MODULE 1

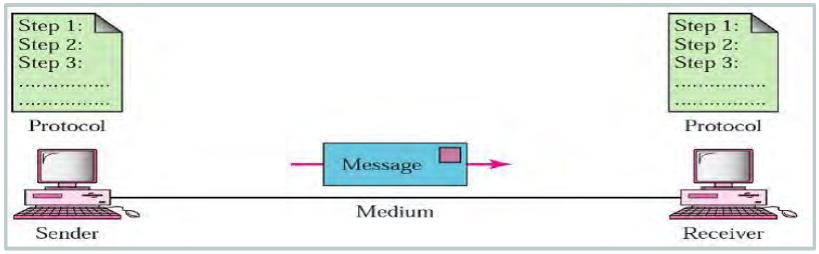
INTRODUCTION

Data Communication :

Exchange of data between two devices through a transmission medium.
The devices must be a part of communication system made up of hardware and software.
A data communication system is said to be effective and efficient if it takes care of:

- Delivery – data delivery to correct destination
- Accuracy – data must be reliable and should not be erroneous at receiver end
- Timeliness – delivery of data in timely manner

COMPONENTS :



- Message – data to be exchanged (text, voice, image or combination of these)
- Sender – device such as computer, workstation, telephone, television that send message
- Receiver – device such as computer, workstation, telephone, television that receives message from sender
- Medium – physical pathway through which message travels from sender to receiver, it can be wired or wireless and makes use of cables, optical fibers, microwaves, radio waves etc.
- Protocols – set of rules that represents an agreement between sender and receiver to have a secure and understanding communication.

NETWORKS :

Collection of devices, called nodes, connected by media links known as communication channel.
Nodes can be any devices with the capability to send or receive data such as computers, printers etc.

Distributed Processing

Instead of a single large machine doing all the works, tasks are divided and given to multiple computers.
Advantages :

- Security/Encapsulation – Limited access and interactions for individual system
- Distributed database – No overhead of single system storing whole database
- Faster problem solving – Multiple system working on part of a single problem
- Security through redundancy – Multiple system run similar program, if one fails others can be consulted
- Collaborative processing – Interactive working between users working on collaborative tasks

Network Criteria

Some important network criteria that must be met for a network to be counted as efficient and effective :

- Performance : Depends on the number of users, type of transmission medium, hardware and software used
- Reliability : Depends on the frequency of failure, recovery time, catastrophe(protection from fire, theft etc.)
- Security : Protection from unauthorized access and viruses

Applications

- Electronic Messaging

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- EDI (Electronic Data Interchange)
- Cellular telephones
- Cable television
- Teleconferencing
- Manufacturing
- Marketing and sales
- Financial services
- Directory Services and Information Services

PROTOCOLS AND STANDARDS :

Protocols are set of rules that represents an agreement between sender and receiver to have a secure and understanding communication.
It defines what is communicated, how it is communicated, and when it is communicated.
Key elements :

- Syntax – format of data, e.g., first 8 bits sender's address, second 8 bits receiver's address, rest bits message
- Semantics – meaning of each section of message, how to interpret specified pattern of bits
- Timing – when and how data should be sent

Standards are widely accepted guidelines that ensures interoperability of data and telecommunication technology and processes.
They provide guidelines for manufacturers, government agencies, other service providers to ensure interconnectivity for national and international interoperability.
Data communication standards fall in two categories :

- de facto(by fact/by convention) - Standards developed by a private company which are used widely as a result of the choices of consumers. Can be *proprietary(closed)* or *non-proprietary(open).*
  Proprietary : wholly owned by company invented them and close off communication between systems produced by different company.
  Non Proprietary : developed by a group or committee and passed into public domain. Allows communication between systems from different vendors.
- de jure(by law/by regulation) - Standards registered at a recognized standards organization

Standards Organizations :
Standards are developed by cooperation among :

- Standards creation committee
- Forums
- Government regulatory agencies

1) Standards Creation Committee
Some noted standards organizations are :
ISO(International Standards Organization, also known as International Organization for Standardization)

- Created in 1947, dedicated to worldwide agreement on international standards.
- Played a vital role in the creation of the Open Systems Interconnection (OSI) model for network communications.

ITU-T(International Telecommunications Union-Telecommunication Standards Sector)

- ITU-T is divided into study groups, each devoted to a different aspect of the industry. National committees (such as ANSI in the United States) submit proposals to these study groups. If the study group agrees, the proposal is ratified and becomes part of the ITU-T standard, issued every four years.
- The best-known ITU-T standards are the V series, which define data transmission over phone lines; the X series, which define transmission over public digital networks; e-mail and directory services; and the Integrated Services Digital Network (ISDN)

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ANSI(American National Standards Institute)

- Private nonprofit corporation and its activities are undertaken with the welfare of the United States and its citizens
- Aims include serving as the national coordinating institution for voluntary standardization in the United States, furthering the adoption of standards as a way of advancing the U.S. economy, and ensuring the participation and protection of the public interests.
- ANSI submits proposals to the ITU-T and is the designated voting member from the United States to the ISO

IEEE(Institute of Electrical and Electronics Engineers)

- Largest professional engineering society in the world involved in developing standards for computing, communication, electrical engineering, and electronics
- Sponsored an important standard for local area networks called Project 802.

EIA(Electronic Industries Association)

- Nonprofit organization devoted to the promotion of electronics manufacturing concerns.
- Activities include public awareness education and lobbying efforts in addition to standards development.
- Developed EIA-232-D, EIA-449, and EIA-530 define serial transmission between two digital devices (e.g., computer to modem).

Telcordia

- Formerly called Bellcore and it is an outgrowth of the Bell Labs.
- Provides research and development resources for the advancement of telecommunications technology and is an important source of draft standards to ANSI.

2) Forums

- Since the standards committee is slow moving and to facilitate the standardization process, many special interest groups have developed forums made up of representatives from interested corporations.
- The forums work with universities and users to test, evaluate, and standardize new technologies.
- The forums present their conclusions to the standards bodies.

Some important forums for the telecommunications industry include the following.

Frame Relay Forum

- Issues under review include flow control, encapsulation, translation, and multicasting.
- Results are submitted to the ISO.

ATM Forum and ATM Consortium

- Promote the acceptance and use of Asynchronous Transfer Mode (ATM) technology.
- Concerned with the standardization of services to ensure interoperability.
- The ATM Consortium is made up of vendors of hardware and software that support ATM.

Internet Society (ISOC) and Internet Engineering Task Force (IETF)

- Concerned with speeding the growth and evolution of Internet communications.
- The Internet Society (ISOC) concentrates on user issues, including enhancements to the TCP/IP protocol suite.
- The IETF is the standards body for the Internet itself. It reviews Internet software and hardware.

3) Regulatory Agencies

- All communications technology is subject to regulation by government agencies such as the Federal Communications Commission (FCC) in the United States.
- Purpose is to protect the public interest by regulating radio, television, and wire/cable communications.

FCC

The FCC has authority over interstate and international commerce as it relates to communications. Every piece of communications technology must have FCC approval before it may be marketed.

Specific FCC responsibilities include the following:

- To review rate and service-charge applications made by telegraph and telephone providers.
- To divide and allocate radio frequencies.
- To assign carrier frequencies for radio and television broadcasts

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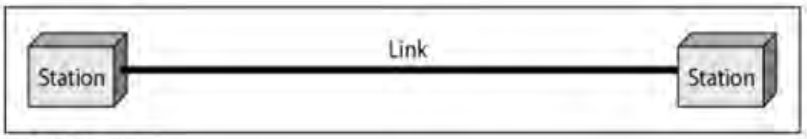
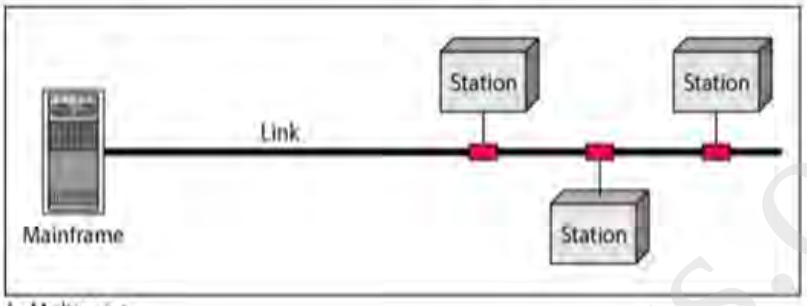
LINE CONFIGURATION

Way in which communication devices are connected to a communication link.
Link is the physical communication pathway through which the data is transferred.
The type of connection can be :

1. Point-to-Point
   Dedicated Link between two devices.
   Entire capacity of link reserved for transmission between the two devices.
2. Multipoint or Multidrop
   More than two devices share the link spatially or temporally.
   Spatially shared – simultaneous use of link
   Time shared – Users take turns



a. Point-to-point



b. Multipoint

TOPOLOGY

Way in which a network is laid out physically or logically.
Geometric representation of relationship of nodes and links.
Relationship can be ***peer to peer***(share link equally) or ***primary-secondary***(one device controls traffic, others transmit accordingly).
Two or more devices connect to a link and two or more links form a topology.
5 basic topologies :
Bus
Ring
Star
Tree
Mesh

- Ring and Mesh are best for peer to peer. Star and tree for primary-secondary.

Bus Topology

- Multipoint
- Single cable(**backbone**) links all devices
- Nodes connected to cable through droplines and tap
- Signal gets weaker as it travels farther (energy loss through heat)
- Easy to install
- Less cabling
- Difficult reconfiguration and fault isolation
- Single break in cable brings the whole network down.

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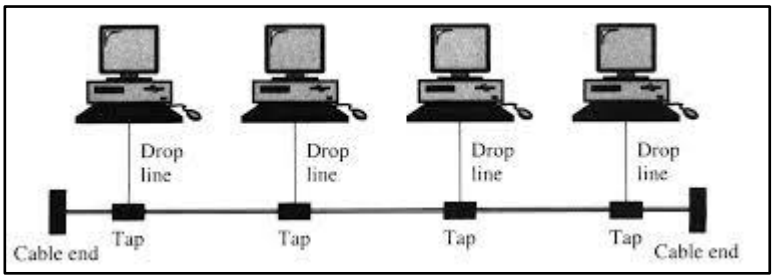
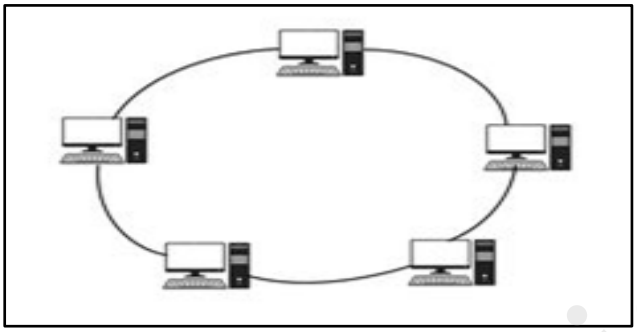
Figure: Bus Topology



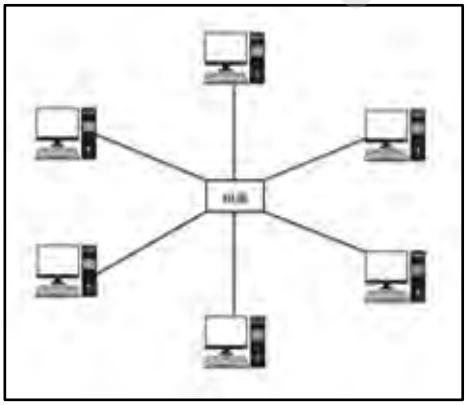
Ring Topology

- Dedicated point to point line configuration to two devices on either side
- Signal passed in one direction until destination is reached
- Each device has repeater, regenerates signal
- Easy to install and reconfigure
- Simple fault isolation
- Unidirectional traffic is a disadvantage
- Break in ring disables entire network, can be solved by using dual ring



Star Topology

- Dedicated point to point link to central controller(hub)
- No direct traffic between devices, controller does exchange of data
- Easy to install and reconfigure
- Robust, one link fail affects only that link
- Easy fault isolation
- More cabling than some topologies
- Hub fail disables entire network



Tree Topology

- Variant of star as nodes are connected to hub
- Different in the case that some nodes are not directly linked to *central hub they are connected to a secondary hub*
- Central node is *active hub*(contains repeater)
- Secondary may be active or passive

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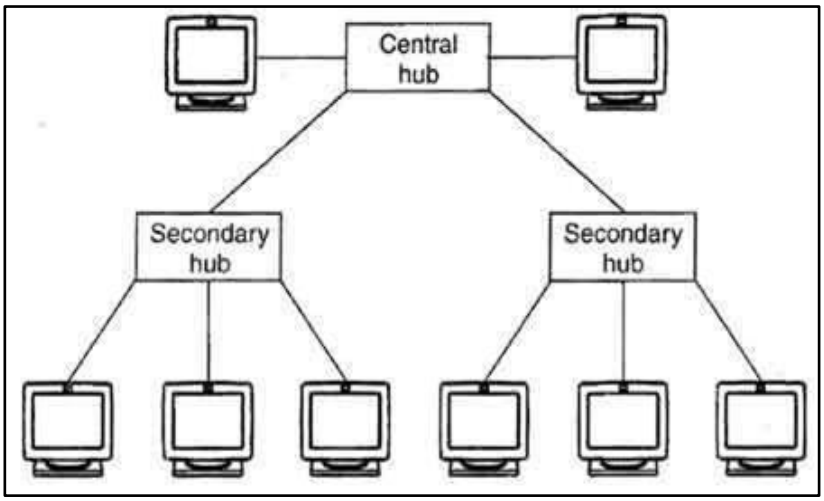
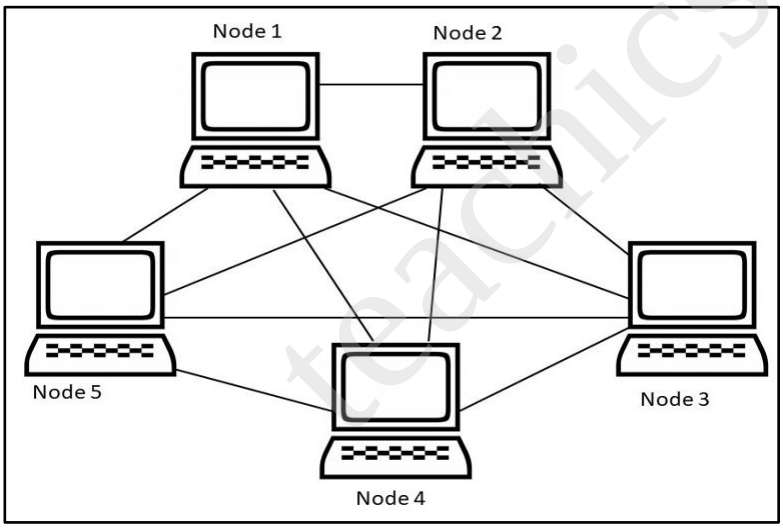
- Secondary hubs allows more devices to be attached
- Pros and cons same as star

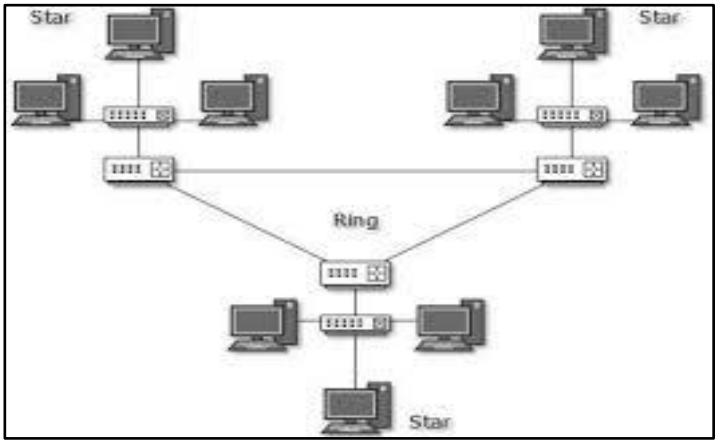


Mesh Topology

- Dedicated point to point link to every other device
- n(n-1)/2 physical links to connect n devices
- Each connection can carry its own data load, eliminates traffic
- Robust, one link fail doesn't bring whole system down
- Privacy, Security
- Fault isolation easy
- Large amount of cabling
- Installation and reconfiguration difficult



Hybrid Topology



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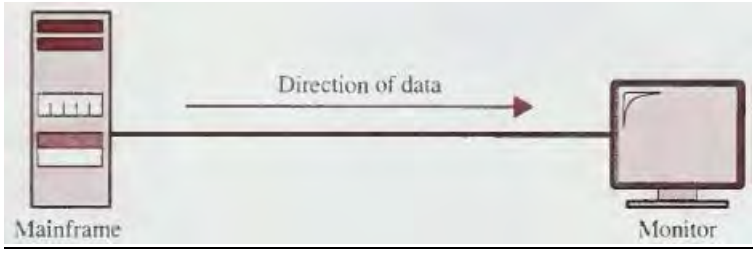
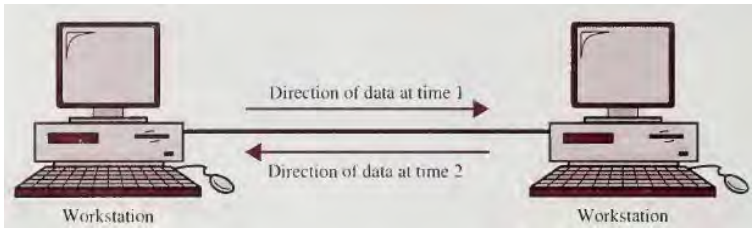
TRANSMISSION MODE

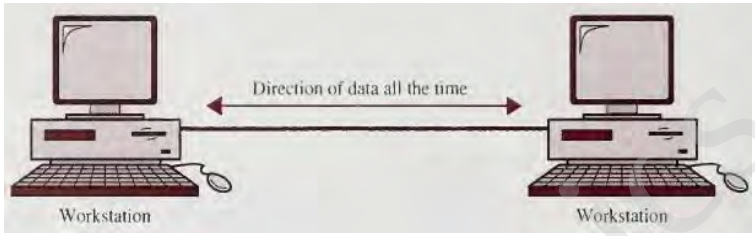
- Defines the direction of signal flow
- Simplex (Flow of data happens only in one direction(Unidirectional). Example : Keyboard to Monitor)



- Half duplex (Flow of data happens in both direction but not at same time(Bi-directional, but not at same time). Example : Walkie-Talkie)



- Full duplex (Flow of data is bidirectional and at same time. Example : Telephone)



Categories of Networks

Networks are categorized according to size, ownership, distance they cover and physical architecture as follows :

LAN(Local Area Network)

- Privately owned, Cover single office, building or campus
- The resources in network such as printer, application programs are shared by computers present in it
- Ethernet and Wi-Fi are two primary ways to enable LAN connections
- Preferably a system can be reserved as a server, which has large disk drive capacity to store major software and others as client who can access the services of server

MAN(Metropolitan Area Network)

- Extend over entire city
- Can be owned by private company or public company such as local telephone company
- May serve as an Internet Service Provider(ISP)
- Can be a single network as cable television, or a number of LANs connected to form larger network
- Devices used to carry data include modem, wire, cable

WAN(Wide Area Network)

- Spread over a large geographical area
- **Switched WAN** network is used to connect multiple end nodes to a switched WAN network to connect to other nodes or the public Internet. Example : asynchronous transfer mode (ATM) network
  Point-to-point wide area network (WAN) consists of two end nodes connected by a leased line. Example : dial-up line that connects a home computer to the Internet
- Devices used for data transmission are Optic wires, Microwaves and Satellites

Other network include PAN(Personal Area Network) which connects a mobile computer, cell phone/PDA and confine to an individual. CAN(Campus Area Network) is a network of multiple interconnected LANs in a

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limited geographical area such as in school campus for getting accessibility in different departments such as administrative office, libraries, research labs, two different buildings etc.

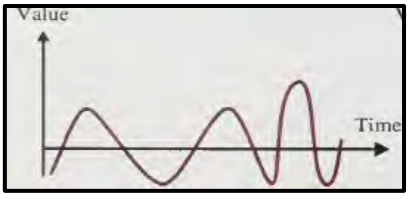
SIGNALS

- Data is sent over a physical medium as signals
- Signals are electromagnetic waves or electrical current used for carrying data from a device to another
- The data and signals that represent data can be of ***analog*** or ***digital*** form

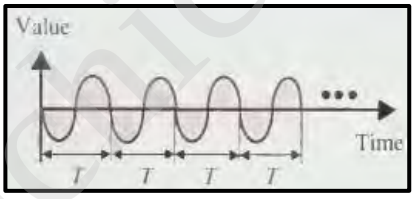
ANALOG SIGNALS

- Analog refers to a continuous phenomenon
- Analog data consist of continuous waves, an example would be sound
- Loudspeaker, microphones, sensors are all analog devices
- Analog signal is a continuous wave form that changes over time
- Both analog and digital signals can be ***periodic*** or ***aperiodic***
- In a ***periodic signal***, a pattern is repeated over same time interval
- A single full pattern is called ***cycle*** and time taken for a cycle is ***period***
- ***Aperiodic signals*** changes constantly without repeating a pattern
- Analog signals can be ***simple*** or ***composite***
- ***Simple analog signal (sine wave)*** cannot be further decomposed and ***composite*** ones can be decomposed to multiple sine waves
- The height of an analog signal is known as ***amplitude***
- ***Frequency*** refers to the number of cycles in one second. Period and frequency are inverse of each other.
- ***Phase*** specifies the location of a point within a wave cycle in a periodic waveform and is measured in degrees or radians

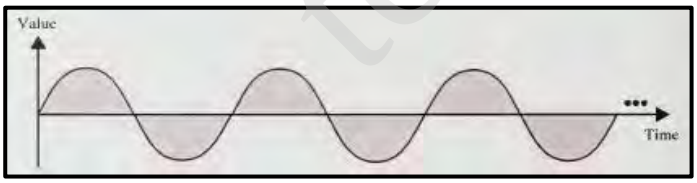
Analog Signal (Aperiodic)



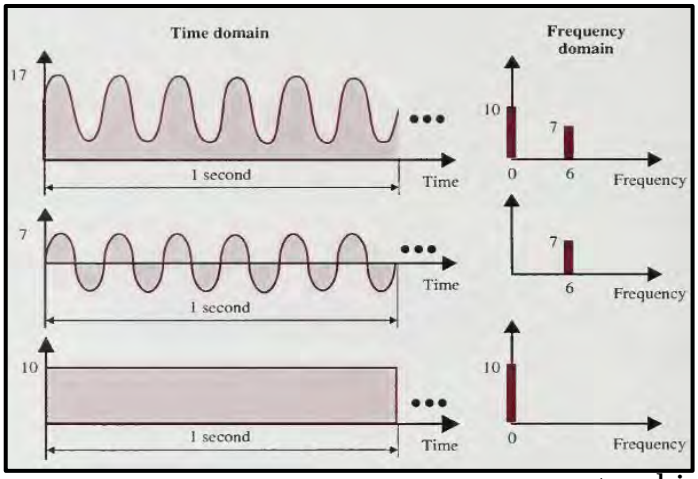
Periodic Analog Signal



Sine wave



Composite signal



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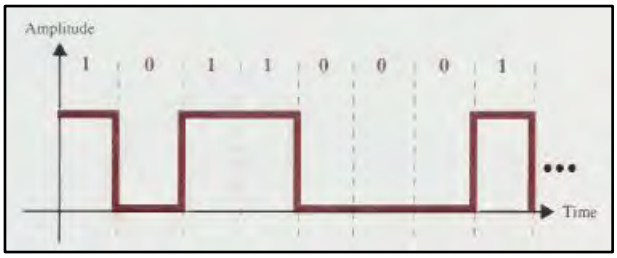
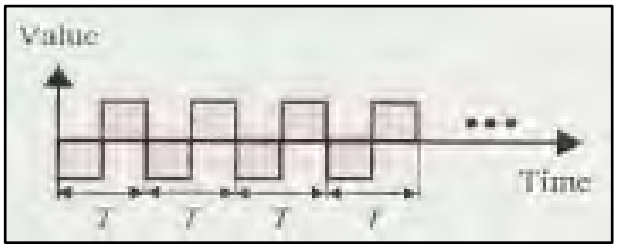
DIGITAL SIGNALS

- Digital data is discrete, discontinuous representation of any data or information
- Digital signal is discrete and have only limited set of values with transition from one value to another being instantaneous
- ***Bit interval*** refers to the time taken to send a single bit
- ***Bit rate*** refers to the number of bit intervals per second or number of bits sent in one second
- Computers, CDs, DVDs are examples of digital devices

Digital signal (Aperiodic)



Periodic digital signal

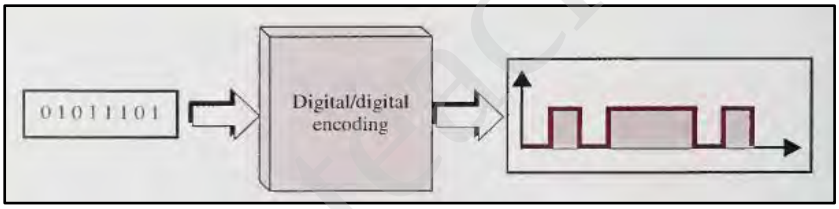


ENCODING AND MODULATING

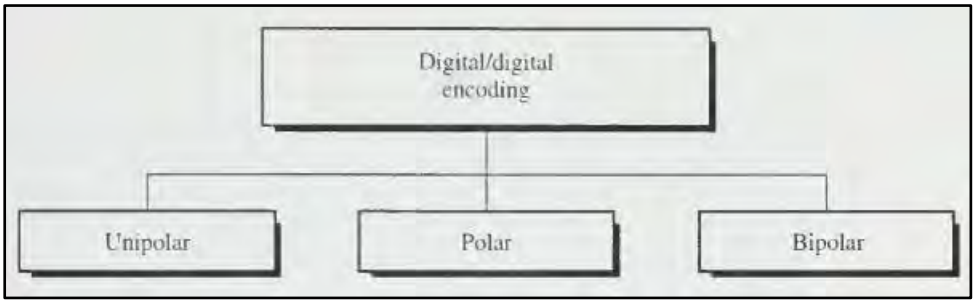
To transform data into signals four conversion methods are prominent. Data stored in the form of 0s and 1s are converted to digital signals to be carried from one place to another. This is called **digital-to-digital conversion** or **encoding digital data into a digital signal**. **Analog-to-digital conversion** or **digitizing an analog signal** involves converting an analog signal into a digital signal **Digital-to-analog conversion** or **modulating a digital signal** is converting digital signal to analog signal Converting analog data to analog signal is called **analog-to-analog conversion** or **modulating an analog signal.**

Digital-to-Digital Conversion

- 1s and 0s are translated into a sequence of voltage pulses that can be propagated over a wire



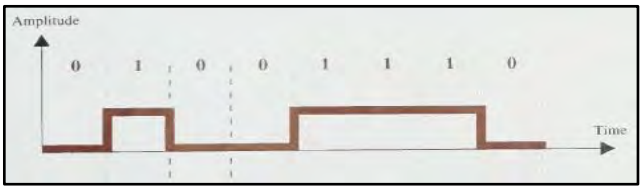
- Three methods of digital-to-digital conversion are available



Unipolar

- Polarity of a pulse represents whether it is positive or negative
- Unipolar encoding uses only one polarity, i.e., either positive or negative voltage represents one of the two binary states, usually 1, and other is represented by zero voltage.
- Hence, unipolar encoding uses only one level of value.
- Problems : Direct current(DC) component(component with zero frequency), synchronization

Unipolar encoding



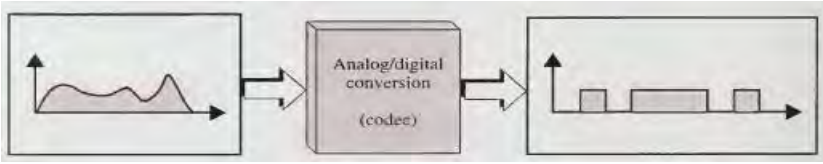
Polar

- Polar encoding uses two voltage levels, one positive and one negative

Bipolar :

- Uses three voltage levels line: positive, negative, and zero.
- zero level is used to represent binary 0.

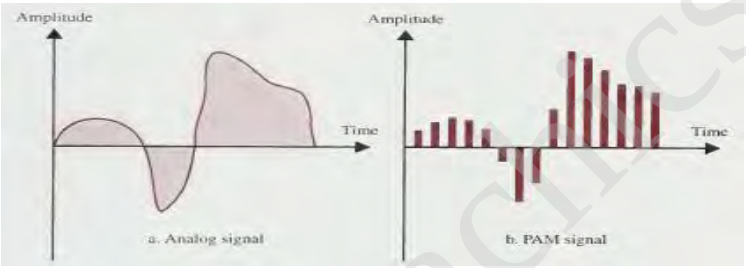
ANALOG-TO-DIGITAL CONVERSION



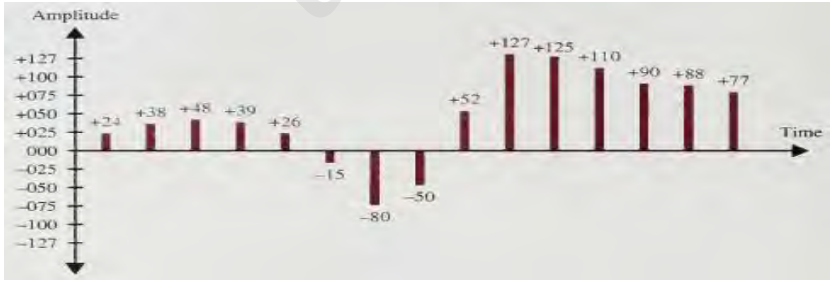
The information represented using a continuous waveform is converted to a series of digital pulses of 1s and 0s.

Steps in conversion

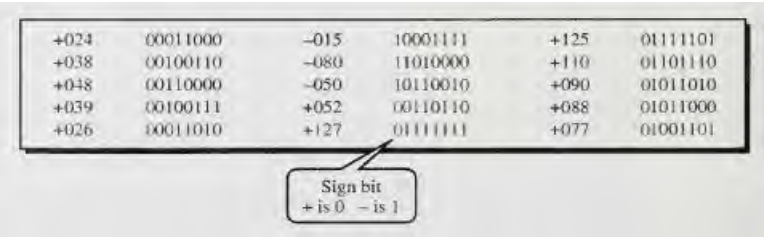
- The amplitude of the analog signal is measured at equal intervals, known as ***sampling***, to generate a series of pulses as shown below. This process is called ***Pulse Amplitude Modulation(PAM)***.



- The next process is ***Pulse Code Modulation(PCM)*** which includes the following procedure.
  1) Integral values in a specific range are assigned to the PAM pulses. This process is known as ***Quantization.***



  2) Each value is converted to binary equivalent (number of bits depends on the level of precision needed). Here, we use 8 bits, 7 bits for magnitude and 8th bit for sign.



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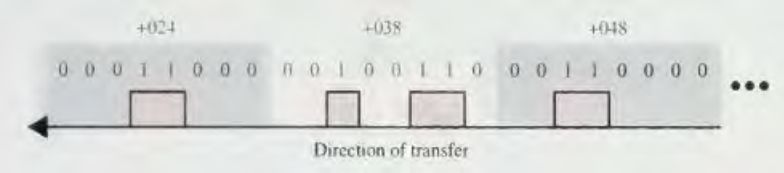
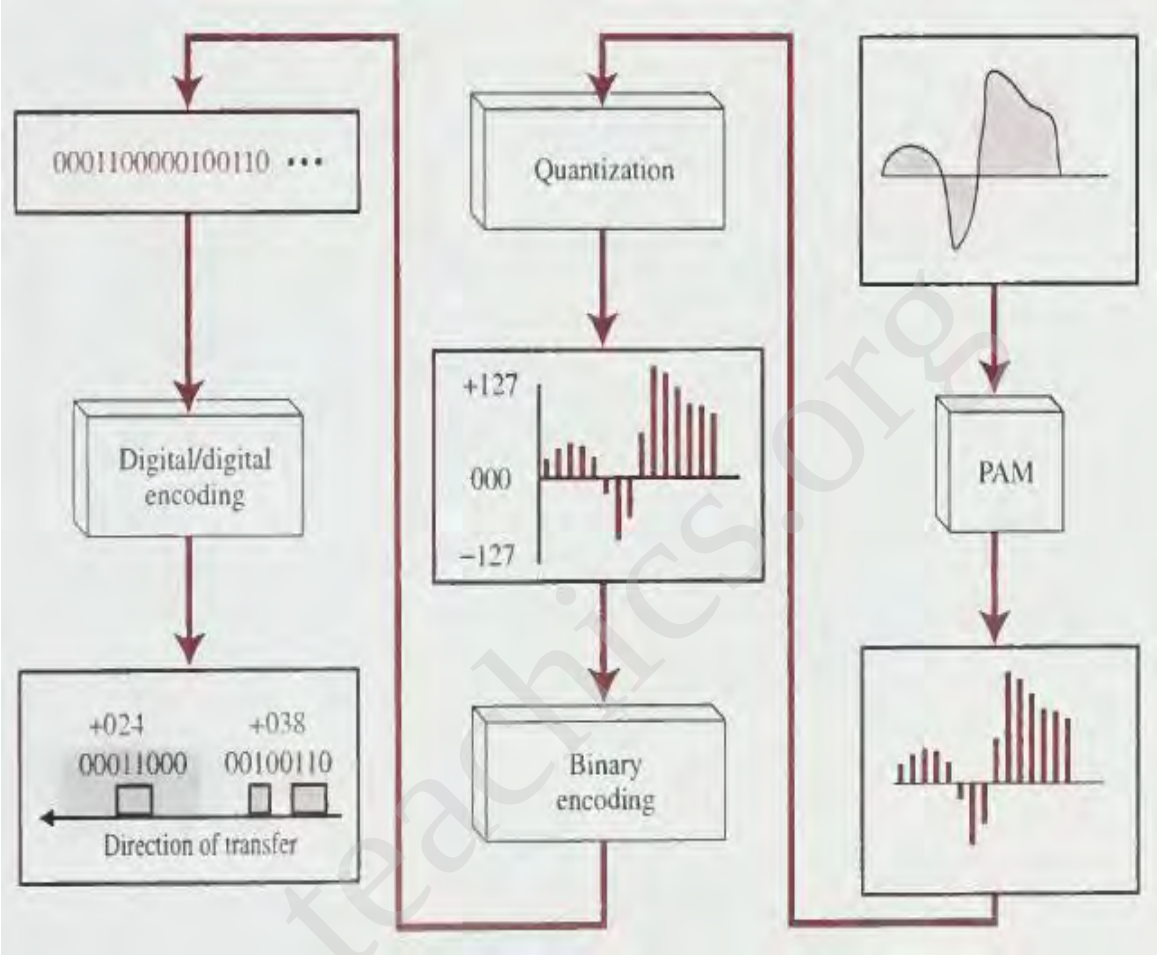
3) Binary bits are converted to digital signals using any digital-to-digital conversion technique. (unipolar conversion shown below)



Complete Process of Analog to Digital Conversion



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Sampling rate :

- According to the Nyquist theorem, the sampling rate must be at least twice the highest frequency of the original signal.
- For an analog signal with maximum frequency 4000 Hz, a sampling rate of 8000 samples per second is needed.
- Sampling rate of twice the frequency of X Hz means that the signal must be sampled even 1/2 X seconds.

Bit rate :

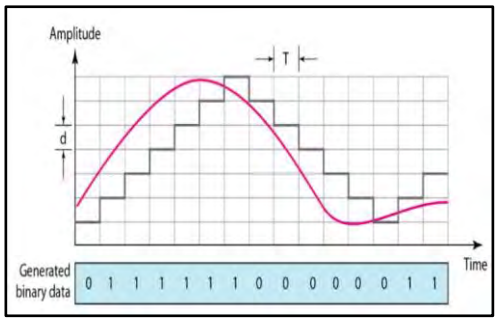
After finding the number of bits per sample, bit rate is calculated as :

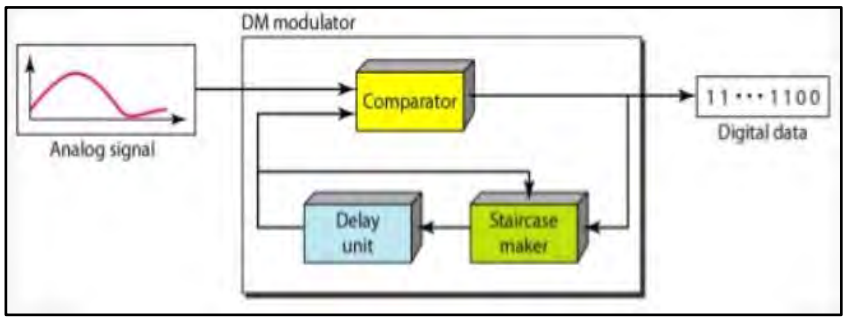
Bit rate = Sampling rate × Number of bits per sample

DELTA MODULATION

- Not complex as PCM modulation
- The analog signal is compared with another signal called *staircase signal.* The step size of staircase is delta (δ). At every sampling interval, if amplitude of signal is larger than the previous step, the next bit is one,

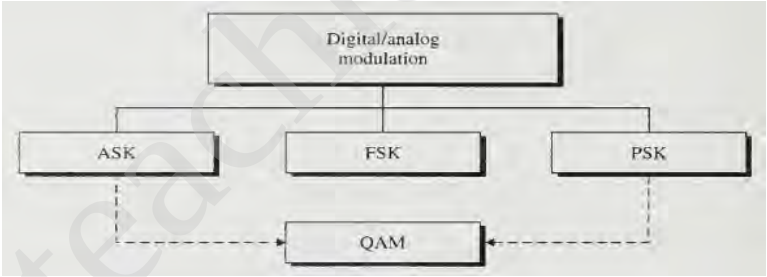
else zero. Hence, a positive delta value indicates one and negative value indicates zero. (Figure given below).





DIGITAL-TO-ANALOG CONVERSION

- Characteristics of an analog signal such as amplitude, frequency, phase are changed in order to incorporate digital information (1s and 0s)
- Methods for modulating an analog signal to hold digital information :
  1) Amplitude Shift Keying(ASK)
  2) Frequency Shift Keying(FSK)
  3) Phase Shift Keying(PSK)
  4) Quadrature Amplitude Modulation (QAM).



Bit Rate : Number of bits transmitted in one second

Baud Rate : Number of signal units per second needed to represent those bits
Hence, bit rate = baud rate × number of bits represented by a signal unit
baud rate = bit rate / number of bits represented by a signal unit

Carrier Signal : A high frequency signal is modified by changing its characteristics such as frequency, amplitude and
phase to represent the digital information. The high frequency signal is known as **carrier signal** or **carrier frequency**. The information signal, which is incorporated into carrier signal is known as **modulating signal**. This process of modification is known as **modulation** or **shift keying.**

Frequency Spectrum : Collection of all component frequencies in a signal is its frequency spectrum

Bandwidth : Width of frequency spectrum or range of frequencies occupied by a signal. It is calculated as [highest frequency – lowest frequency] of the range in the frequency spectrum.

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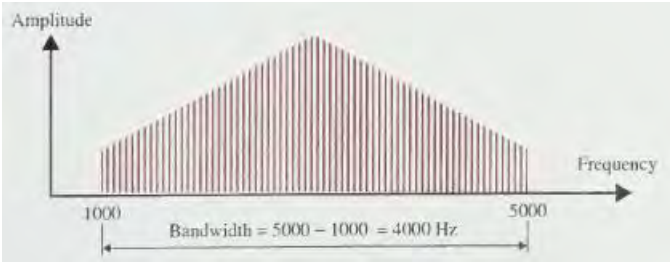
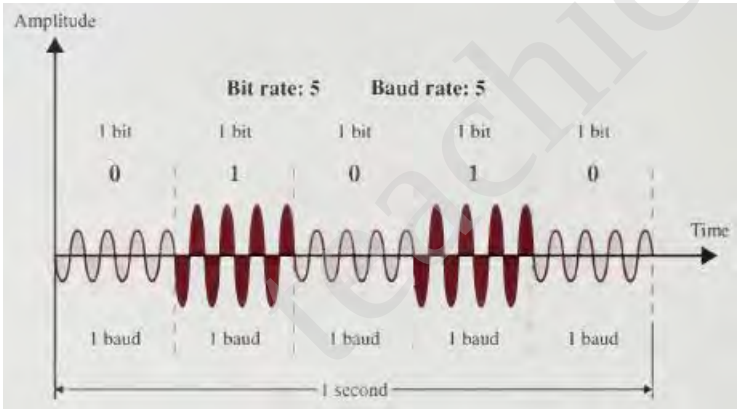


Bandwidth = High Frequency – Low Frequency

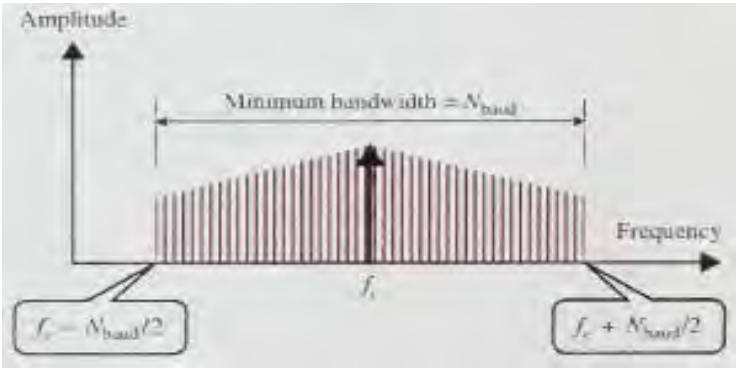
Amplitude Shift Keying(ASK)

- Frequency and phase remain constant, only amplitude changes
- Based on 0 or 1, the peak amplitude of the signal is different and corresponding peak amplitude is constant during each bit duration
- High noise interference
- On-Off-Keying (OOK) is an ASK technique in which one of the bit values is represented by no voltage and hence there is a reduction in the amount of energy required to transmit information
- Significant range in the spectrum of ASK modulated signal is :
  $f_c - N_{baud}/2$ to **$f_c + N_{baud}/2$** with the carrier frequency f_c at the middle and baud rate N_{baud}
- Bandwidth requirements for ASK are calculated using the formula
  $BW = (1 - d) \times N_{baud}$
  where
  BW is the bandwidth
  N_{baud} is the baud rate
  d is a factor related to the condition of the line

ASK



Bandwidth of ASK



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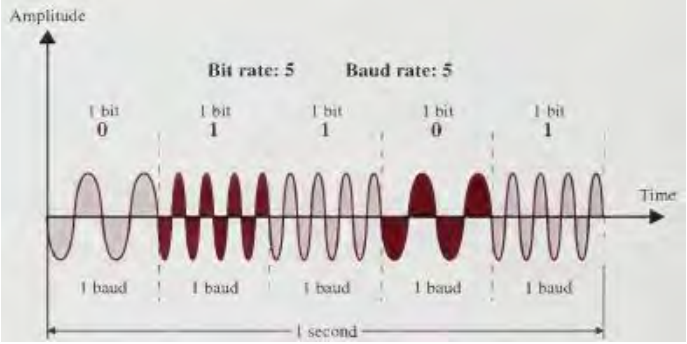
Frequency Shift Keying (FSK)

- Frequency of the carrier signal changed to represent binary 1 or 0 and both peak amplitude and phase remain constant
- The frequency of the signal during each bit duration is constant but different for 0 and 1

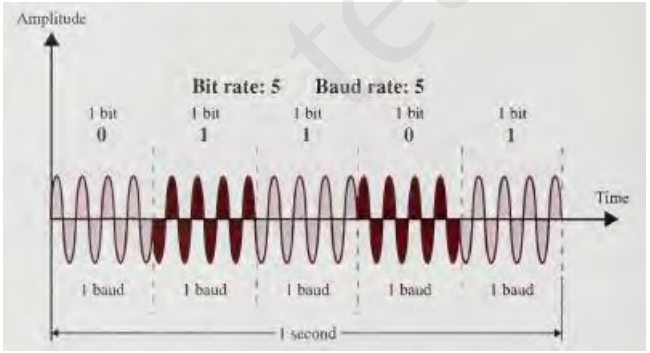


- Although FSK shifts between two carrier frequencies, the process of modulation produces a composite signal that is a combination of many simple signals, each with a different frequency
- FSK spectrum is the combination of two ASK spectra centered around carrier frequencies f_{c0} and f_{c1} (of two carrier signals)
- Bandwidth for FSK is baud rate of the signal plus the frequency shift (difference between the two carrier frequencies): BW = $(f_{c1} - f_{c0}) + N_{baud}$

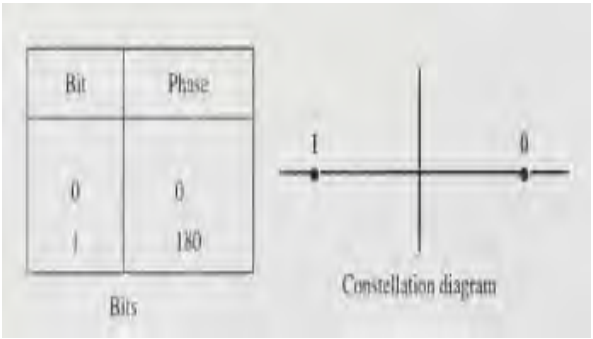
Phase Shift Keying(PSK)

- Phase of the carrier is altered to represent binary 1 or 0 while peak amplitude and frequency remain constant
- If binary 0 is represented by a phase of 0 degree, phase can be changed to 180 degrees to send binary 1
- The phase of the signal during each bit duration is constant and differ based on whether it is 0 or 1
- When two different phases (0 and 180 degrees) are used, it is known as **2-PSK or binary PSK**
- **Constellation or phase-state diagram** shows the relationship between bits and phase by illustrating only the phases
- No noise degradation as in ASK, no bandwidth limitations as in FSK.
- The minimum bandwidth required for PSK transmission is the same as that required for ASK transmission

PSK



Constellation Diagram



Four variations of signal to represent two bits each can be used known as **4-PSK or Q-PSK** as :

- 0 degree represents 00
- 90 degrees represents 01
- 180 degrees represents 10
- 270 degrees represents 1 1

The pair of bits represented by each phase is called a **dibit** and data transmission is two times faster than 2-PSK. This idea cab be extended to 8-PSK with eight different phases and each shift can represent three bits (one **tribit**) at a time of phases is a power of two. To send ***n*** bits at a time 2^n phases are needed.

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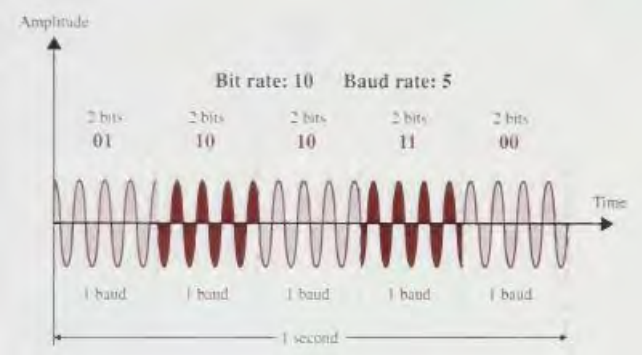
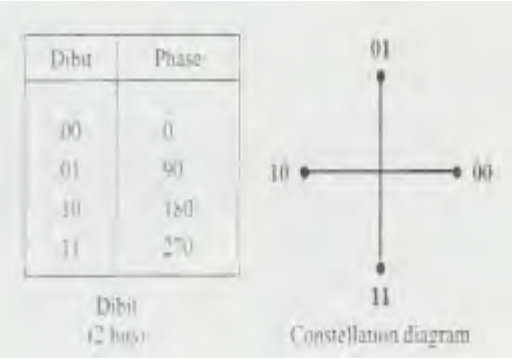
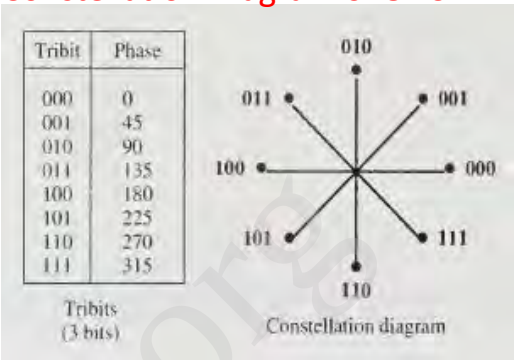
4 PSK



Constellation Diagram of 4 PSK

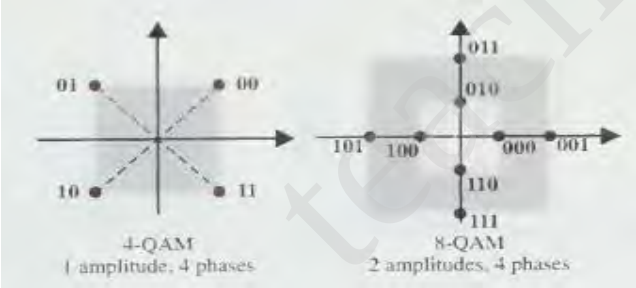


Constellation Diagram of 8 PSK



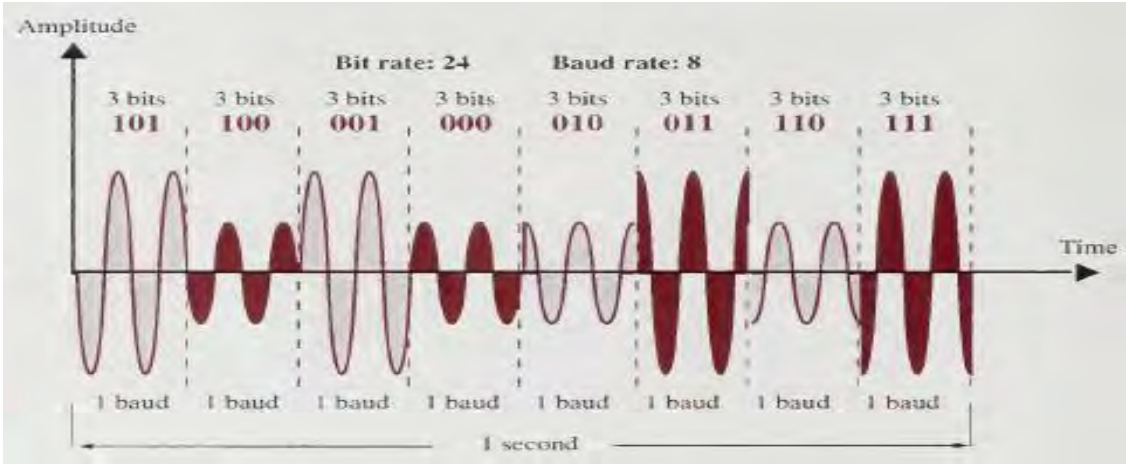
Quadrature Amplitude Modulation (QAM)

- Combines ASK and PSK
- Any measurable number of changes in amplitude can be combined with any measurable number of changes in phase
- 4-QAM and 8-QAM are shown below



- Since amplitude changes are prone to noise and require greater shift differences than phase changes, the number of phase shifts used by a QAM system is always larger than the number of amplitude shifts.

8 QAM



ANALOG TO ANALOG CONVERSION

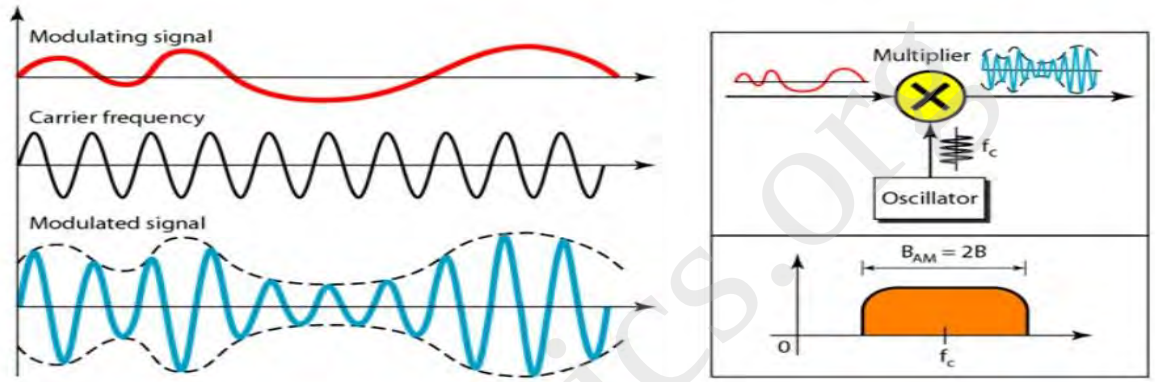
- This kind of modulation is needed if the medium is bandpass in nature or if only a bandpass channel is available for one
- In the case of a radio station, a narrow bandwidth to each radio station is allotted. Analog signal produced by each station is a low-pass signal in the same range. Therefore, to listen to all stations the low-pass signals must be shifted to a different range.

Types

- Amplitude Modulation
- Frequency Modulation
- Phase Modulation

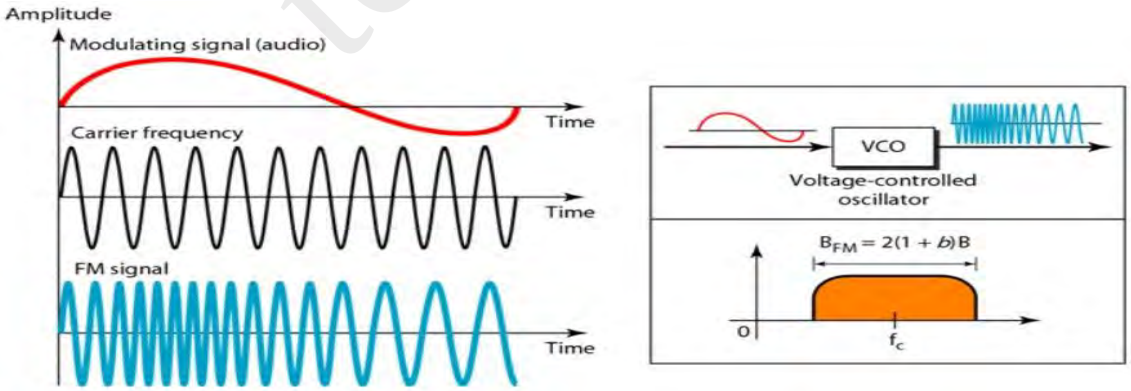
Amplitude Modulation(AM)

- Amplitude varies with changing amplitudes of the modulating signal while frequency and phase remain the same
- Implemented by using a simple multiplier because the amplitude of the carrier signal needs to be changed according to the amplitude of the modulating signal
- Total bandwidth required, $B_{AM} = 2B$, where B is the bandwidth of the modulating signal



Frequency Modulation

- Frequency of the carrier signal is modulated to reflect changing voltage level (amplitude) of the modulating signal
- Implemented by using voltage controlled oscillator, that changes frequency of the input voltage
- Total bandwidth, $B_{FM} = 2(1+\beta)B$, where β is a factor that depends on modulation technique with a common value of 4



Phase Modulation

- Phase of the carrier signal is modulated to reflect changing voltage level (amplitude) of the modulating signal
- PM is the same as FM with one difference as the instantaneous change in the carrier frequency is proportional to the amplitude of the modulating signal in FM and it is proportional to the derivative of the amplitude of the modulating signal in PM

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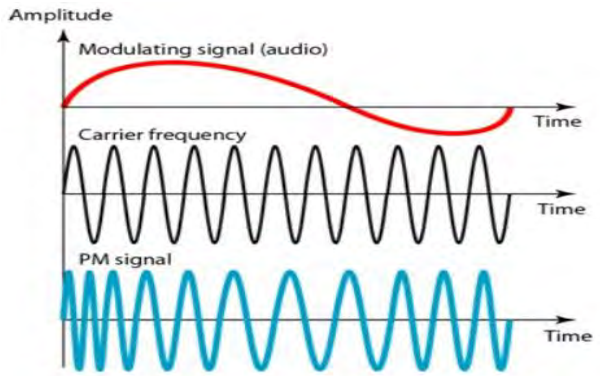
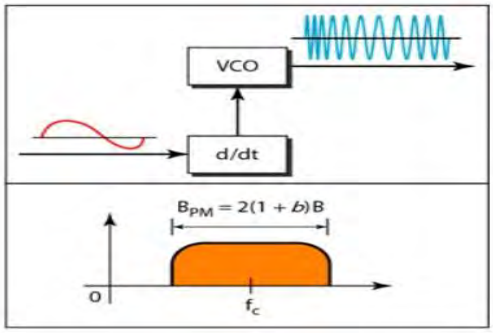
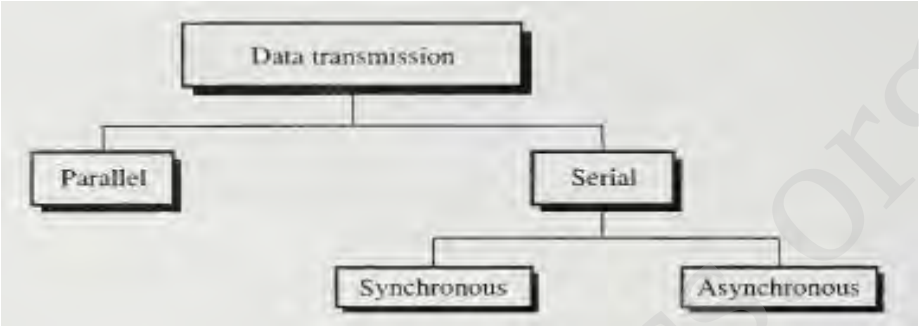
- Total bandwidth,
  $B_{FM} = 2(1+\beta)B$, β is a factor based on modulation technique



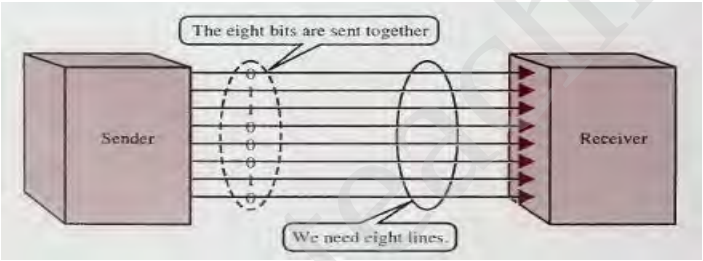


DIGITAL DATA TRANSMISSION



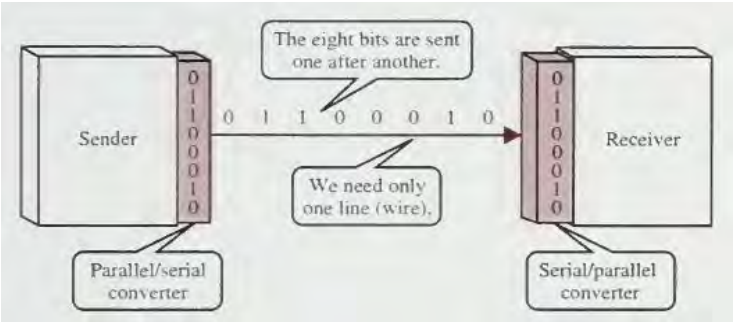
Parallel Transmission

n bits of data sent at a time through *n* communication channels such as wires



Serial Transmission

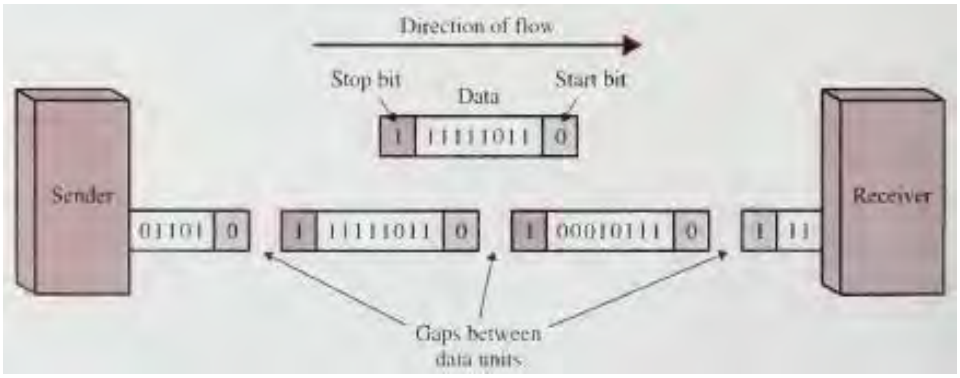
- Bits are sent one by one in serial fashion through single communication channel
- Can be **synchronous** or **asynchronous**
- Needs conversion devices at interface between sender and communication line, and between line and receiver since communication within a device is parallel



1) Asynchronous Transmission

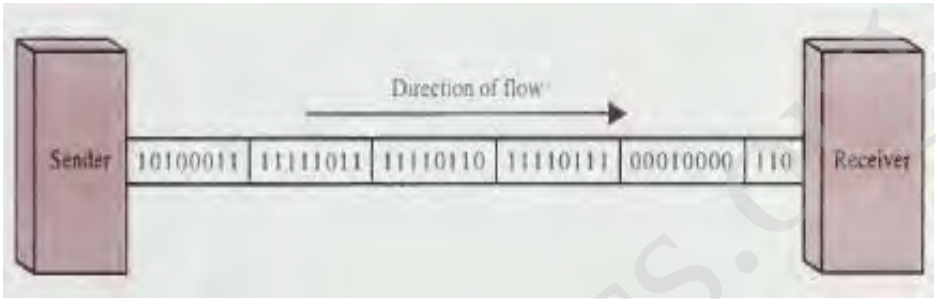
- Bits are grouped as bytes and sent as a unit without any synchronizing pulse or timer

- A **start bit**(usually zero), and a **stop bit**(or more than one stop bit, usually 1s) are sent to mark the beginning and end of each byte
- A gap may be provided between each byte transmission

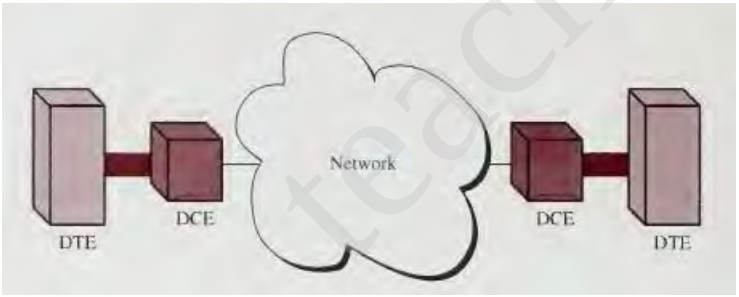


2) Synchronous Transmission

- Bits are sent in long *frames* which contains multiple bytes without any gap or additional bits
- Receiver must be synchronized with the incoming sequence of bits to count and divide them into bytes



DTE-DCE INTERFACE



Data Terminal Equipment(DTE)

- Any device that is a source or destination of binary data
- Generates data to be sent to the receiver and passes it to DCE
- It can be a terminal, computer, printer or any other device

Data Circuit-Terminating Equipment(DCE)

- Data generated by DTE is converted to analog or digital signal to be sent over communication channel
- Another DCE at receiver's side receives the data, converts it to a form suitable for the DTE there and delivers it
- Hence, DCE transmits or receives analog or digital signals through a network
- Modem is an example of a DCE

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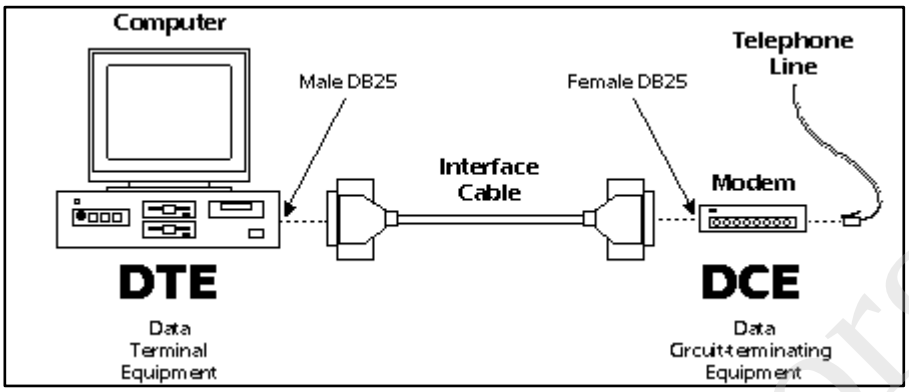
DTE-DCE Interface Standards

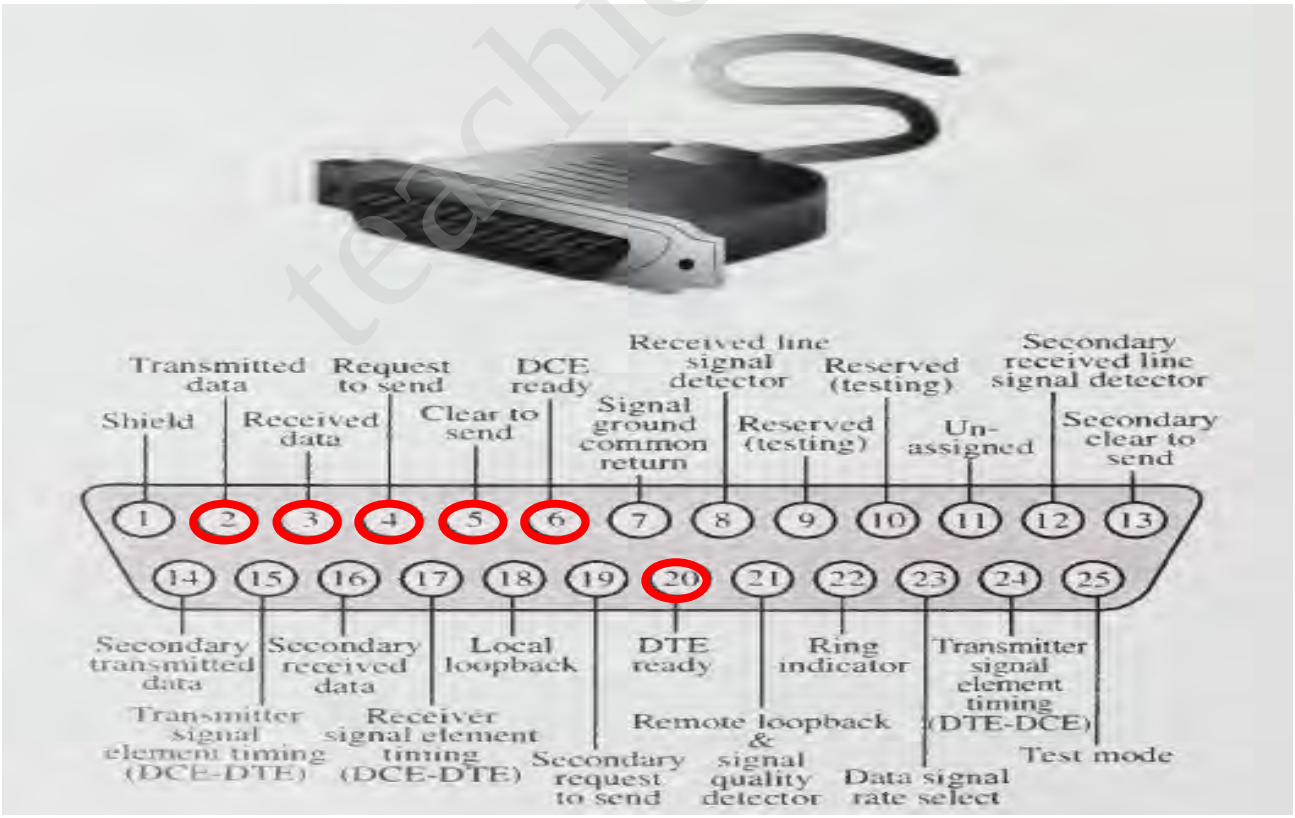
- Organizations such as Electronic Industries Association**(EIA)** and International Telecommunication Union-Telecommunication Standards Committee**(ITU-T)** have developed standards that define the ***mechanical, electrical and functional*** of the connection between DTE and DCE
- Some EIA standards are EIA-232, EIA-442, EIA-449
- ITU-T standards are called V-series and X-series such as X.21

EIA-232 Standard

- Issued as RS 232 (RS-Recommended Standard) and have been revised many times
- Mechanical specifications by the standard define a 25-wire cable with male and female DB-25 pin connector attached to either end. DB-25 connector represents a plug with 25 pins or receptacles based on whether it is male or female connector.



- Electronic specification defines the voltage level and type of signal to be transmitted in either direction between DTE and DCE
- Functional specifications describes functions of each pin in the connector. As many of the pins were unused most of the time, DB-9 implementation came into act.



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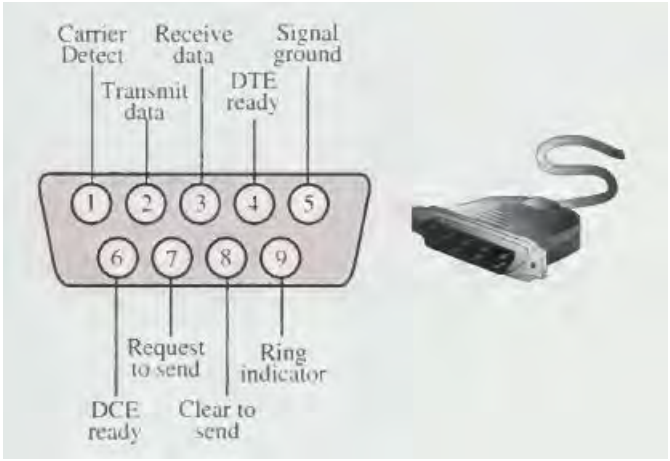
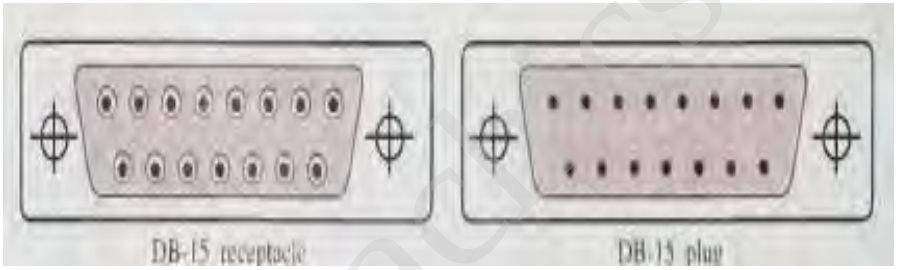
- EIA 449 defines new functions and characteristics for the interface and also a combination of two connectors was proposed (DB-37 and DB-9) with 46 total pins. The secondary channels of EIA 232 were used rarely and hence the functions of secondary channel was given to DB-9 implementation.



- A ***null modem*** is a communication method where transmit and receive lines are crosslinked to directly connect two DTEs using RS-232 cable

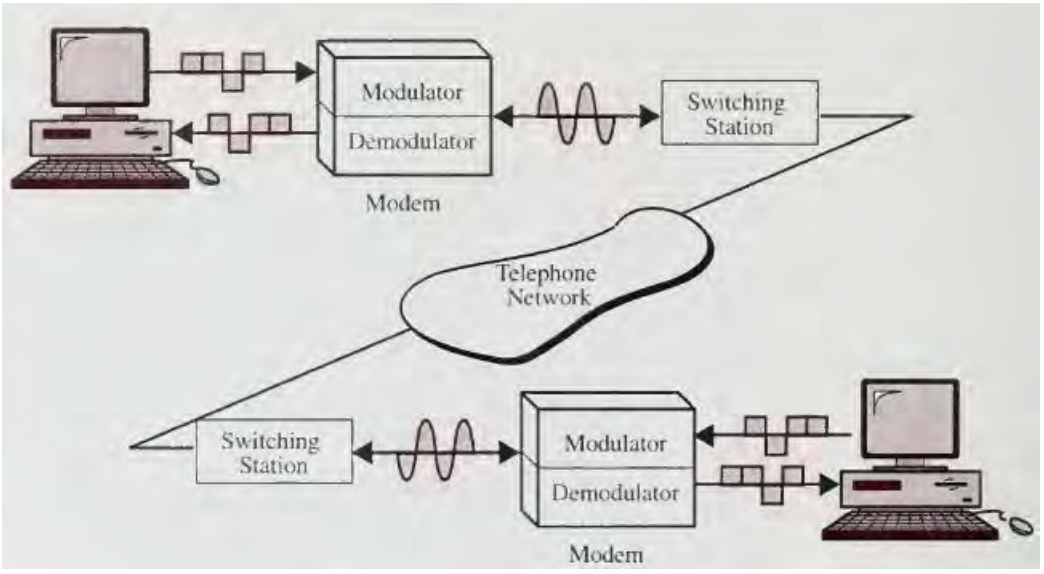
X.21 Standard

- Standard designed by ITU-T
- Large portion of circuits in EIA interface is used for control information
- X.21 eliminates control circuits by having additional circuit logic for both DTE and DCE
- The control information is sent as control codes, rather than using separate pins and lines
- Hence, it has fewer pins but need added circuit logic to convert control codes to bit streams



MODEMS

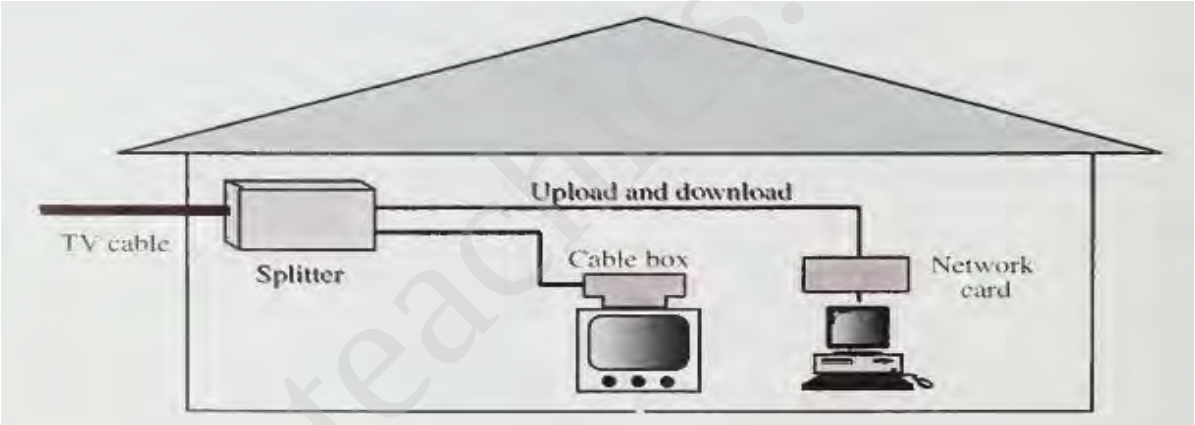
- Modem is a type of DCE and is abbreviation for *modulator-demodulator*
- Modulator converts digital signal into analog signal, demodulator converts analog signal into digital signal



- The personal computers(PCs) act as DTEs and generate digital signals, transfer it through an interface such as EIA 232 to the DCEs which are the modems
- DCE at sender's side modulates the signal, passes it to a switching station, which directs it to the network
- Modulated signal is received by the demodulation function of the modem at receiver's side, converts it into digital signal and passes it to the PC
- DCEs must be compatible with other DCEs and its own DTE
- The data transmission rate of a modem depends on the type of encoding or modulating used and the bandwidth of the medium

CABLE MODEMS

- Traditional modems use telephone lines, which have narrow bandwidth
- If bandwidth is high, higher data rates can be acquired
- Cable modems use coaxial cable provided by cable TV which can have a bandwidth of 750MHz and more
- This bandwidth is normally divided into 6MHz bands using FDM(Frequency Division Multiplexing)
- Each band provides a TV channel, two bands can be used for downloading and uploading information from the Internet
- A splitter directs TV bands to TV set and internet access bands to PC
- **Downloading** requires 6MHz bandwidth in a range above 40MHz. Demodulation technique used is 64-QAM (6 bits at a time), hence, information can be downloaded at a rate of 6MHz x 6 = 36Mbps. However, PCs are not yet capable of receiving data at this rate and is usually lower than this.
- **Uploading** requires 6MHz bandwidth in a range below 40MHz. Modulation technique used is QPSK (2 bits at a time), hence, information can be uploaded at a rate of 6MHz x 2 = 12Mbps. However, the rate is lower in reality.



TRANSMISSION MEDIA

- Transmission medium can be anything that can carry information from a source to destination
- It can be free space, metallic cable, fiber optic cable or anything else
- The information is carried as electromagnetic signals, which are a combination of electrical and magnetic fields that includes power, voice, radio waves, infrared light, visible light, ultraviolet light, and X, gamma, and cosmic rays. Each of these constitutes a portion of the *electromagnetic spectrum* but not all portions of the spectrum are used for telecommunications.
- Transmission media can be divided into two broad categories :
    1) Guided Media
    2) Unguided Media

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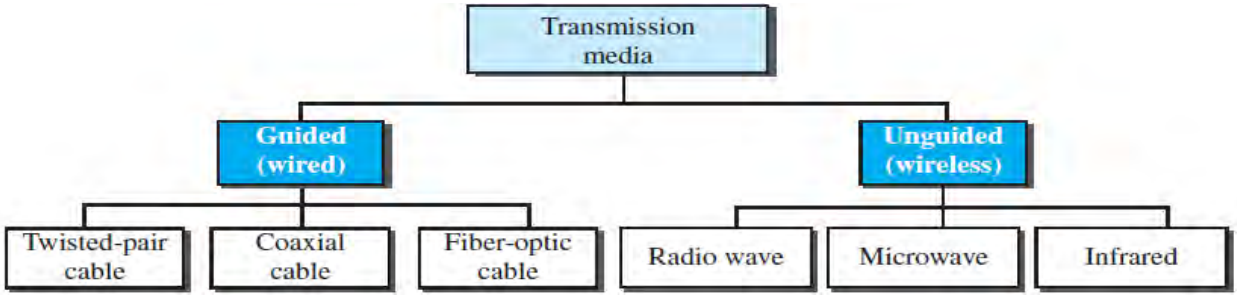
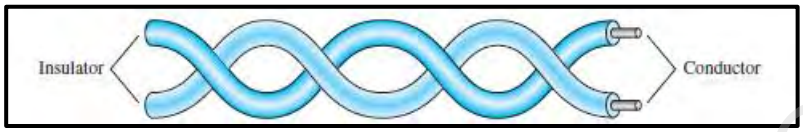


GUIDED MEDIA

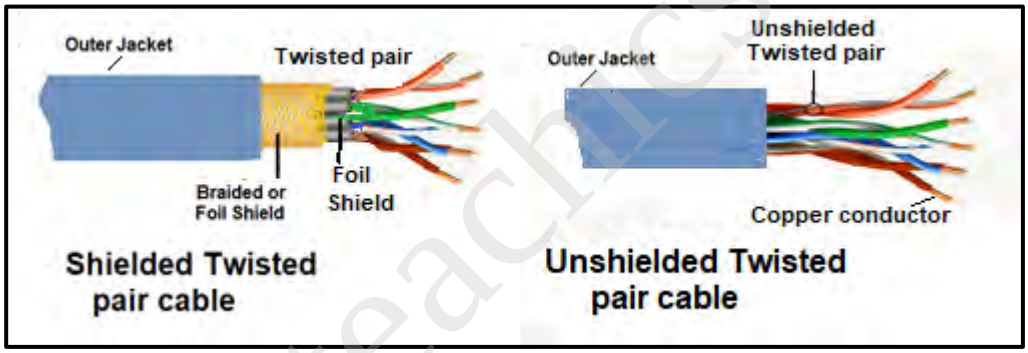
- Signal traveling through guided media is directed and contained by the physical limits of the medium which include **twisted-pair cable, coaxial cable, and fiber-optic cable**
- Twisted-pair and coaxial cable use metallic (copper) conductors that sends and receives signals in the form of electric current while optical fiber is a cable that sends and receives signals in the form of light

Twisted Pair Cables

- Consist of two conductors like copper which are twisted together and both have individual plastic insulation



- It comes in two forms : **Unshielded Twisted Pair(UTP) Cable** and **Shielded Twisted Pair(STP) Cable**



- Wires are twisted to eliminate external interference which may modify the information. By twisting each of the wire will have its share of interference which may have been affecting only the closest wire if they were parallel. Hence, the external waves cancel out due to the twist.

Unshielded Twisted Pair(UTP) Cable

- Consist of two conductors each with its own colored plastic insulation for identification. Colors are used both to identify the specific conductors in a cable and to indicate which wires belong in pairs and how they relate to other pairs in a larger bundle.
- Most frequently used UTP connector is RJ45 (shown below)

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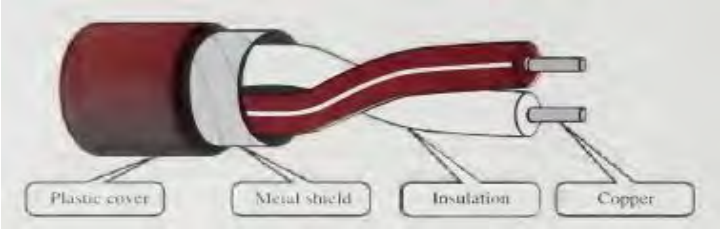
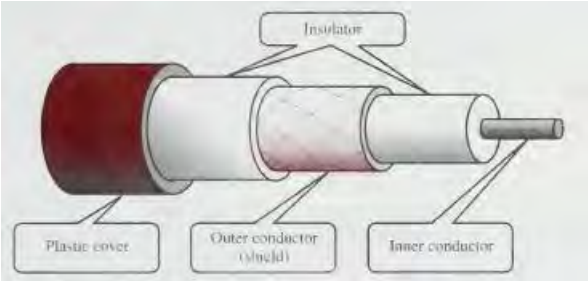
Shielded Twisted Pair(STP) Cable

- Cable has a metal foil or braided-mesh covering around each pair of insulated conductors which prevents the penetration of electromagnetic noise and **crosstalk**(undesired effect when one line picks up signal from another line)



Coaxial Cable(coax)

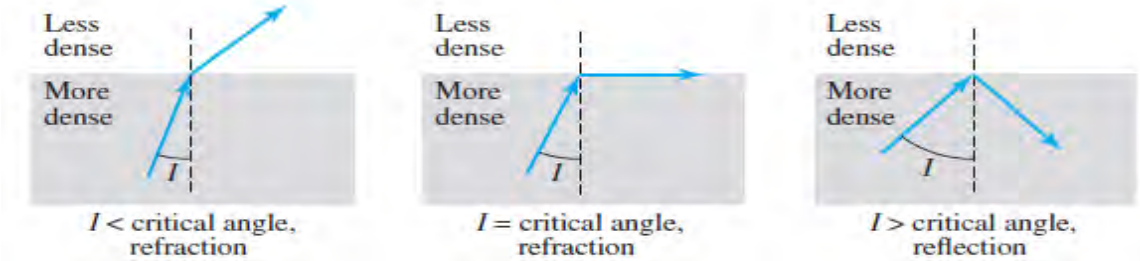
- Can carry signals of higher frequency range than twisted pair cables
- It has a core conductor enclosed in an insulating sheath which in turn, is surrounded by a braided metal. The braided metal is again covered by an insulator and whole together contained in a plastic cover as shown below.
- The metallic wrap acts as shield against noise and as a second conductor



- Connectors mostly used are Bayonet Network Connector(BNC)[shown below] and two forms of BNC which are T-connector and Terminators

Optical Fiber (or Fiber-Optic) Cable

- Made of glass or plastic and transmits signals in the form of light
- A light travels straight in a uniform medium and changes the direction of ray when another medium or substance is encountered
- When the encounter happens, the light gets **refracted** or **reflected**
- The light is reflected only if the **angle of incidence** is greater than the **critical angle**



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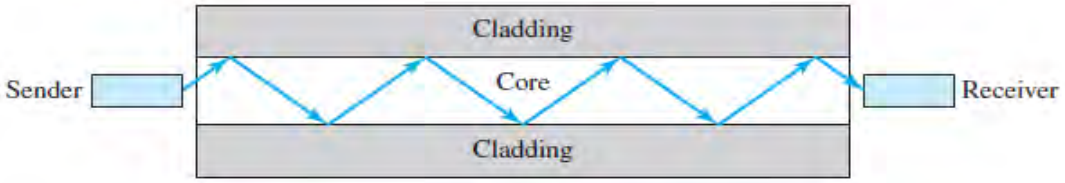
- Optical fiber uses the reflection property to transmit the light
- A glass or plastic core is surrounded by a cladding of less dense glass or plastic
- The difference in density of core and surrounding should be such that the light passing through core gets reflected by the surrounding rather than refracting



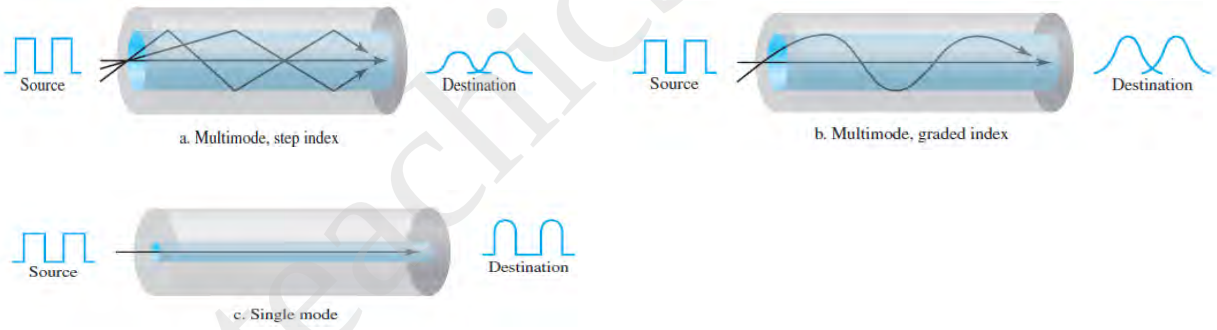
- The propagation of light can be in either of the two modes as shown below

Multimode

- Multiple beams of light pass through different paths in the core
- Step-Index : Density of core is constant from center to edges and hence, a beam moves straight until it reaches the cladding where the angle of the beam is altered at a sudden moment
- Graded Index : Density is highest at core and lowers towards edges resulting in lower distortion of beams

Single Mode

- Used step index fiber and a highly focused source of light causing the beams to move almost horizontal
- It has lower density and diameter
- The lower density helps in maintaining critical angle close enough to 90 degrees making the propagation of beams horizontal



UNGUIDED MEDIA *(wireless communication)*

- Transmit electromagnetic waves without using any physical media
- Signals are broadcasted through free space
- Unguided signals travel from source to destination through different ways such as :
- Ground propagation(radio waves travel through lowest portion of atmosphere, they are low in frequency and spreads in all directions from an antenna)
- Sky propagation(high frequency radio waves radiate upward to ionosphere and are reflected backwards)
- Line-of-sight propagation(very high frequency signals are transmitted in straight lines from antenna to antenna)

Radio Waves

- Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz
- Omnidirectional in nature and are propagated in all directions by using **omnidirectional antennas**
- Susceptible to interference by other antennas
- Applications : AM and FM radio, television, cordless phones

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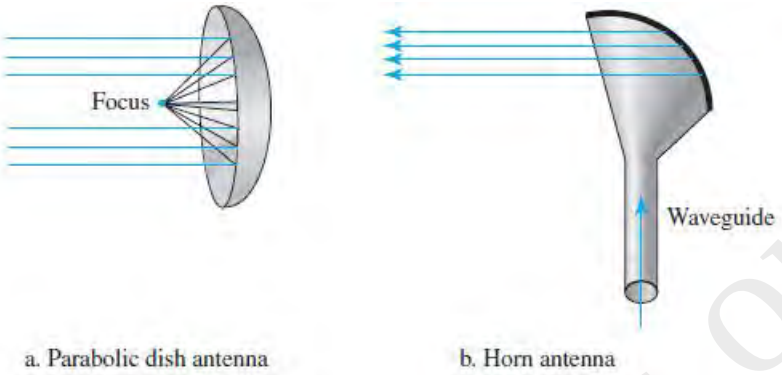
Microwaves

- Electromagnetic waves having frequencies between 1 and 300 GHz
- Unidirectional in nature and uses **unidirectional antennas** that send out signals in one direction
- Sending and receiving antennas must be aligned (line-of-sight)
- Two types of antennas are used for microwave communications
- **Parabolic dish antenna** is based shape of a parabola. Every line parallel to the line of symmetry (line of sight) reflects off the curve at angles such that all the lines intersect at a common point called the focus. Outgoing transmissions are broadcast through a horn aimed at the dish. The microwaves hit the dish and are deflected outward in a reversal of the receipt path.
- H**orn antenna** looks like a gigantic scoop. Outgoing transmissions are broadcast up a stem and deflected outward as parallel beams by the curved head. Received transmissions are collected by the scooped shape in a manner similar to the parabolic dish, and are deflected down into the stem.
- Application : cellular phones, satellite networks, and wireless LANs



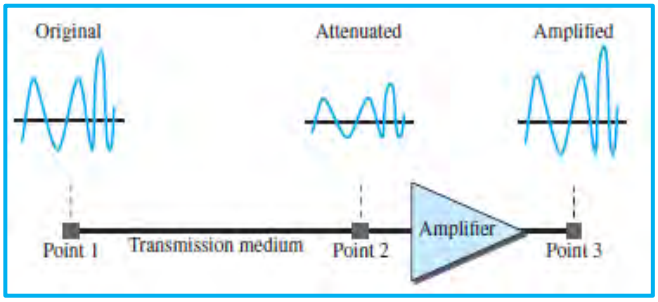
a. Parabolic dish antenna b. Horn antenna

Infrared waves

- Frequencies from 300 GHz to 400 THz
- Used for short-range communication
- Applications : Communication between devices such as keyboards, mice, PCs, and printers. Some manufacturers provide a special port called the **IrDA(***Infrared Data Association* **) port** that allows a wireless keyboard to communicate with a PC.

TRANSMISSION IMPAIRMENT

- Imperfections of transmission media causes signal impairment which results in receiving a signal different from what was sent
- Three causes of impairment are :
- **Attenuation :** It means a loss of energy spent in overcoming the resistance pf the medium (energy loss in the form of heat). To overcome this impairment, amplifiers are used to amplify the signal. Unit of **decibel(dB)** is used to show if a signal has gained or lost strength. It is measured as relating strength of signal at two different points. Negative value indicates attenuation and positive indicates amplification. [$dB=10 \log_{10} (P2/P1)$]



- **Distortion :** It happens when the signal changes shape. Distortion occurs in composite signal transmission, where different component frequencies have different duration of delays at the receiver end causing a change in phase. (Figure shown below)

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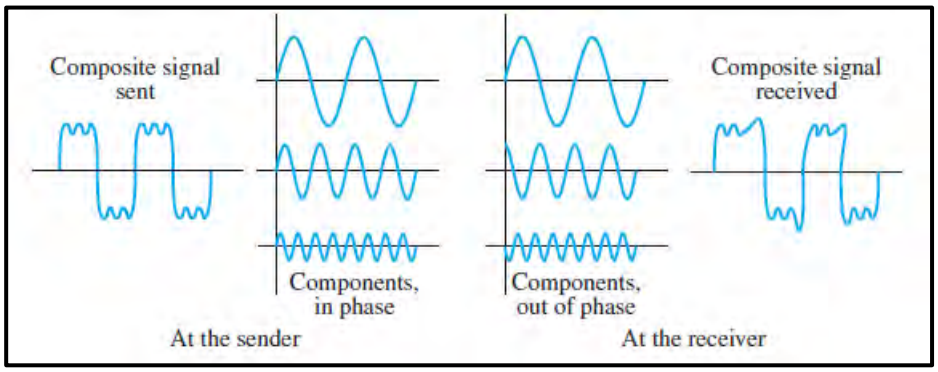
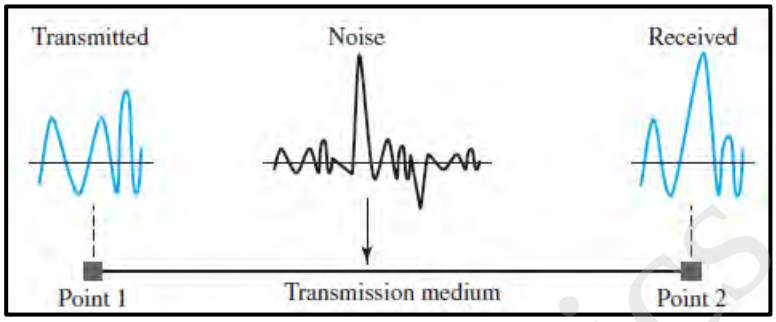


- **Noise :** Several types of noise such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal. Thermal noise is the random motion of electrons in a wire which creates an extra signal. Induced noise comes from sources such as motors and appliances. Crosstalk is the effect of one wire acting as sending antenna and the other as receiving antenna. Impulse noise is a spike (a signal with high energy in a very short time) that comes from power lines, lightning, etc. The **signal-to-noise ratio** is defined as :
  SNR = average signal power/ average noise power



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