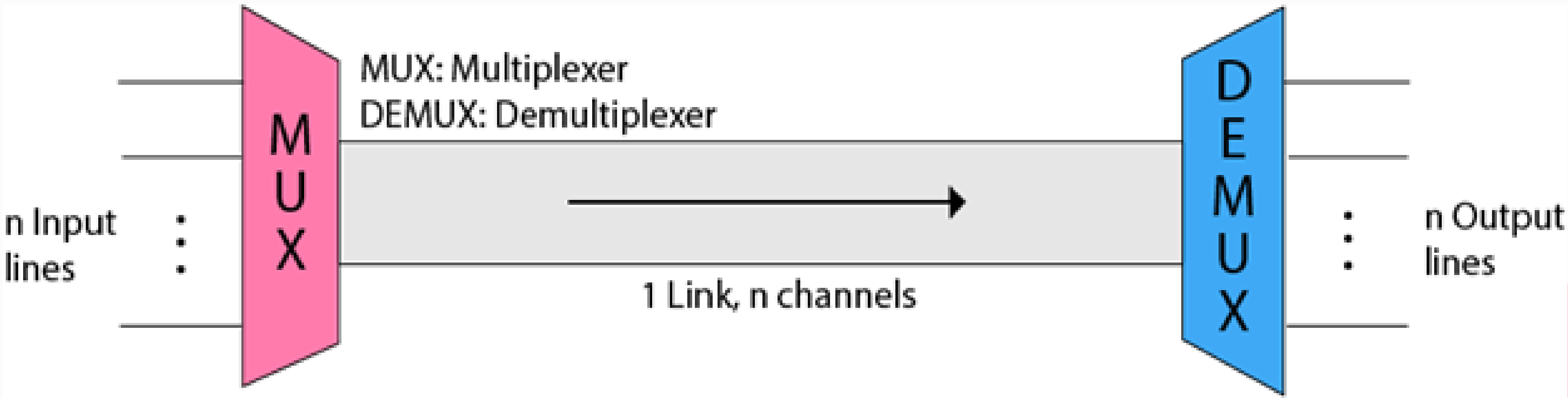


Multiplexing

- Multiplexing is a technique used to combine and send the multiple data streams over a single medium.
- The process of combining the data streams is known as multiplexing and hardware used for multiplexing is known as a multiplexer.
- Multiplexing is achieved by using a device called Multiplexer (MUX) that combines n input lines to generate a single output line.
- Demultiplexing is achieved by using a device called Demultiplexer (DEMUX) available at the receiving end.
- DEMUX separates a signal into its component signals (one input and n outputs).



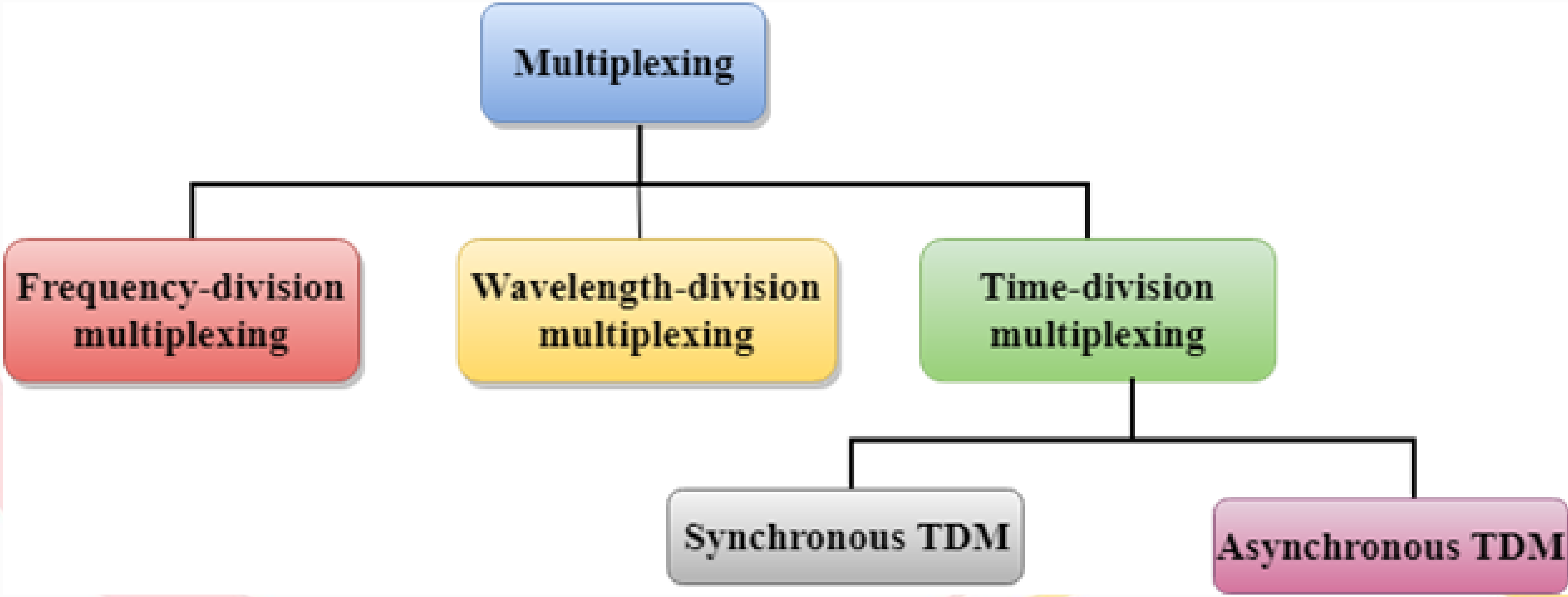
Multiplexing and Demultiplexing



- Multiplexing → n to one
- Demultiplexing → one to n

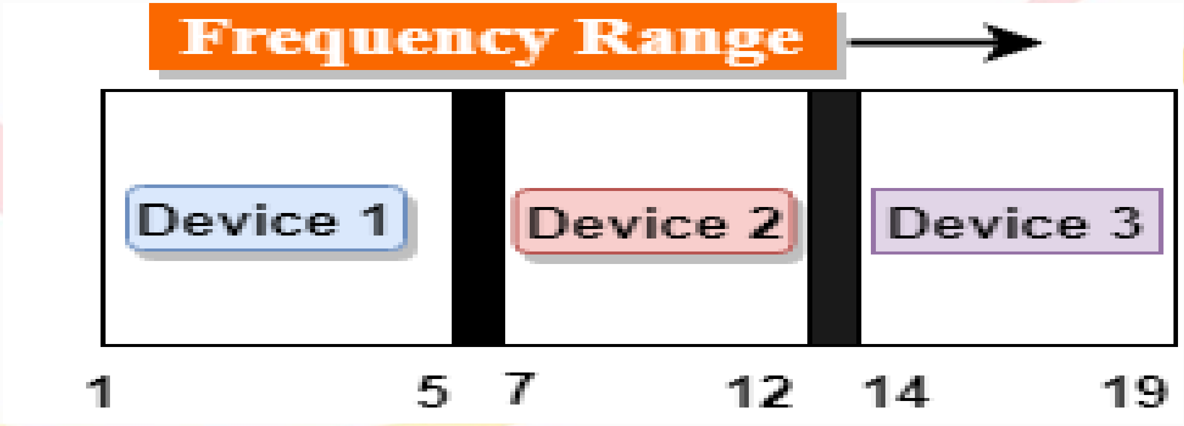
Advantages of Multiplexing

- More than one signal can be sent over a single medium.
- The bandwidth of a medium can be utilized effectively.
- Efficient use of resources by allowing multiple signals or data streams to share the same communication channel simultaneously.
- Increased capacity of the communication channel, accommodating more data streams or users without requiring additional infrastructure.
- Cost-effectiveness by reducing the need for dedicated channels or resources for each individual signal.
- Flexibility in accommodating various types of signals and data streams, such as voice, data, and video.
- Scalability to accommodate an increasing number of users or devices as demand grows.


Multiplexing
Frequency-division multiplexing
Wavelength-division multiplexing
Time-division multiplexing
Synchronous TDM
Asynchronous TDM

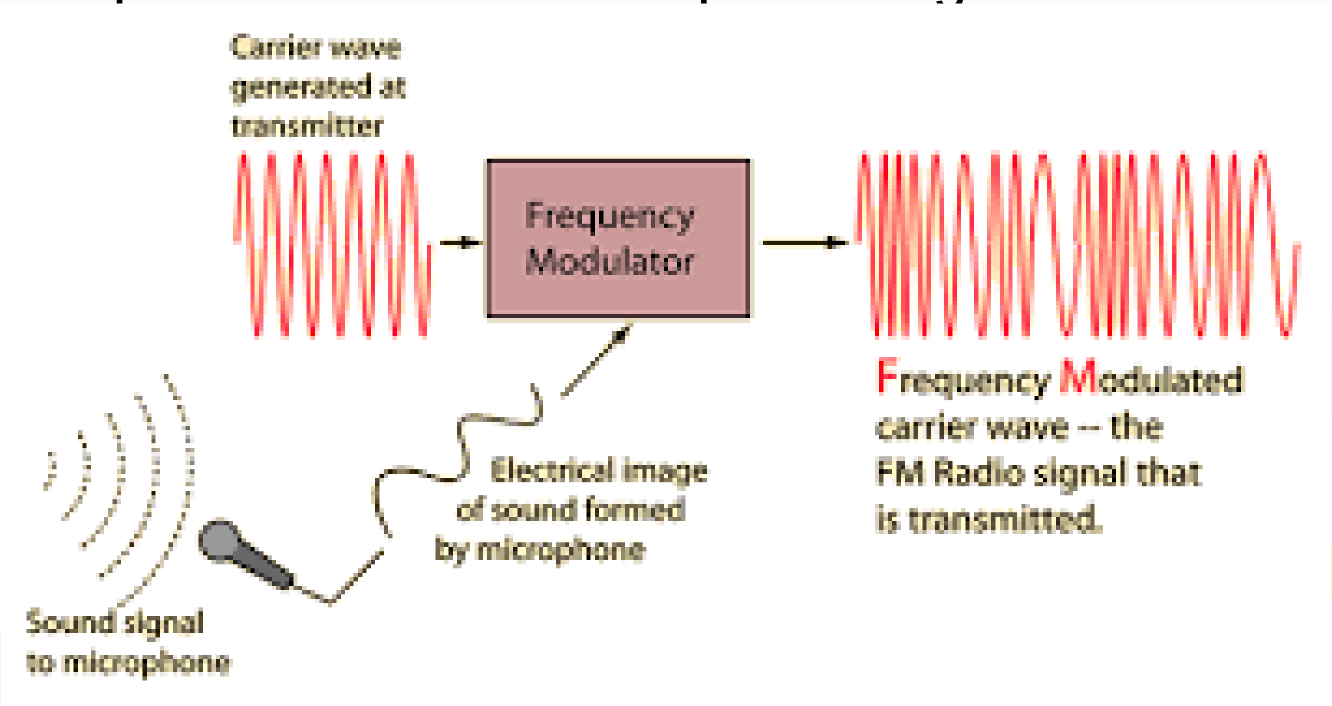
Frequency-division Multiplexing (FDM)

- It is an analog technique.
- Frequency Division Multiplexing is a technique in which the available bandwidth of a single transmission medium is subdivided into several channels.
- A single transmission medium is subdivided into several frequency channels, and each frequency channel is given to different devices. Device 1 has a frequency channel of range from 1 to 5.



FDM

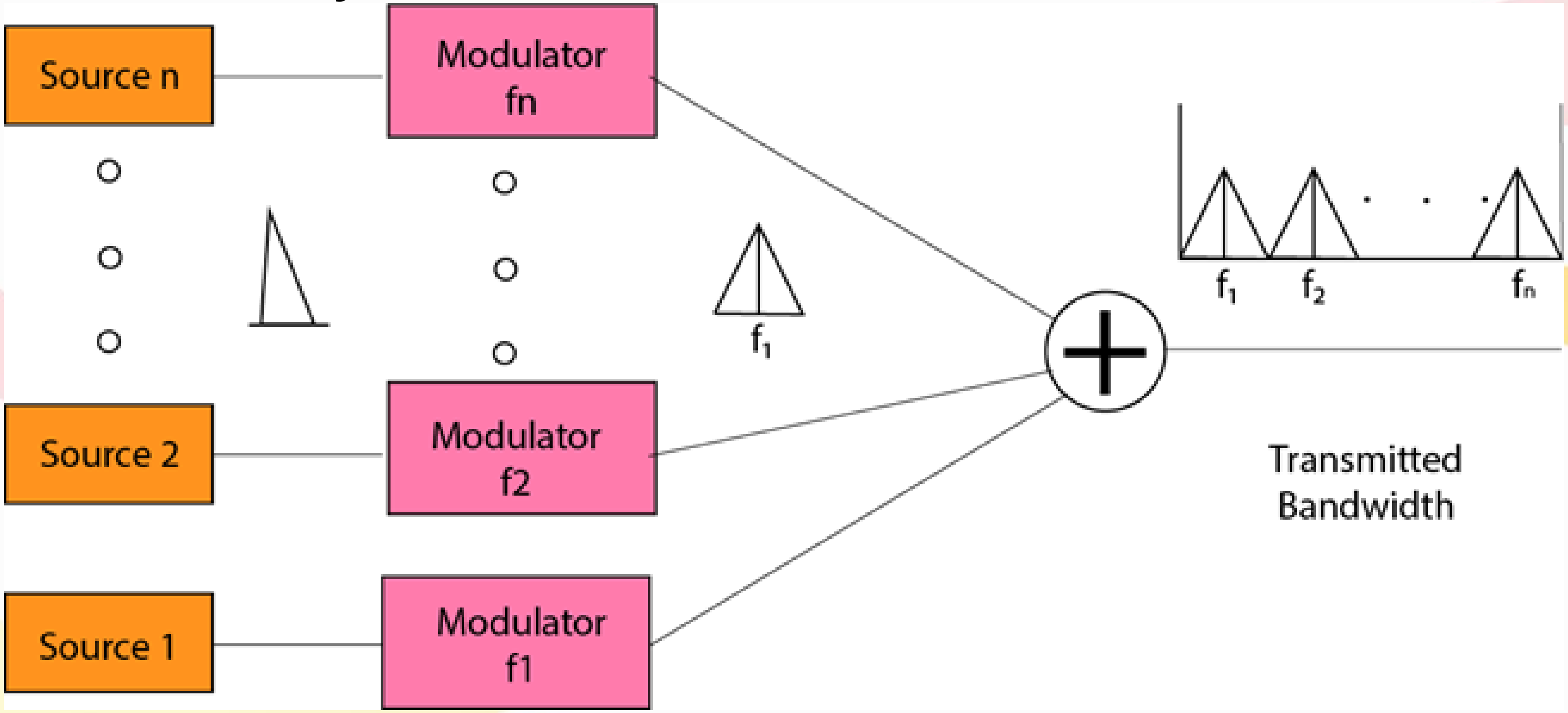
- The input signals are translated into frequency bands by using modulation techniques, and they are combined by a multiplexer to form a composite signal.



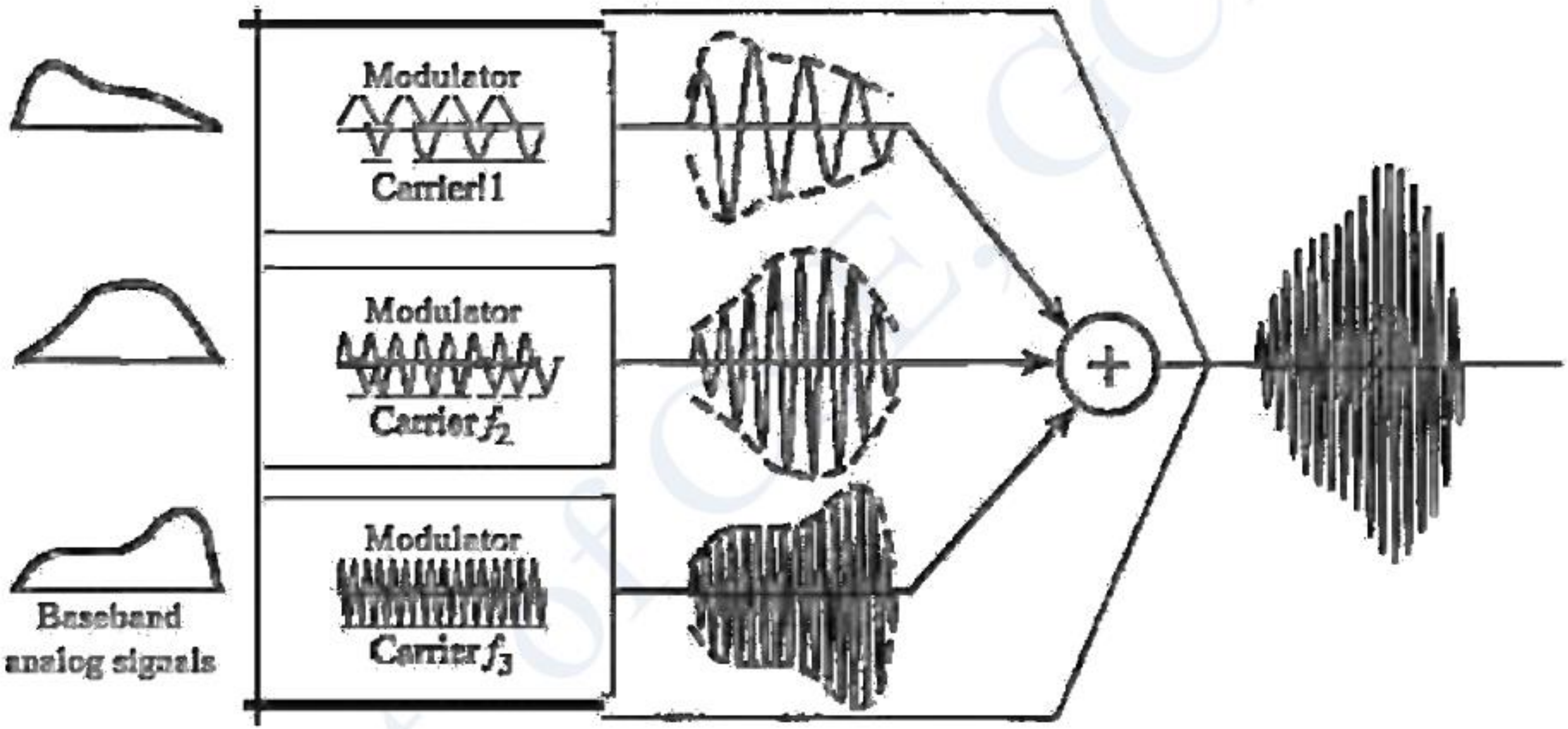
- The main aim of the FDM is to subdivide the available bandwidth into different frequency channels and allocate them to different devices.

FDM

- Using the modulation technique, the input signals are transmitted into frequency bands and then combined to form a composite signal.
- The carriers which are used for modulating the signals are known as sub-carriers. They are represented as f1,f2..fn.
- FDM is mainly used in radio broadcasts and TV networks.



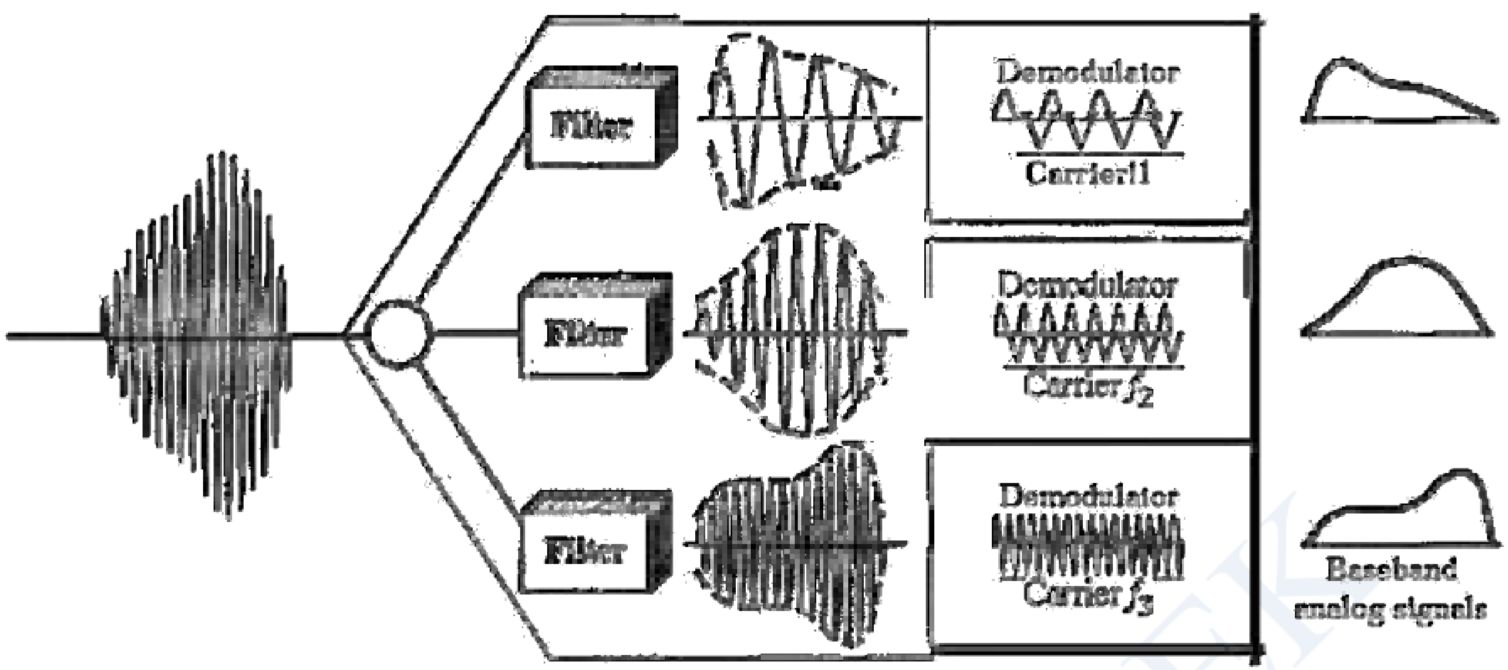
FDM



Modulator
Carrier f1
Modulator
Carrier f_2
Modulator
Carrier f_3
Baseband analog signals
+

Demultiplexing

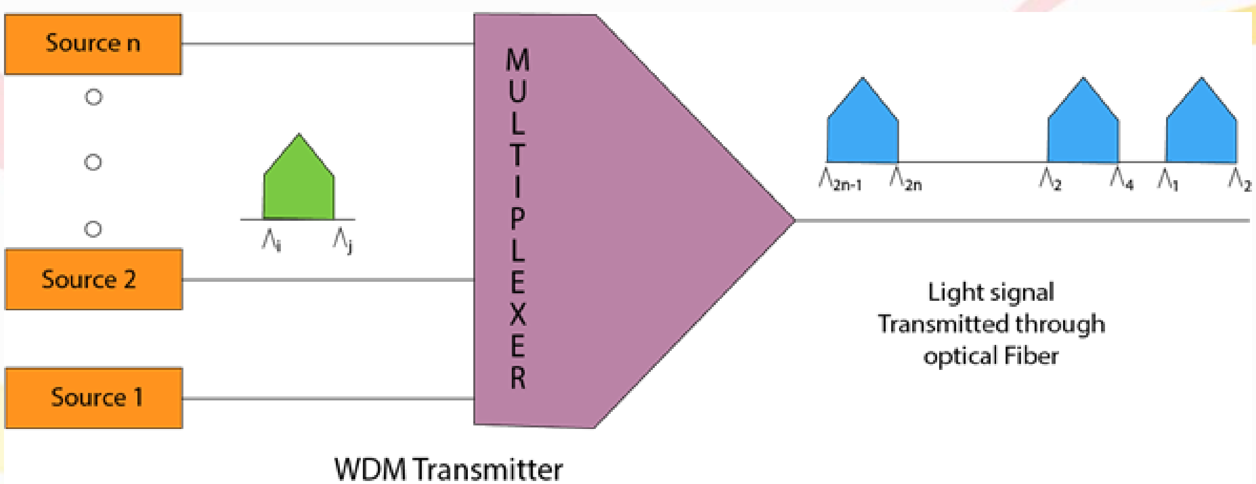
- The de-multiplexer uses a series of filters to decompose the multiplexed signal into its constituent component signals.
- The individual signals are then passed to a demodulator that separates them from their carriers and passes them to the output lines



- **Advantages Of FDM:**
  - FDM is used for analog signals.
  - FDM process is very simple and easy modulation.
  - Does not require synchronization between sender and receiver.
- **Disadvantages Of FDM:**
  - It suffers the problem of crosstalk and interference.
  - A Large number of modulators are required.
  - It requires a high bandwidth channel.
- **Applications Of FDM:**
  - FDM is commonly used in TV networks.
  - It is used in FM and AM broadcasting.
  - Each FM radio station has different frequencies, and they are multiplexed to form a composite signal. The multiplexed signal is transmitted in the air.

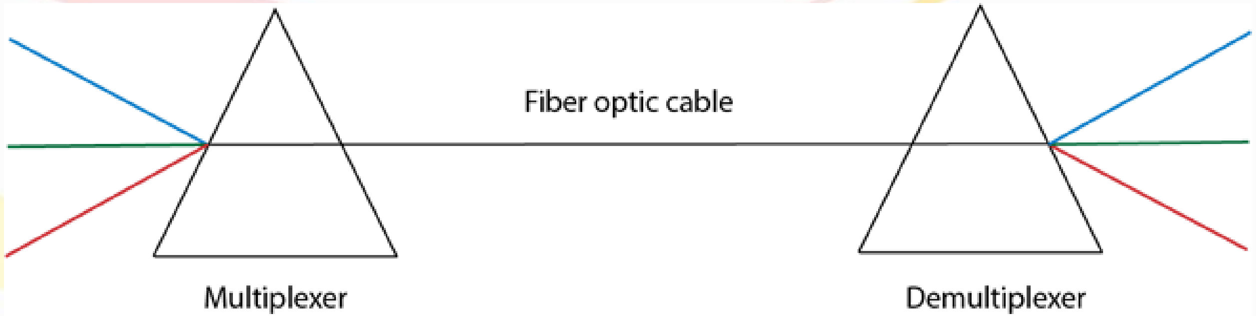
Wavelength Division Multiplexing (WDM)

- Wavelength Division Multiplexing is same as FDM except that the optical signals are transmitted through the fiber optic cable.
- WDM is used on fiber optics to increase the capacity of a single fibre.
- It is used to utilize the high data rate capability of fiber optic cable.
- It is an analog multiplexing technique.



WDM

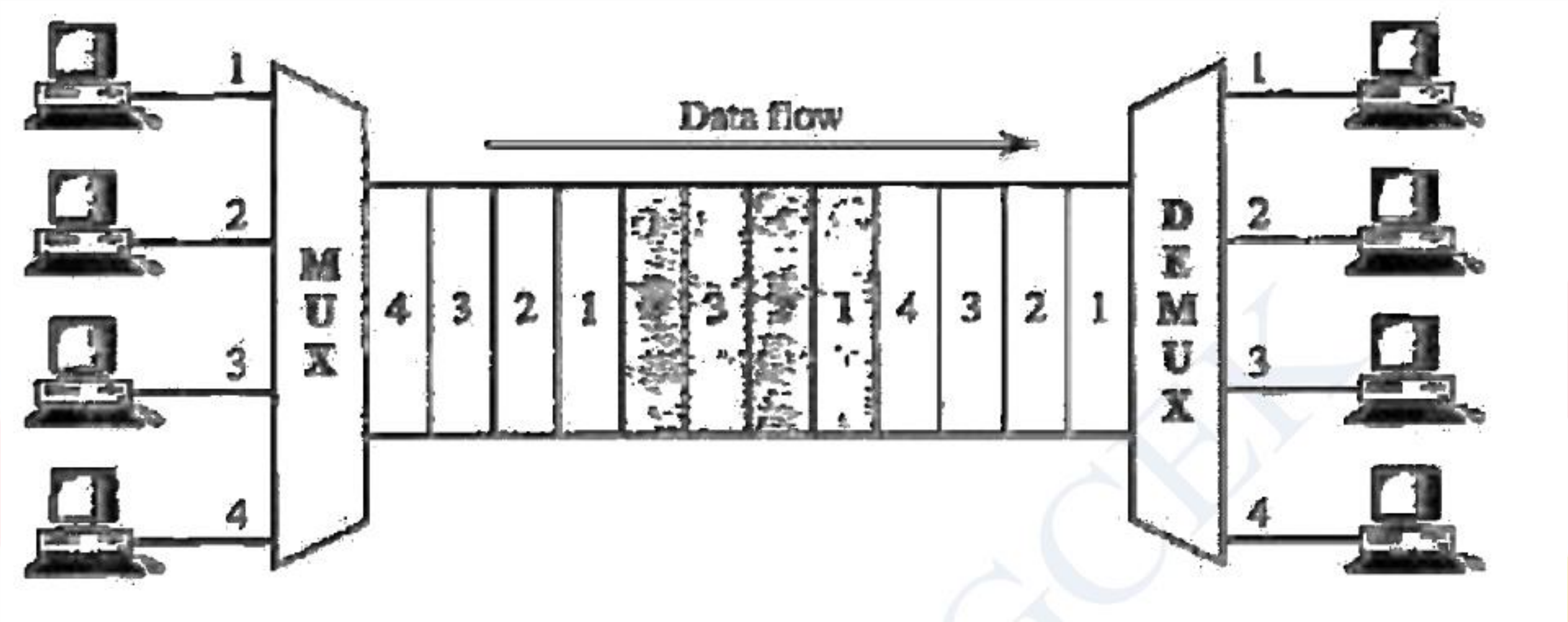
- Optical signals from different source are combined to form a wider band of light with the help of multiplexer.
- At the receiving end, demultiplexer separates the signals to transmit them to their respective destinations.
- Multiplexing and Demultiplexing can be achieved by using a prism.
- Prism can perform a role of multiplexer by combining the various optical signals to form a composite signal, and the composite signal is transmitted through a fibre optical cable.
- Prism also performs a reverse operation, i.e., demultiplexing the signal.



Time Division Multiplexing

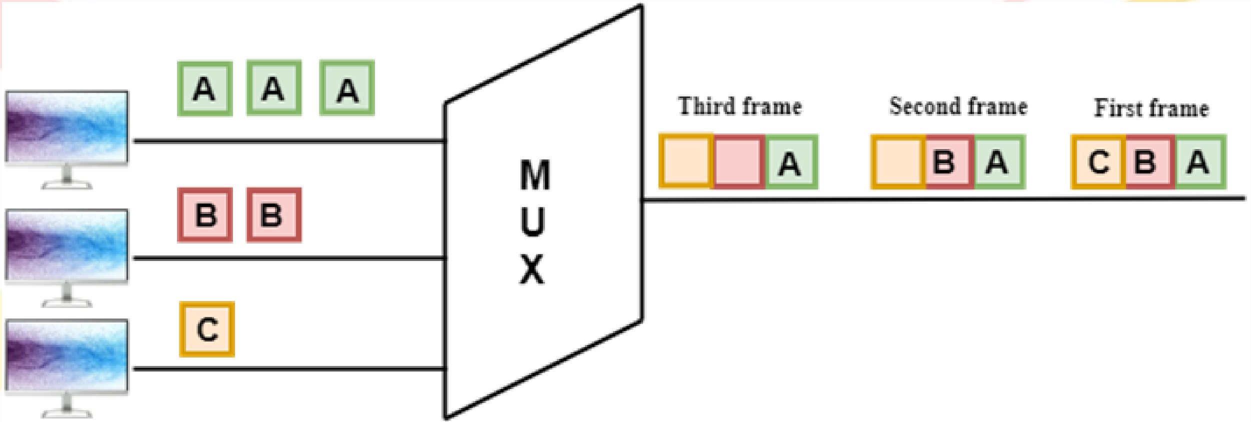
- Digital technique.
- In Frequency Division Multiplexing Technique, all signals operate at the same time with different frequency, but in case of Time Division Multiplexing technique, all signals operate at the same frequency with different time.
- In Time Division Multiplexing technique, the total time available in the channel is distributed among different users.
- Therefore, each user is allocated with different time interval known as a Time slot at which data is to be transmitted by the sender.
- A user takes control of the channel for a fixed amount of time.

TDM

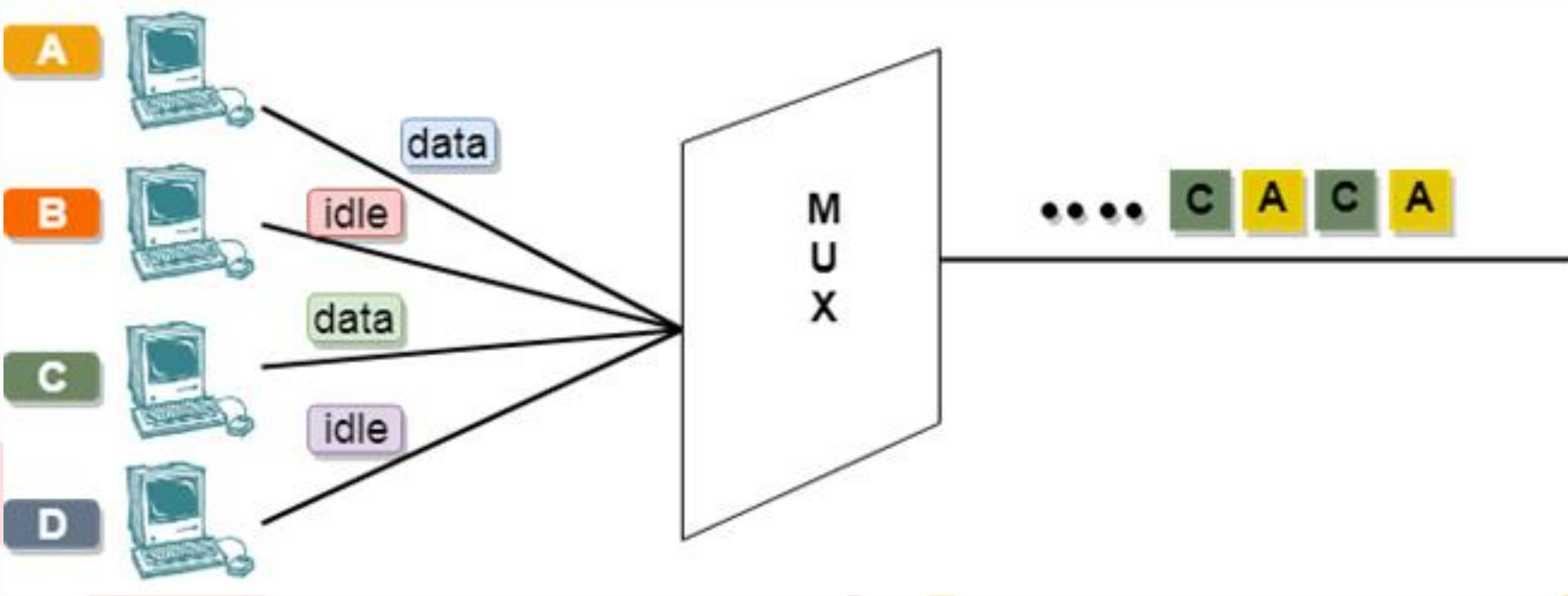


Synchronous TDM

- A Synchronous TDM is a technique in which time slot is preassigned to every device.
- Each device is given some time slot irrespective of the fact that the device contains the data or not.
- If the device does not have any data, then the slot will remain empty.
- The most popular Synchronous TDM are T-1 multiplexing, ISDN multiplexing, and SONET multiplexing.
- If there are n devices, then there are n slots.



Asynchronous TDM



Asynchronous TDM

- An asynchronous TDM is a technique in which time slots are not fixed as in the case of Synchronous TDM.
- Time slots are allocated to only those devices which have the data to send
- Asynchronous Time Division multiplexor transmits only the data from active workstations.
- An asynchronous TDM technique dynamically allocates the time slots to the devices.
- Asynchronous Time Division multiplexor accepts the incoming data streams and creates a frame that contains only data with no empty slots.
- In Asynchronous TDM, each slot contains an address part that identifies the source of the data.

ADDRESS	DATA

Synchronous and Asynchronous TDM

- The difference between Asynchronous TDM and Synchronous TDM is that many slots in Synchronous TDM are unutilized, but in Asynchronous TDM, slots are fully utilized.
- This leads to the smaller transmission time and efficient utilization of the capacity of the channel.
- In Synchronous TDM, if there are n sending devices, then there are n time slots. In Asynchronous TDM, if there are n sending devices, then there are m time slots where m is less than n (m<n).

DATA ENCODING

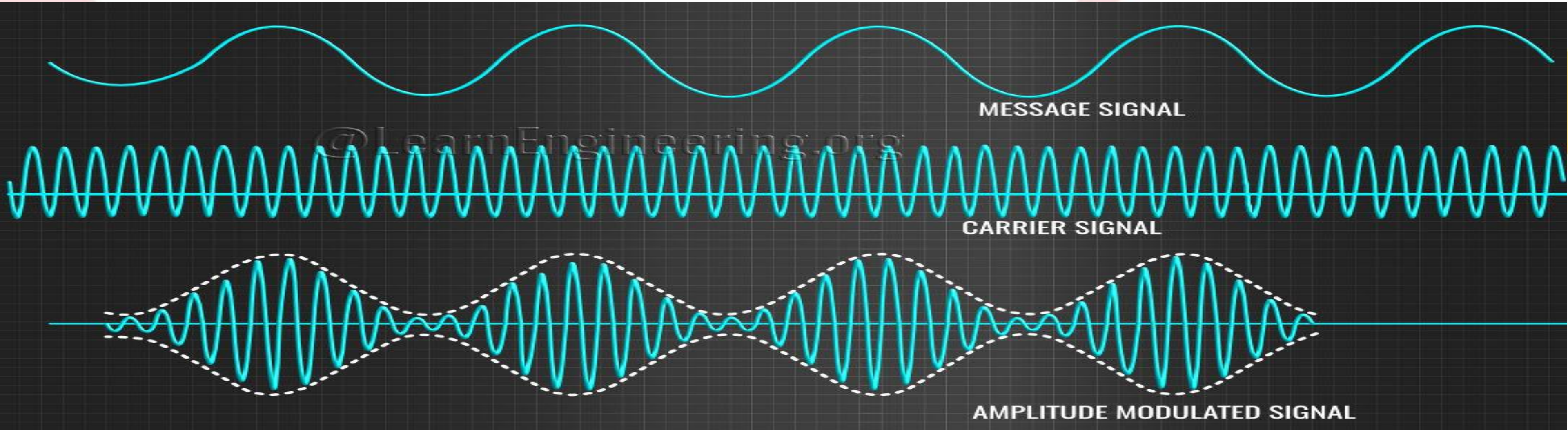
- Data encoding is the process of converting data from one format or representation to another for efficient transmission, storage, or processing.
- It involves transforming raw data into a structured or encoded form that can be easily interpreted, transmitted, and decoded by computer systems or communication devices.
- Purposes
  - Compression
  - Error Detection and Correction
  - Security- Encryption and Decryption
  - Interoperability

Encoding Techniques

- **Analog data to Analog signals** –
  - The **modulation techniques** such as Amplitude Modulation, Frequency Modulation and Phase Modulation of analog signals, fall under this category.
- **Analog data to Digital signals** –
  - This process can be termed as **digitization**, which is done by Pulse Code Modulation PCM. Hence, it is nothing but digital modulation.
- **Digital data to Analog signals** –
  - The modulation techniques such as Amplitude Shift Keying ASK, Frequency Shift Keying FSK, Phase Shift Keying PSK, etc., fall under this category.
- **Digital data to Digital signals** –
  - There are several ways to map digital data to digital signals. Some of them are – Unipolar NRZ, RZ, Bipolar, AMI etc

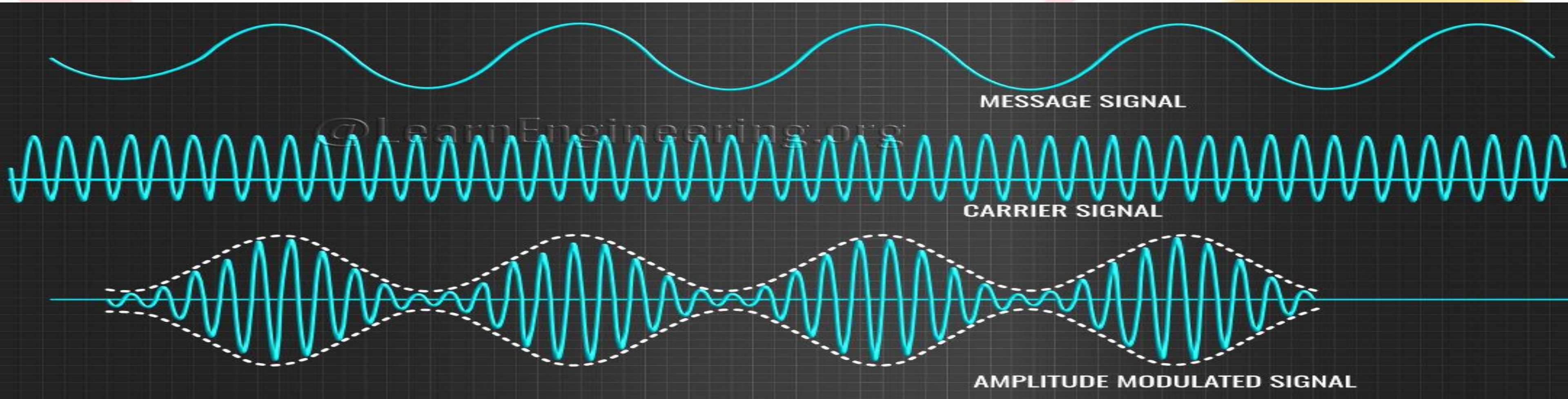
Modulation

- Modulation is the process of →changing the parameters/characteristics (Amplitude, Frequency and Phase) of the carrier signal→ in accordance with the different parameters of the modulating signal.
- A message carrying signal has to get transmitted over a distance and for it to establish a reliable communication, it needs to take the help of a high frequency signal which should not affect the original characteristics of the message signal.



Modulation

- The characteristics of the message signal, if changed, the message contained in it also alters.
- Hence it is a must to take care of the message signal.
- A high frequency signal can travel up to a longer distance, without getting affected by external disturbances.
- We take the help of such high frequency signal which is called as a carrier signal to transmit our message signal. Such a process is simply called as Modulation.



Advantages of Modulation

- **Reduced Antenna size**

When the transmission occurs over free space, the antennae radiate the signa and the receiver receives it. To operate efficiently, antennae need to be in the c of the magnitude of the wavelength of the transmitted signal.

$$L = \lambda = \frac{u}{\vartheta} = \frac{(3*10^8)}{\vartheta} Hz$$

Speech frequencies range from 20 Hz to 20 kHz. Suppose this is a frequency of : kHz, and it is radiated out to a receiver through a channel of free space.

$$Length\ of\ Antennae = \frac{3*10^8}{20*10^3} = 15000m = 15km$$

It is impossible to build an antenna this big. Instead, say we give modulation a chance and use a 1000 kHz carrier wave to carry the signal. The length of the antennae now would be;

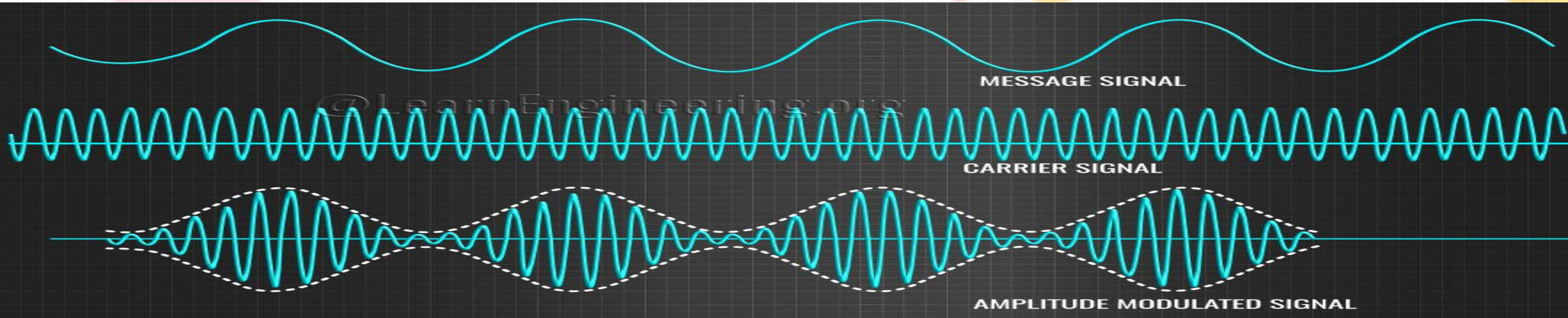
$$Length\ of\ Antennae = \frac{3*10^8}{1000*10^3} = 300m$$

Advantages

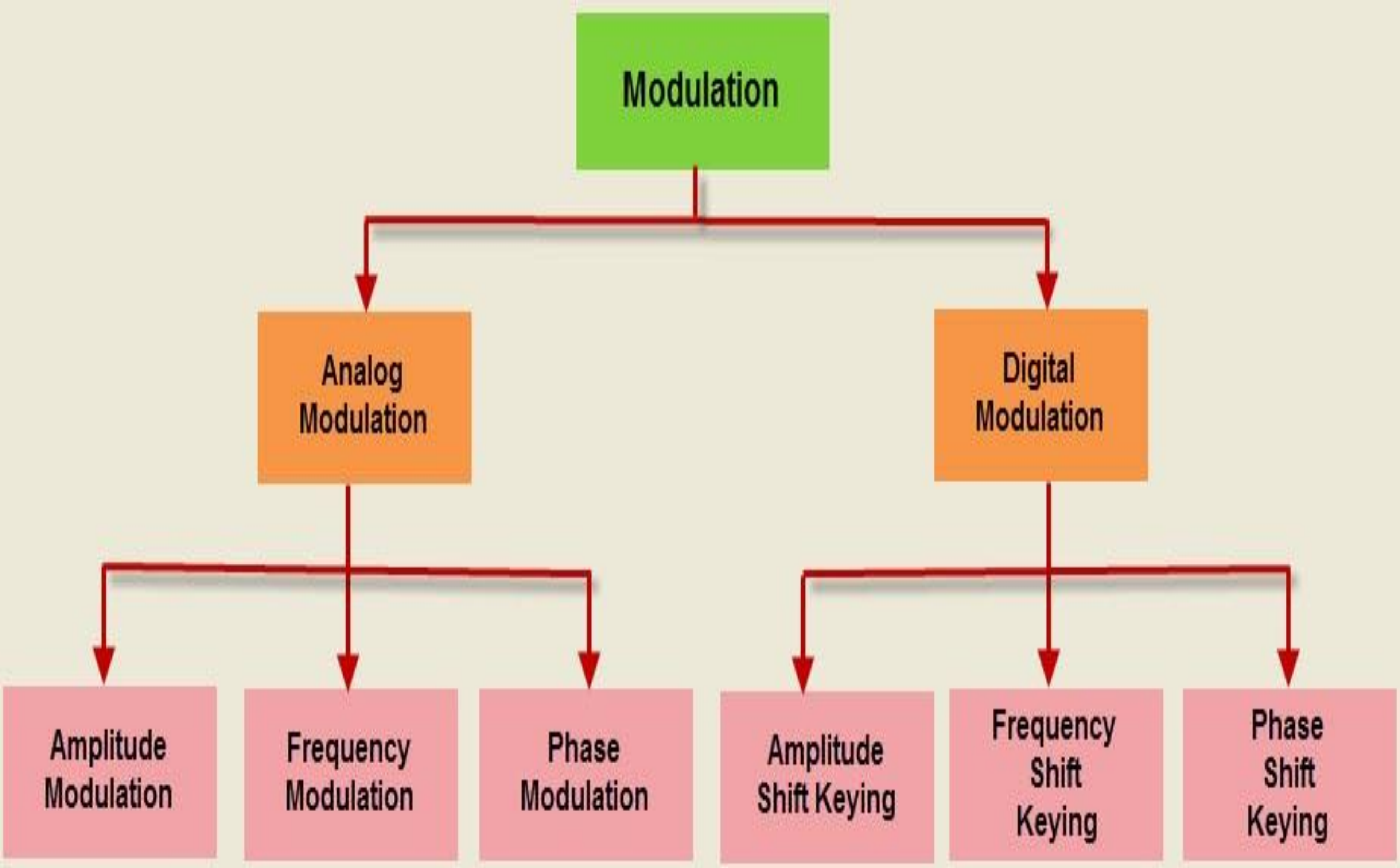
- **Bandwidth Efficiency:**
- **Noise Immunity**
- **Improved Transmission Range:**
- **Compatibility with Communication Systems:**
- **Higher Data Rates:**
- **Security and Encryption**

Signals in the Modulation Process

- **Message or Modulating Signal**:
  - The signal which contains a message to be transmitted
  - It is a baseband signal, which has to undergo the process of modulation, to get transmitted.
- **Carrier Signal:**
  - The high frequency signal which has a certain phase, frequency, and amplitude but contains no information, is called a carrier signal.
  - It is an empty signal.
  - It is just used to carry the signal to the receiver after modulation.
- Modulated Signal:
  - The resultant signal after the process of modulation, is called as the modulated signal.



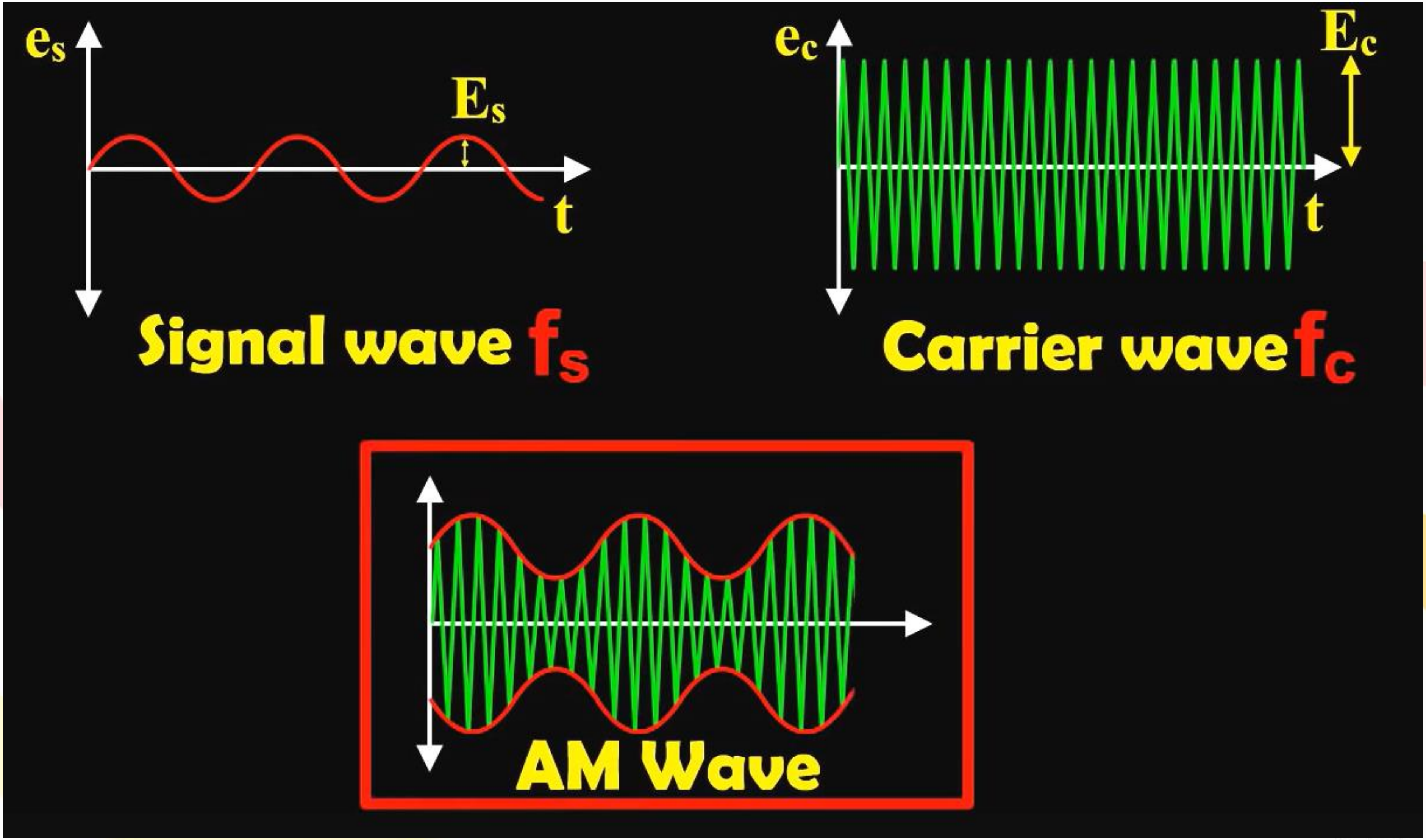
Types of Modulation



Analog Modulation

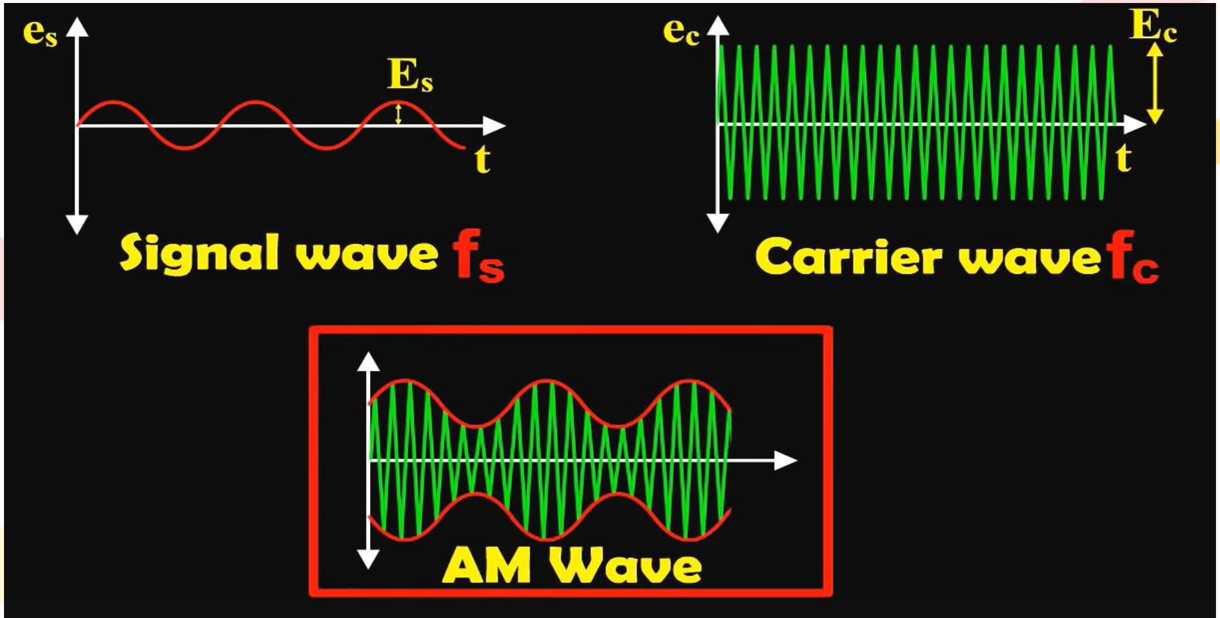
- Analog modulation is a technique where an analog signal is modulated onto a carrier wave by varying the amplitude, frequency, or phase of the carrier wave in proportion to the analog signal's characteristics.
- This process results in the generation of an analog modulated signal that can be transmitted over a communication channel.
- Include Amplitude Modulation (AM), Frequency Modulation (FM), and Phase Modulation (PM).
- Analog modulation is commonly used in broadcast radio, analog television, and voice communication systems.

Amplitude Modulation



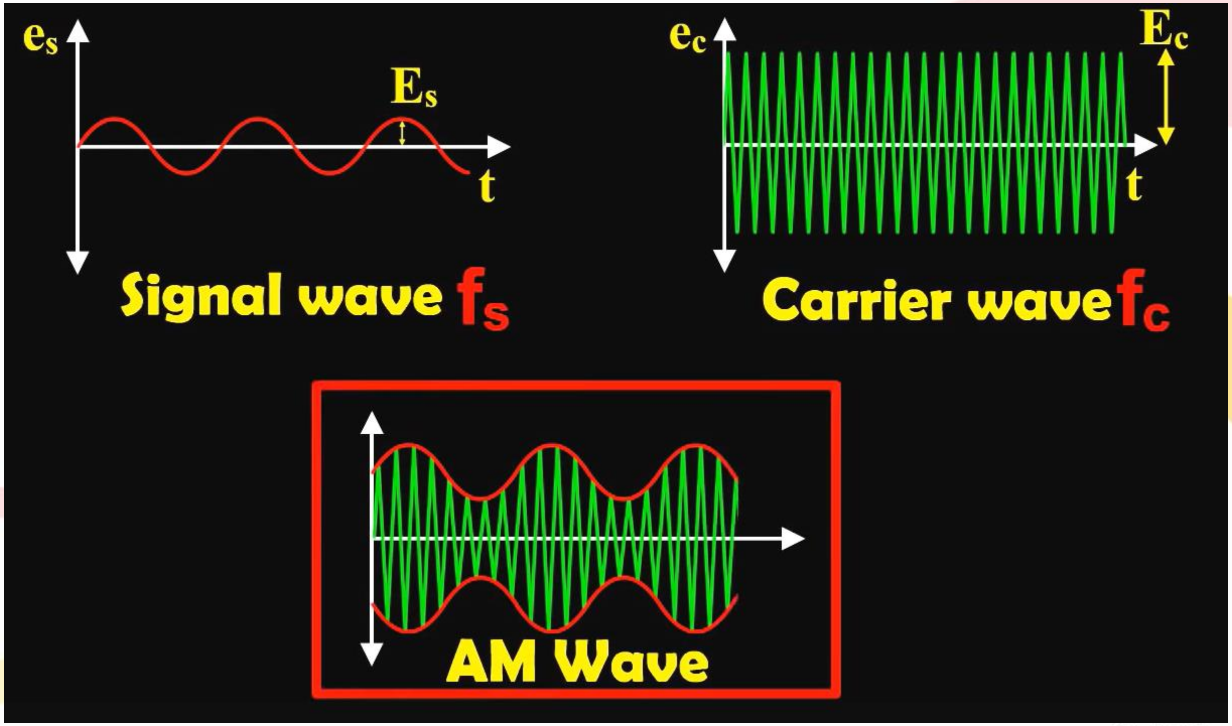
Amplitude Modulation (AM)

- Amplitude Modulation (AM) is a modulation technique used in telecommunications and signal processing, **where the amplitude of a carrier wave is varied in proportion to the amplitude of the modulating signal** (the baseband signal) being transmitted.
- This process effectively "embeds" the information of the modulating signal onto the carrier wave.



How AM works

- **Carrier Wave:** The carrier wave is a high-frequency signal with a constant frequency and amplitude.
- **Modulating Signal:** The modulating signal is the signal that carries the information to be transmitted. It typically has a much lower frequency than the carrier wave and represents the original message or data.



How AM works

- **Modulation Process:** In amplitude modulation, the amplitude of the carrier wave is varied (modulated) in proportion to the amplitude of the modulating signal.
- When the modulating signal has a positive amplitude, the amplitude of the carrier wave increases. Conversely, when the modulating signal has a negative amplitude, the amplitude of the carrier wave decreases.

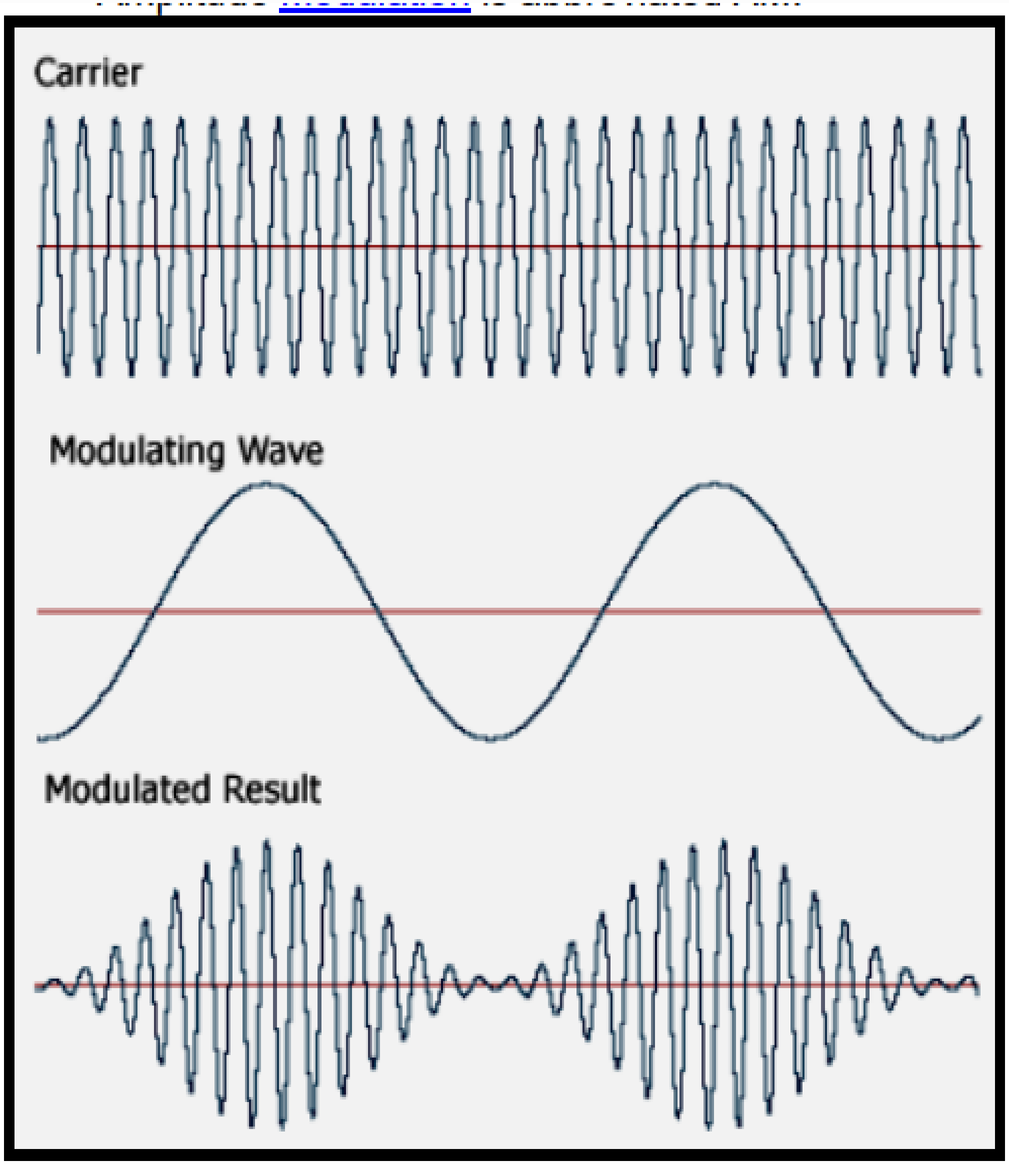
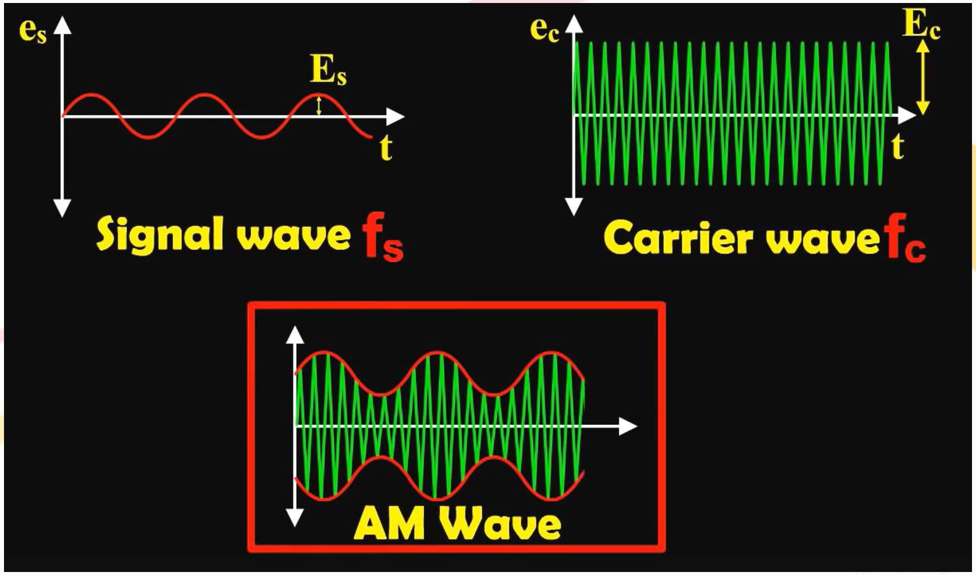


Figure : Amplitude modulation (AM)

How AM works

- **Amplitude Variation**: The extent of the amplitude variation (modulation depth) depends on the amplitude of the modulating signal.

- **Modulated Signal:** The result of amplitude modulation is a modulated signal that consists of the carrier wave with its amplitude varying in accordance with the modulating signal. This modulated signal contains the information encoded in the modulating signal.



Advantages of AM:

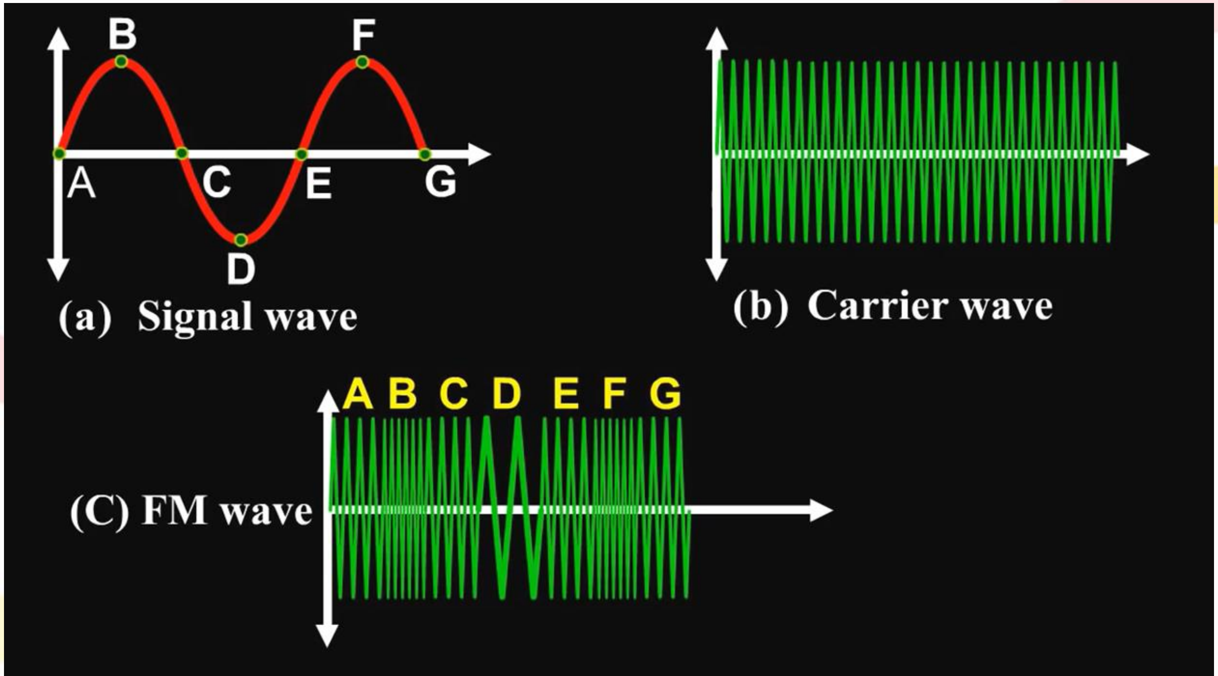
- Simplicity of implementation
- Wide coverage area, suitable for long-range broadcasting.
- Simple and inexpensive receivers, making it accessible

Disadvantages of AM:

- Lower fidelity compared to other modulation techniques,
- susceptible to noise and interference.
- Limited bandwidth efficiency
- Requires relatively high transmitter power
- Not well-suited for stereo or data transmission, primarily used for audio signals.

Frequency Modulation(FM)

- Frequency Modulation (FM) is a modulation technique, where the frequency of a carrier wave is varied in proportion to the amplitude of the modulating signal (the baseband signal) being transmitted.
- Unlike amplitude modulation (AM), where changes occur in the amplitude of the carrier wave, in FM, changes occur in the frequency of the carrier wave.



Modulation Process

- In frequency modulation, the frequency of the carrier wave is varied (modulated) in proportion to the amplitude of the modulating signal.
- When the modulating signal has a positive amplitude, the frequency of the carrier wave increases.
- Conversely, when the modulating signal has a negative amplitude, the frequency of the carrier wave decreases.

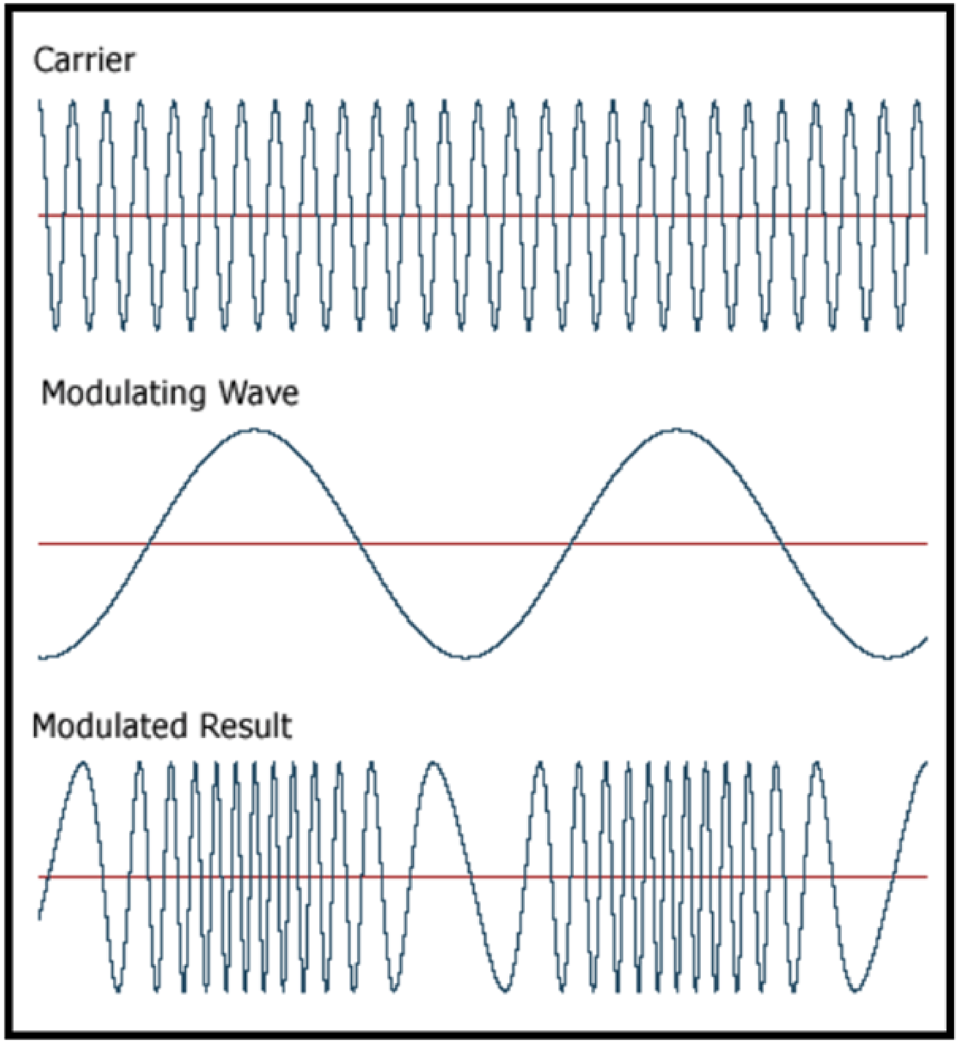


Figure : Frequency modulation (FM)

Application of FM

- Frequency modulation is commonly used in radio broadcasting, two-way radio communication, and various other applications where high-fidelity audio transmission is desired.
- FM radio stations transmit their audio content by modulating the frequency of the carrier wave, allowing listeners to tune in and receive the broadcast using FM radio receivers.

FM: Advantages

- Better noise immunity compared to amplitude modulation (AM),
- Resistance to amplitude variations
- Wide bandwidth efficiency, allowing for the transmission of multiple channels within a given frequency band.
- Improved signal quality, especially in high-frequency ranges, resulting in clearer reception and less distortion.
- Suitable for high-fidelity audio transmission, making it ideal for FM radio broadcasting and music transmission.

FM: Disadvantages

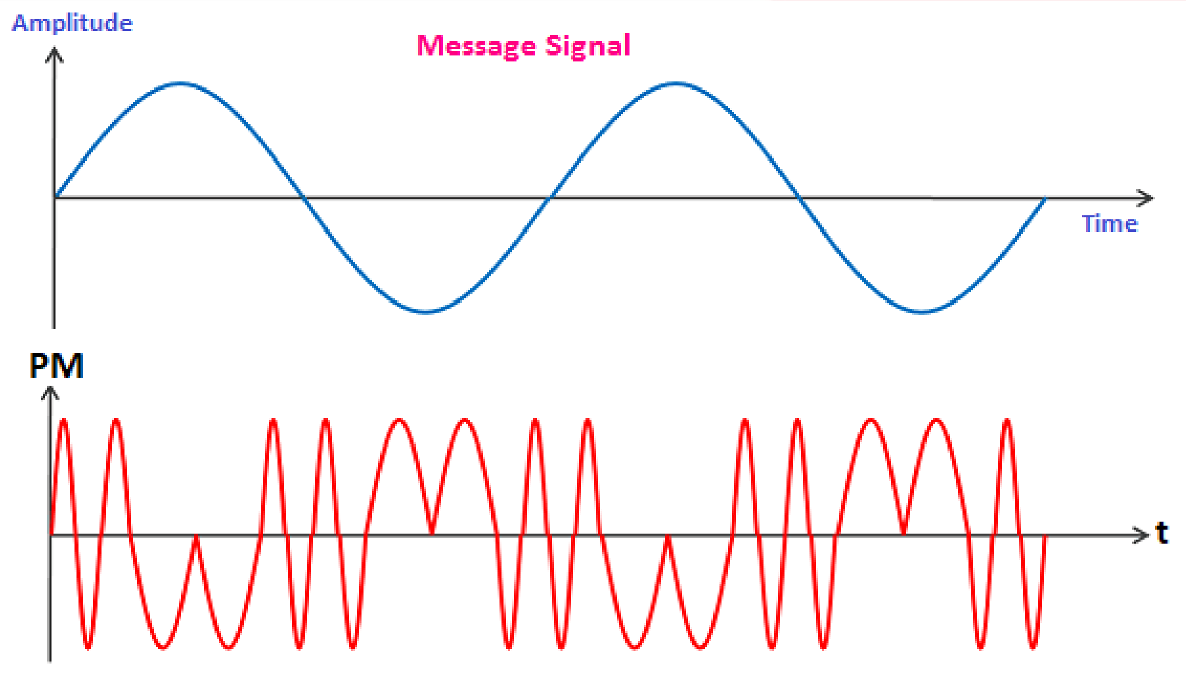
- **Complexity** of modulation and demodulation circuits, leading to higher implementation costs.
- **Lower power efficiency** compared to amplitude modulation (AM), requiring higher transmitter power for long-range broadcasting.
- **Limited coverage area** compared to amplitude modulation (AM), particularly in areas with obstacles or terrain features that affect signal propagation.
- Susceptibility to frequency-selective fading, resulting in occasional signal dropout or interference in certain environments.
- Less historical use in emergency communication compared to amplitude modulation (AM), due to its shorter range and higher power requirements.

Phase Modulation

- Phase Modulation (PM) is a modulation technique, where the phase of a carrier wave is varied in proportion to the amplitude of the modulating signal (the baseband signal) being transmitted.
- In PM, changes occur in the phase of the carrier wave, rather than its amplitude or frequency.

Modulation Process

- In phase modulation, the phase of the carrier wave is varied (modulated) in proportion to the amplitude of the modulating signal.
- When the modulating signal has a positive amplitude, the phase of the carrier wave shifts in one direction.
- Conversely, when the modulating signal has a negative amplitude, the phase of the carrier wave shifts in the opposite direction.



Advantages of Phase Modulation (PM):

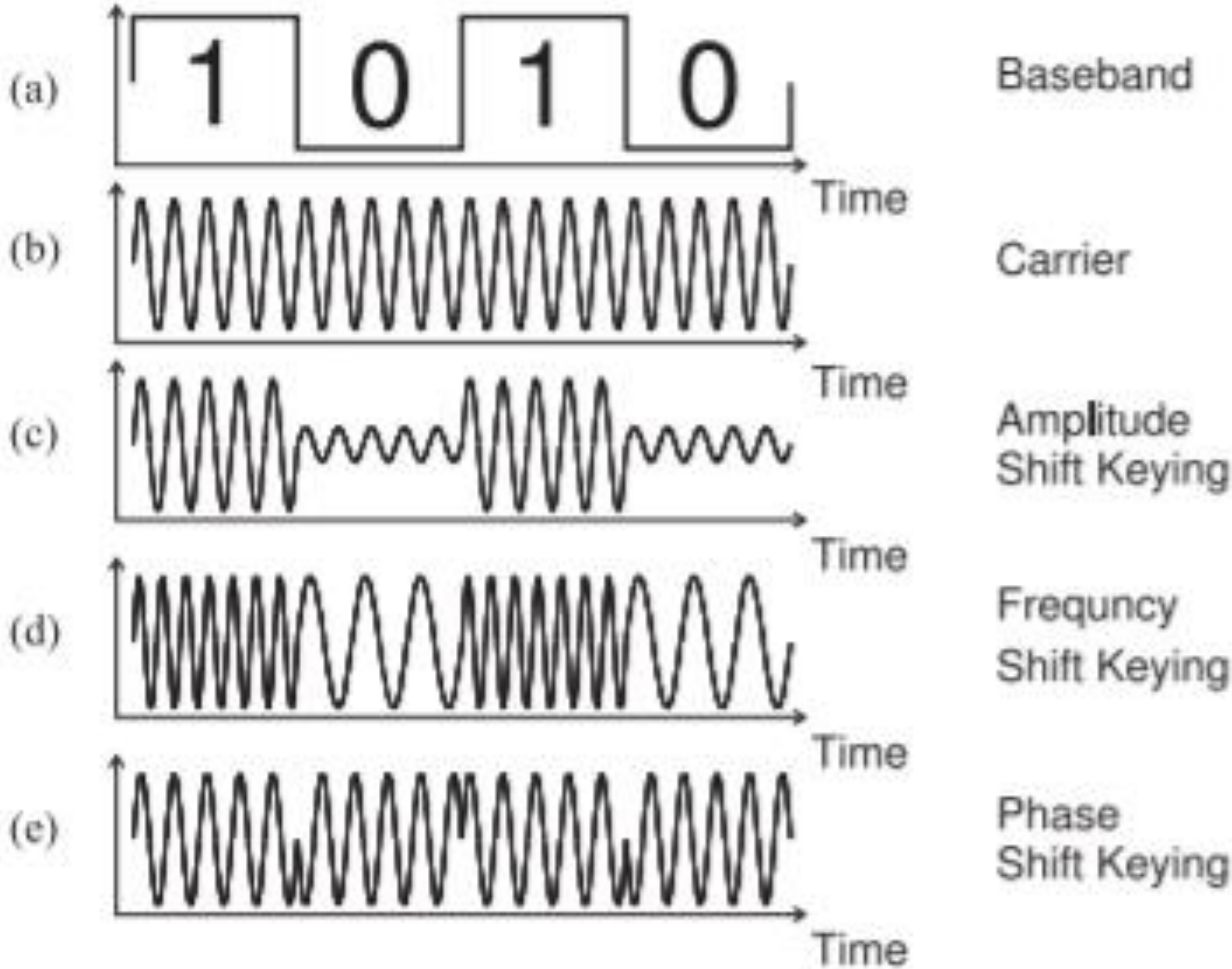
- Resistance to amplitude variations, making it less susceptible to changes in signal amplitude or signal-to-noise ratio.
- Wide bandwidth efficiency, allowing for the transmission of multiple channels within a given frequency band.
- Improved signal quality and noise immunity,

Disadvantages of Phase Modulation (PM):

- Complexity of modulation and demodulation circuits, leading to higher implementation costs.
- Limited coverage area compared to amplitude modulation (AM), particularly in areas with obstacles or terrain features that affect signal propagation.
- Higher power requirements compared to amplitude modulation (AM), especially for long-range broadcasting or high-speed data transmission.

Digital Modulation

- Digital modulation is a technique where digital data is modulated onto a carrier wave by varying one or more of the carrier wave's characteristics, such as amplitude, frequency, or phase, to represent the digital data.
- This process results in the generation of a digital modulated signal that can be transmitted over a communication channel.
- Digital modulation techniques include
  - Amplitude Shift Keying (ASK),
  - Frequency Shift Keying (FSK),
  - Phase Shift Keying (PSK),
  - Quadrature Amplitude Modulation (QAM), and others.
- Digital modulation is commonly used in digital communication systems such as wireless networks, satellite communication, and digital television.


(a)
1
0
1
0
Time
Baseband
(b)
Time
Carrier
(c)
Time
Amplitude
Shift Keying
(d)
Time
Frequncy
Shift Keying
(e)
Time
Phase
Shift Keying

Amplitude Shift Keying (ASK)

- Amplitude Shift Keying (ASK) is a modulation technique where digital data is transmitted by varying the amplitude of a carrier wave according to the binary signal being transmitted.
- In ASK, the presence of a particular binary symbol is represented by one amplitude level, while the absence of the symbol is represented by another amplitude level.

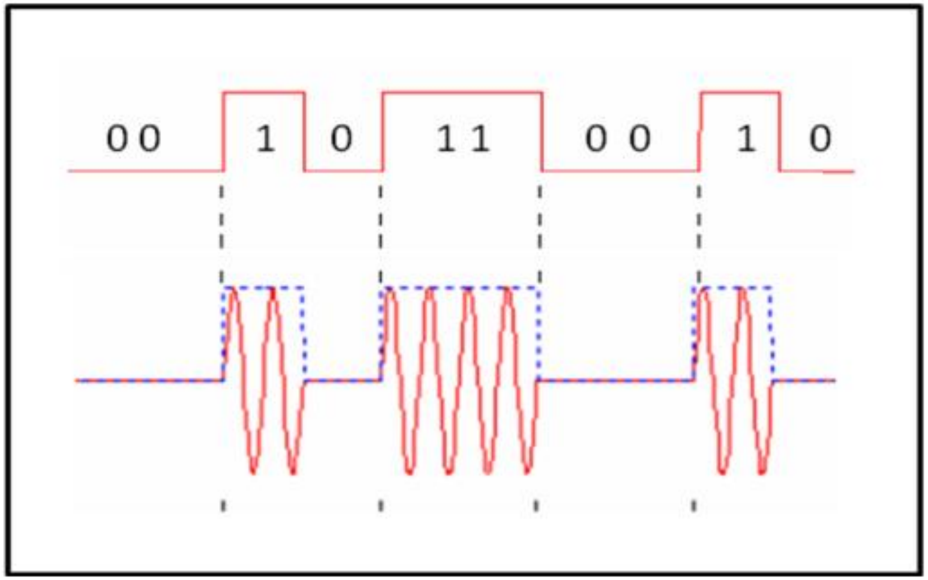


Figure : Amplitude Shift Keying (ASK

Modulation Process

- **Carrier Wave**: The carrier wave is a high-frequency signal with a constant frequency and phase.
  - It serves as the "carrier" for the modulating signal.
- **message/modulating signal**: The digital data to be transmitted is represented as a series of binary symbols (0s and 1s).
- **Modulation Process**:
  - In Amplitude Shift Keying, the amplitude of the carrier wave is varied to represent the binary symbols.
  - For example, one amplitude level (A1) can represent a binary "1", while another amplitude level (A0) can represent a binary "0".
- **Modulated Signal**: The result of Amplitude Shift Keying is a modulated signal that consists of the carrier wave with its amplitude varying in accordance with the binary data.
  - This modulated signal contains the information encoded in the binary symbols.

FREQUENCY SHIFT KEYING (FSK)

- Frequency Shift Keying (FSK) is a digital modulation technique where digital data is transmitted by varying the frequency of a carrier wave according to the binary signal being transmitted.
- In FSK, the presence of a particular binary symbol is represented by one frequency,
- while the absence of the symbol is represented by another frequency.

FSK Modulation process

- In Frequency Shift Keying, the frequency of the carrier wave is varied to represent the binary symbols.
- For example, one frequency (f1) can represent a binary "1",
- while another frequency (f2) can represent a binary "0".

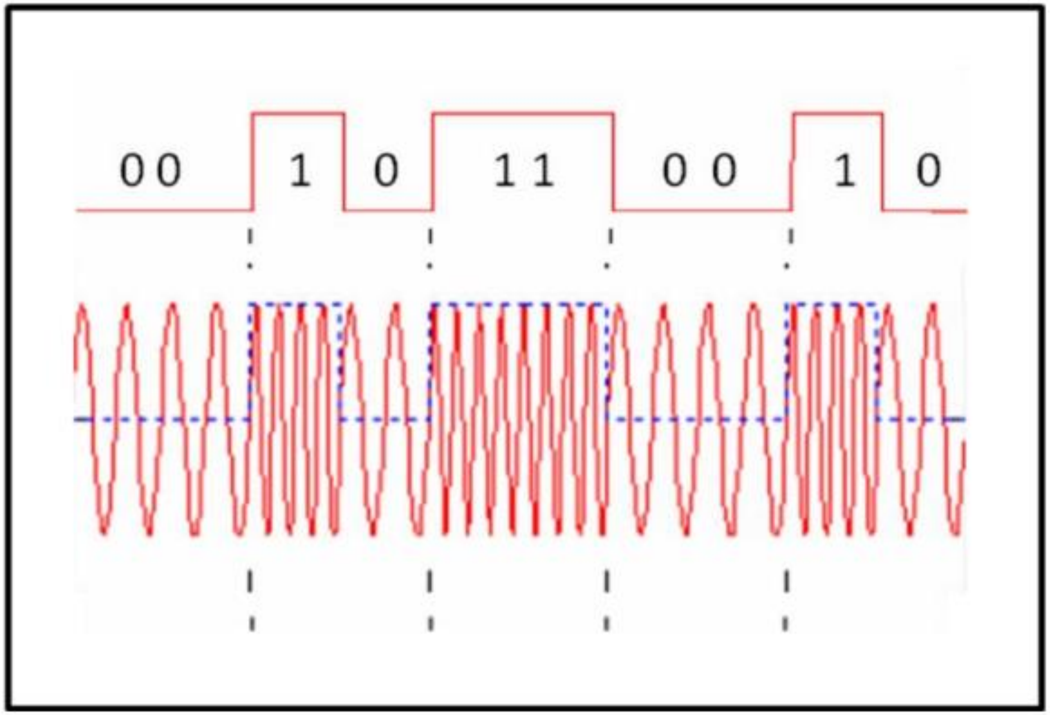


Figure : Frequency Shift Keying (FSK)

PHASE SHIFT KEYING (PSK)

- Phase Shift Keying (PSK) is a digital modulation technique where digital data is transmitted by varying the phase of a carrier wave according to the binary signal being transmitted.\
- In PSK, different phase shifts represent different binary symbols.

Modulation Process:

- In Phase Shift Keying, the phase of the carrier wave is varied to represent the binary symbols.
- Different phase shifts correspond to different binary symbols.
- For example, one phase shift (ϕ1) can represent a binary "1",
- while another phase shift (ϕ2) can represent a binary "0".

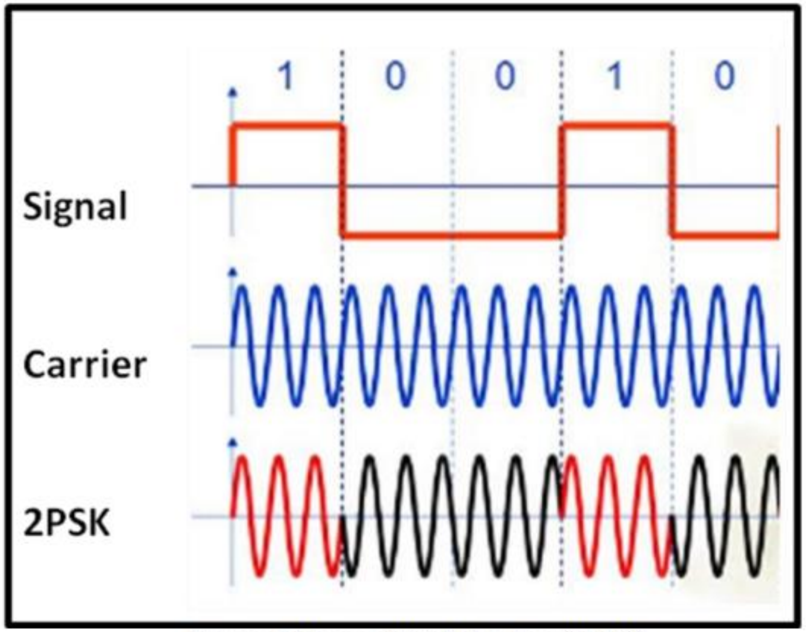


Figure: Phase Shift Keying (PSK)

END of UNIT 3

Thank You.