UNIT 3:
PHYISCAL LAYER

CONTENTS

Introduction; Circuits (Circuit Configuration, Data Flow, Multiplexing); Communication Media (Twisted Pair Cable, Coaxial Cable, Fiber-Optic Cable, Radio, Microwave, Satellite, Media Selection); Digital Transmission of Digital Data (Coding, Transmission Modes, Digital Transmission, How Ethernet Transmits Data); Analog Transmission of Digital Data (Modulation, Capacity of a Circuit, How Modems Transmit Data); Digital Transmission of Analog Data (Translating from Analog to Digital, How Telephones Transmit Voice Data, How Instant Messenger Transmits Voice Data, Voice over Internet Protocol).

- **Physical Layer:**
- The physical layer includes all the hardware involved in a network, such as servers, clients, and circuits.
- **Circuits** are crucial for data transmission. They consist of:
  - **Physical media:** Like cables and wireless signals.
  - **Special devices:** That help data travel through these media.
- **Understanding Circuits**
- **Two Meanings of Circuit:**

1. **Physical Circuit:**
   1. **Definition:** The actual hardware (e.g., cables) connecting two devices.
   2. **Example:** The twisted pair wire that connects a computer to a local network (LAN) in an office.
2. **Logical Circuit:**
   1. **Definition:** The way data is transmitted, not the physical connection.
   2. **Example:** A T1 connection that specifies the data transmission speed, not the type of wire used.

- **Key Points:**
- **Physical Circuit Example:** The Ethernet cable connecting your computer to a router.
- **Logical Circuit Example:** An internet service described as "100 Mbps," which tells you the speed of the connection, not the cable type.
- **Combining Physical and Logical Circuits:**
- Sometimes, **one physical circuit** (one wire) can carry **multiple logical circuits** (separate data streams).
  - **Example:** A single fiber optic cable used by an internet service provider can carry multiple internet connections.
- Conversely, **one logical circuit** can travel over **several physical circuits**.
  - **Example:** Your data from home to a website travels over several types of connections (cable, fiber optics, wireless).

- **Functions of Physical Layer**
- The physical layer consists of all the functions required to transmit a bitstream over a physical medium. Physical layer devices or layer 1 devices are Hub, Repeater, Modem, Cables.
- **Main Functions**
- The physical layer handles the basic task of sending a stream of bits (0s and 1s) over a physical medium, such as a cable or through the air.
- **Devices in the Physical Layer:**
- Hub
- Repeater
- Modem
- Cables
- **Main Functions:**

1. **Representation of Bits:** The physical layer takes the raw bitstream (0s and 1s) and converts it into signals.
2. **Types of Signals:**
    1. Electrical signals for cables
    2. Optical signals for fiber optics
    3. Radio or microwave signals for wireless communication
3. **Transmission:** It ensures these signals are transmitted over the chosen medium (cables, optical fibers, Wi-Fi, etc.).

2. **Data Rate (Transmission Rate):**

The number of bits sends each second is also defined by the physical layer. In other words, the physical layer defines the duration of a bit also.

3. Synchronization of bits:

It is necessary to have synchronization between sender and receiver at the bit level.

4. **Line configuration:**

Physical layer is concerned with connection of devices to the channel or medium, whether point to point or multi-point.

5. **Physical topology:**

The physical topology determines how devices are connected to create a network. Devices can be using a mesh topology, a star topology, a ring topology or a bus topology.

6. **Transmission mode:**

The mechanism of transferring data or information between two linked devices connected over a network is referred to as transmission mode.

- **Physical characteristics of media (Transmission medium):**

It represents the types of transmission medium i.e; guided medium or unguided medium.

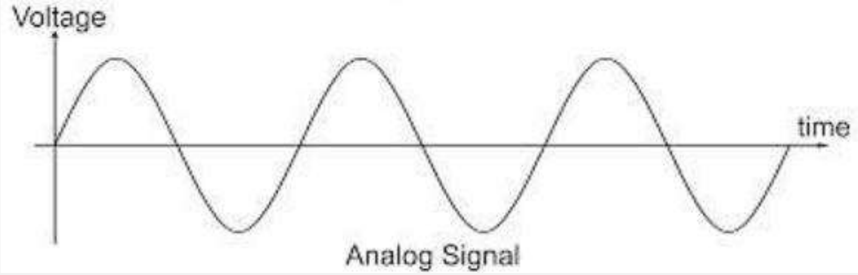
DATA AND SIGNALS

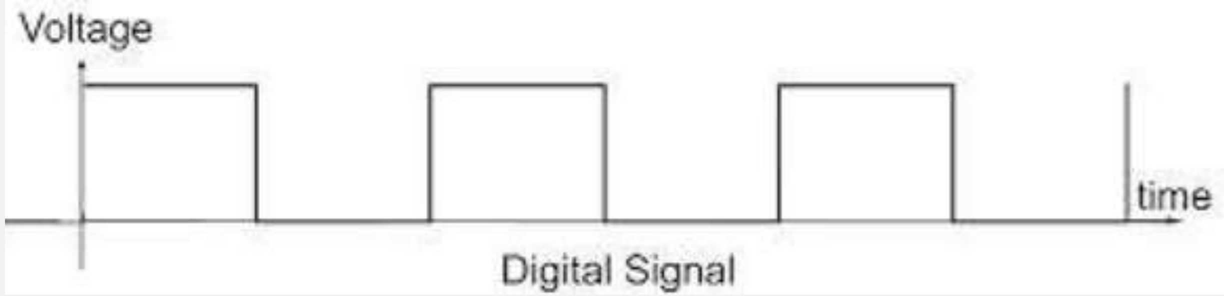
- The term analog data refers to information that is continuous; digital data refers to information that has discrete states. To be transmitted, data must be transformed to electromagnetic signals

- Analog and Digital signals:

A signal is an electromagnetic or electrical current that is used for carrying data from one system or network to another. A message encoded using electric current is called an electronic signal

Analog Signal	**Digital Signal**
•An analog signal is a continuous signal that represents physical measurements.	•Digital signals are time separated signals which are generated using digital modulation.
•It is denoted by sine waves.	•It is denoted by square waves.
•It uses a continuous range of values that help to represent information.	•Digital signal uses discrete 0 and 1 to represent information.
•The analog signal bandwidth is low.	•The digital signal bandwidth is high.
•Temperature sensors, FM radio signals, Light sensor, are examples of Analog signals.	•Computers, CDs, DVDs are some examples of Digital signal.

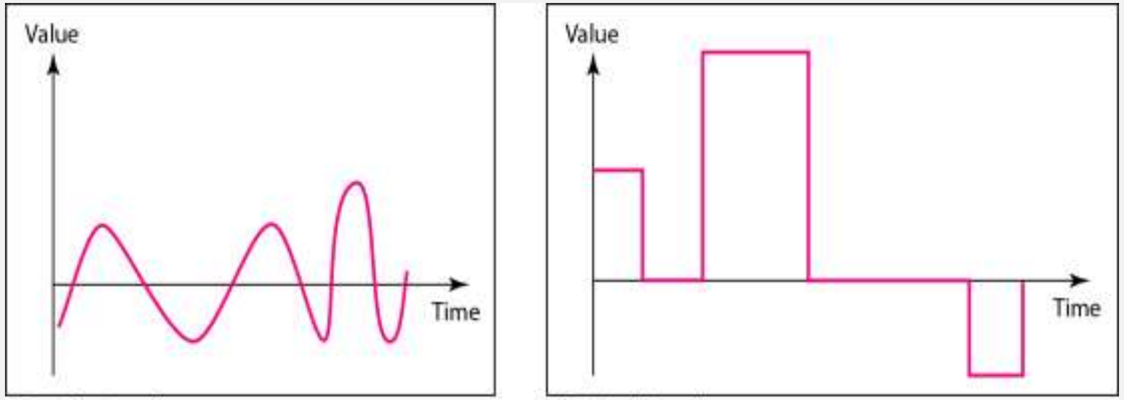




- **Signal:**

It is the encoding of data in the form of electric or electromagnetic form. A signal can be defined as a function of one or more variables in time or frequency which conveys information generally about state or behavior of a physical phenomena. Signal can be broadcast in two ways:

1. Time domain concept
2. Frequency domain concept



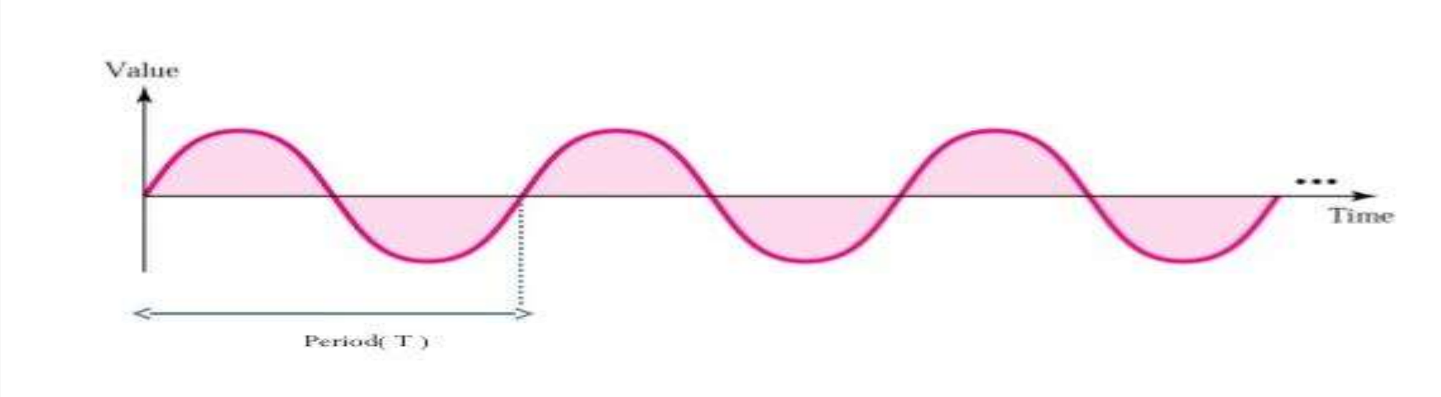
a. Analog signal b. Digital signal

1.Time Domain concept

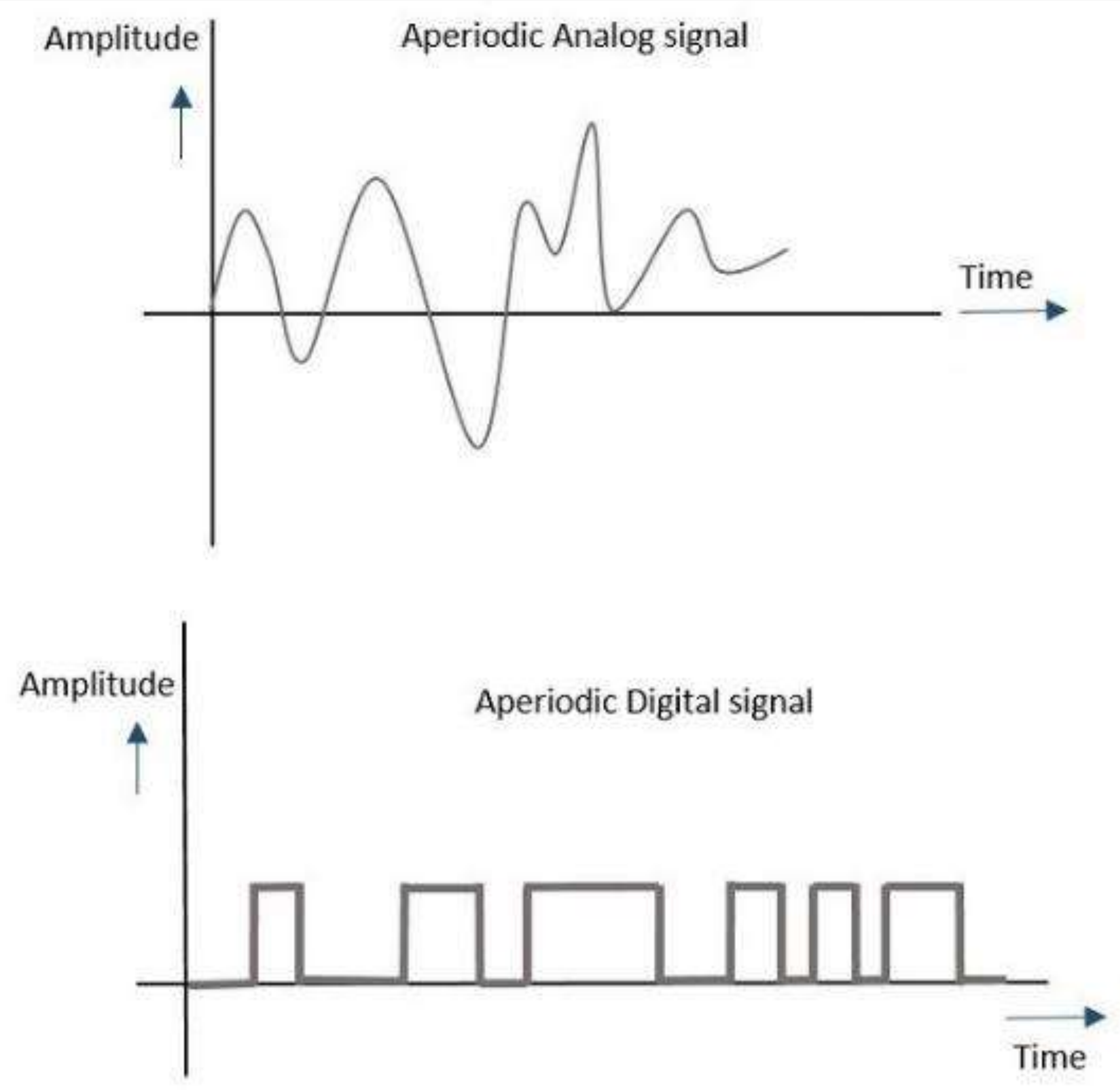
The time domain concept in data communication refers to the analysis of signals or functions in terms of their values at specific points in time. In other words, **it is the study of how a signal changes over time**. This concept is used to understand the behavior of signals in various communication systems, including digital and analog systems.

- What It Means: Looking at how a signal changes over time.
- Example: Imagine you're watching a video of someone speaking. You see their voice go up and down as they talk. This is like watching a signal in the time domain.
- Use: Helps to see what happens at each moment. For example, you can see each beat in a heartbeat.

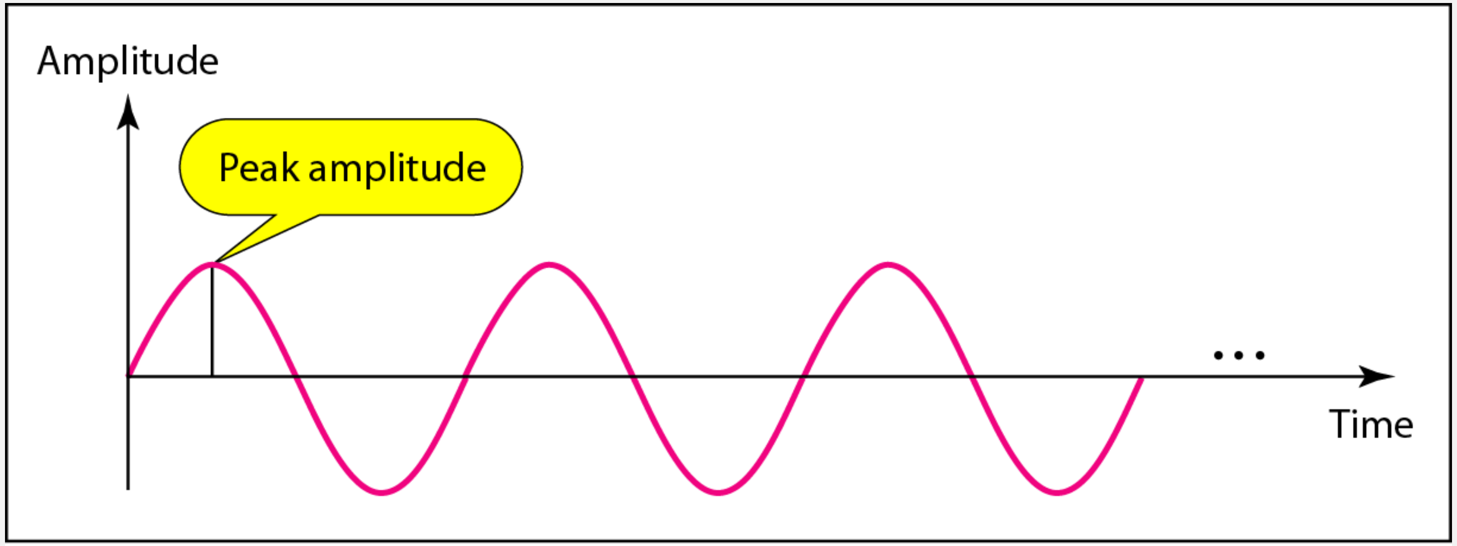
- **Periodic Signal:**
- **What It Means:** A signal that repeats itself at regular intervals over time.
- **Example:** Think of a clock ticking every second. Each tick happens at the same interval.
- **Visualization:** Imagine a wave that looks the same at regular intervals. For instance, a sine wave that repeats every cycle.
- **Characteristics:**
  - **Consistency:** The pattern of the signal is consistent and predictable.
  - **Repetition:** The signal's pattern repeats over a fixed period called the "period.“



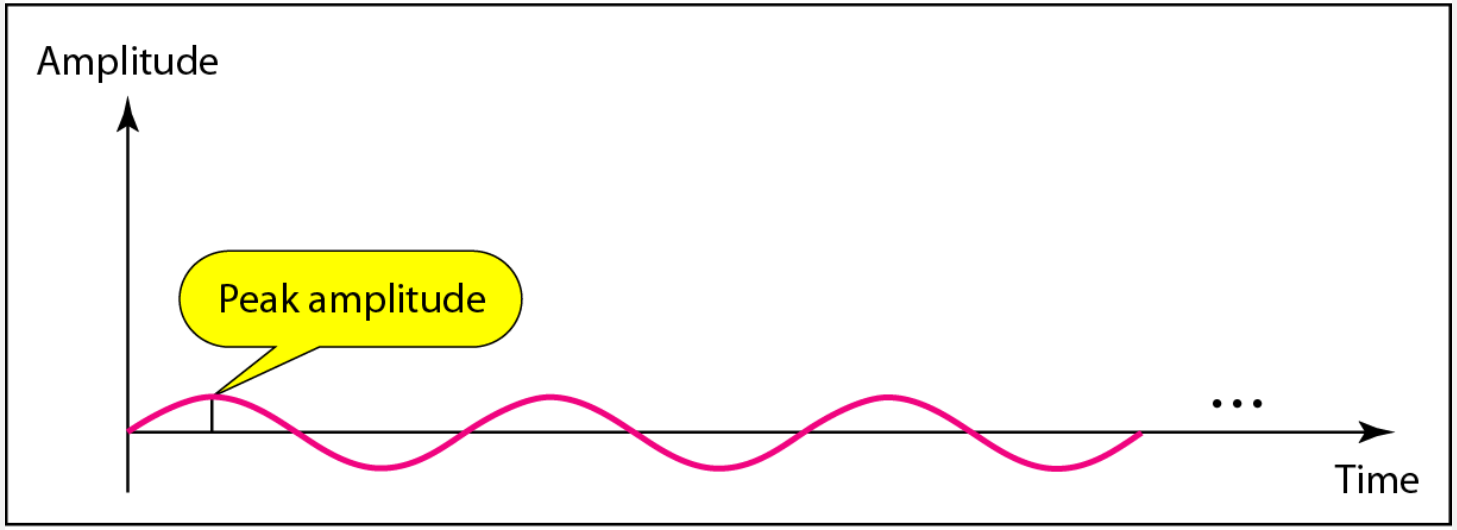
- **Non-Periodic Signal:**
- **What It Means:** A signal that does not repeat itself at regular intervals.
- **Example:** Think of someone talking. The sounds made vary and do not repeat in a regular pattern.
- **Visualization:** Imagine a wave that changes in an unpredictable way, with no repeating pattern.
- **Characteristics:**
  - **Variability:** The pattern of the signal is irregular and unpredictable.
  - **No Repetition:** The signal's pattern does not repeat over time.


Amplitude
Aperiodic Analog signal
Time
Amplitude
Aperiodic Digital signal
Time

- **Amplitude:**
- **Definition:** The amplitude of a signal is its height and represents the signal's strength.
- **Measurement:** Measured in voltage.
- **Symbol:** Denoted by ‘A’.
- **What It Shows:** How powerful or intense the signal is.
- **Visualization:** Imagine a wave on a graph. The amplitude is the height of the wave from its middle line to its peak.
- **Key Points:**
- **Higher Amplitude:** Means a stronger signal.
- **Lower Amplitude:** Means a weaker signal.
- **Simple Example:**
- **Sound Wave:** A louder sound has a higher amplitude, and a quieter sound has a lower amplitude



a. A signal with high peak amplitude



b. A signal with low peak amplitude

- Frequency:
- **Frequency** is the number of occurrences of a repeating event per unit of time

OR

- Frequency is how often something happens within a specific amount of time.
- Measurement: It is measured in cycles per second, called Hertz (Hz).
- Symbol: Denoted by ‘f’.
- What It Shows: How often the signal repeats itself.

- **Key Points:**
- **Higher Frequency:** Means the signal repeats more often.
- **Lower Frequency:** Means the signal repeats less often.
- **Mathematical Formula:** The time period (t) is the inverse of the frequency.
    - Formula: $t=1/f$
    - Where t is the time period (how long one cycle takes).
- Example:
- If your heart beats 60 times in one minute, the frequency is 1 beat per second, or 1 Hz.
- F= Number of heartbeats/ time period in seconds
- F = 60 beats / 60 seconds = 1 beat per second (Herts or Hz)

- Example: There are two dogs walking in a circle. First dog can walk the circle 6 times in 2 seconds and second dog can walk 4 time in 2 seconds what is the frequency?
- First dog:

Circles: 6

Circles Time: 2 seconds

Frequency Calculation:

- Frequency f1=Number of circles/ Time= 6 circles /2 seconds=3 Hz

- For second dog:

F = 4/2 = 2 Hz

So Dog 1's Frequency: 3 Hz (can walk the circle 3 times per second)

Dog 2's Frequency: 2 Hz (can walk the circle 2 times per second)

- The period of signal is 100ms. What is its frequency in kilohertz?

First Convert 100ms to second: 100ms/1000 = 0.1 seconds

So, t = 0.1

F = 1 / t

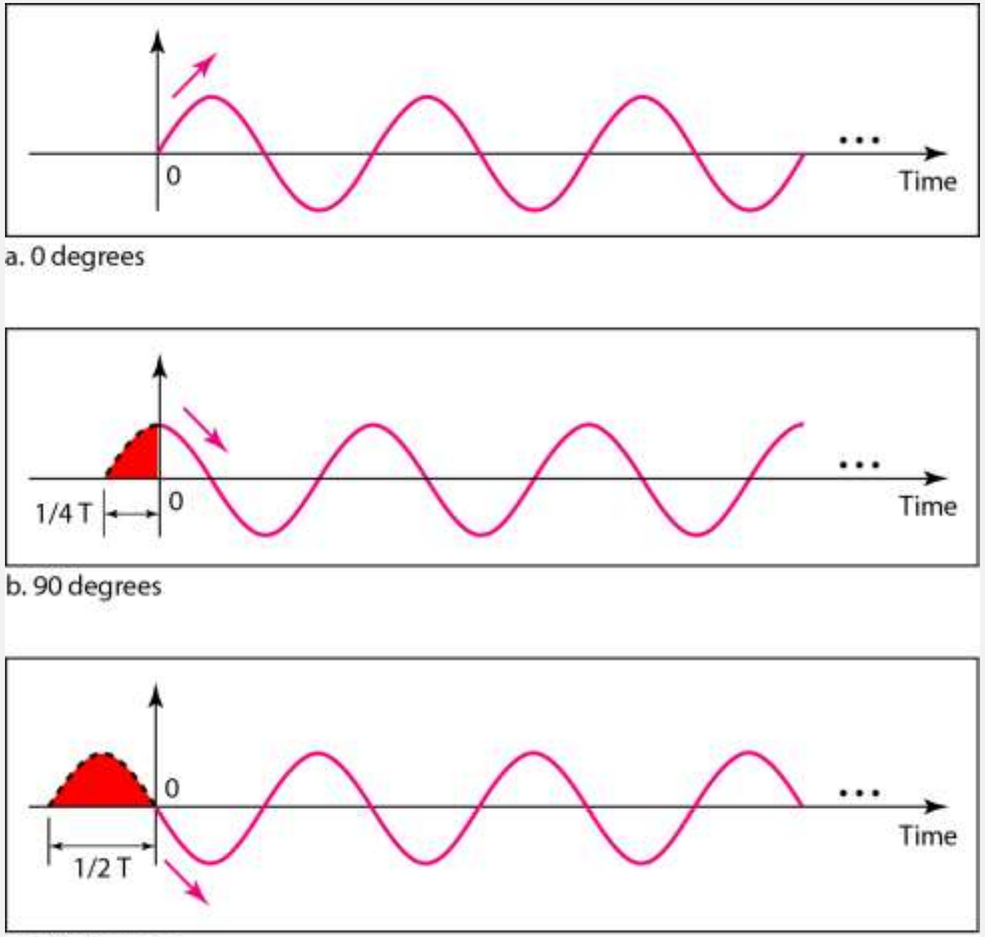
F= 1/ 0.1 = 10 Hz

To convert hz to khz

1 KHz = 1000 Hz

F = 10 hz / 1000 = 0.01 Khz

- Phase:
- Describe the position of wave relation to time 0
- Unit: Radians / Degrees



a. 0 degrees
b. 90 degrees
c. 180 degrees

0 Degrees

•**Wave Start**: The sine wave begins at the origin (0) and starts moving upward.

•**Wave Pattern**: This is the basic, unshifted wave. It follows the regular sine pattern, starting from zero, peaking, crossing zero again, and reaching a negative peak before returning to zero.

90 Degree wave

The wave is shifted by 90 deg, equivalent to one quarter.

Wave start: wave begins at maximum positive amplitude.

Effect: this shift causes the wave to reach its peak at the point where the 0 degree wave is just starting. The entire wave is moved to the left by quarter f its cycle

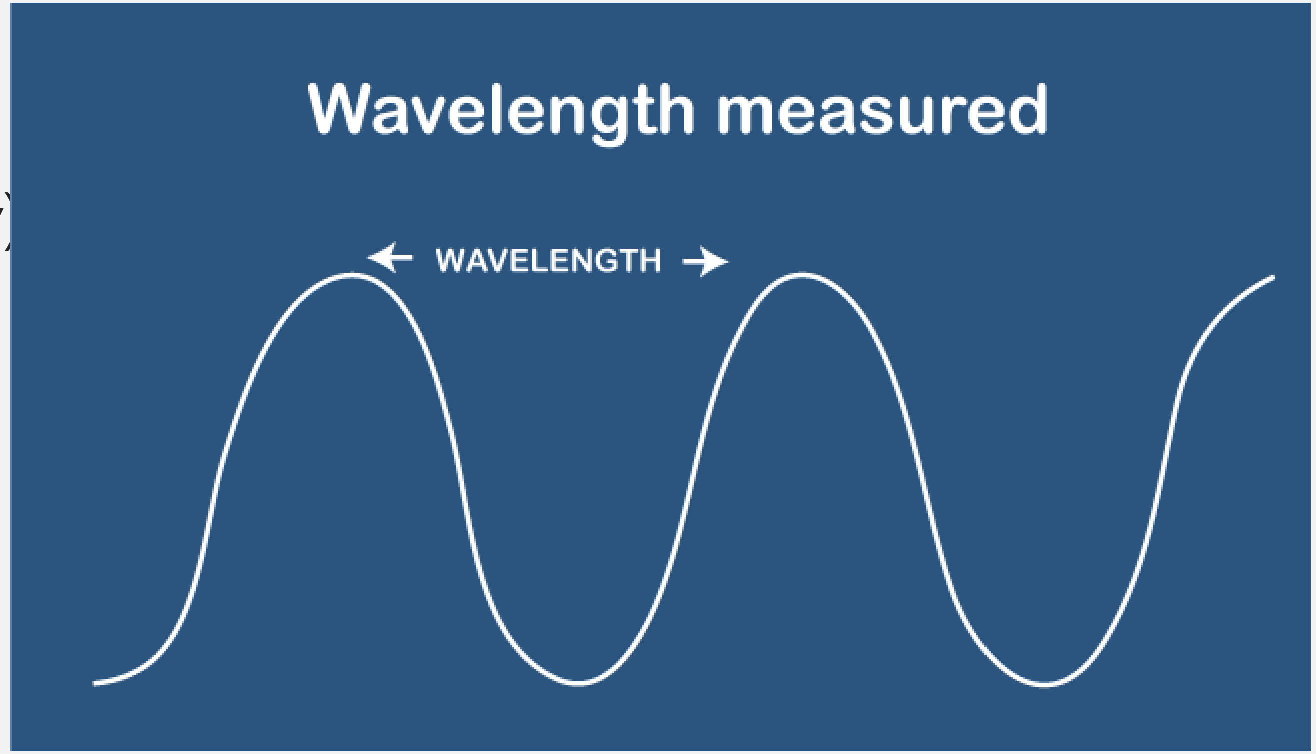
180 Degree Wave

The wave is shifted 180 degree, whish is half of it period

Wave start: wave starts at its minimum amplitude, which is opposite to 0 degree wave's starting point

Effect: this shift causes the wave to begin at negative peak, moving upward zero to its positive peak. Wave is shafted to the left by half circle.

- Wavelength
- Wavelength is the distance between two identical points on consecutive waves. It is also known as the distance occupied by a single and it is denoted by λ
- Wavelength = λ=v / f
- λ (lambda) is the wavelength,
- v is the wave's speed (velocity)
- f is the frequency of the wave.



- 2. Frequency Domain Concept

- Represents signals in terms of their frequency components, useful for analyzing and processing signals in various applications.

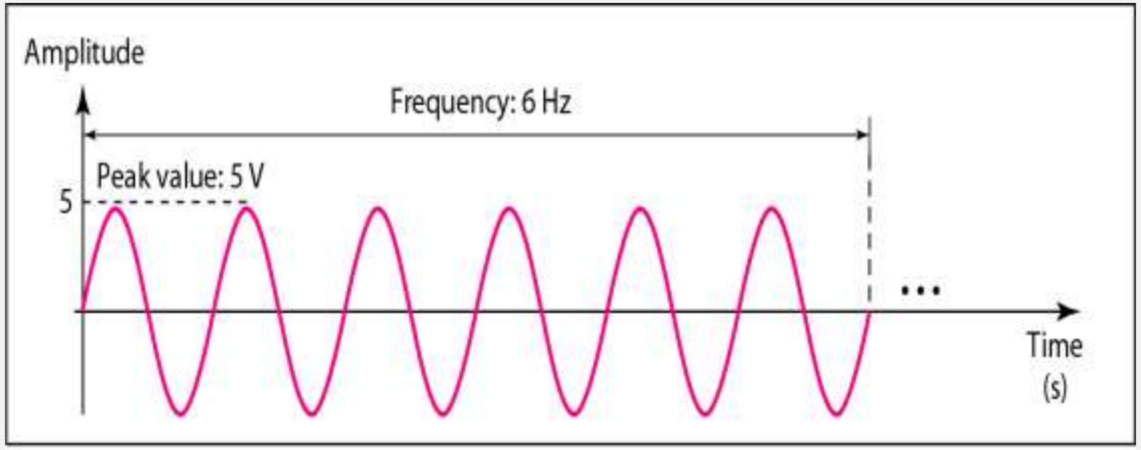
Explanation:

a. Time Domain (Top Graph):

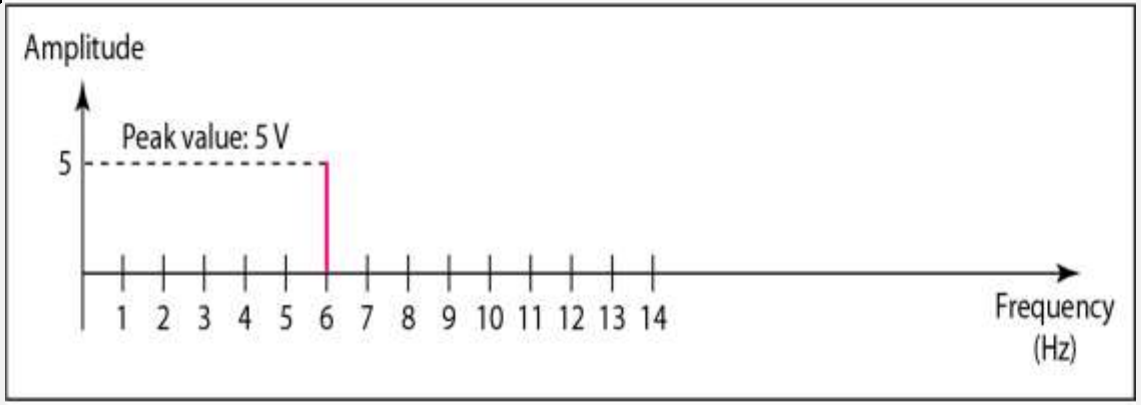
- **Graph Description:**
  - The x-axis represents time (in seconds).
  - The y-axis represents amplitude (in volts).
  - The sine wave oscillates with a peak value of 5 volts and a frequency of 6 Hz.
- **Key Points:**
  - **Amplitude:** The height of the wave from the centerline to the peak is 5 volts.
  - **Frequency:** The wave completes 6 cycles every second (6 Hz).

b. Frequency Domain (Bottom Graph):

- **Graph Description:**
  - The x-axis represents frequency (in Hertz, Hz).
  - The y-axis represents amplitude (in volts).
- **Key Points:**
  - **Single Peak at 6 Hz:** There is a single peak at 6 Hz with an amplitude of 5 volts.
  - This means that the sine wave in the time domain has one frequency component, which is 6 Hz.

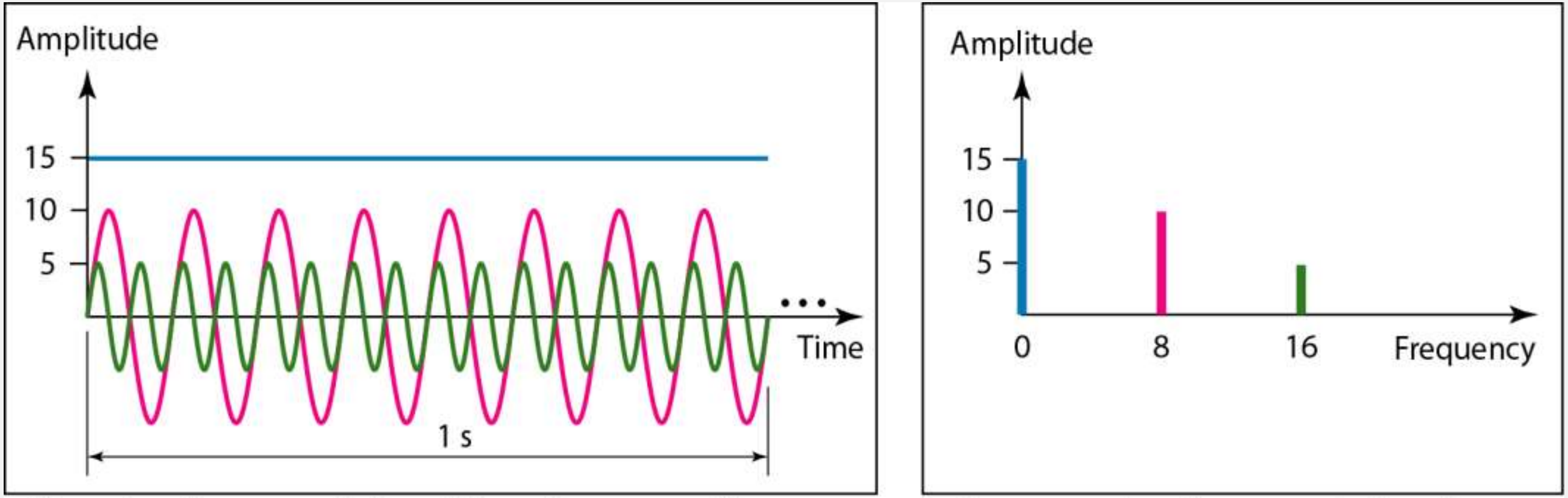


a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)



b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

- Draw the diagram for time domain and frequency domain
- 5V amplitude with 16Hz Frequency
- 10V amplitude with 8Hz Frequency
- 15V amplitude with 0Hz Frequency



a. Time-domain representation of three sine waves with frequencies 0, 8, and 16

b. Frequency-domain representation of the same three signals

- **Spectrum:**
- **Definition:** The spectrum is the range of all the frequencies that a signal contains.
- **Explanation:** Think of the spectrum like a rainbow, but instead of colors, it shows all the different frequencies in a signal.
- **Example:** If you have a radio signal, its spectrum would include all the different frequencies that make up that signal.
- **Bandwidth:**
- **Definition:** Bandwidth is a measure of how much information can be sent from one place to another in a given amount of time.
- **Units:** It can be measured in Hertz (Hz) if talking about frequencies, or in bits per second (bps) if talking about data transfer.
- **Mathematical Formula:** Bandwidth=Highest Frequency−Lowest Frequency
- **Example:** If a signal has frequencies ranging from 20 Hz to 50 Hz:
- Bandwidth=50 Hz−20 Hz=30 Hz

- **Bit rate:**
- It is a rate at which information can be transmitted in 1sec. It is measured in terms of bits per second (bps).

- **Baud Rate:**
- Total number of bits used to represent a single information.
- Example: 3- 11 (2 bit)
- 3- 011 (3 bit)
- 3- 0011 (4 bit)

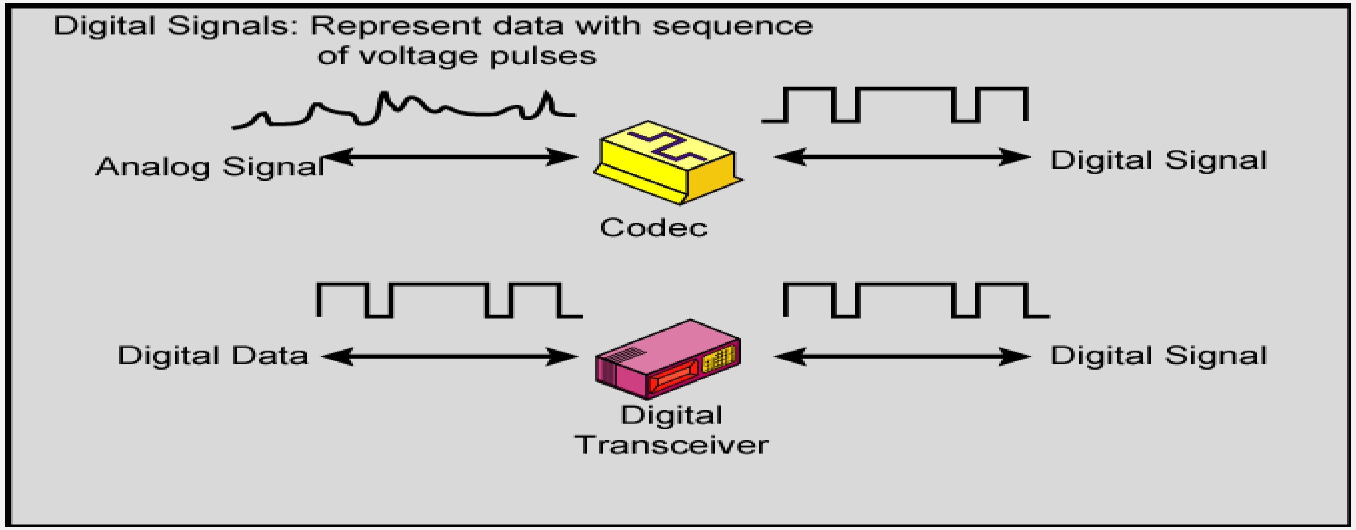
- **Analog and Digital Data Transmission:**
- **Analog Data:**
- 1. Audio Signals: (Human Speech)
- frequency range 20Hz-20kHz (speech 100Hz-7kHz)
- easily converted into electromagnetic signals
- Varying volume converted to varying voltage. The telephone handset contains a simple mechanism for making such a
- conversion. can limit frequency range for voice channel to 300-3400Hz
- 2. Video Signals: (produced by Video Camera)
- Frequency range 0 to 6 MHz
- **Digital Data:**
- as generated by terminals, computers, and other data processing equipment and then converted into digital voltage pulses for transmission uses two constant (dc) voltage levels, one level for binary 1 and one level for binary 0.
- In a communications system, data are propagated from one point to another by means of electromagnetic signals. Both analog and digital signals may be transmitted on suitable transmission media.

- **Analog Transmission Overview:**

1. **Signal Types:**
    1. In analog transmission, signals can originate as either analog or digital but are sent as continuously varying electromagnetic waves (analog signals).
    2. These signals can be transmitted over various media depending on the frequency spectrum used.
2. **Transmission Media:**
    1. **Wired Media:** Includes twisted pair cables, coaxial cables, and fiber optic cables.
    2. **Unguided Media:** Includes atmospheric or space propagation, where signals are transmitted through the air or space without physical conduits.
3. **Content Independence:**
    1. Analog transmission focuses on the transmission of signals rather than their content. It doesn't inherently process or interpret the data being transmitted.
4. **Signal Amplification:**
    1. For long-distance transmission, amplifiers are used to boost the signal's energy.
    2. However, amplifiers also increase the noise in the signal, which can distort the original signal.

- **Digital Transmission Overview:**

1. **Signal Type:**
    1. Digital transmission uses sequences of voltage pulses, known as digital signals, transmitted over wire media.
2. **Data Conversion:**
    1. Both analog signals and digital data from the source are converted into digital form for transmission.
3. **Analog to Digital Conversion:**
    1. Analog data is converted to digital using a **codec** (coder-decoder).
    2. The codec takes an analog signal (like voice) and approximates it as a bit stream.
4. **Digital Data Representation:**
    1. Digital data is directly represented by digital signals without the need for conversion.

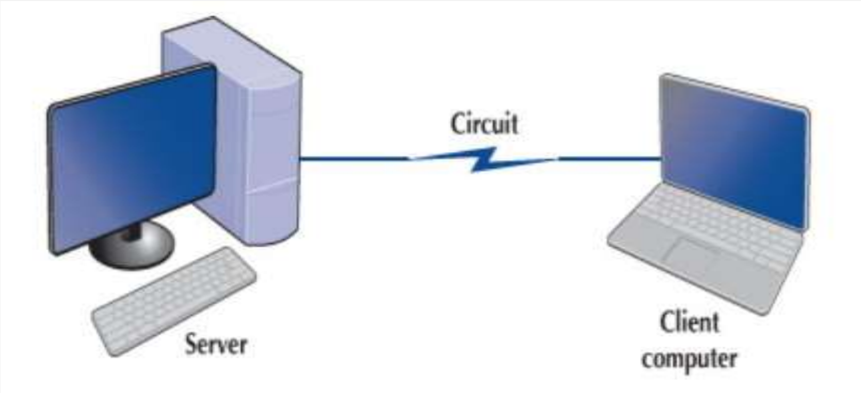


- **Digital Transmission over Analog Transmission**
- • Digital technology
- - Continuous drop in cost and size of digital circuits as compared to Analog equipment
- • Data Integrity
- - Digital signals are less susceptible to noise and repeaters are used instead of amplifiers, so maintains data integrity
- • Capacity Utilization
- - Easier to multiplex several digital signals
- • Security and Privacy
- - Encryption technique can be used
- • Integration
- - All signals in different format (audio, video or text) are integrated into a common format of 1 and 0.

- **Circuit Configuration Overview:**

1. **Basic Layout:**
    1. Circuit configuration refers to the physical layout of a circuit.
2. **Types of Configurations:**
    1. There are two fundamental types: **point-to-point** and **multipoint**.
3. **Point-to-Point Communication:**
    1. **Definition:** A circuit that connects two specific points, such as one computer to another.
    2. **Also Known As:** Dedicated circuit, because it is exclusively used by these two devices.
    3. **Use Case:** Ideal when the devices generate enough data to fully utilize the circuit's capacity.

- When an organization builds a network using point- to-point
- circuits, each computer has its own circuit running from itself to the
- other computers. This can get very expensive, particularly if there is
- some distance between the computers. Despite the cost, point-to-
- point circuits are used regularly in modern wired networks to
- connect clients to switches, switches to switches and routers, and
- routers to routers.



- **Multipoint Circuit Overview:**

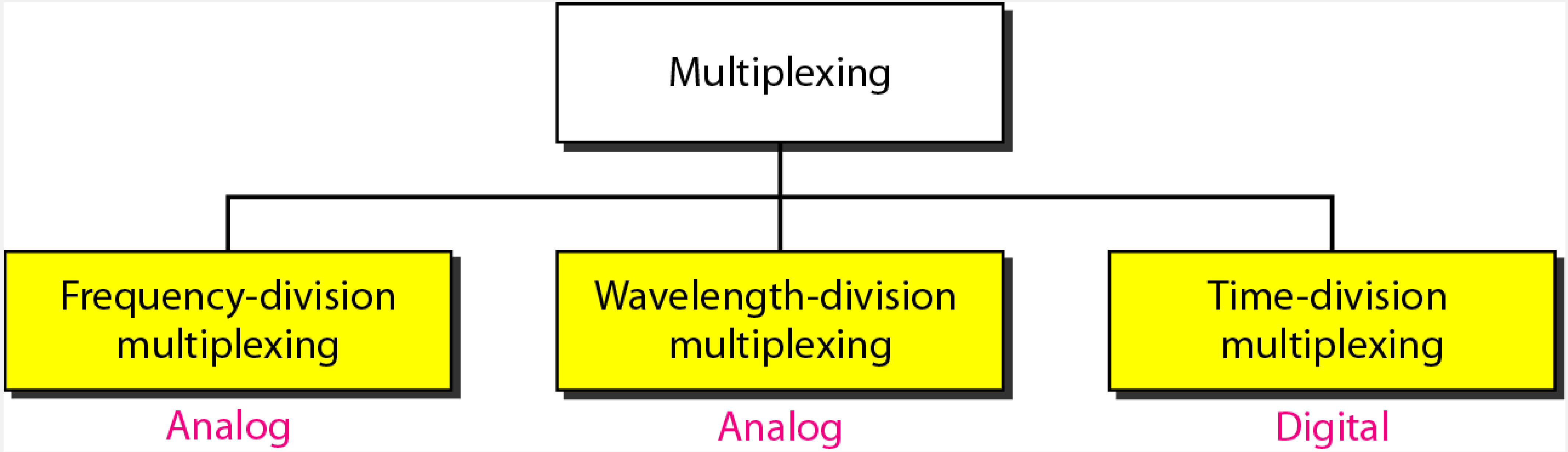
1. **Definition:**
    1. A configuration where multiple computers share the same circuit.
2. **Characteristics:**
    1. Only one computer can use the circuit at a time.
    2. Other computers must wait their turn to send or receive data.
3. **Advantages:**
    1. Reduces the amount of cabling required.
    2. Efficiently uses the communication circuit's capacity.
4. **Use Cases:**
    1. Ideal when devices don’t need continuous access to the full circuit capacity.
    2. Preferred when point-to-point circuits are too costly.
5. **Wireless Circuits:**
    1. Almost always multipoint, as multiple devices share the same radio frequencies and take turns transmitting.

- DATA FLOW
- Circuits can be designed to permit data to flow in one direction or in both directions. Actually, there are three ways to transmit: simplex, half-duplex, and full-duplex

1. **Simplex:**
    1. **Definition:** Data flows in one direction only.
    2. **Example:** Television broadcast, where the signal is sent from the station to your TV.
2. **Half-Duplex:**
    1. **Definition:** Data can flow in both directions, but not at the same time.
    2. **Example:** Walkie-talkies, where you press a button to talk and release to listen.
3. **Full Duplex:**
    1. **Definition:** Data can flow in both directions simultaneously.
    2. **Example:** Telephone calls, where both parties can speak and listen at the same time.

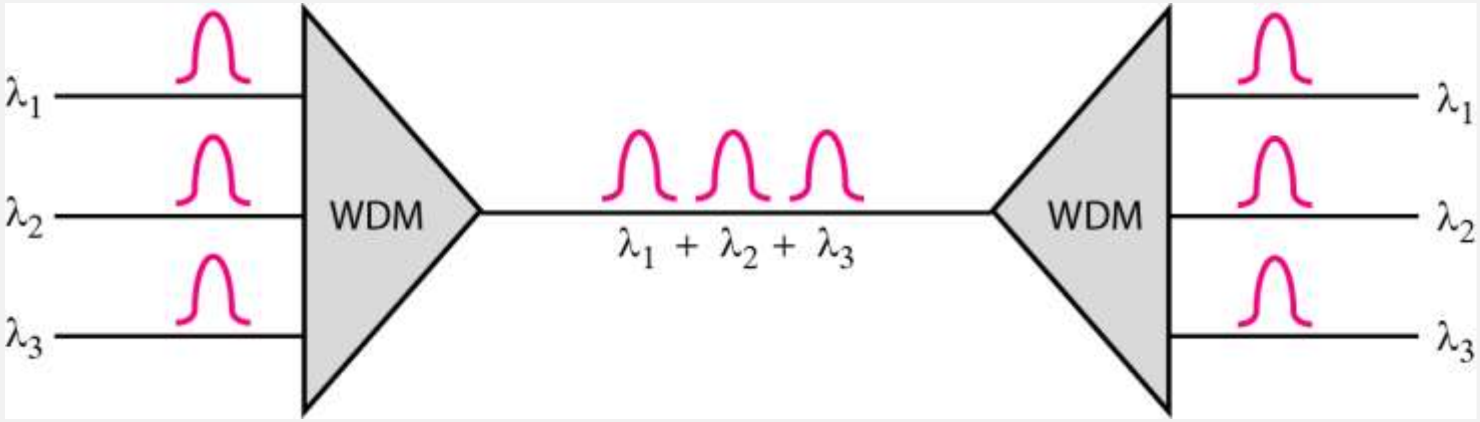
- Multiplexing Techniques
- It is the process in which multiple signals coming from multiple sources are combined and transmitted over a single communication/physical line.
- n input lines share the bandwidth of one link.
- Multiplexer(MUX) combines input lines into a single stream(many-to-one).
- De-multiplexer(DEMUX) separates the stream back into its component transmissions and directs them to corresponding lines.
- Channel:- portion of a link that carries a transmission between a given pair of lines.

- **Categories of multiplexing**

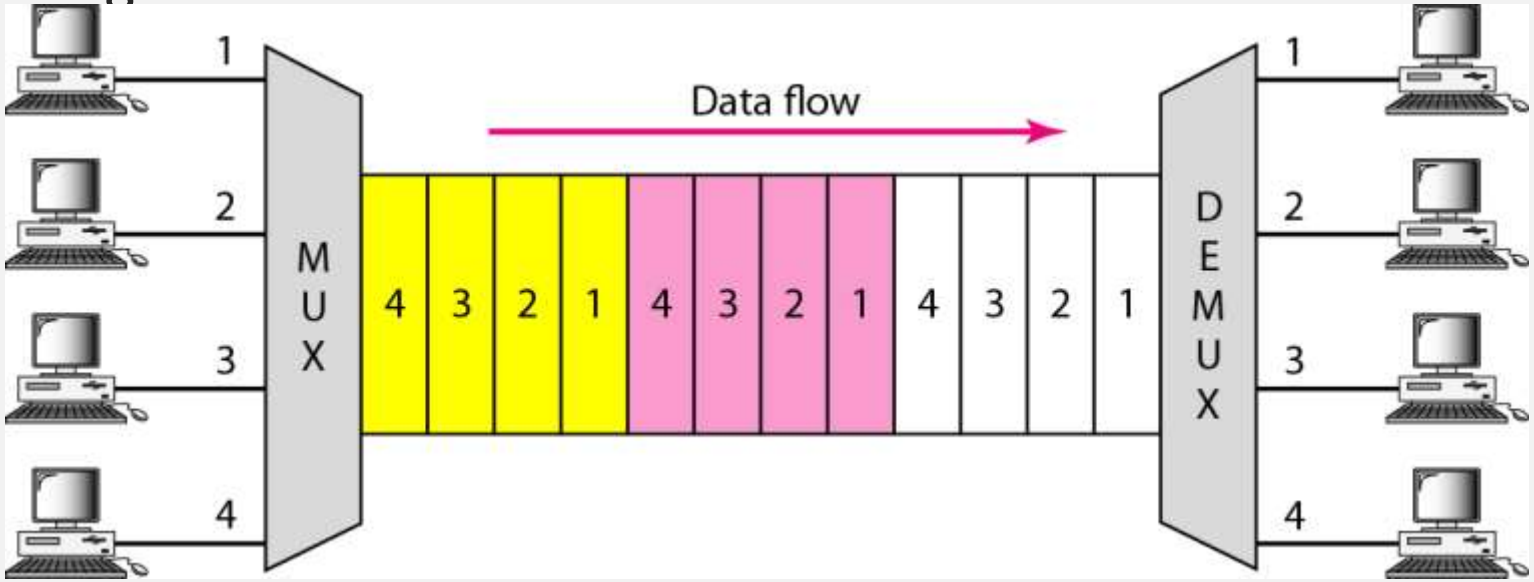


- **Frequency-division multiplexing (FDM)**
- Frequency division multiplexing is defined as a type of multiplexing where the bandwidth of a single physical medium is divided into a number of smaller, independent frequency channels.
- Frequency Division Multiplexing is used in radio and television transmission.
- Channels are separated by certain guard bands to prevent interference

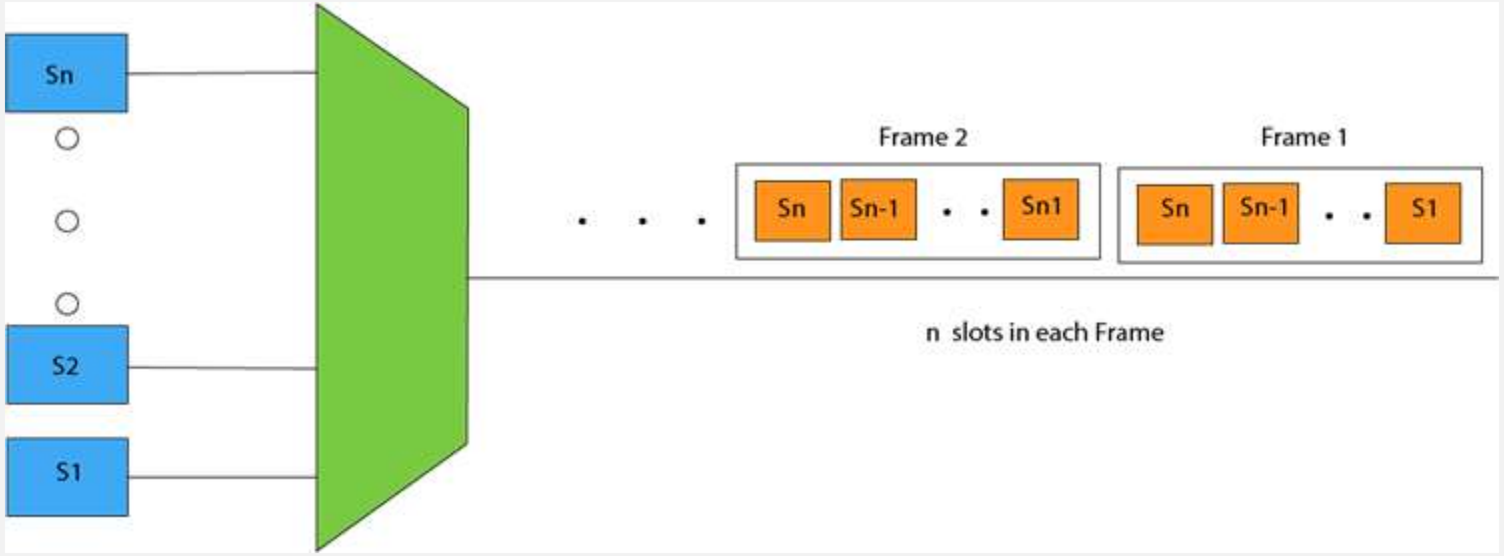
- **Wavelength-division multiplexing (WDM)**
- Conceptually same as FDM but multiplexing and de-multiplexing involve optical signals transmitted through fiberoptic channels.
- Very narrow beams of light(many colors or wavelengths) from different sources are combined to make a wider band of light



- **Time Division Multiplexing (TDM):**
- 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.
- n TDM, the signal is transmitted in the form of frames.



- **Synchronous Time Division Multiplexing**
- A Synchronous TDM is a technique in which time slot is preassigned to every device.
- In Synchronous TDM, 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
- If there are n devices, then there are n slots.



- **Statistical Time Division Multiplexing**
- Dynamic Allocation: Time slots are dynamically assigned to input lines based on demand. Only active data streams that have data to send are allocated slots.
- Efficiency: STDM is designed to handle variable data rates and optimizes bandwidth usage by reducing the number of unused slots.
- In statistical TDM, a slot need to carry data as well as the address of the destination because there are no pre-assigned or reserved slots.
- Suitable for networks where data traffic is bursty and unpredictable, such as in packet-switched networks.

- **Advantages and Disadvantages of multiplexing techniques**

Multiplexing Techniques	Advantages	Disadvantages
Frequency Division Multiplexing	- Simple - Popular with radio, TV, cable TV, All the receivers, such as cellular telephones, do not need to be at the same location	- Noise problems due to analog signals - Waste bandwidth - Limited by frequency ranges
Synchronous Time Division Multiplexing	- Digital signals - Relatively simple	- Waste bandwidth
Statistical Time Division Multiplexing	- More efficient use of bandwidth frame can contain control and error information - Packets can be of varying size	- More complex than synchronous time division multiplexing
Wavelength Division Multiplexing	- Very high capacities over fiber signals can have varying speeds scalable	- Cost - Complexity

- **Communication Media (Transmission Media)**
- A transmission medium is required to carry information from a source to a destination. The information is usually a signal that has to travel a long distance. For this the transmission media can be wired or wireless.
- In wired transmission, the signal travels along the cable from one device to another. But in wireless transmission the electromagnetic waves are transmitted without using a physical conductor.

- Types of Communication Media
- **1. Guided Media (Bounded Media):**
- These media transmit signals electrically or light over cable or wire. Eg: twisted pair cable, coaxial cable, and optical fiber.
- Following are the three common types of guided media:
- 1. Twisted Pair
- 2. Coaxial Cable
- 3. Optical Fiber

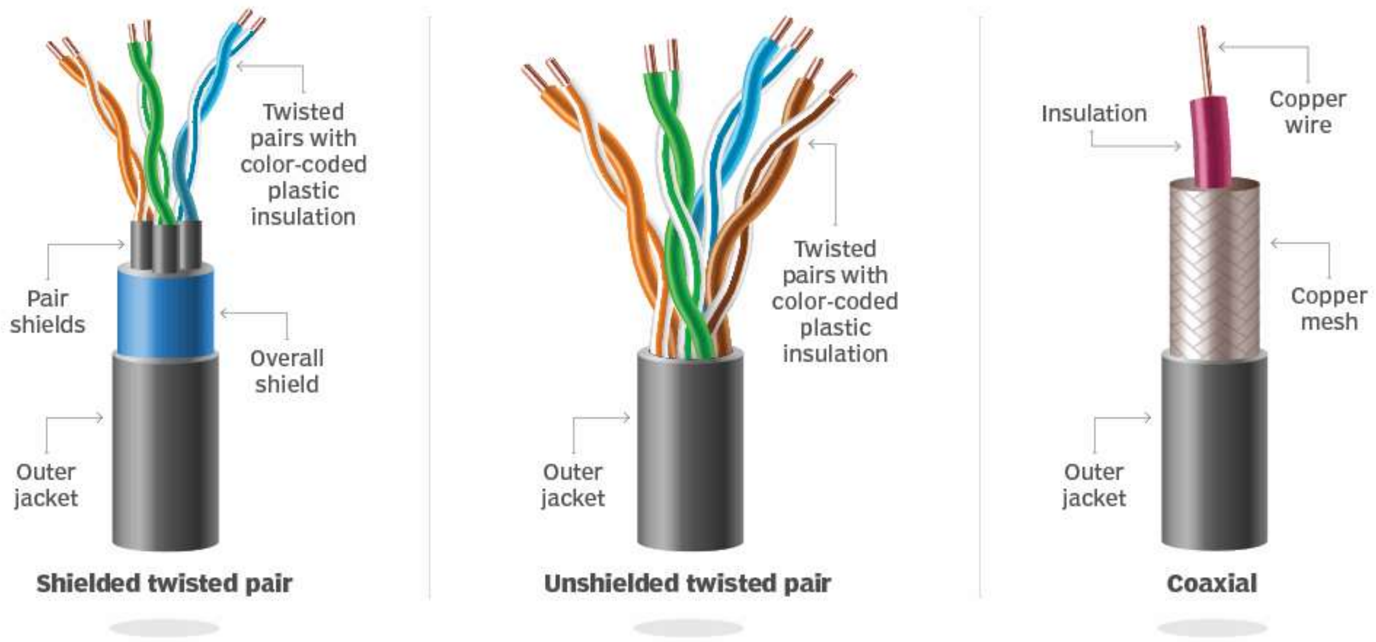
- **2. Unguided Media (Unbounded Media):** These media transmit data through the open air.eg: radio waves or infrared signals and satellite.

- **Twisted Pair Cable:**
- **Description:** Consists of pairs of insulated copper wires twisted together. The twisting helps reduce electromagnetic interference and crosstalk between pairs.
- **Types:**
  - **Unshielded Twisted Pair (UTP):** Commonly used in telephone and Ethernet cables. It is less expensive and easier to work with than shielded varieties but more susceptible to interference.
  - **Shielded Twisted Pair (STP):** Includes an additional shielding layer that provides better protection against interference, making it suitable for environments with significant electrical noise.
- **Use Cases:** Widely used in telecommunication and networking for local area networks (LANs).
- **Coaxial Cable:**
- **Description:** Consists of a central conductor, an insulating layer, a metallic shield, and an outer insulating layer. The design minimizes interference and allows for high-frequency signal transmission.
- **Types:**
  - **Baseband Coaxial Cable:** Used for digital signals in LANs.
  - **Broadband Coaxial Cable:** Used for analog signals, such as cable television.
- **Use Cases:** Commonly used in cable television distribution, internet connections, and some types of local area networks.

UTP Categories - Copper Cable

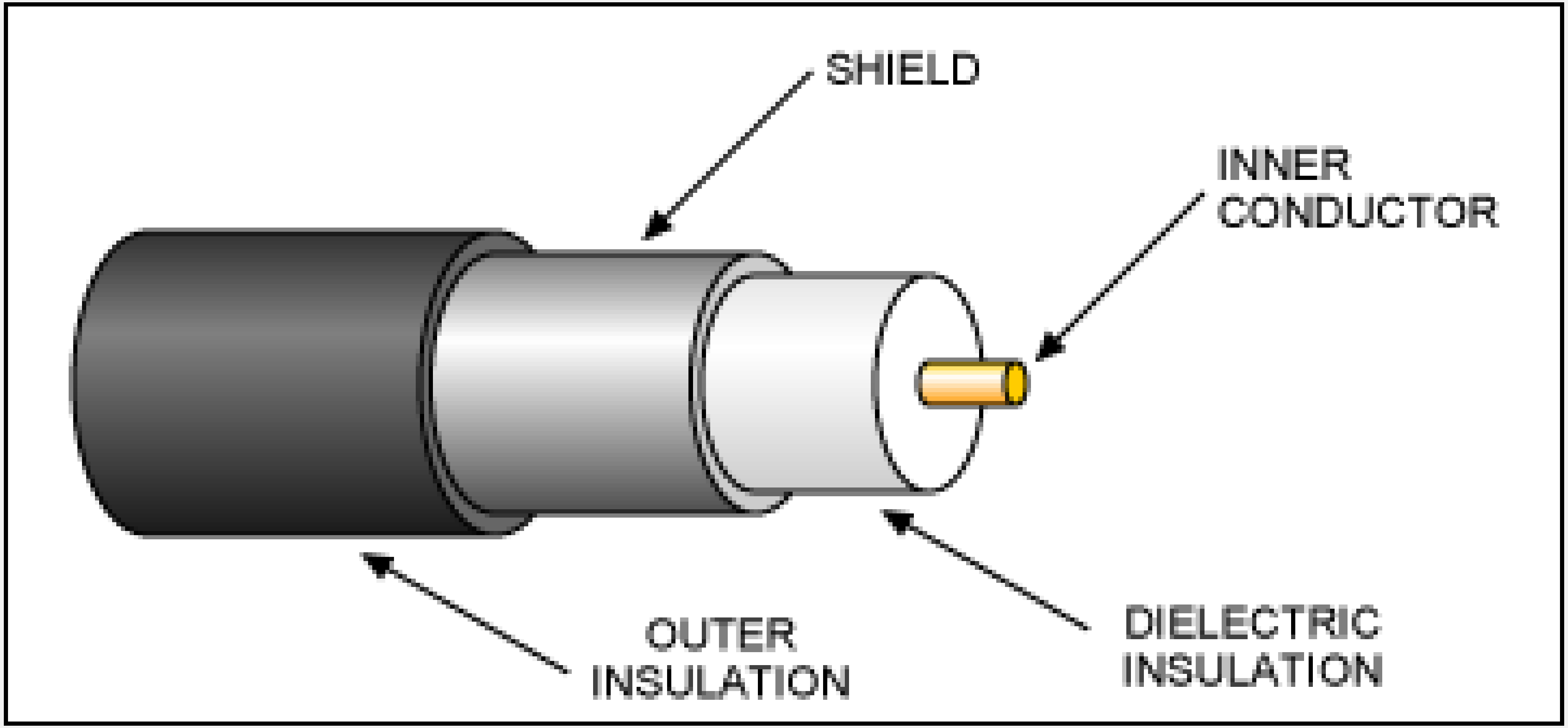
UTP Category	Data Rate	Max. Length	Cable Type	Application
CAT1	Up to 1Mbps	-	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	-	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Rink & 10BASE-T Ethernet
CAT4	Up to 16Mbps	100m	Twisted Pair	Token Ring Networks
CAT5	Up to 100Mbps	100m	Twisted Pair	Ethernet, FastEthernet, Token Ring
CAT5e	Up to 1 Gbps	100m	Twisted Pair	Ethernet, FastEthernet, Gigabit Ethernet
CAT6	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT6a	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT7	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (100 meters)

Enterprise cable options compared



ILLUSTRATIONS: ZUPERIA/GETTY IMAGES

- **Coaxial Cable:**
- Coaxial cable (coax) carries high frequency signals than twisted-pair cables.
- Coax has a central core conductor of solid wire enclosed in an insulator, which is covered by an outer conductor of metal foil. This outer conductor completes the circuit.
- Outer conductor is also enclosed in an insulator, and the whole cable is protected by a plastic cover. It was the foundation for Ethernet networks in the 1980s and remained a popular transmission medium for many
- years.
- Over time, however, twisted-pair cabling has replaced coax in most of the modern LANs.
- A coaxial cable is made up of a central copper wire called a core surrounded by an insulator and then a braided metal shield.

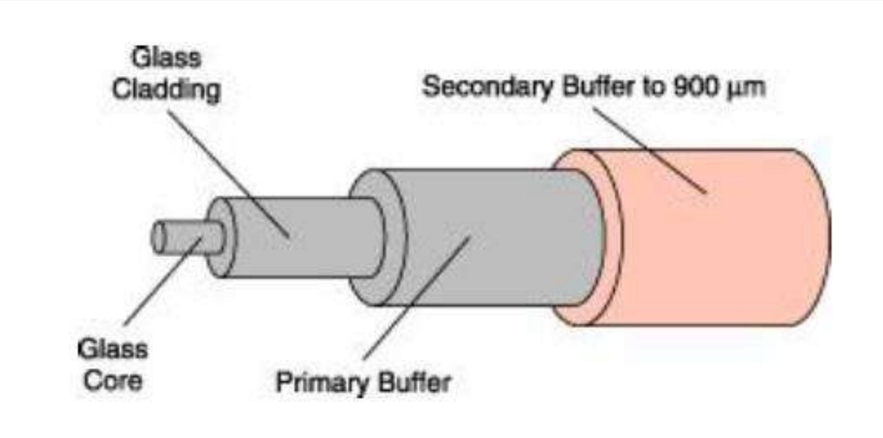

SHIELD
INNER CONDUCTOR
OUTER INSULATION
DIELECTRIC INSULATION

- i) **The jacket or outer insulation protects the cable from** the external environment. It is usually made of rubber or sometimes Polyvinyl chloride (PVC) or Teflon.
- ii) **The shield (Metal envelope) surrounding the cables protects** the data transmitted on the medium from interference (noise) that could corrupt data.
- iii) **The insulator surrounding the central core is made of** a dielectric material that prevents any contact with the shield that could cause electrical interactions or short circuit.
- iv) **The core, which actually transports the data, generally** consists of a single copper strand or several braided strands

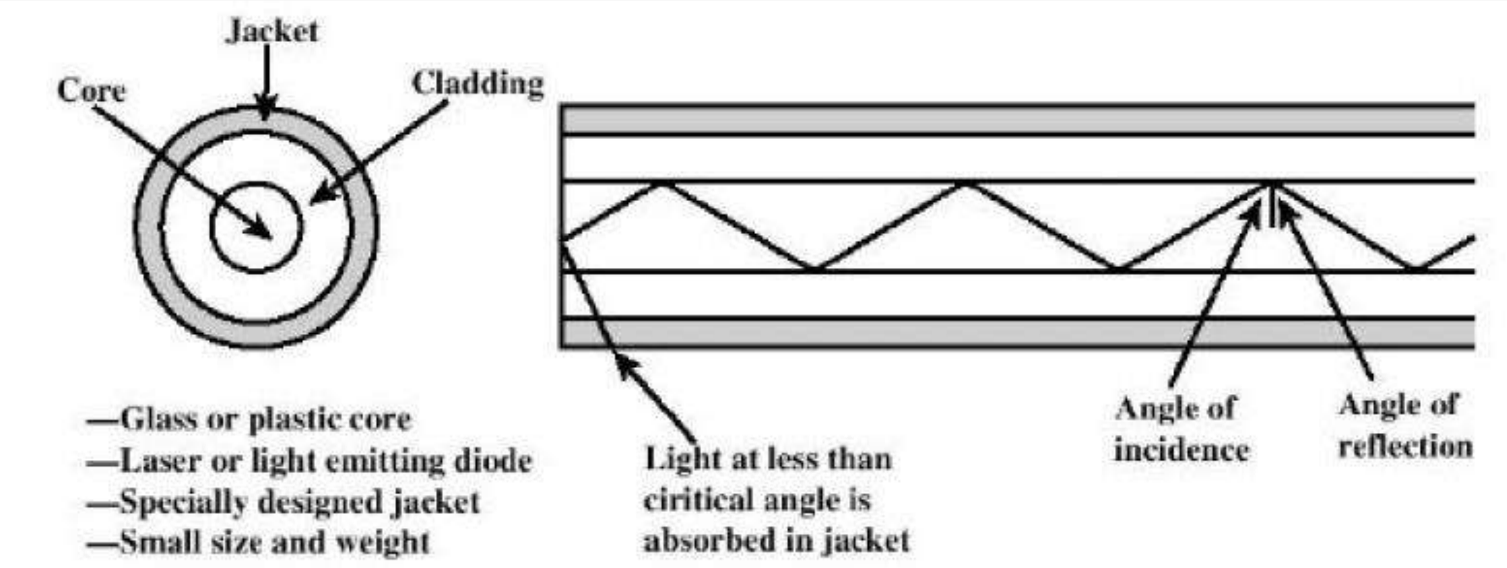
- Because of its insulation and protective braiding, coaxial cable has a high resistance to interference from noise. It can also carry signals farther than twisted pair cabling before amplification of the signals becomes necessary, although not as far as fiber optic cabling.
- Normally, two types of coaxial cable are used.
- 1. **10Base2 – Thin Coaxial Cable (called Thinnet or** CheaperNet) is a thin cable (6 mm in diameter), that is white or grayish by convention. It is very flexible and can be used in most networks by connecting it directly to the network card. It is able to transport a signal up to around 185 meters without line loss. It is part of the RG-58 family whose impedance (resistance) is 50 ohms. The different types of thin coaxial cables are differentiated by the central part of the cable (core).
- 2. **10Base5 – Thick Coaxial Cable (Thicknet or Thick** Ethernet and also called Yellow cable, because of its yellow color – by convention) is a shielded cable with thicker diameter (12 mm) and 50 ohm impedance. It was used for a long time in Ethernet networks, which is why it is also known as “Standard Ethernet Cable”. Given that it has a larger-diameter core, it is able to carry signals over long distances: up to 500 meters without line loss (and without signal amplification). It has a bandwidth of 10 Mbps and is very often used as a backbone to connect networks whose computers are connected with Thinned. However, because of its diameter, it is less flexible than Thinnet.

- **Optical Fiber:**
- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- To understand optical fiber, we first need to explore several aspects of the nature of light.
- Light travels in a straight line as long as it is moving through a single uniform substance.
- If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction.
- Fiber optics, or optical fiber, refers to the medium and the technology associated with the transmission of information as light pulses along a glass or plastic strand or fiber.
- A fiber optic cable can contain a varying number of these glass fibers - from a few up to a couple hundred.
- This system of transmission works on the principle of Total Internal reflection.

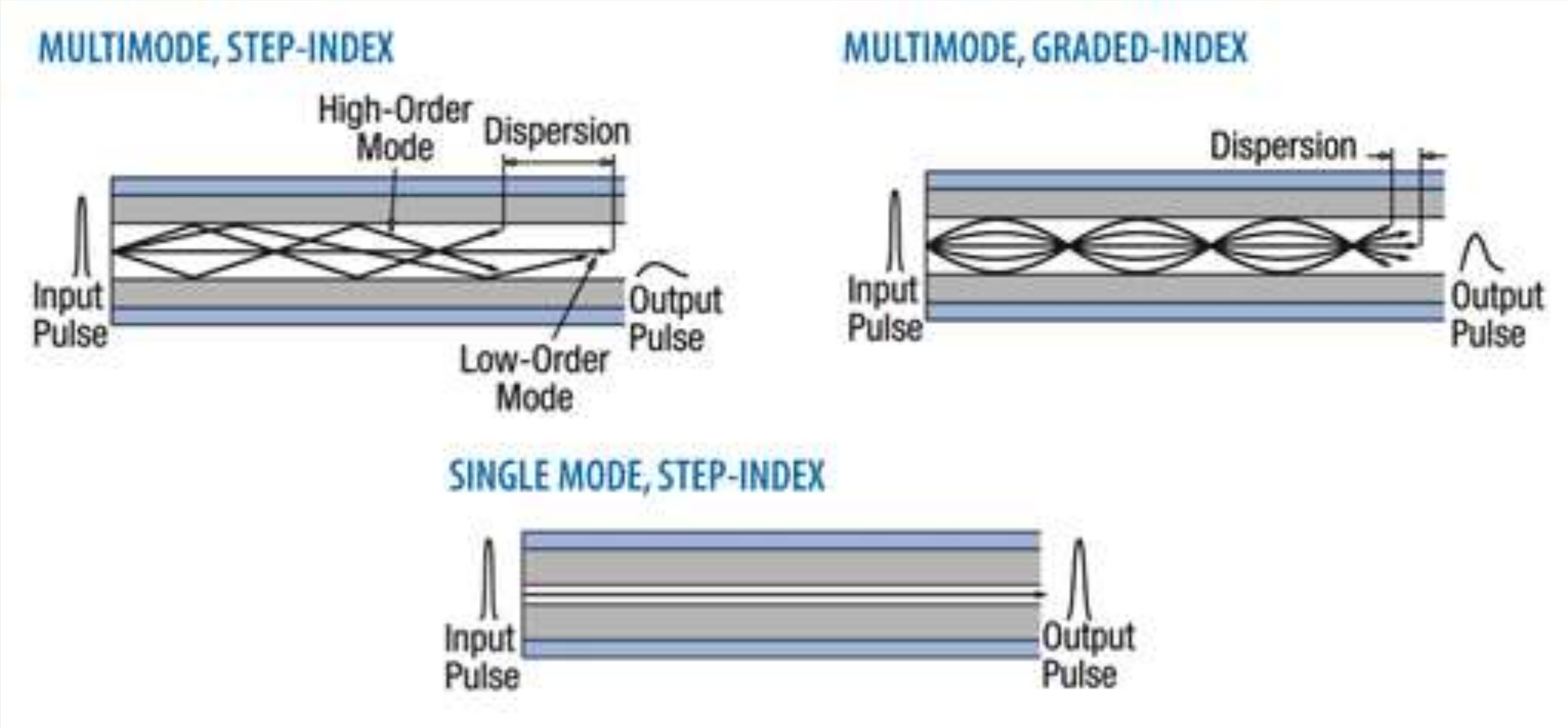
- All fibers consist of a number of sub-structures including:
- **A core, which carries most of** the light, surrounded by
- **A cladding, which bends the light** and confines it to the core, surrounded by
- **A substrate layer (in some fibers) of glass which does not carry** light, but adds to the diameter and strength of the fiber, covered by
- **A primary buffer coating, this provides the first layer of** mechanical protection, covered by
- **A secondary buffer coating, this protects the relatively fragile primary coating**



- What is Total Internal Reflection?
- Light can be trapped inside a material, bouncing around without escaping. This happens when light hits the boundary between two materials at a specific angle.
- Optical Fibers and Light
- Optical fibers are made of glass designed to keep light inside. The glass core is surrounded by a cladding, which is denser.
- How It Works
- Light travels through the core of the fiber. When light hits the core-cladding boundary, it bends sharply. Instead of escaping, the light reflects back into the core.



- Current technology supports two modes: multimode and single mode for propagating light along optical channels, each requiring fiber with different physical characteristics. Multimode can be implemented in two forms: step-index or graded-index



- **Single Mode:**
- • It uses step index fiber and has a smaller diameter.
- • The density (index of refraction) is low.
- • Light travels parallel to the axis, creating little pulse dispersion.
- • Telephone and cable television network install such fiber.
- **Multimode:**
- • Multiple beams form a light source move through the core in different paths.
- • It has a little big diameter.
- • It gives high bandwidth at high speeds.

- **i) Step Index Fiber:**
- The density of the core remains constant from the center to the edge.
- It has low density, which results on abrupt change, this alters the angle of beam’s motion.
- Best suited for transmission over short distances.
- **ii) Graded Index:**
- It is one with varying densities.
- It contains a core in which the density is highest at the center and decreases gradually to its lowest at the edge.
- Decreases the distortion of signal through cable.

Twisted pair cable	Co-axial cable	Optical fiber
1. Transmission of signals takes place in the electrical form over the metallic conducting wires.	1. Transmission of signals takes place in the electrical form over the inner conductor of the cable.	1. Signal transmission takes place in an optical forms over a glass fiber.
2. In this medium the noise immunity is low.	2. Coaxial having higher noise immunity than twisted pair cable.	2. Optical fiber has highest noise immunity as the light rays are unaffected by the electrical noise.
3. Twisted pair cable can be affected due to external magnetic field.	3. Coaxial cable is less affected due to external magnetic field.	3. Not affected by the external magnetic field.
4. Cheapest medium.	4. Moderate Expensive.	4. Expensive
5. Low Bandwidth.	5. Moderately high bandwidth.	5. Very high bandwidth
6. Attenuation is very high.	6. Attenuation is low.	6. Attenuation is very low.
7. Installation is easy.	7. Installation is fairly easy.	7. Installation is difficult.

- **Radio Waves**
- Electromagnetic waves ranging in frequencies between 3 KHz and 1 GHz are normally called radio wave, Radio waves are omnidirectional. When an antenna transmits radio waves, they are propagated in all directions.
- **Omnidirectional Propagation:**
- Radio waves spread in all directions.
- No need for aligned sending and receiving antennas.
- Can cause interference if another antenna uses the same frequency.

- Radio waves, particularly with those of low and medium frequencies, can penetrate walls. This characteristic can be both an advantage and a disadvantage. It is an advantage because, an AM radio can receive signals inside a building. It is a disadvantage because we cannot isolate a communications to just inside or outside a building.

- **Applications of Radio Waves:**
- The omnidirectional characteristics of radio waves make them useful for multicasting in which there is one sender but many receivers.
- AM and FM radio, television, maritime radio, cordless phones, and paging are examples of multicasting.

- **Advantages of Radio Waves**
- Wires are not needed as they travel through air, thus a cheaper form of communication.
- Some radio waves are reflected off the ionosphere, so can travel around the Earth.
- Radio wave can carry a message instantaneously over a wide area.
- Aerials to receive radio waves are simpler than for microwaves.
- **Disadvantages of Radio Waves**
- The range of frequencies that can be accessed by existing technology is limited, so there is a lot of competition amongst companies for the use of the frequencies
- Travel in a straight line, so repeater stations may be needed

- **Micro Waves**
- Definition: Electromagnetic waves with frequencies between 300MHz and 300 GHz.
- Unidirectional Propagation:
- Can be narrowly focused.
- Requires alignment of sending and receiving antennas.
- Reduces interference between multiple antenna pairs.
- Propagation Characteristics:
- Line-of-Sight: Towers must be in direct view of each other; distant towers need to be taller.
- Wall Penetration: High-frequency microwaves cannot penetrate walls, which can be a disadvantage for indoor receivers.
- Wide Bandwidth: The microwave band is almost 299 GHz wide, allowing for wider sub-bands and high data rates.
- Regulation**:** Some band portions require permission from authorities for use.

- **Unidirectional Antenna for Microwaves:**
- Microwaves need unidirectional antennas that send out signals in one direction. Two types antennas are used for microwave communications: Parabolic Dish and Horn.

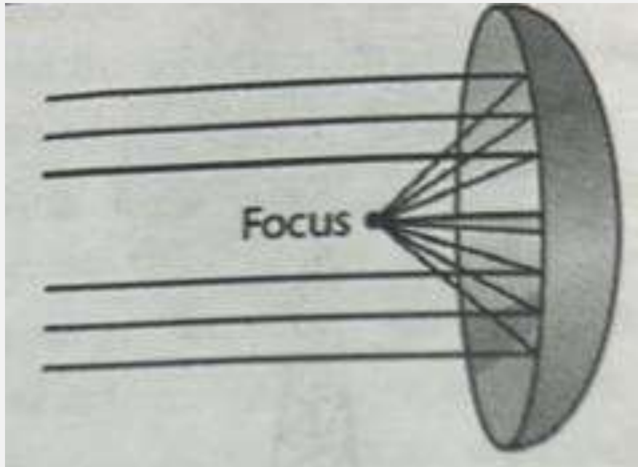


Figure 3.36: Dish antenna

A **parabolic antenna works as a funnel, catching a wide range of waves** and directing them to a common point. In this way, more of the signal is recovered than would be possible with a single-point receiver

Figure 3.37: Horn antenna

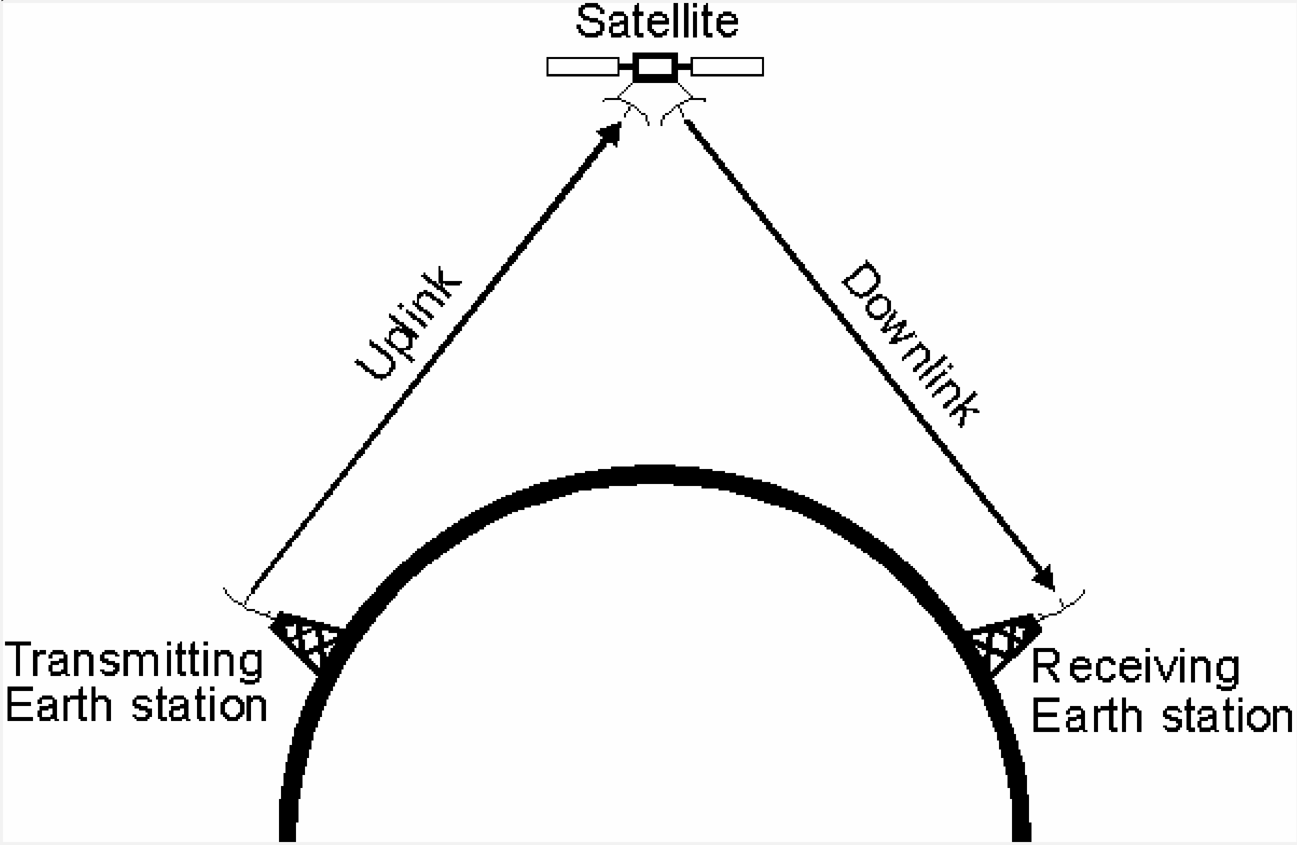
A **horn antenna looks like a gigantic scoop. Outgoing transmissions are** broadcast up a stem and deflected outward in a series of narrow parallel beams by the curved head. Received transmissions are collected by the scooped shape of the horn, in a manner similar to the parabolic dish, and are deflected down into the stem.

- **Application:**
- Microwaves are very useful when unicast(one-to one) communication is needed between the sender and the receiver. They are used in cellular phones, satellite networks and wireless LANs.
- There are two types of Microwave Transmission:
- 1. Terrestrial Microwave
- 2. Satellite Microwave
- **Advantages of Microwaves**
- Wires are not needed as they travel through air, thus a cheaper form of communication.
- Microwave passes through the ionosphere, so are suitable for satellite to Earth transmission.
- Microwave can be modified to carry many signals at one time, including data, television pictures and voice message.
- **Disadvantages of Microwaves**
- Absorbed very easily by natural, e.g., rain, and made objects, e.g., concrete. They are also absorbed by living tissue and may cause harm by their cooking effect Microwaves suffer from attenuation due to atmospheric conditions.
- Need special aerials to receive them.
- Travel in a straight line, so repeater stations may be needed

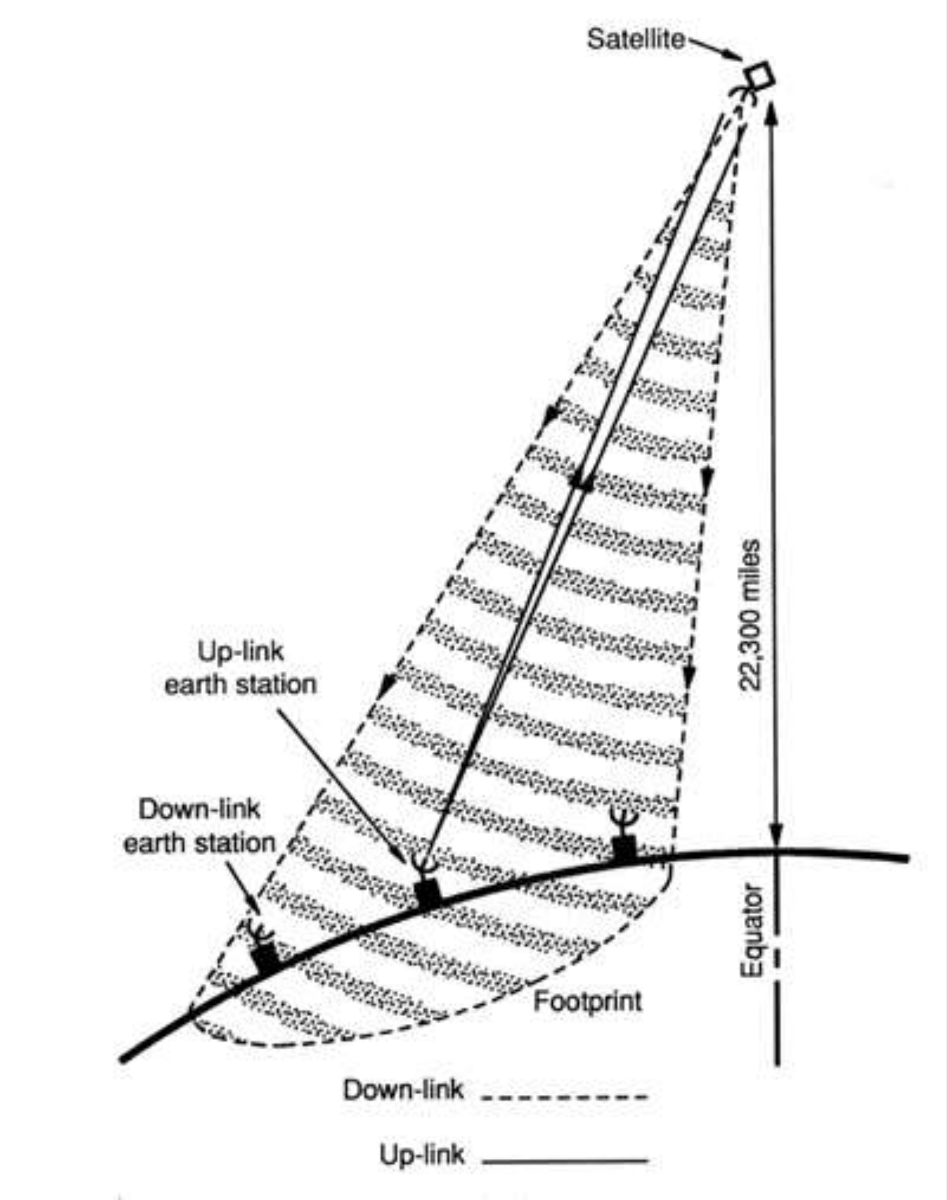
- **Terrestrial Microwave**
- **Definition:**
  Microwave communication that occurs on the Earth's surface using ground-based antennas.
- Long-haul telecommunications as an alternative to coaxial cable or optical fiber.
- **Unidirectional and Focused:**
- Requires alignment of transmitting and receiving antennas.
- Reduces interference with other systems.
- **Line-of-Sight Transmission**:
- Antennas must be directly visible to each other.
- Towers may need to be very tall for long-distance communication
- **Applications:**
- Used for voice and television transmission.
- Increasingly used for short point-to-point links between buildings (e.g., closed-circuit TV, data links between LANs).
- **Long-Distance Transmission:**
- Achieved using a series of relay towers.
- Point-to-point links are connected over the desired distance.

- **Communication Satellites**
- **Microwave Transmission:**
  - Ideal for large, geographically dispersed organizations.
  - Used for home Internet service, especially in rural areas.
- **Geostationary Orbits:**
  - Satellites are positioned directly over the equator.
  - Rotate in synchronization with the Earth, appearing stationary.
- **Microwave Relay Stations:**
  - Act as fixed points for microwave transmission on the ground.
  - Orbits are placed 36,000 km above the Earth's surface.

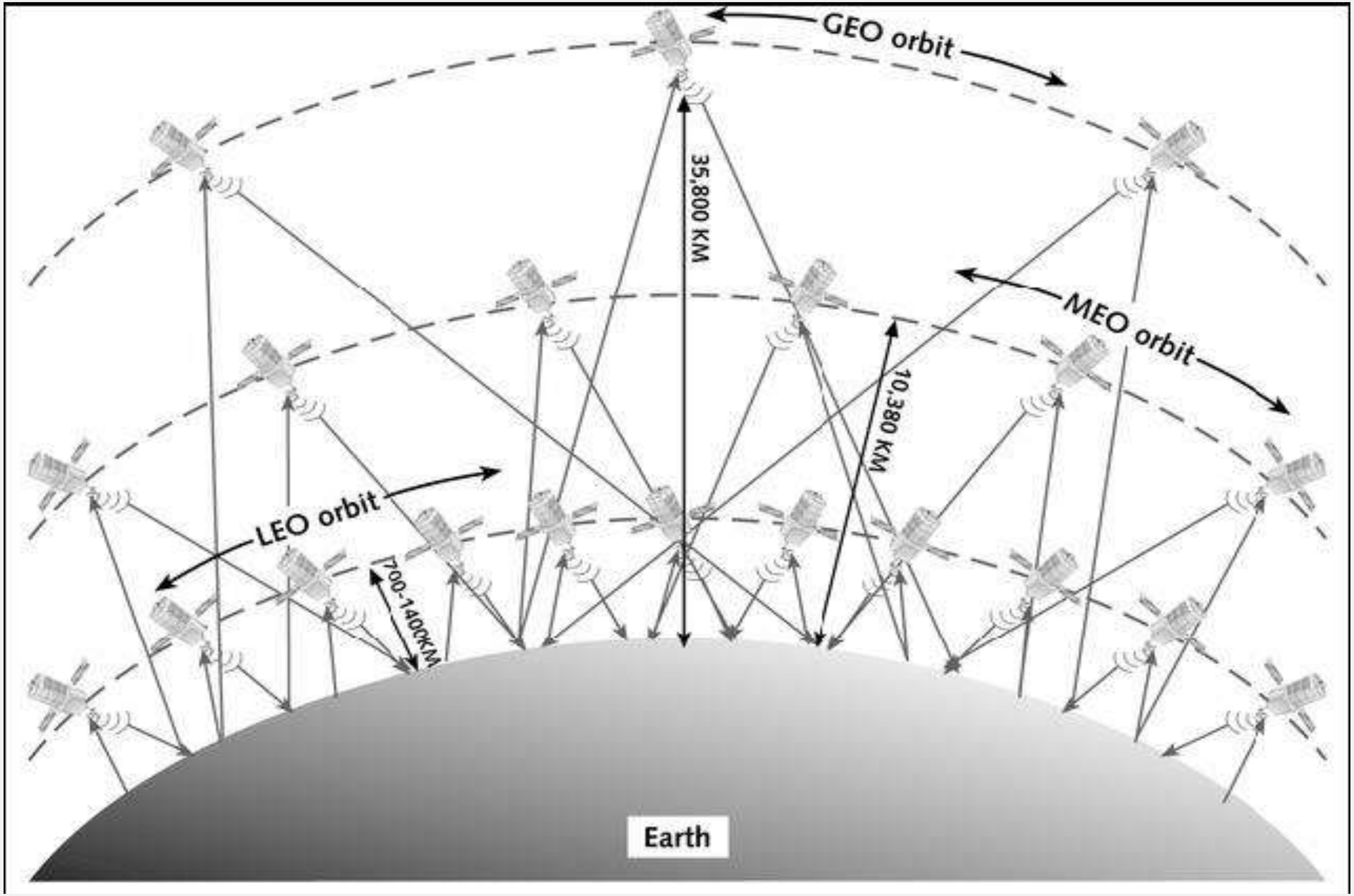
- The two stations can use a satellite as a relay station for their communication.
- • One Earth Station sends a transmission to the satellite. This is called a Uplink. It’s frequency is 6 GHz.
- • The satellite Transponder converts the signal and sends it down to the second earth station. This is called a Downlink.(4 GHz)



- **Satellite Footprint**
- **Definition:**
  - The area on the Earth's surface covered by a satellite's signal.
- **Coverage:**
  - Determines where signals can be received and transmitted.
  - Varies based on satellite's altitude, frequency, and antenna design.
- **Footprint Shape:**
- Typically elliptical or circular, depending on satellite's orientation
- and beam pattern.



- Types of Satellite
- 1. **GEO(Geostationary Earth Orbit):**
- These satellites are in orbit 35,863 km above the earth’s surface along the equator.
- Objects in Geostationary orbit revolve around the earth at the same speed as the earth rotates. This means GEO satellites remain in the same position relative to the surface of earth.
- **2. LEO(Low Earth Orbit):**
- LEO satellites are much closer to the earth than GEO satellites, ranging from 500 to 1,500 km above the surface.
- LEO satellites don’t stay in fixed position relative to the surface, and are only visible for 15 to 20 minutes each pass**.**
- **MEO(Medium Earth Orbit):**
- A MEO satellite is in orbit somewhere between 8,000 km and 18,000 km above the earth’s surface.
- MEO satellites are similar to LEO satellites in functionality.
- MEO satellites are visible for much longer periods of time than LEO satellites, usually between 2 to 8 hours.


GEO orbit
35,800 KM
MEO orbit
10,380 KM
LEO orbit
700-1400KM
Earth

- **Service Types of satellite communication**
- • Service Types
- Fixed Service Satellites (FSS)
  - • Example: Point to Point Communication
- Broadcast Service Satellites (BSS)
  - • Example: Satellite Television/Radio
  - • Also called Direct Broadcast Service (DBS).
- Navigation Service Satellites
  - • Example: Air, Ship, Navigation.
- Mobile Service Satellites (MSS)
    - • Example: Satellite Phones

- ***Frequency bands***
- • Different kinds of satellites use different frequency bands.
- ✦ L–Band: 1 to 2 GHz, used by MSS
- ✦ S-Band: 2 to 4 GHz, used by MSS, NASA, deep space research
- ✦ C-Band: 4 to 8 GHz, used by FSS
- ✦ X-Band: 8 to 12.5 GHz, used by FSS and in terrestrial imaging, ex:
- military and meteorological satellites
- ✦ Ku-Band: 12.5 to 18 GHz: used by FSS and BSS
- ✦ K-Band: 18 to 26.5 GHz: used by FSS and BSS
- ✦ Ka-Band: 26.5 to 40 GHz: used by FSS

- **Infrared Waves Frequency Range:** 300 GHz to 400 THz
  - **Wavelengths:** 700 nm to 1 mm
  - **Position:** Between visible light and radio waves on the electromagnetic spectrum
- **Short-Range Communication**
  - Ideal for short distances
  - Cannot penetrate walls, reducing interference between systems
- **Applications**
  - **Remote Controls:** Use near-infrared light via LEDs to operate TVs and other devices without interfering with neighboring remotes
  - **Limitations:** Not suitable for long-range communication or outdoor use due to interference from sunlight
- **Data Transmission**
  - Used in fiber optic cables to transmit data efficiently

- **Applications of Infrared Waves**
- The infrared band, almost 400 THz, has an excellent potential for data transmission. Such a wide bandwidth can be used to transmit digital data with a very high data rate.
- The Infrared Data Association (IrDA), an association for sponsoring the use of infrared waves, has established standards for using these signals for communication between devices such as keyboards, mouse, PCs and printers.
- Infrared signals can be used for short-range communication in a closed area using line- of-sight propagation.

- **Advantages of Infrared Waves**
- Can detect people inside burning buildings and cars.
- Useful in the military for identifying targets.
- Used in scientific experimentation to identify the heat of an object.
- Easy to tell what the readings on an infrared camera mean.

- • **Disadvantages of Infrared Waves**
- Can cause minor burns if exposed to skin for long period of time.
- Can cause cataracts in the eyes after long exposure.
- Cheap laser pointers, if without an IR filter, can damage your eyes with Infrared light after a little while of exposure

- Media Selection
- **Choosing the Best Media**
- Challenging due to continuous improvements
- Key factors: network type, cost, transmission distance, security, error rates, and transmission speed
- **Network Type**
- WAN: microwaves, satellite
- LAN: twisted pair, coaxial cable, radio
- Fiber-optic: versatile for any network
- **Cost Considerations**
- Twisted pair: cheapest
- Coaxial cable: moderately priced
- Fiber-optic: most expensive
- Wireless cost depends on distance:
- Short (hundreds of meters): radio
- Moderate (hundreds of miles): microwave
- Long: satellite

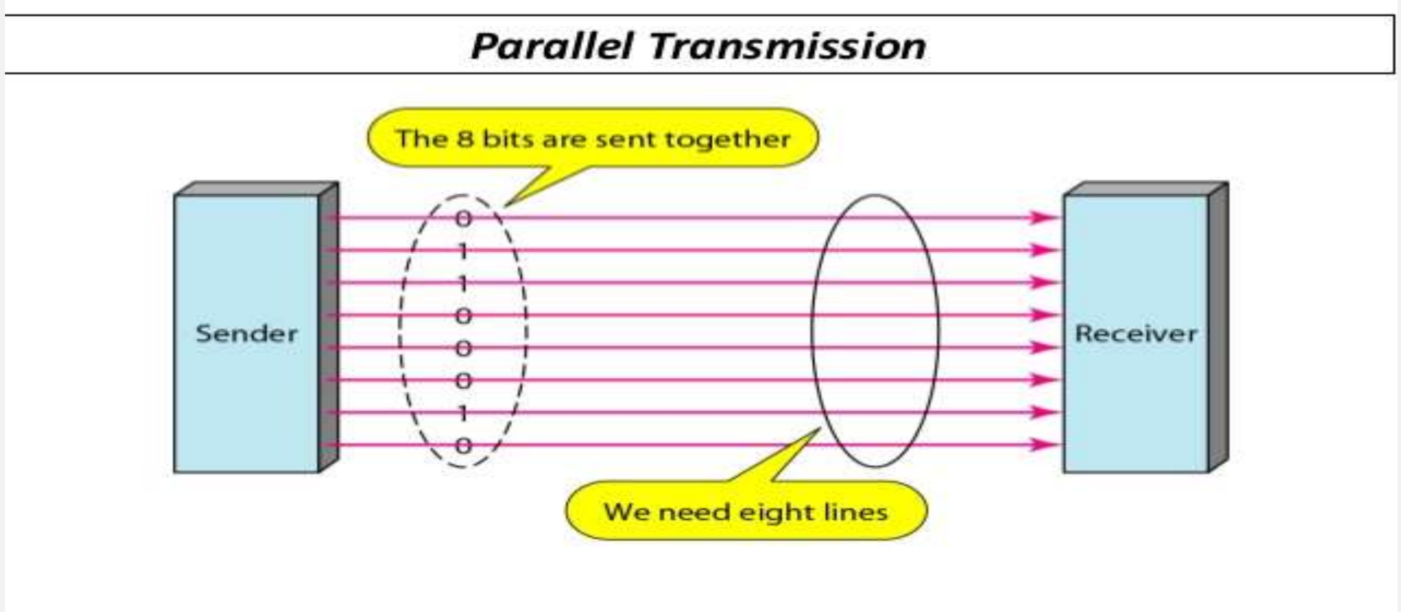
- **Transmission Distance**
- Twisted pair and radio: 100–300 meters
- Coaxial cable: 200–500 meters
- Fiber optics: up to 75 miles, new types over 600 miles
- **Security**
- Wireless (radio, microwave, satellite): least secure
- Guided media (twisted pair, coaxial, fiber optics): more secure
- Fiber optics: most secure
- **Error Rates**
- Wireless: highest error rates due to interference
- Fiber optics: lowest error rates
- Coaxial cable: moderate error rates
- Twisted pair: higher error rates than fiber and coaxial, but better than wireless
- **Transmission Speeds**
- Twisted pair and coaxial: 1 Mbps to 1 Gbps
- Fiber-optic: 1 Gbps to 40 Gbps
- Wireless (radio, microwave, satellite): 10–100 Mbps

- **Digital Transmission of Digital Data**
- **Binary Data:**
  - Computers produce data in binary form (0s and 1s).
- **Coding Scheme:**
  - **Purpose:** To ensure both sender and receiver understand the data.
  - **Definition:** A coding scheme is a standard system that represents letters, numbers, and symbols in binary.
- **Characters:**
  - **Definition:** Symbols with a specific meaning (e.g., letters A, B, numbers 1, 2, or special symbols ? and &).
  - **Representation:** Characters are represented by groups of bits (binary 0s and 1s).
- **Coding Scheme:**
  - **What It Is:** The set of binary codes used to represent all characters in a system.

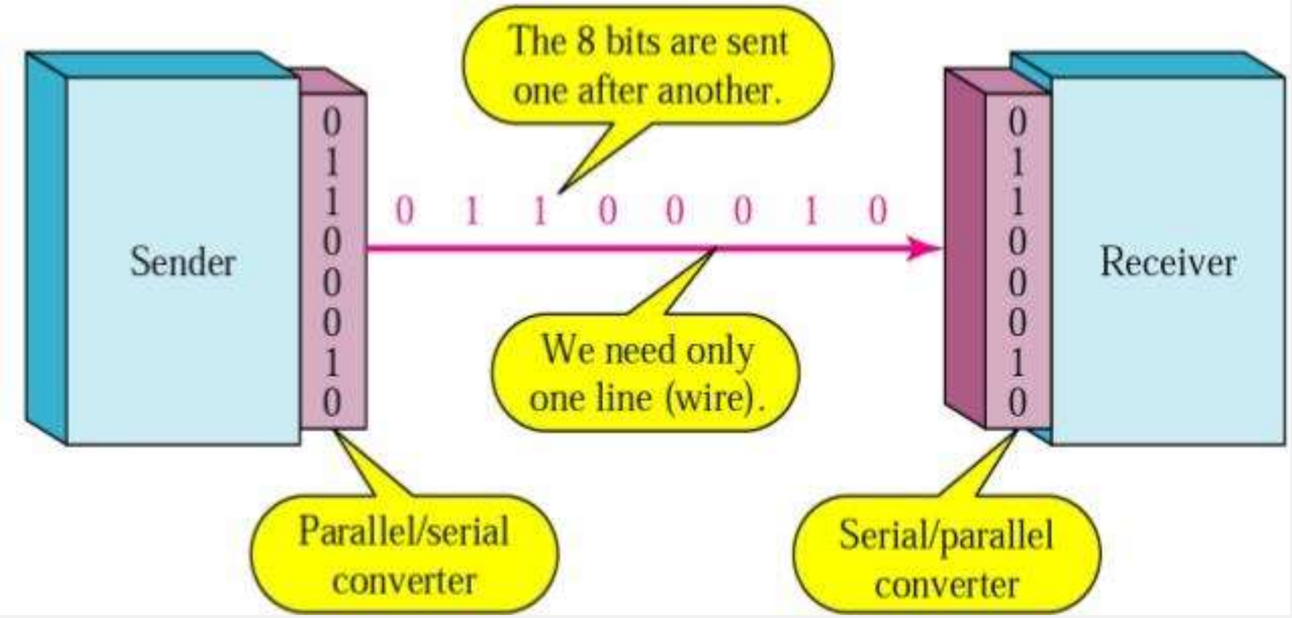
- **Understanding Bytes and Coding Schemes**
- **Byte:**
  - **Definition:** A group of consecutive bits treated as a unit.
  - **Size:** Typically 8 bits.
  - **Purpose:** Represents one character.
- **Bit Groups for Characters:**
  - Characters can be represented by different bit lengths (5, 6, 7, 8, or 9 bits).
- **Example:**
  - Character 'A' can be represented as an 8-bit group (e.g., 01000001).
- **Predominant Coding Schemes:**
  - **ASCII (American Standard Code for Information Interchange):**
    - **7-bit ASCII:** 128 character combinations.
    - **8-bit ASCII:** 256 character combinations.
    - **Usage:** Most common in microcomputers and data communications.
  - **ISO 8859:** A family of 8-bit character encodings.
  - **Unicode:** A comprehensive encoding system supporting many languages and symbols.
- **Combination Calculation:**
  - **Formula:** 2^number_of_bits
  - **Example:** 2^7 = 128 characters, 2^8 = 256 characters.

- **ISO 8859:**
  - **Definition:** An 8-bit code standardized by the International Standards Organization.
  - **Features:** Includes ASCII codes and additional characters for European languages (e.g., accented letters).
- **Unicode:**
  - **Definition:** A comprehensive coding scheme to represent a wide range of characters from different languages.
  - **Versions:**
    - **UTF-8:** An 8-bit version, similar to ASCII, supports many characters.
    - **UTF-16:** Uses 16 bits (2 bytes) per character, enabling representation of a larger range of characters including Cyrillic, Chinese, and more.

- Transmission mode
- Parallel Transmission:
- **Definition**: Multiple bits are transmitted simultaneously across multiple channels or wires.
- **Structure**: Uses multiple data lines, one for each bit (e.g., 8 lines for an 8-bit data transfer).
- **Speed**: Generally faster for short distances due to simultaneous bit transfer.
- **Distance**: Suitable for short-distance communication because of signal degradation and crosstalk over longer cables.
- **Complexity**: More complex and costly due to the need for multiple wires and precise synchronization.
- **Applications**: Used in internal computer buses, older printer connections (parallel ports), and scenarios requiring high-speed data transfer.



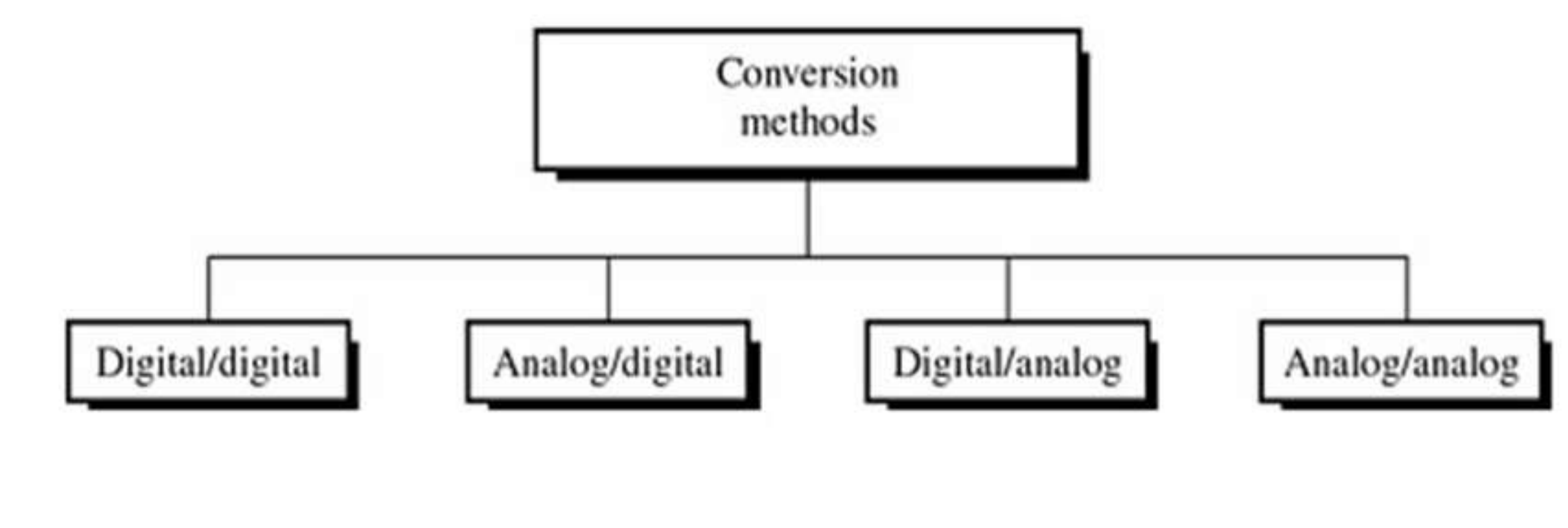
- **Serial Transmission**
- **Definition**: Bits are transmitted one after another over a single channel or wire.
- **Structure**: Uses a single data line, transmitting bits sequentially.
- **Speed**: Slower than parallel for short distances, but effective over long distances.
- **Distance**: Better for long-distance communication;
- **Complexity**: Simpler and less costly with fewer wires and less synchronization needed.
- **Applications**: Common in modern data communications, including USB, SATA, and Ethernet.



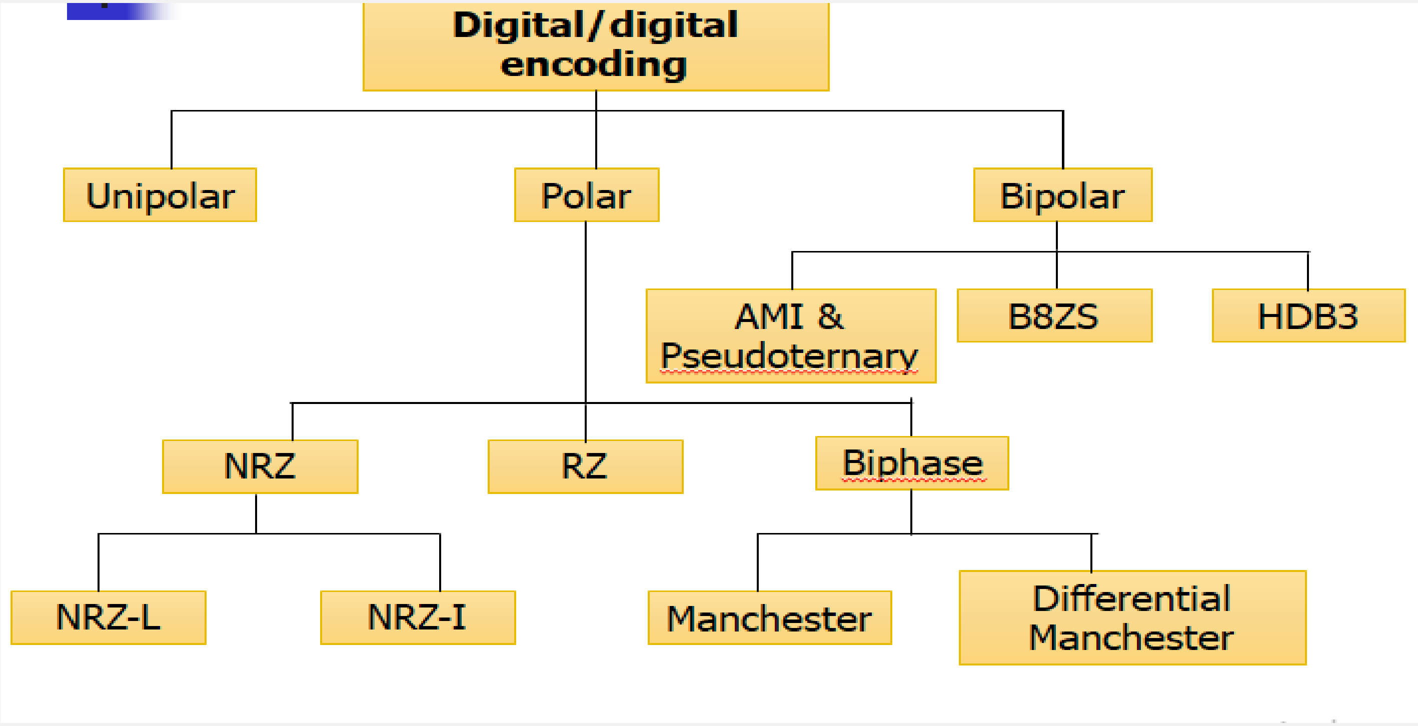
- Serial Transmission occurs in two ways
- **Synchronous Serial Transmission**
- **Definition**: Data is transmitted in a continuous stream, synchronized by a shared clock signal between the sender and receiver.
- **Clock Signal**: Both devices use a clock signal to ensure that data is sent and received at the same rate, maintaining synchronization.
- **Efficiency**: More efficient for large volumes of data since it doesn't require start and stop bits.
- **Applications**: Commonly used in high-speed data communication, such as Ethernet and USB.
- **Asynchronous Serial Transmission**
- **Definition**: Data is transmitted one byte at a time, with each byte framed by start and stop bits to signal the beginning and end.
- **Start/Stop Bits**: Each data packet is preceded by a start bit and followed by one or more stop bits to signify the packet's boundaries.
- **Flexibility**: More flexible in terms of timing, as each packet is self-contained and doesn't rely on a shared clock.
- **Applications**: Used in lower-speed communication, such as RS-232 serial ports, and for situations where data is sent intermittently.

- **Key Differences**
- **Synchronization**: Synchronous requires a clock signal; asynchronous uses start/stop bits.
- **Efficiency**: Synchronous is more efficient for continuous data; asynchronous is better for sporadic data transfer.
- **Complexity**: Synchronous requires more precise timing; asynchronous is simpler to implement.

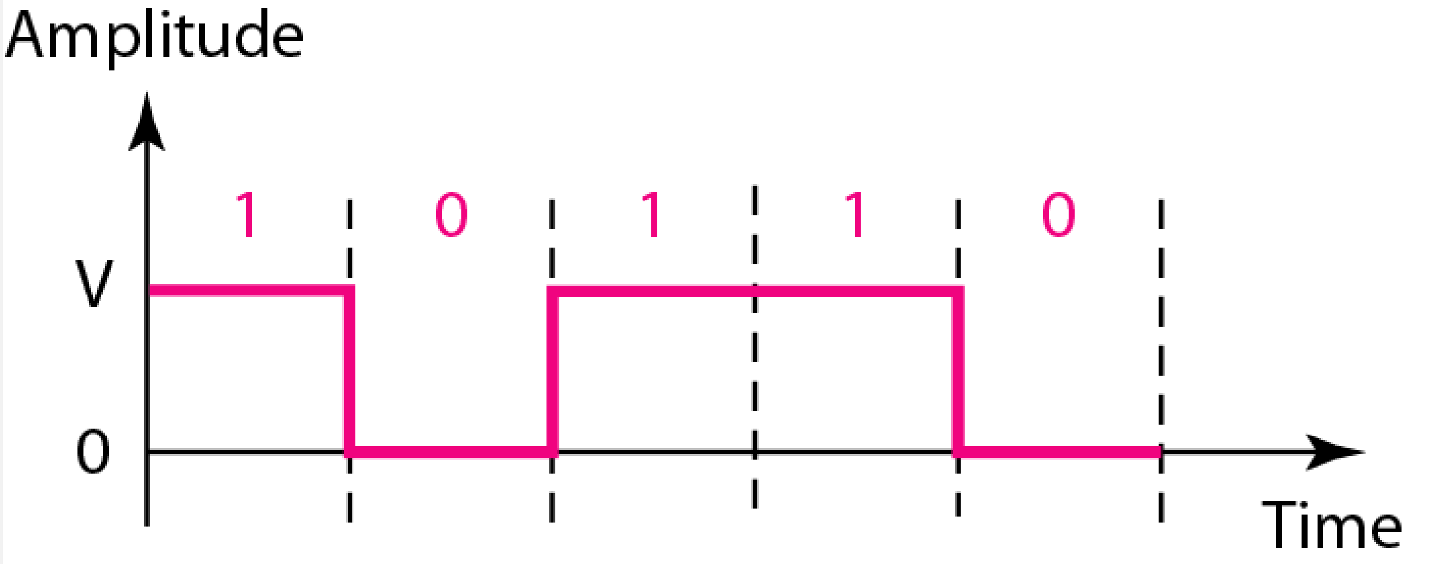
- Data Encoding
- Encoding is the process by which data is converted into digital format for efficient transmission of storage. There are four conversion methods



- **Digital to Digital Conversion**
- It's the process of converting digital information into a digital signal. This is done using different encoding methods.
- **Why is it Important?**
- Computers and digital devices generate data in binary form (0s and 1s). To transmit this data over networks or store it, we need to convert it into a form that can be easily understood and processed.



- **Unipolar:**
- In this type 1s are encoded as a positive value and 0s are encoded as 0 value.



- **Polar Encoding:** Uses two levels of voltages, positive and negative, to represent binary 0 and 1
- Types of polar encoding are:

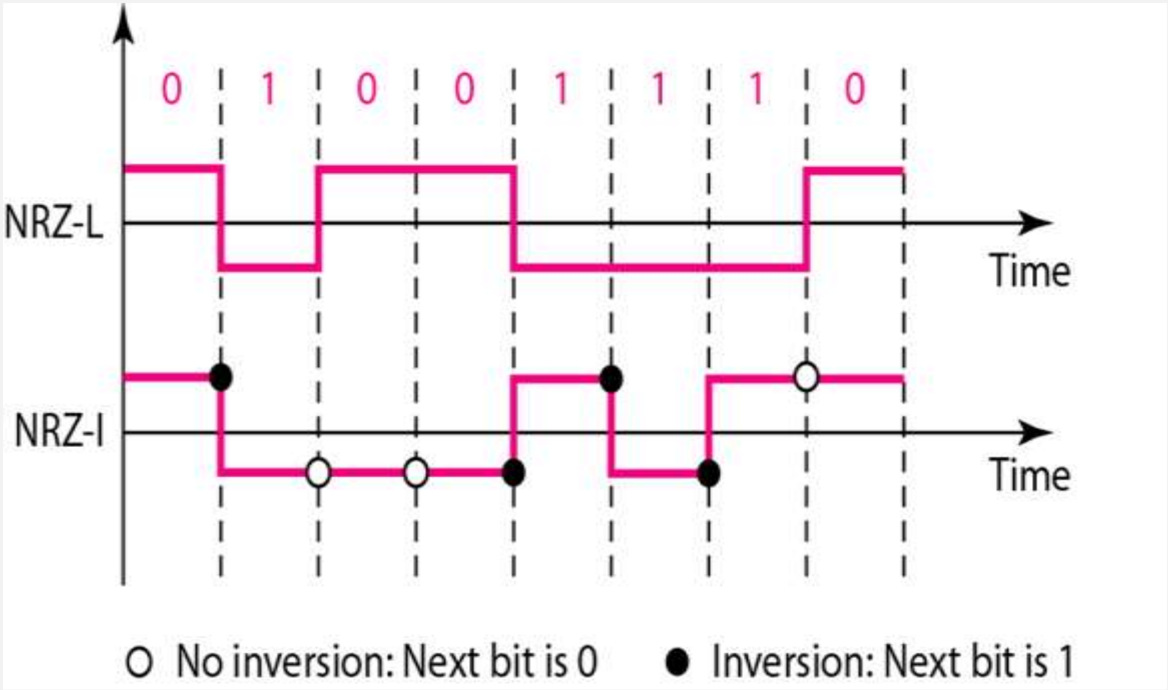
a. NRZ (Non- Return to Zero)

b. RZ (Return to Zero)

c. Biphase

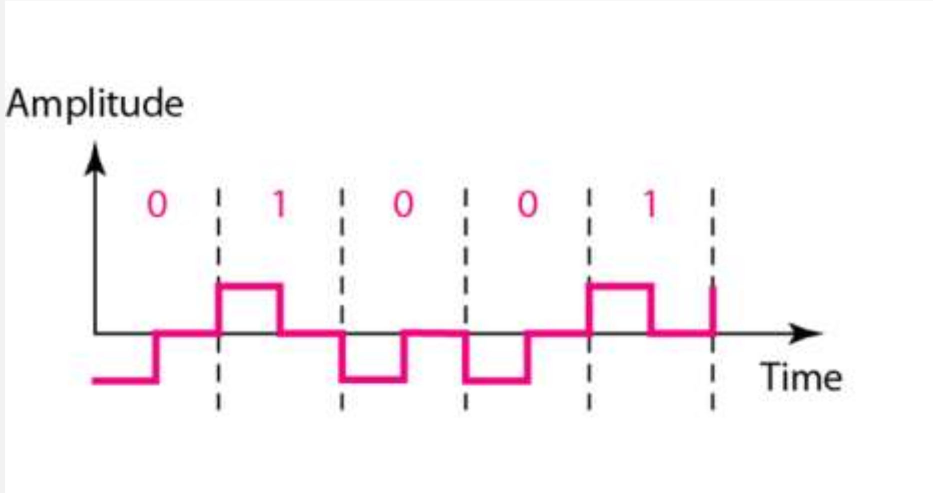
- NRZ(Non-return to zero): In NRZ encoding, the level of the signal is always either positive or negative. The two most popular methods of NRZ transmission are:
- i. NRZ - Level (NRZ-L)
- ii. NRZ - Inversion (NRZ-I)

- **NRZ-Level (NRZ-L):**
- **Basic Idea:** The level of voltage determines the value of the bit.
- **How It Works:**
  - There are two voltage levels: one positive and one negative.
  - A positive voltage usually represents a bit value of 0, and a negative voltage represents a bit value of 1 (or vice versa).
- **Key Point:** The voltage level is constant throughout the bit period and directly indicates the bit value.
- **Advantages:** Simple and straightforward to implement.
- **Disadvantages:** Long sequences of identical bits can cause synchronization issues.
- **NRZ-Inversion (NRZ-I):**
- **Basic Idea:** Changes in voltage level (inversions) determine the value of the bit.
- **How It Works:**
  - An inversion in the voltage level represents a bit value of 1.
  - No inversion (the voltage stays the same) represents a bit value of 0.
- **Key Point:** A 1 bit causes a change in voltage level, while a 0 bit keeps the voltage level unchanged.
- **Advantages:** Better for synchronization because it avoids long sequences without transitions.
- **Disadvantages:** More complex to interpret since it relies on detecting changes.



- **NRZ-Level (NRZ-L):**
- The value of the bit is determined directly by the voltage level.
- There is no change in voltage level to indicate different bits within a sequence; the same voltage level is maintained throughout the bit period.
- A specific voltage level represents a bit value (e.g., high voltage for 0 and low voltage for 1, or vice versa).
- **NRZ-Inversion (NRZ-I):**
- The value of the bit is determined by the presence or absence of a transition in the voltage level.
- A change in voltage level represents a 1, while no change represents a 0.
- It is the change in voltage, rather than the level itself, that encodes the bit information.

- **Return to Zero (RZ) Encoding** is another method of encoding binary data into digital signals. It uses three levels: positive, zero, and negative.
- A high (positive) voltage is used to start the representation of a 1, and then it returns to zero halfway through the bit interval. A low (negative) voltage is used to start the representation of a 0, and it also returns to zero halfway through the bit interval.

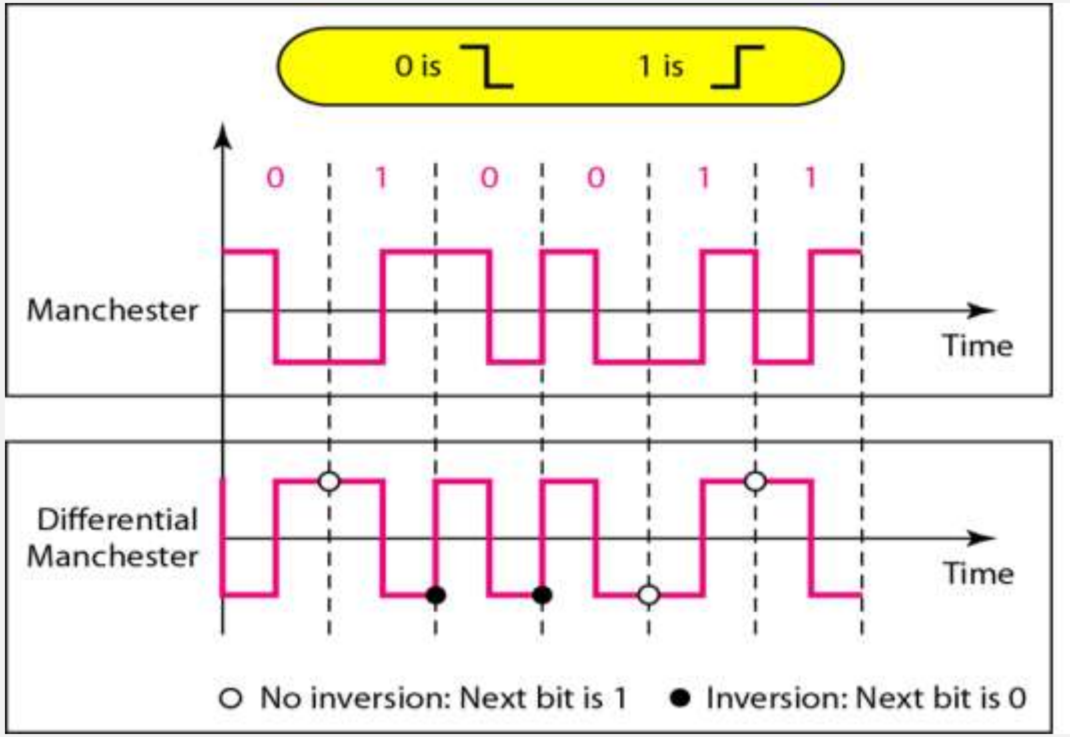


- **Biphase:**
- In this method the signal changes at the middle of the bit interval but does not returned to 0 instead it continues to the opposite pole. Two types of biphase.
- i. Manchester ii. Differential Manchester
- **i. Manchester:**
- - consists of combining the NRZ-L and RZ schemes.
- **- In this encoding, the duration of a bit is divided into two halves.**
- Every symbol has a level transition in the middle: from high to
- low or low to high. Uses only two voltage levels. A low to high
- transition represents 1 and high to low represents 0

- **ii. Differential Manchester:**
- - consists of combining the NRZ-I and RZ schemes.
- Every symbol has a level transition in the middle. But the level at
- the beginning of the symbol is determined by the symbol value.
- One symbol causes a level change the other does not

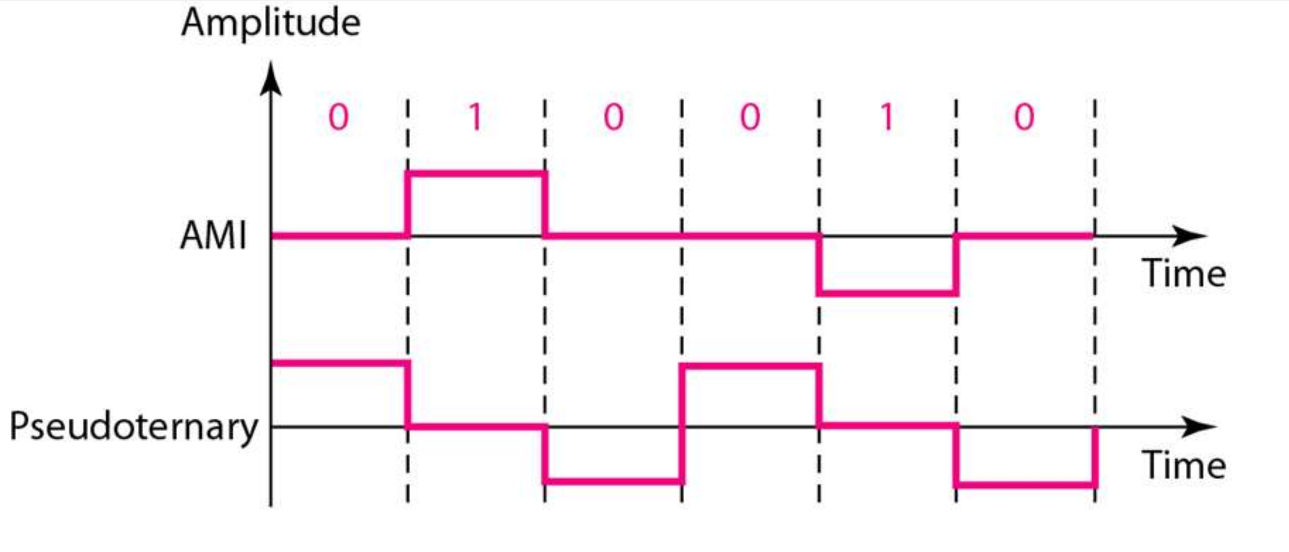
- 0= transition(move +v to -v or –v to +v)
- 1= no change in voltage (continue)

0 – inversion
1- no inversion

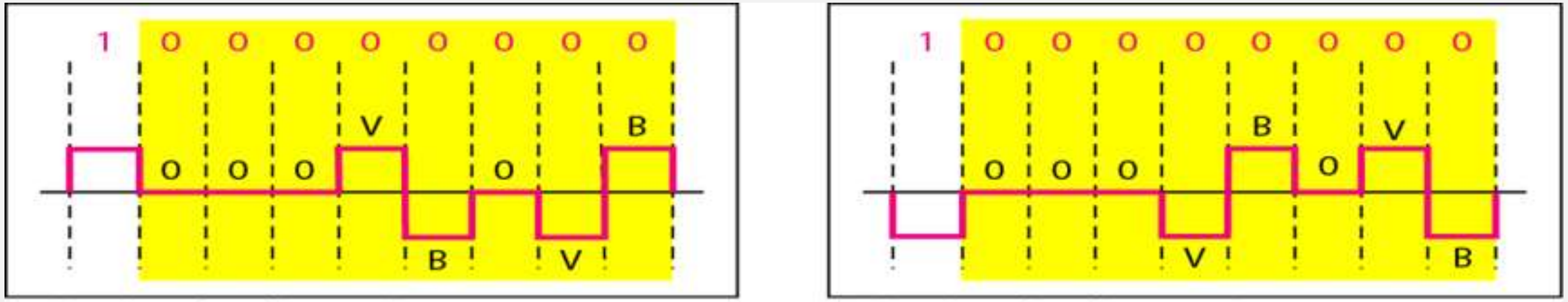


- **Bipolar:**
- - It uses 3 voltage levels: positive, negative and zero.
- - Types:
- i. AMI (Alternate Mark Inversion)
- ii. B8ZS (Binary 8 zero substitution)
- iii. HDB3 (High Density Bipolar 3)

- **Bipolar Alternate Mark Inversion (AMI):**
- - the “0” symbol is represented by zero voltage and the “1”
- symbol alternates between +V and -V.
- In pseudoternary encoding, a binary 0 is represented by alternating positive and negative voltages (non-zero), and a binary 1 is represented by a zero voltage level.



- B8ZS:
- ➢ Bipolar With 8 Zeros Substitution
- ➢ Based on bipolar-AMI
- ➢ If octet of all zeros and last voltage pulse preceding was
- positive, encode as 000+-0-+
- ➢ If octet of all zeros and last voltage pulse preceding was
- negative, encode as 000-+0+-



a. Previous level is positive. b. Previous level is negative.

- HDB3:
- - It is used into the bipolar AMI pattern every time 4
- consecutive 0s are encountered instead of waiting for 8
- expected by B8ZS.
- - In HDB3 if 4 0s come one after another, we change the pattern
- in 1 of 4 ways based in the polarity of the previous 1 and
- number of 1s since last substitution.

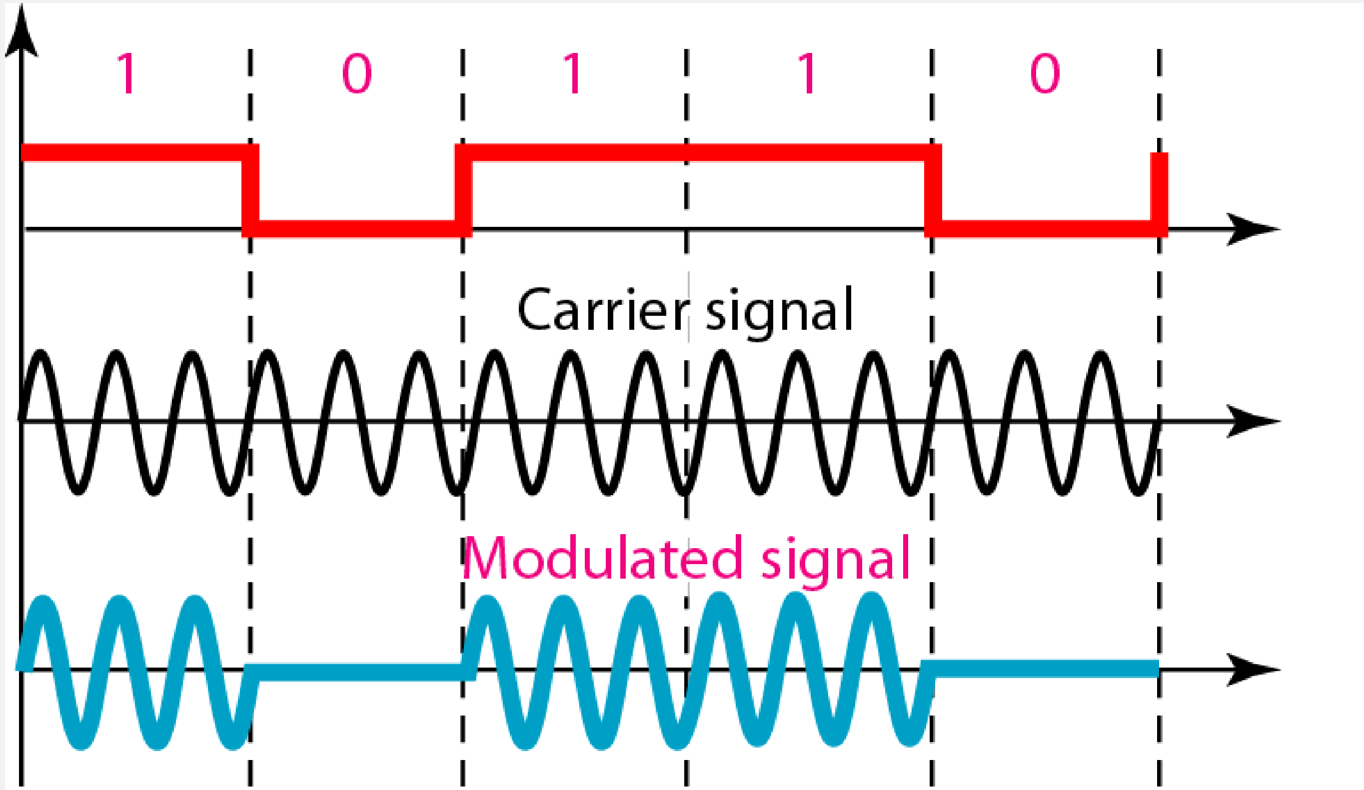
Polarity of Preceding Pulse	Number of 1s since last substitution	
	Odd	Even
-	0 0 0 -	+ 0 0 +
+	0 0 0 +	- 0 0 -

- How Ethernet Transmits Data
- Ethernet and LANs: Ethernet is the most common technology for local area networks (LANs), like those used in computer labs. It transmits data using digital signals over cables.
- Serial and Parallel Transmission: Ethernet can use either serial or parallel transmission. In serial transmission, bits are sent one after another over a single channel.
- Data Rate Example: One version of Ethernet sends data at 10 million bits per second (10 Mbps). If 8 bits make up a character, this translates to about 1.25 million characters per second.
- Manchester Encoding: Ethernet uses a method called Manchester encoding to send data. In this scheme:
- The signal changes in the middle of each bit period.
- A change from high to low represents a binary 0.
- A change from low to high represents a binary 1.
- This method helps detect errors because if there is no change in the middle, an error is likely
- Manchester encoding ensures that the signal remains synchronized and errors can be detected easily, making data transmission more reliable.

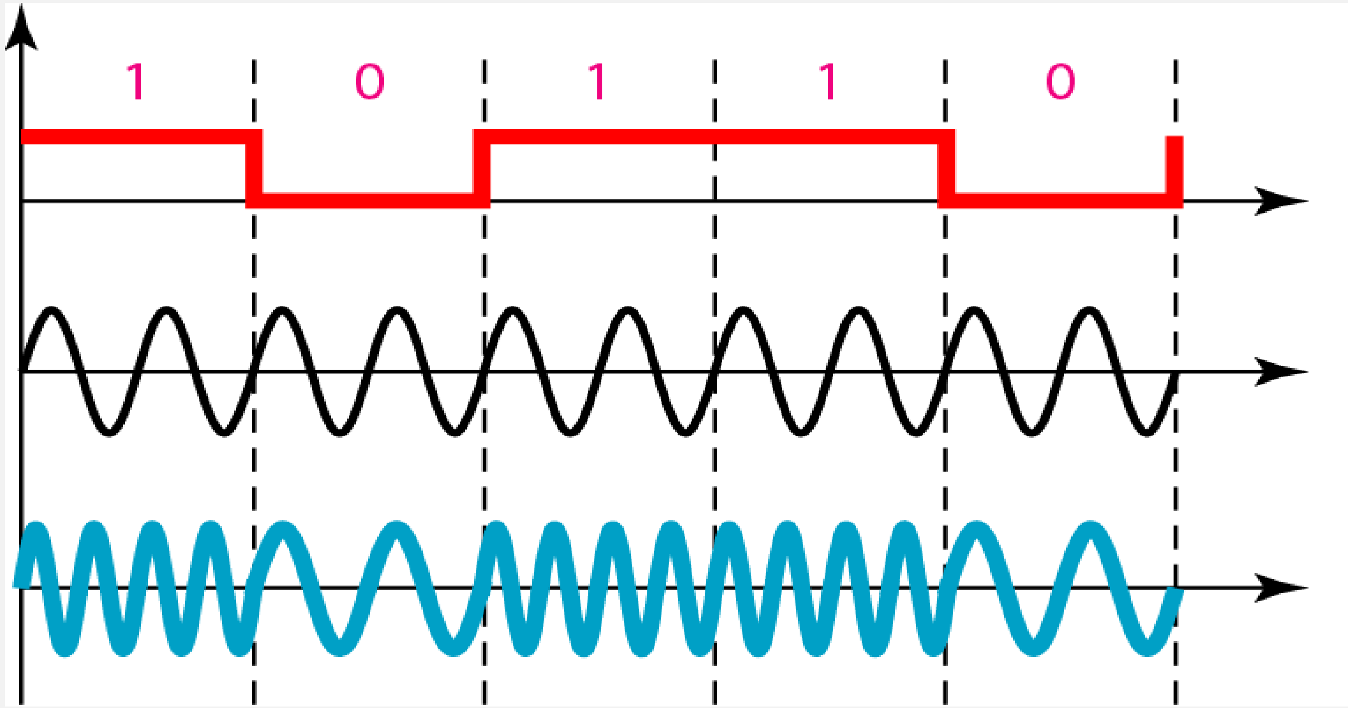
- **Digital to Analog Conversion**
- It is the process of changing one of the characteristics of an analog signal based on the information in digital data. A sine wave is defined by these characteristics:
- - Amplitude
- - Frequency
- - Phase
- When we vary one of these characteristics we create a different version of that wave.
- So, by changing one characteristic of a simple electric signal, we can use it to represent digital data.

- There are three mechanism for modulating digital data into an analog signal:
- \- (AM)Amplitude Shift Keying (ASK)
- \- (FM)Frequency Shift Keying (FSK)
- \- (PM)Phase Shift Keying (PSK)
- **Modulation:** It changes some part of a high-frequency signal (the carrier) according to the lower-frequency signal that carries the actual information.
- **Need of Modulation:**
- \- To protect signal from noise and interference
- \- Transmitting to a longer distance
- \- Transmitting signal efficiently through the channel.

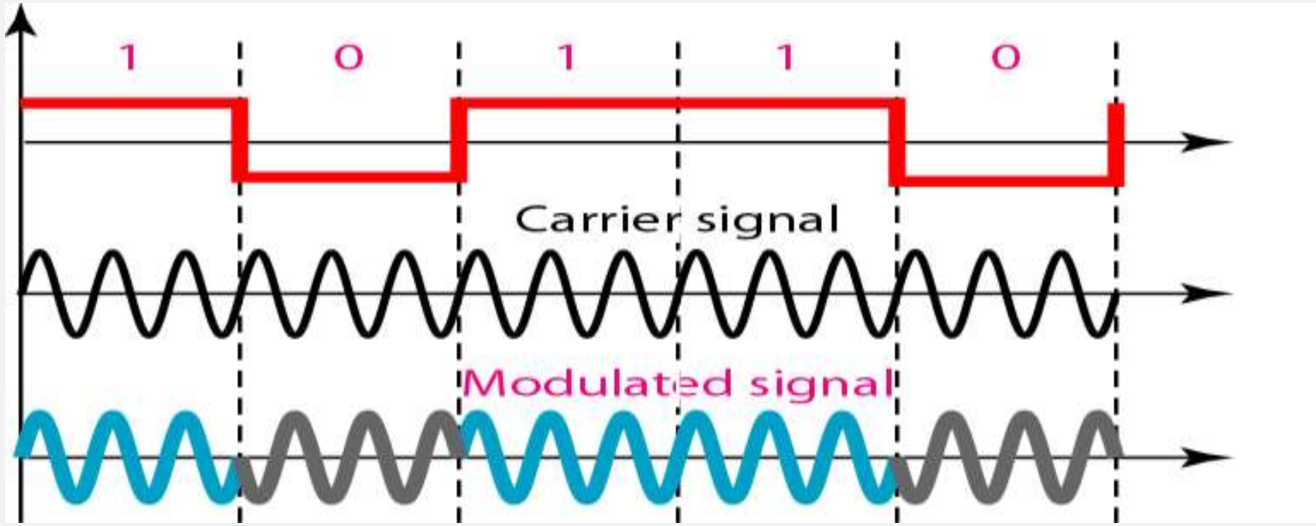
- **Amplitude Shift Keying (ASK):**
- In this technique frequency and phase of the signal remains constant but the amplitude of the signal will be changed.
- In the figure highest amplitude is represented by 1. In this case when the **sending device wants to transmit a 1**, it would send a high amplitude wave. AM is more susceptible to noise(more error during transmission them FM and PM)



- **Frequency Shift Keying (FSK):**
- - In this technique amplitude and phase of the signal remains constant but the frequency of the signal will be changed.
- Technique where by each 0 and 1 represent a number of wave per second. In this case the amplitude does not vary.
- One frequency is the symbol defines to be 1 and different frequency is the symbol defines to be 0
- The in figure the higher frequency wave symbol equals a binary 1 and lower frequency is 0



- **Phase Shift Keying (PSK): / (Binary PSK)**
- -In this technique amplitude and frequency of the signal remains constant but the phase of the signal will be changed.
- Phase refers to the direction in which wave begins.
- The wave that starts by moving up and to right is called 0 degree phase and wave that starts down and right is 180 degree phase.
- In the Diagram:
- Binary 1:The modulated signal aligns with the carrier signal (no phase shift).
- Binary 0:The modulated signal is inverted (shifted by 180 degrees) compared to the carrier signal.



- Sending Multiple Bits Simultaneously.
- Each of the three basic modulation techniques (AM, FM, and PM) can be refined to send more than 1 bit at one time.
- For example, basic AM sends 1 bit per wave (or symbol) by defining two different amplitudes, one for a 1 and one for a 0.
- It is possible to send 2 bits on one wave or symbol by defining four different amplitudes It is also possible to combine modulation techniques—that is, to use AM, FM, and PM techniques on the same circuit. **For example, we could combine AM with four defined amplitudes (capable of sending 2 bits) with FM with four defined frequencies (capable of sending 2 bits) to enable us to send 4 bits on the same symbol.**
- One populaire technique Is quadrature amplitude modulation (QAM). QAM involves splitting the symbol into eight different phases (3 bits) and two different amplitudes (1 bit), for a total of 16 different possible values. Thus, one symbol in QAM can represent 4 bits, while 256-QAM sends 8 bits per symbol. 64-QAM and 256-QAM are commonly used in digital TV services and cable modem Internet services.
- For example:
- **16-QAM** uses 16 different combinations of phase and amplitude, allowing each symbol to represent 4 bits of data.
- **256-QAM** uses 256 combinations, allowing each symbol to represent 8 bits of data able modem Internet services. This means that higher QAM levels can carry more data in each symbol, making them ideal for services like digital TV and high-speed interne

- **Bit Rate vs. Baud Rate**
- Understanding the difference between bit rate and baud rate is crucial when discussing data transmission, especially in the context of digital communications.
- **1. Bit Rate:**
- **Definition**: Bit rate is the number of bits transmitted per second in a communication channel. It is usually measured in **bits per second (bps)**.
- **Representation**: Bit rate directly represents the amount of data being transferred. For example, a bit rate of 1000 bps means 1000 bits are transmitted every second.
- **Higher Bit Rate**: A higher bit rate indicates more data is being transmitted per second, leading to potentially faster data transfer rates.
- **2. Baud Rate:**
- **Definition**: Baud rate refers to the number of signal units or symbols transmitted per second. It is measured in **symbols per second**.
- **Representation**: Each signal unit or symbol can represent multiple bits, depending on the modulation scheme used. For example, in Binary Phase Shift Keying (BPSK), each symbol represents 1 bit, so the baud rate equals the bit rate. In 16-QAM, each symbol represents 4 bits, so the baud rate is one-fourth the bit rate.
- **Higher Baud Rate**: A higher baud rate means more signal changes per second, which doesn’t necessarily translate to more bits being transmitted if each signal carries only 1 bit.

- **Relationship Between Bit Rate and Baud Rate:**
- **Basic Relationship**: Bit Rate=Baud Rate×Number of Bits per Symbol\text{Bit Rate} = \text{Baud Rate} \times \text{Number of Bits per Symbol}Bit Rate=Baud Rate×Number of Bits per Symbol
- **Example 1**: In a simple binary system (like BPSK) where each symbol represents 1 bit, if the baud rate is 1000 symbols per second, the bit rate is also 1000 bps.
- **Example 2**: In 16-QAM, each symbol represents 4 bits. If the baud rate is 1000 symbols per second, the bit rate would be 4000 bps (1000 symbols/second × 4 bits/symbol).

- Capacity of a Circuit
- **Data Capacity**: This is the fastest speed at which you can send data over a communication circuit, measured in bits per second (bps).
- **Bit Rate Calculation**:
  - Bit rate is calculated by multiplying the number of bits sent with each symbol by the number of symbols you can send per second (the symbol rate).
  - **Example**: If you're sending 4 bits with each symbol, and you can send 4000 symbols per second, then the bit rate is 16,000 bps.
- **2. What Affects the Symbol Rate?**
- **Bandwidth**: This is the range of frequencies the circuit can carry. It's like the width of a highway—the wider it is, the more cars (or data) can travel on it.
  - For example, human hearing ranges from 20 Hz to 14,000 Hz, so the bandwidth is 13,880 Hz.
- **Signal-to-Noise Ratio (SNR)**: This is the comparison of the strength of the data signal to the background noise. A higher SNR means a clearer signal and faster possible data transmission.
  - **Noisy Circuit**: If the circuit has a lot of noise, the symbol rate might be lower.
  - **Clear Circuit**: With less noise, you can reach the maximum symbol rate allowed by the bandwidth.

- **Analog vs. Digital Transmission**
- **Analog Transmission**:
  - The symbol rate usually matches the bandwidth. So, if a circuit has a 4000 Hz bandwidth, you can send 4000 symbols per second.
- **Digital Transmission**:
  - Digital circuits can sometimes send symbols faster than the bandwidth. For example, some digital methods can send up to twice as many symbols as the bandwidth allows.
  - **Example**: On a standard telephone line with 4000 Hz bandwidth, you could send 8000 symbols per second using certain digital techniques.
- **4. Practical Examples**
- **Standard Telephone Line**:
  - Bandwidth: 4000 Hz
  - Using basic AM (1 bit per symbol), the maximum data rate is 4000 bps.
  - Using QAM (4 bits per symbol), you can reach a data rate of 16,000 bps.
- **High-Bandwidth Circuit**:
  - If you have a circuit with a 10 MHz bandwidth using 64-QAM, which sends 6 bits per symbol, you can achieve a bit rate of 60 Mbps.

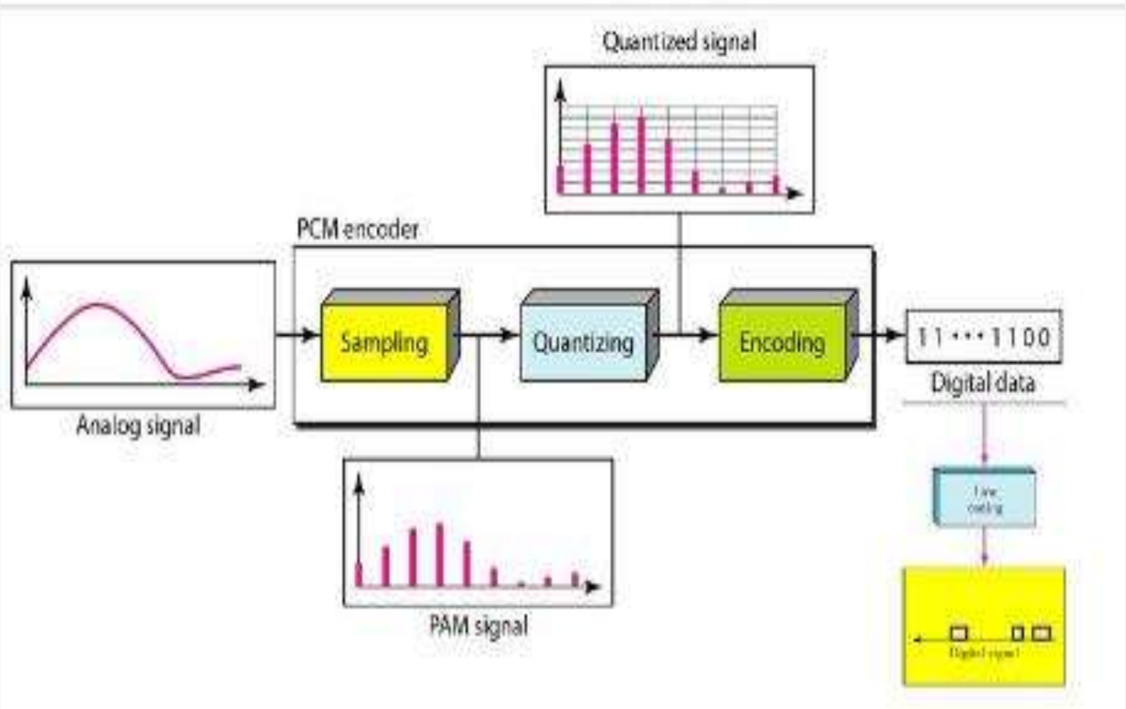
- **How Modems Transmit Data**
- **What is a Modem?**
  - "Modem" stands for **modulator/demodulator**.
  - It converts digital data from a computer (in the form of electrical pulses) into an analog signal. This conversion is necessary for sending data over traditional analog phone lines.
- **Types of Modems:**
  - **Dial-up Modems:** Older technology, using phone lines for internet access.
  - **Cable Modems:** Modern technology, using cable TV lines for faster internet.
  - Regardless of type, both communicating modems must be compatible with the same standard.
- **Transmission Standards:**
  - There are standards that modems follow to ensure compatibility, allowing any modem of the same standard to communicate with another.
- **Data Transmission Rate:**
  - The modem's speed, measured in bits per second (bps), is crucial for determining how quickly data can be sent.
  - Other factors, like line quality, also impact the overall data transmission speed.

- **Translating from Analog to Digital**
- Many sources of information are analog, which means they must be converted to digital form for further processing (eg: before they can ne encrypted). There are two basic approaches: pulse code modulation and delta modulation.

• Pulse Code Modulation (PCM):

• The most common technique to change an analog signal to digital data (digitization) is called pulse code modulation (PCM). A PCM encoder has three processes (sampling, quantizing, encoding) as shown in figure below:

- The analog signal is sampled.
- The sampled signal is quantized.
- The quantized values are encoded as streams of bits



- **Analog-to-Digital Conversion (ADC) Process**

1. **Sampling**:
   1. **What it is**: This is the first step in converting an analog signal to a digital one. The analog signal is measured, or "sampled," at regular intervals, every TTT seconds.
   2. **Why it matters**: The rate at which you sample is crucial. According to the **Nyquist Theorem**, to accurately capture all the details of the original signal, your sampling rate must be at least twice the highest frequency present in the signal.
2. **Quantization**:
   1. **What it is**: After sampling, you get a series of discrete points. Quantization involves mapping these points to a set of fixed values. Essentially, it's like rounding off these points to the nearest value within a defined range.
   2. (Quantization is like rounding off numbers in math. Imagine you have a list of measurements, but instead of writing down every exact number, you round each one to the nearest whole number.)
   3. **Why it matters**: This process converts the sampled values into a form that can be represented digitally, but it's an approximation. The range between the maximum and minimum signal values determines the "resolution" or accuracy of this approximation.
3. **Encoding**:
   1. **What it is**: The quantized values are then converted into binary code. This is what a computer or digital device can store and process.
   2. **Why it matters**: The bit depth, or the number of bits used for each sample, determines how precisely the signal's amplitude is represented. More bits mean a higher fidelity digital representation of the original analog signal.

- **Delta Modulation**

1. **What It Is**:
    1. Delta Modulation is a method for converting an analog signal into a digital one, similar to Pulse Code Modulation (PCM).
    2. Instead of sending the exact value of each sampled point, Delta Modulation sends the difference between the current sample and the previous one.
2. **How It Works**:
    1. **Initial Value**: First, it sends one starting value.
    2. **Differences**: After that, it only sends small changes (or differences) between each sample point and the one before it. If the signal hasn't changed much, this difference is small and can be represented with fewer bits.
3. **Why It's Used**:
    1. Because it sends differences rather than full values, Delta Modulation can often use fewer bits, making it more efficient when the signal doesn't change rapidly.
4. **Tradeoff**:
    1. **Error Sensitivity**: The main downside is that if there's an error in transmission (like a lost or damaged value), it affects not just that one value but all the following ones. This can lead to a bigger mistake in interpreting the signal.
    2. **When to Use PCM**: For systems where data loss or changes are expected, Pulse Code Modulation (PCM) is preferred because it doesn't have this cascading error problem.

- **Delta Modulation**
- Imagine you have an analog signal that varies over time, and you've sampled this signal at regular intervals. Here are the sample values:
- **Sample 1:** 5
- **Sample 2:** 6
- **Sample 3:** 7
- **Sample 4:** 6
- **Pulse Code Modulation (PCM)**
- In PCM, you would send each of these sample values directly:
- Send: 5, 6, 7, 6
- In Delta Modulation, you do something different:

1. **Send the First Value:**
    1. Start by sending the first sample value as it is: 5.
2. **Send Differences:**
    1. **Sample 2:** Instead of sending 6, you send the difference between 6 and the previous value (5). Difference = 6 - 5 = +1
    2. **Sample 3:** The next difference is 7 - 6 = +1
    3. **Sample 4:** The final difference is 6 - 7 = -1

- So, in Delta Modulation, you'd send the data as:
- Send: 5, +1, +1, -1

- **How Telephone Calls Work**

1. **Your Voice as an Analog Signal**:
    1. When you speak into a telephone, your voice is captured as an analog signal. This is a continuous wave that represents the sound of your voice.
2. **Sending the Signal**:
    1. The telephone sends this analog signal through the wires (the local loop) from your home to the telephone company's network.
3. **Old vs. New Technology**:
    1. In the past, this analog signal would travel through the entire telephone network as is, just like it did when Alexander Graham Bell invented the telephone in 1876.
    2. With modern digital technology, things have changed. The telephone companies now convert these analog signals into digital signals for most of the journey.
4. **Digital Conversion**:
    1. **At the Telephone Switch**: When your analog signal reaches the first telephone switch (a kind of hub in the network), it's converted into a digital signal by a device called a codec. This is done because digital signals are more reliable and can carry more data over longer distances without losing quality.
    2. **Through the Network**: This digital signal travels through the phone network, moving between different switches and cables.
5. **Back to Analog**:
    1. **At the Destination Switch**: When the digital signal reaches the switch near the person you're calling, another codec converts it back into an analog signal.
    2. **To the Recipient's Phone**: Finally, this analog signal travels through the local loop to the other person's phone, where it's turned back into sound that they can hear.

- **How Instant Messenger Transmits Voice Data**

1. **Voice Data and Bandwidth**:
   1. Transmitting voice data digitally typically requires a bandwidth of (64 Kbps). This provides good sound quality but can be too demanding for many networks, especially those with lower speeds.
2. **ADPCM to the Rescue**:
   1. **What It Is**: ADPCM (Adaptive Differential Pulse Code Modulation) is a technique used to compress voice data so that it can be sent over lower-speed digital circuits without using too much bandwidth.
   2. **How It Works**:
      1. Instead of sending each piece of the audio signal independently, ADPCM focuses on sending the differences between each part.
      2. It "predicts" what the next sound should be based on the previous ones, then only sends the difference between the prediction and the actual sound.
      3. This difference is smaller, so it can be compressed, reducing the amount of data that needs to be sent.
3. **Why It's Useful**:
   1. **Efficient Compression**: By adapting to the signal and only sending the necessary information, ADPCM can transmit voice data efficiently while still keeping the sound quality good enough for clear conversations.
   2. **Real-Time Applications**: This makes ADPCM perfect for real-time communication tools like Instant Messenger, Voice over IP (VoIP), and digital phone systems, where saving bandwidth and reducing delays are crucial

- **Voice over Internet Protocol (VoIP)**

1. **What Is VoIP?**:
    1. VoIP is a technology that allows you to make voice calls and send multimedia content over the internet instead of traditional phone lines.
2. **How It Works**:
    1. **Conversion**: It starts by converting your voice, which is an analog signal, into digital data.
    2. **Packetization**: This digital data is then broken down into small pieces called packets.
    3. **Internet Transmission**: These packets are sent over the internet to the person you're calling.
    4. **Reconversion**: If the person is using a regular phone, the digital data is converted back into analog sound at their end.
3. **Protocols and Quality**:
    1. VoIP uses protocols like **SIP** (Session Initiation Protocol) and **H.323** to manage call setup and control.
    2. To ensure clear calls, VoIP uses Quality of Service (QoS) techniques to prioritize voice data, reducing delays and maintaining high sound quality.