CS601 Midterm Notes 2020

123 Topics:

Virtual University	**CS601 Data Communication** **ALI RAZA**	**Virtual University Of Pakistan**

Data Communication

Topic # 01

Introduction the course: Data communication course basically about communication.

Data: Data can take different forms but it is need for communication.

Communication as always been a human need just like food water, shirt, from the very begging of time. We cannot survive without communication. Communication in initial times took different forms.

Trends and advancements: Today the trends and advancements given us means and ways of Communication which are much better than actually use and what we use in initial time. We don't have those fires, anymore. We have got laptop, we have got smartphones, we have got ability to communicate to send text, to send audios, videos from point

A to point B in split second today.

What is taught in this course?

In this course we will cover only those topics which are related to communication That What happened, if we want to send anything from point A to point B. We will go behind the scenes and we will understand and try to understand what happens.

What is not taught in this course?

we will not cover this course, we will not look at things like software applications, things like what happens when the information leaves your local machine or phone or sending device.

Tips and tricks to do well:

Text books and if u have text book so only read Data communication topic and Skip all those topics which are related to networking

Text and References:

Data Communication is a reference book if you want to buy you can easily buy.

Data Communication is a very interesting Subject you will enjoy.

Topic # 02

Introduction to Data

Communication:

It's all about Sharing of information between two parties. It can be remote or local.

Telecommunications:

Tele means distance, communication is the Sharing information.

Communication at a distance includes telephony, telegraph and television etc.

Data communication:

Exchange of data between two devices via some form of transmission media. Both the source and transmission make up a source system. Whatever connects the Source system to the destination system is called Transmission system or medium. Then the Receiver receives the data and then as part of the destination system. It converts that data into format that Can be understood by the destination. we send data from workstation like laptop, Computer, mobile. Our modem took It and transfer to next device and then other reviver modem receive data and send to Server.

Topic # 03

Effectiveness of a Communication

We have already read about data Communication. Today we discuss some Characteristics of data communication.

There are your characteristics:

Delivery Accuracy Timeliness. Jitter

Delivery:

Delivery is the basic characteristics for any digital system. Delivery of information basically characterized that now well data communication is performing.

Accuracy: The system must deliver the data accurately. Data that have been altered in a transmission and left uncorrected are unusable. So only accurate and efficient data should be sent to others.

Timeliness:

The system must deliver data in a timely manner. Data delivered late is useless. In the case of video and audio, timely delivery means delivering data as they are produced, In the same order that they are produced, and without significant delay.

Jitter: Jitter refers to the variation in the packet arrival time. It is the uneven delay in the delivery of audio or video packets.

Topic # 04

In lecture no # 4 we just explore more about characteristics of data Communication, with the help of diagrams.

Topic # 05

Components of a Data Communication system

There are five components of a data communication system.

1.Sender 2. Receiver 3. Transmission medium 4. message 5. protocol

Message: Message is the information of data which you want to send point A to B.

Sender: Sender is the device like computer, laptop, mobile phone, it can be mic if you make audio

call, it can be camera of video call.

Receivers: Receiver is the device which receive the data. It can be anything.

Transmission medium: It is the physical path from De the sender to the receiver. There is also fixed transmission medium, like copper wire, it can be Libre optic cable. There is also wireless transmission medium it can be radio waves etc.

Protocol: A protocol is a standard Set of rules that allow electronic devices to commune with each other. Those rules include what type of data may be transmitted, what commands are used to send and receive data and. how data transfers and confirms. you can think of a protocol as a spoken language.

Topic # 06

Data Representation and Data flow

As we know about data that data can be Text. Numbers. images. Audio, video.

Data Representations: Data Representation refers to the form in which data is stored, processed and transmitted. Such as text Images into digital data that can be manipulated by electronic devices.

Data flow: How data flows from point A to B.

There are 3 modes that we are going to talk about

simplex mode, Half-Duplex, full Duplex.

Simplex: It's mean if we send data from one device to another is unidirectional, as in a one-way. Street, only one of the two devices on a link can transmit, the other can only receive. The simplex made is used to send data in one direction.

Hall-Duplex: In half duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending the other can only receive.

full-duplex mode: In fall duplex modes transmission is simultaneously bi- directions. The devices can transmit and receive Simultaneously.

Topic # 07

Networks

Networks: Interconnection of a set of devices Capable of communication. whether local or wide network. It consists of two components, Host and Connecting device.

Host: A network host is a computer or the other device Connected to a computer network. A host may work as a server offering information resources, services and applications to users or other hosts on the network.

Connecting Device: connecting devices are bridges between the different parts of a document that all the pieces together into one Coherent package.

A network also must be able to meet a certain number of criteria.

1. Performance:
2. Reliability:
3. Security:

Performance: Performance of a network Pertains to the measure of service quality of Perceived by the user. The characteristics of performance are (Throughout, Delay).

Reliability: The problem of sending a packet from a source to a destination as a single data link is considered. Reliable communication is defined as the delivery of a set of packets in order, and without any losses or duplicate.

Security: Data Security is a process of Protecting files, database, and accounts on a network by adopting a set of controls, applications and techniques, that identify the relative importance of different data sets their sensitivity, regulatory compliance requirements and then applying appropriate protections to secure those resources.

(**Throughput):** tells you how much data was transferred from a source at any given time.

(Delay :-) network delay refers to the amount of time it takes.

Topic # 08

Physical Structure

Physical Structure consists of network. Attribute. link

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There are two types of connection point to point and multipoint.

Type of connection(point-to-point) (multipoint)

Link. A link is a communications pathway that transfers data from one device to another. For Communication to occur, two devices must be Connected in the same link at the same way to the link at the Same time. Connections. When two devices are linked together, they connect with each other.

point to point: The point to point provides a dedicated connection between two devices, the entire capacity of the link is reserved for transmission the data between those two devices only.

Multipoint: Connections more than two devices are sharing a link the entire capacity either shared spatially or temporally. This means that either every computer shares a specific of the link or each computer shares space with the link at a specific time when being used.

Topic # 09

Physical topology

The **physical topology** is the way you physically lay out the network, like a map, and the logical **topology** is the way the information flows on the network. Usually, the **physical** and logical **topology** is the same, but sometimes they can differ, such as in a **physical** star/logical ring **topology**.

Topic # 10

physical layout of network:

Network topology is the layout pattern of interconnections of the various elements (links, nodes, etc.) of a computer network. Network topologies may be physical or logical. Physical topology means the physical design of a network including the devices, location and cable installation. Logical topology refers to how data is actually transferred in a network as opposed to its physical design. In general, physical topology relates to a core network whereas logical topology relates to basic network.

Physical Topologies:

1. **Mesh Topology:**

Mesh topology is a type of networking where all nodes cooperate to distribute data amongst each other. they are typically used for things like home automation, smart HVAC control, and smart buildings. A mesh network is a local network topology in which the infrastructure nodes connect directly, dynamically and non-hierarchically to as many other nodes as possible and cooperate with one another to efficiently route data from/to clients.

2. **star topology**:

A **star topology** is a **topology** for a Local Area **Network** (LAN) in which all nodes are individually connected to a central connection point, like a hub or a switch. A **star** takes more cable than e.g. a bus, but the benefit is that if a cable fails, only one node will be brought down.

Topic # 11

3. **Bus Topology:**

A **bus topology** is a **topology** for a Local Area **Network** (LAN) in which all the nodes are connected to a single cable. The cable to which the nodes connect is called a "backbone". If the backbone is broken, the entire segment fails.

4. **Ring topology**

A **ring topology** is a **network** configuration where device connections create a circular data path. Each networked device is connected to two others, like points on a circle. Together, devices in a **ring topology** are referred to as a **ring network**.

Topic # 12

Network Type

Network Classification:

Size

Geographical coverage

Ownership.

The **Network** allows computers to connect and communicate with different computers via any medium. LAN, MAN and WAN are the three major types of the **network** designed to operate over the area they cover. There are some similarities and dissimilarities between them.

Local Area Networks (LANs)

A **local area network** (**LAN**) is a collection of devices connected together in one physical location, such as a building, office, or home. A **LAN can** be small or large, ranging from a home **network** with one user to an enterprise **network** with thousands of users and devices in an office or school.

Usually privately owned

Connects some hosts in a single office, building, or campus

Can be as simple as two PCs and a printer in someone's home office

Can extend throughout a company

Host Address

Topic # 13

Wide Area Network (WANs)

Wider geographical spam than a LAN

Spans a town, a state, a country, or even the world

Interconnects connecting devices such as switches, routers, or modems

Normally created and run by communication companies

Wide area network connects different devices together

There are three types of wide area network:

1. Point to point wan
2. Switched wan
3. internetwork

In computer networking, **Point-to-Point** Protocol (PPP) is a Data link layer (layer 2) communications protocol between two routers directly without any host or any other networking in between. It can provide connection authentication, transmission encryption, and compression.

WAN Switching is a technology where computers are connected to each other over a long distance, using telephone lines and satellite communications utilizing serial transmission.

internetwork devices are all devices that can communicate with other **networks**, i.e., when there are other devices (like a router) that give those devices access to a different physical or virtual **network**.

Topic #14

Switching

Internetwork is basically switched network. You always have a need of switched network from one part to another part. Switched network forward traffic from one part two another part.

There are two types of Switching:

Circuit switched network:

Packet switched network

Data communications network in which data is divided into small segments known as packets. These are divided so that each packet forms part of a complete message that can be routed through a network of switches to its destination independently of all other packets forming the same message.

Topic# 15

The Internet

- **An internet (note the lowercase I) is two or more networks that can communicate with each other**
- **The Internet (uppercase I), and is composed of thousands of interconnected networks.**
- **Accessing the Internet**
- An Internet service provider (ISP)) is an organization that provides services for accessing, using, or participating in the Internet. Internet service providers can be organized in various forms, such as commercial, community-owned, non-profit, or otherwise privately owned.
- Peering is a method that allows two networks to connect and exchange traffic directly without having to pay a third party to carry traffic across the Internet. The Internet consists of over 25,000 autonomous systems that independently route traffic. Peering is often used as a method by which these systems can interact and exchange traffic, allowing it to flow from one end user, over the Internet, to another end user.
- **How a Peering Works:** An Internet exchange point provides a single location for all the hardware necessary to connect multiple networks. Internet exchange providers have membership forms on their websites that you can fill out to apply for space at their colocation. If you are approved, they will contact you directly to facilitate your physical connection to their colocation.

Topic# 16

Internet History

- **Telegraph and Telephone networks, before 1960:**
    - **Constant-rate communication only**

1947 Agency od USA present the ARPAnet.

- **ARPANET- Packet Switched**

In 1973 once again by WinTV albomycin

- **Birth of the Internet &TCP/IP**

In 1980 Also present internet in advance level

- **MILNET**
- **CSNET**

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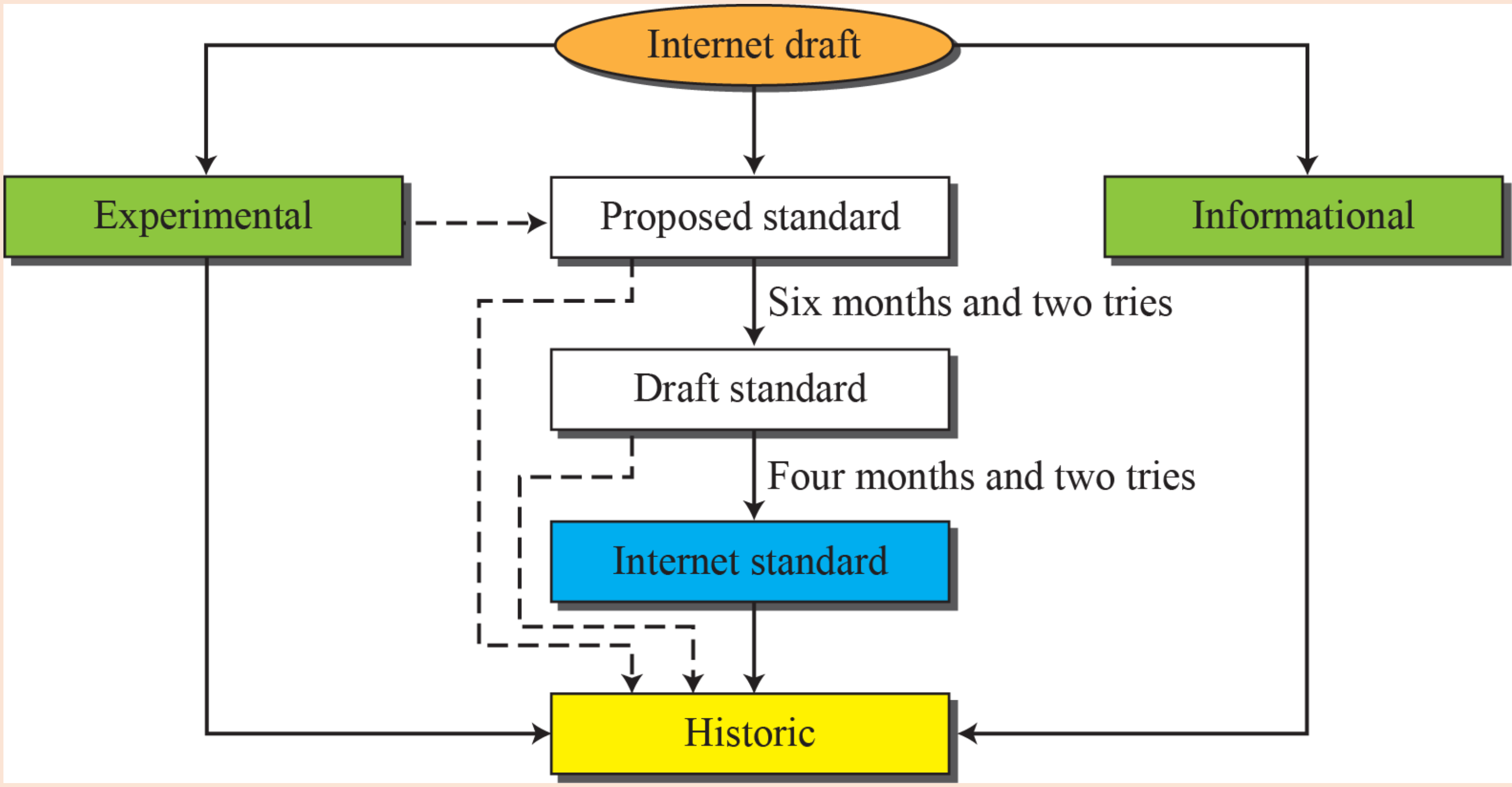
- **NSFNET**
- **Internet Today**
- **In 1990's it introduces as a more effective way of communication till today.**

Topic# 17:

Internet standard and administration

- **Internet draft**
- **Request for Comments (RFC)**
  - ✓ **Proposed Standard**
  - ✓ **Draft Standard**
  - ✓ **Internet Standard**
  - ✓ **Historic**
  - ✓ **Experimental**
  - ✓ **Informational**



Internet start from internet Draft, and internet draft request for comments and proposed to standard level and it take at least six months and two tries of implementation of drafting and then Draft standard take four months and two tries of converting from Drat to Internet standard and then all point become history of experiment and information.

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Administrations:

Who control who manage and who RFC:

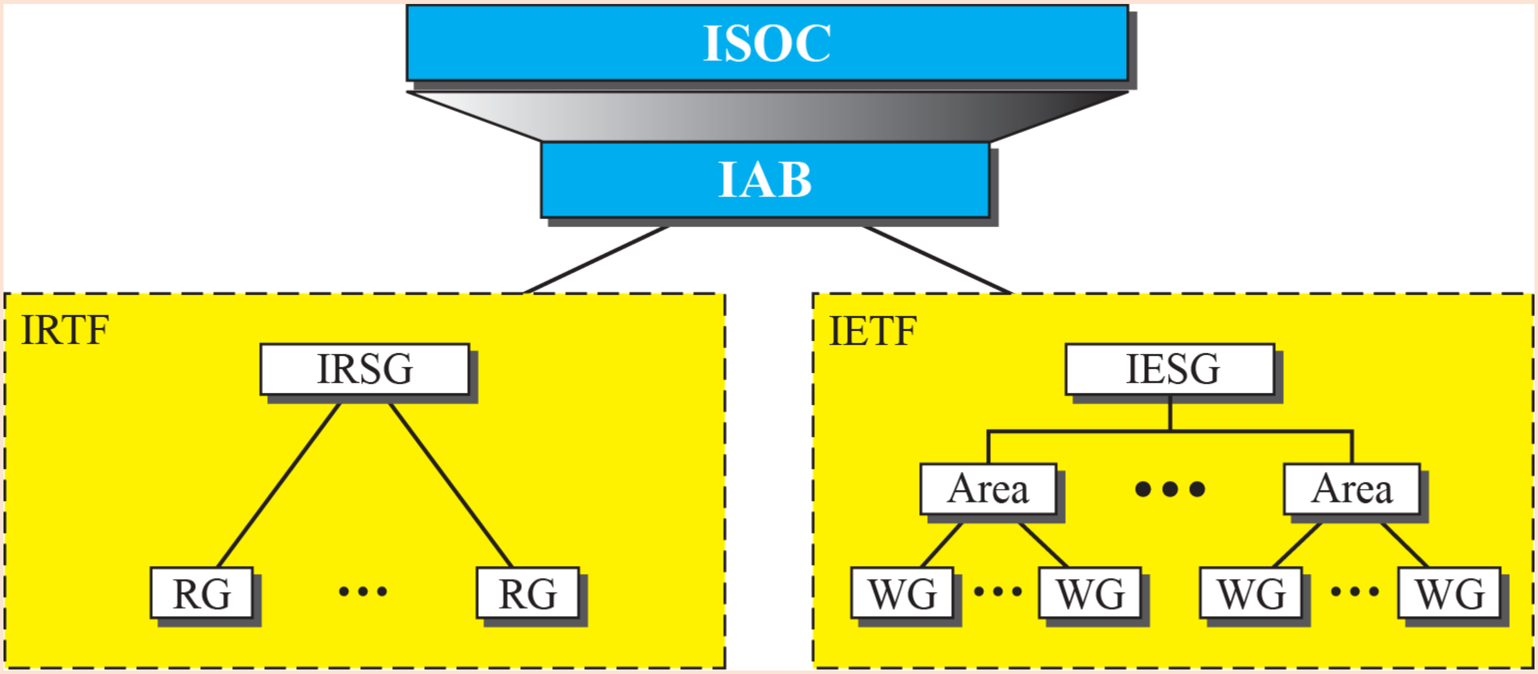
ISOC: Internet society

IAB: Internet Architecture Board

IRTF: Internet research TransForce

IETF: Internet Engineering TransForce

Have multiple groups of working are controlled by them:



Topic#18

Protocol Layering - Introduction

- **Protocol**

Rules that both the sender and receiver and all intermediate devices need to follow to be able to communicate effectively

A **protocol** is a standard set of rules that allow electronic devices to communicate with each other. These rules include what type of data may be transmitted, what commands are used to send and receive data, and how data transfers are confirmed. You can think of a **protocol** as a spoken language.

- **Protocol Layering**

Simple Communication: only one simple protocol

Complex Communication, we need a protocol at each layer, or Protocol Layering

Protocol Layering - Example Scenario 1

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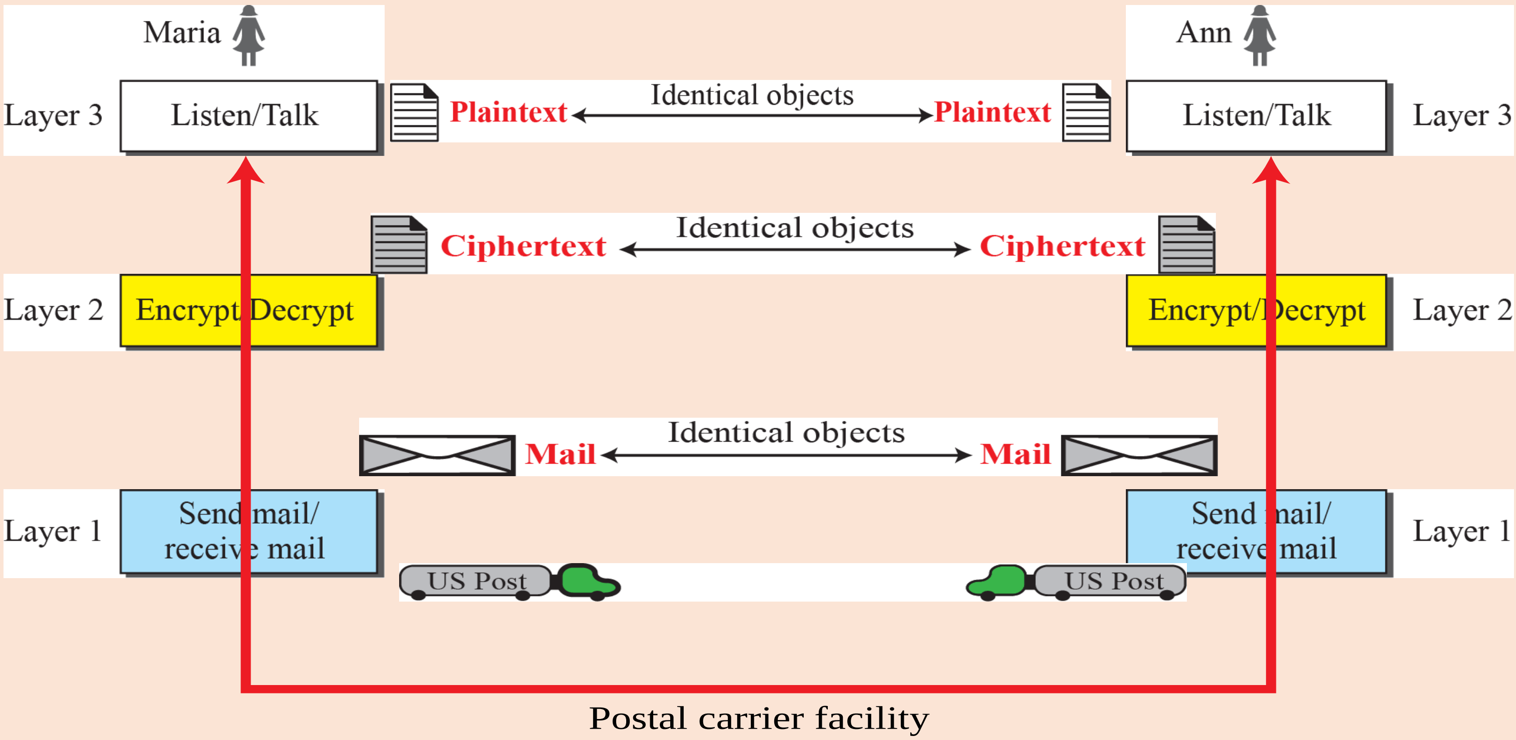
Topic#19

Protocol Layering - Example Scenario 2



Protocol Layering - Advantages and Disadvantages

Layer 1 convert verbally speech into text

Layer 2 convert plain text to encrypted text

Layer 3 took this text and put it in analog and then send it by this way.

Topic # 20

Protocol Layering - Advantages and Disadvantages

- **Advantages**
  - ✓ Modularity
  - ✓ Separation of Service & Implementation

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✓ Reduced Complexity & Cost

- **Disadvantages**

  ✓ None Really!

Topic # 21

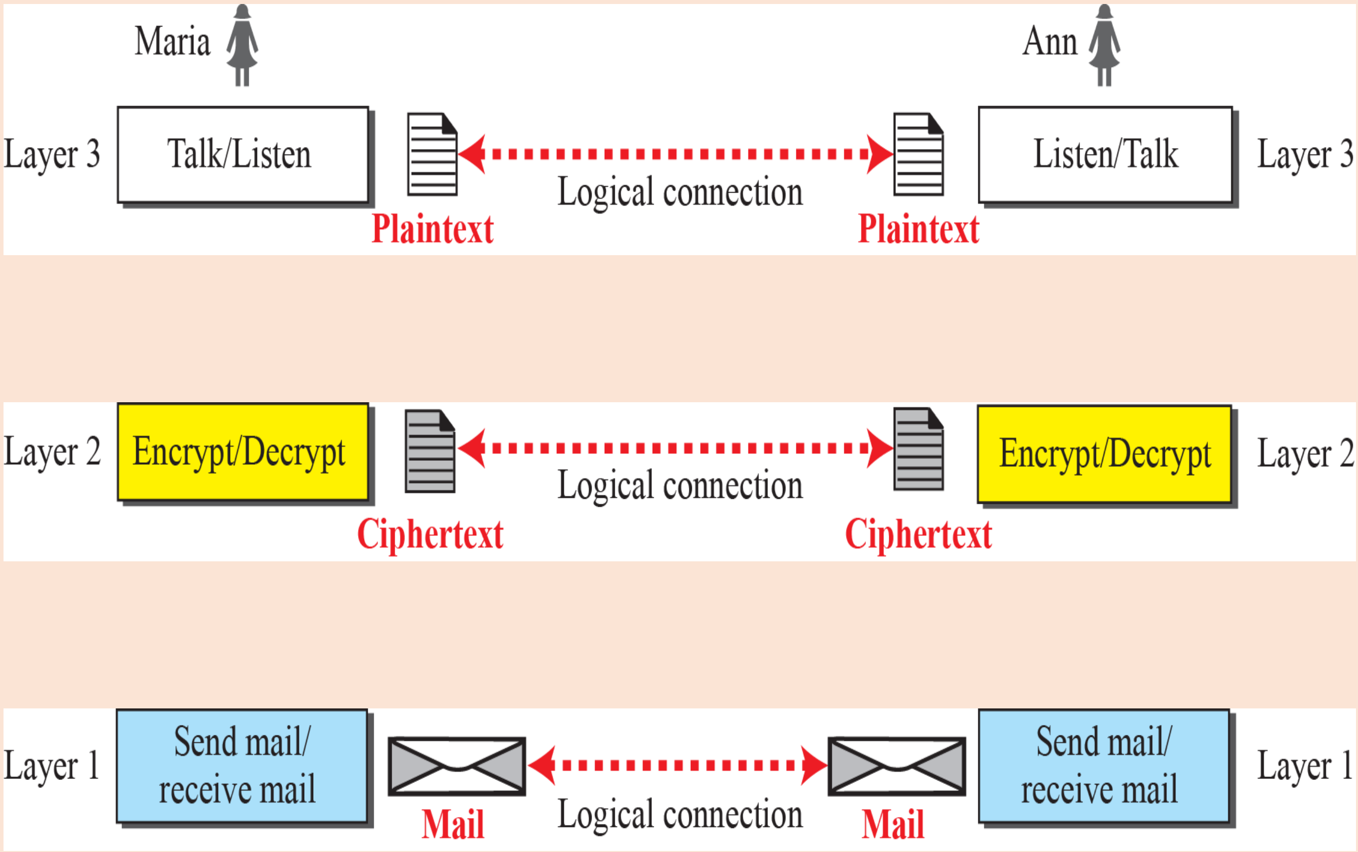
Protocol Layering - Principles

- **Two Principles**

  ✓ Bidirectional Communication → Each Layer performs two opposite tasks in each direction

  ✓ Two objects under each layer at both sites should be identical

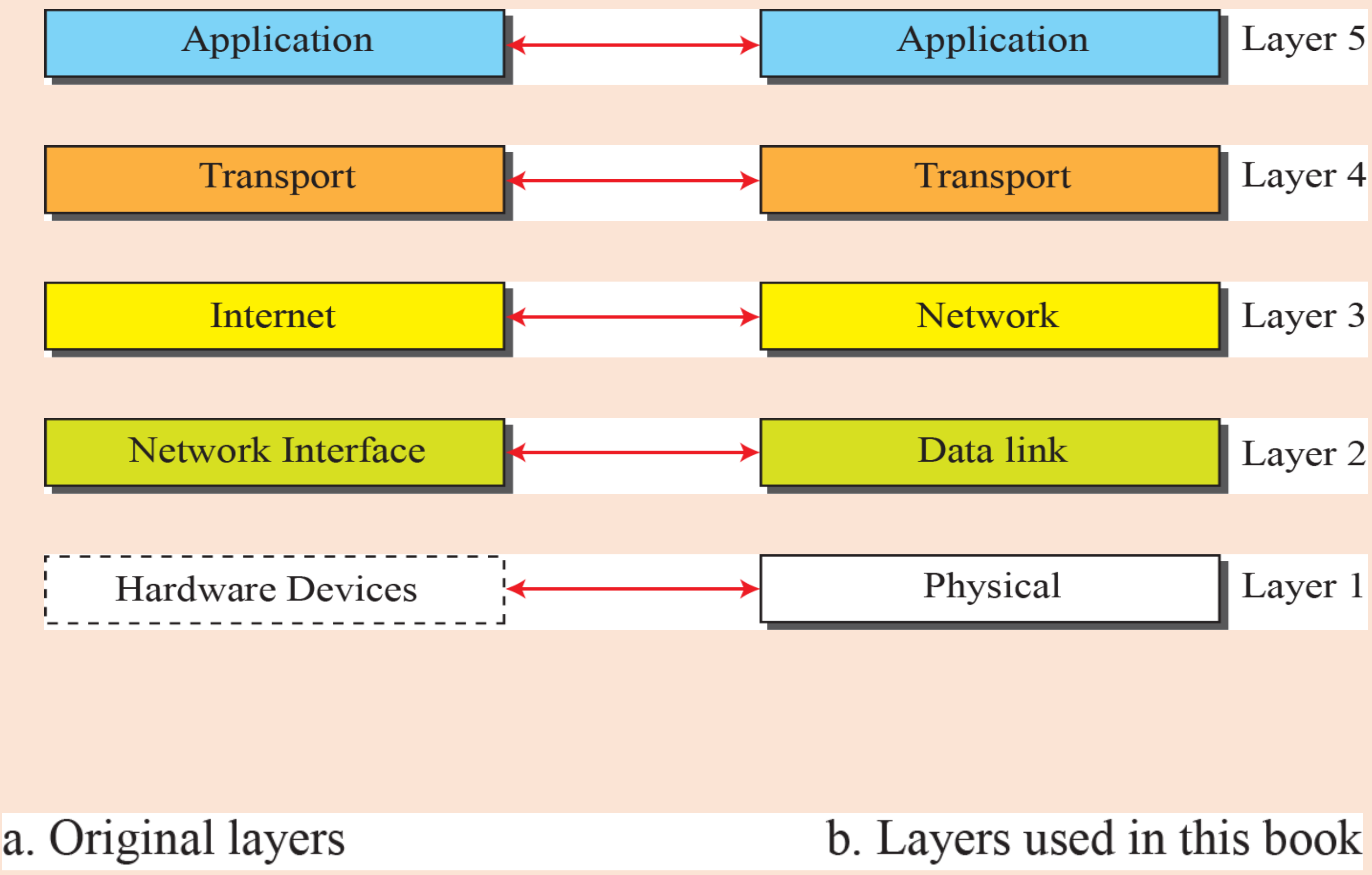
The first principle dictates that if we want bidirectional communication, we need to make each layer so that it is able to perform two opposite tasks, one in each **direction**. The second principle that we need to follow in protocol layering is that the two objects under each layer at both sites should be identical.

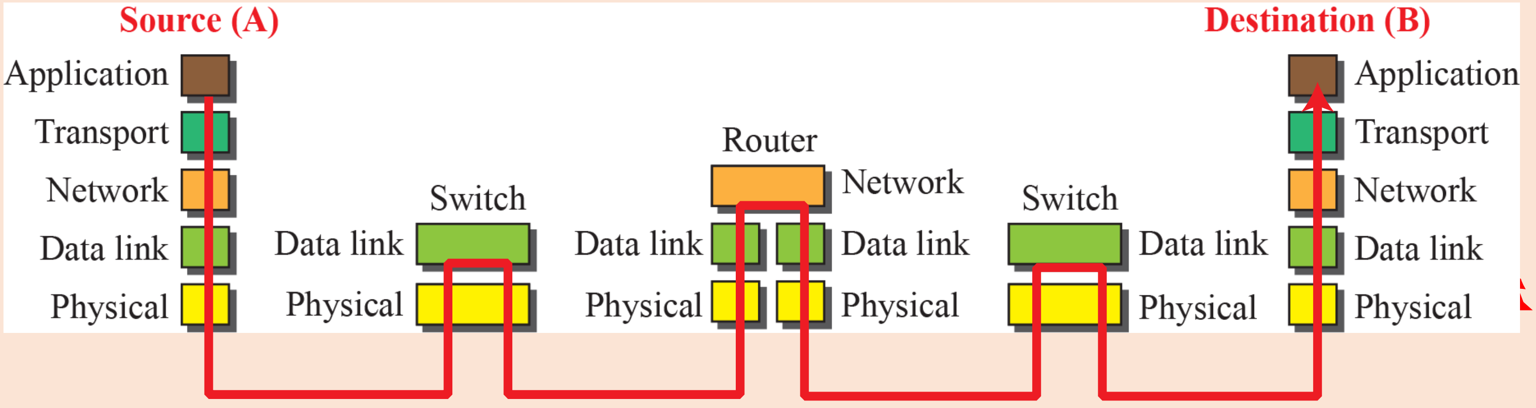


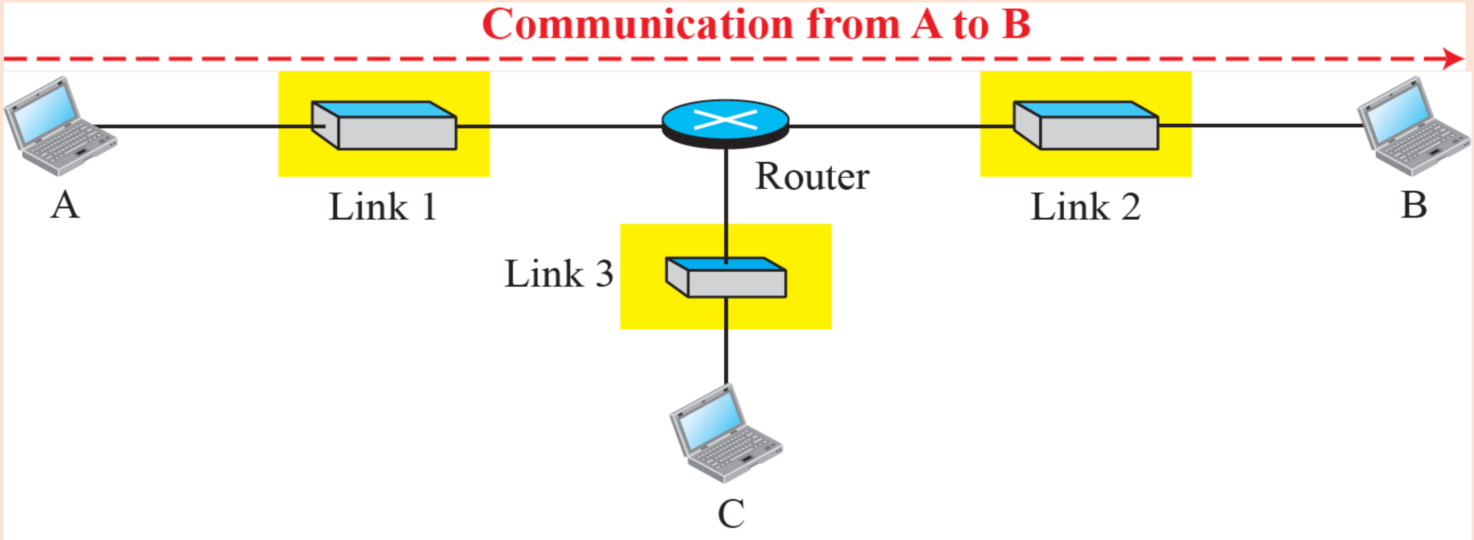
Topic# 22

TCP/IP Protocol Suite

- **TCP/IP Protocol Suite**
  - ✓ Protocol suite used in Internet today
  - ✓ Each Layer provides specific functionality
  - ✓ Hierarchical Protocol
  - ✓ Presented in 1973 and chosen to be the official protocol of Internet in 1983
- **TCP/IP Protocol Suite**







Topic # 23

TCP/IP Protocol Suite – Function of Layers

TCP: The Transmission Control Protocol is one of the main protocols of the Internet protocol suite. It originated in the initial network implementation in which it complemented the Internet Protocol. Therefore, the entire suite is commonly referred to as TCP/IP.

IP: The Internet Protocol is the principal communications protocol in the Internet protocol suite for relaying datagrams across network boundaries. Its routing function enables internetworking, and essentially establishes the Internet.

- **Logical Connections between TCP/IP Layers**

In the **TCP/IP protocol** suite, what are the **identical objects** at the sender and the receiver sites when we think about the logical connection at the application **layer**? **Identical objects** are (messages). Q2-5. A host communicates with another host using the **TCP/IP protocol** suite.

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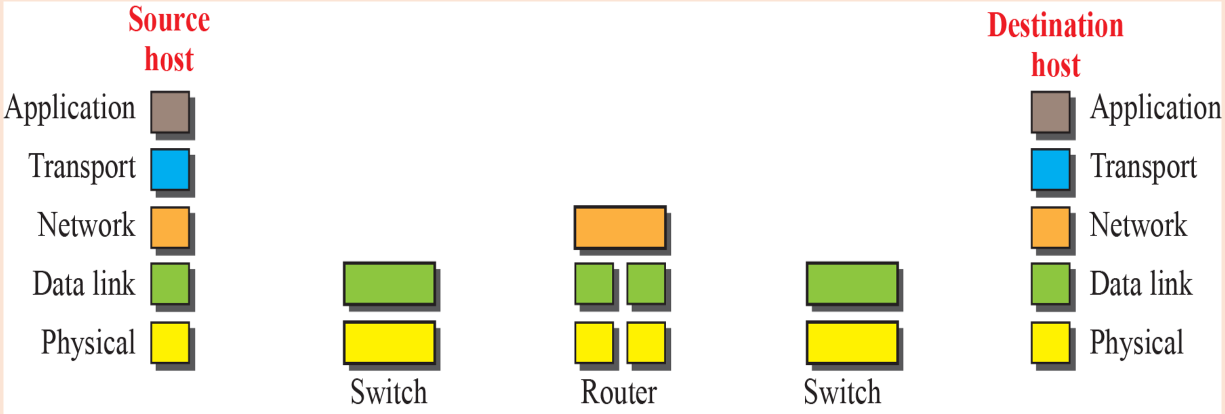
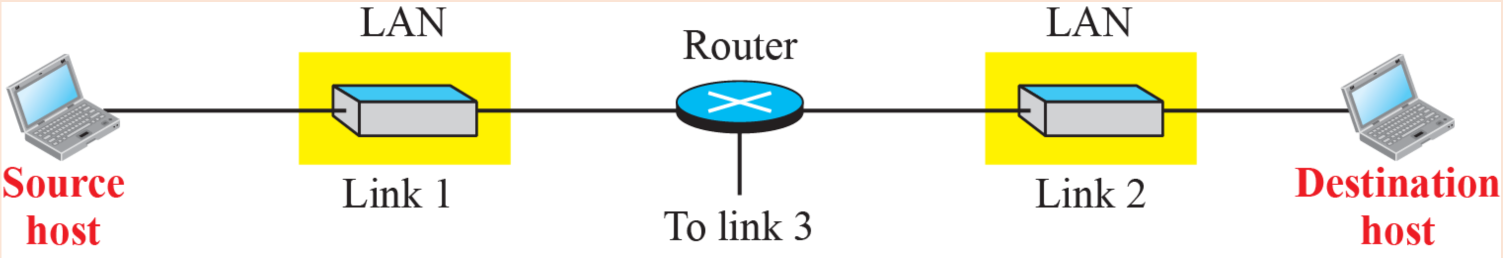
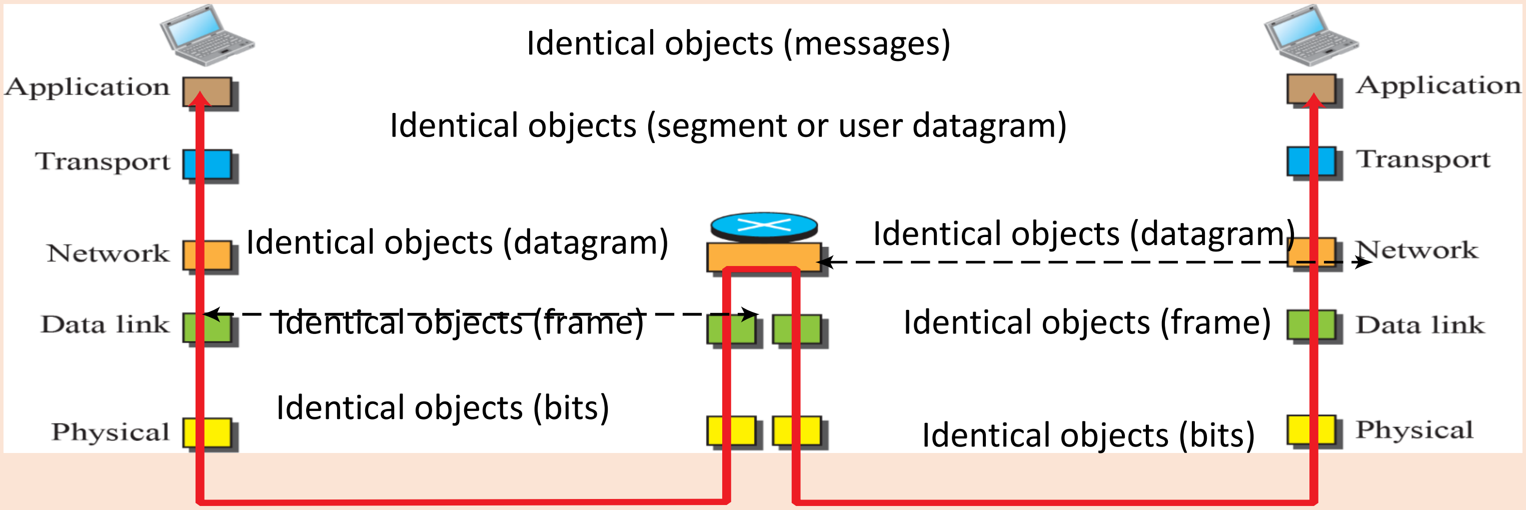




Topic # 24:

TCP/IP Protocol Suite – Function of Layers



Topic#25:

TCP/IP Protocol Suite – Layer Description

Application Layer:

An application layer is an abstraction layer that specifies the shared communications protocols and interface methods used by hosts in a communications network. The application layer abstraction is used in both of the standard models of computer networking: The Internet Protocol Suite and the OSI model.

Transport Layer:

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In computer networking, the transport layer is a conceptual division of methods in the layered architecture of protocols in the network stack in the Internet protocol suite and the OSI model. The protocols of this layer provide host-to-host communication services for applications

Layer 4 of the OSI Model: **Transport Layer** provides transparent transfer of data between end users, providing reliable data transfer services to the upper **layers**. The **transport layer** controls the reliability of a given link through flow control, segmentation and DE segmentation, and error control.

Network Layer:

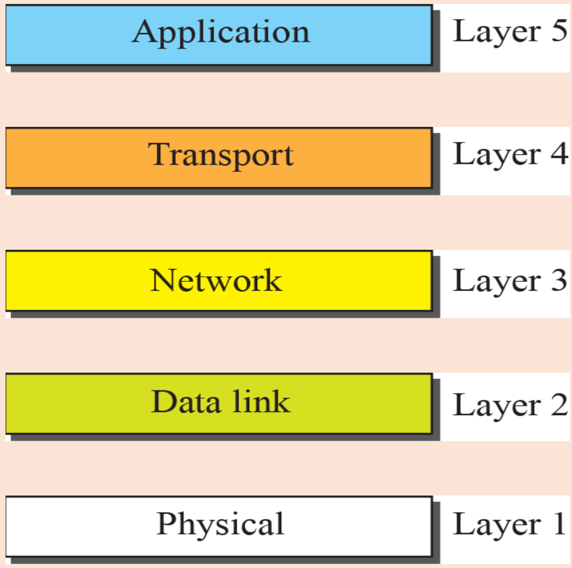
In the seven-layer OSI model of computer networking, the network layer is layer 3. The network layer is responsible for packet forwarding including routing through intermediate routers.

DATA Link Layer:

The data link layer, or layer 2, is the second layer of the seven-layer OSI model of computer networking. This layer is the protocol layer that transfers data between nodes on a network segment across the physical layer.

Physical Layer:

In the seven-layer OSI model of computer networking, the physical layer or layer 1 is the first and lowest layer. This layer may be implemented by a PHY chip. The physical layer defines the means of transmitting raw bits over a physical data link connecting network nodes.



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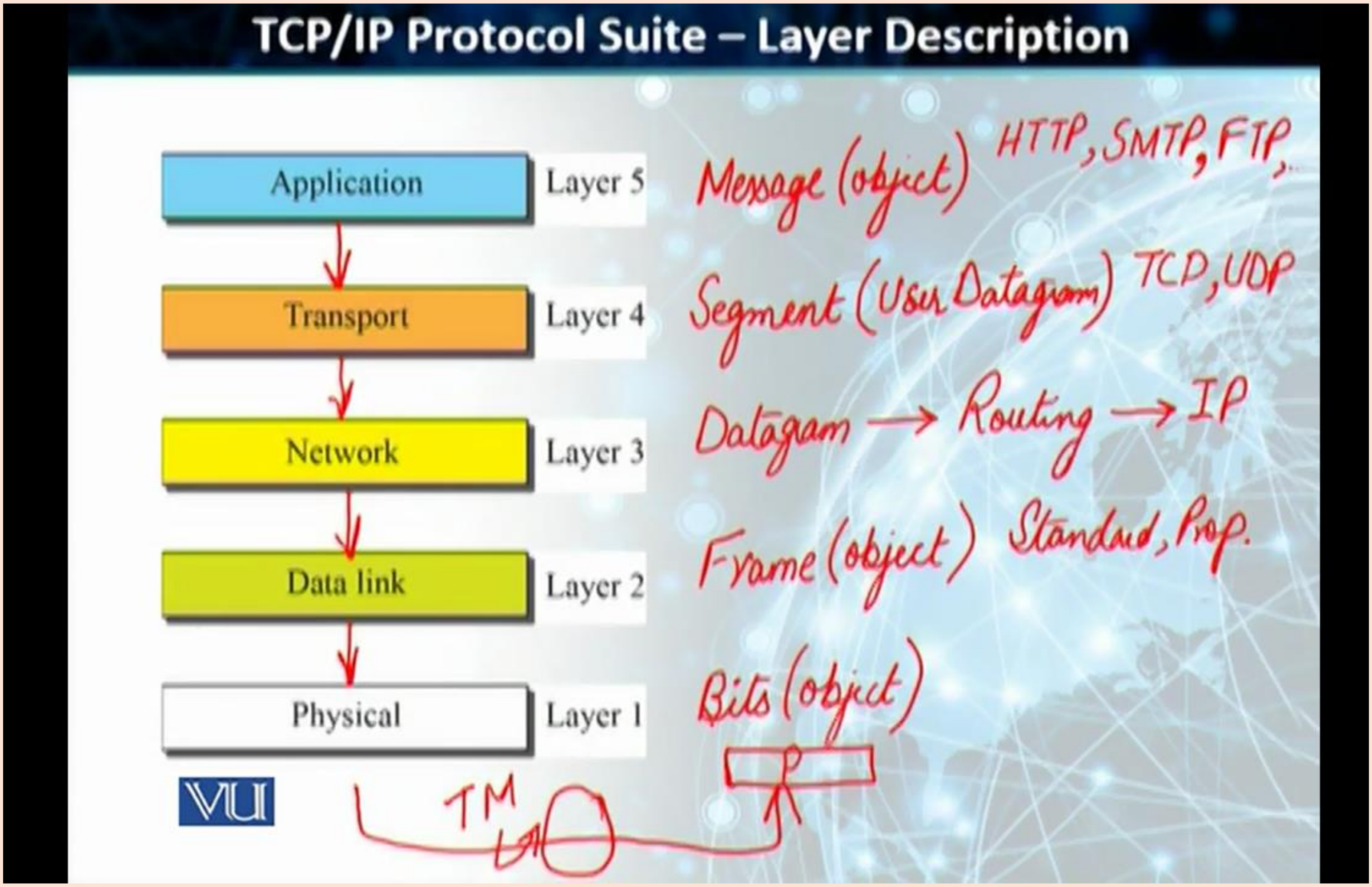


Topic # 26:

Encapsulation & Decapsulation

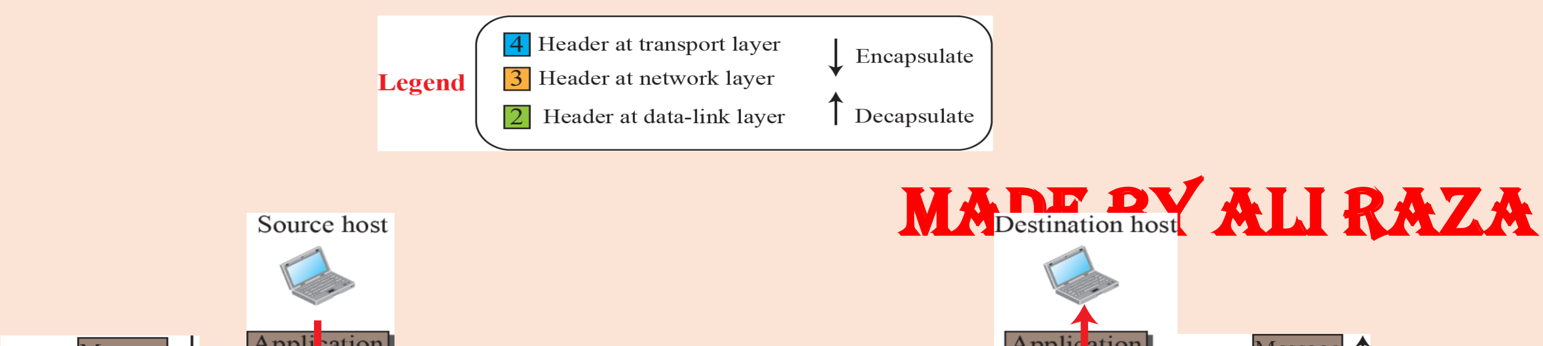
- **Important Concept in Internet Protocol Layering**
- **Layer Header**

Encapsulation

In computer networking, encapsulation is a method of designing modular communication protocols in which logically separate functions in the network are abstracted from their underlying structures by inclusion or information hiding within higher level objects.

Decapsulation

Decapsulation is the process of opening up encapsulated data that are usually sent in the form of packets over a communication **network**. It can be literally defined as the process of opening a capsule, which, in this case, refers to encapsulated or wrapped-up data.



Addressing in TCP/IP Protocol Suite

- **Every communication needs at least two addresses:**
  - ✓ **Source Address &**
  - ✓ **Destination Address**
- **Addressing by Layer**
- **Physical Layer is an exception**

Packet names	Layers	Addresses
Message	Application layer	Names
Segment / User datagram	Transport layer	Port numbers
Datagram	Network layer	Logical addresses
Frame	Data-link layer	Link-layer addresses
Bits	Physical layer	

Topic # 27:

Open Systems Interconnection (OSI) Model

- **International Organization for Standardization (ISO)**
- **ISO established in 1947**
- **Close to three-fourths of countries represented**
- **In 1970's Introduced OSI Model in late 1970s**
- **OSI: a 7-Layer Model**
- **Application Layer:**
- An application layer is an abstraction layer that specifies the shared communications protocols and interface methods used by hosts in a communications network. The application layer abstraction is used in both of the standard models of computer networking: The Internet Protocol Suite and the OSI model.

Presentation Layer:

- In the seven-layer OSI model of computer networking, the presentation layer is layer 6 and serves as the data translator for the network. It is sometimes called the syntax layer.
- **Session Layer:**
- In the seven-layer OSI model of computer networking, the session layer is layer 5. The session layer provides the mechanism for opening, closing and managing a session between end-user application processes, i.e., a semi-permanent dialogue.
- **Transport Layer:**
- In computer networking, the transport layer is a conceptual division of methods in the layered architecture of protocols in the network stack in the Internet protocol suite and the OSI model. The protocols of this layer provide host-to-host communication services for applications
- **Layer** 4 of the OSI Model: **Transport Layer** provides transparent transfer of data between end users, providing reliable data transfer services to the upper **layers**. The **transport layer** controls the reliability of a given link through flow control, segmentation and DE segmentation, and error control.
- **Network Layer:**
- In the seven-layer OSI model of computer networking, the network layer is layer 3. The network layer is responsible for packet forwarding including routing through intermediate routers.
- **DATA Link Layer:**
- The data link layer, or layer 2, is the second layer of the seven-layer OSI model of computer networking. This layer is the protocol layer that transfers data between nodes on a network segment across the physical layer.
- **Physical Layer:**
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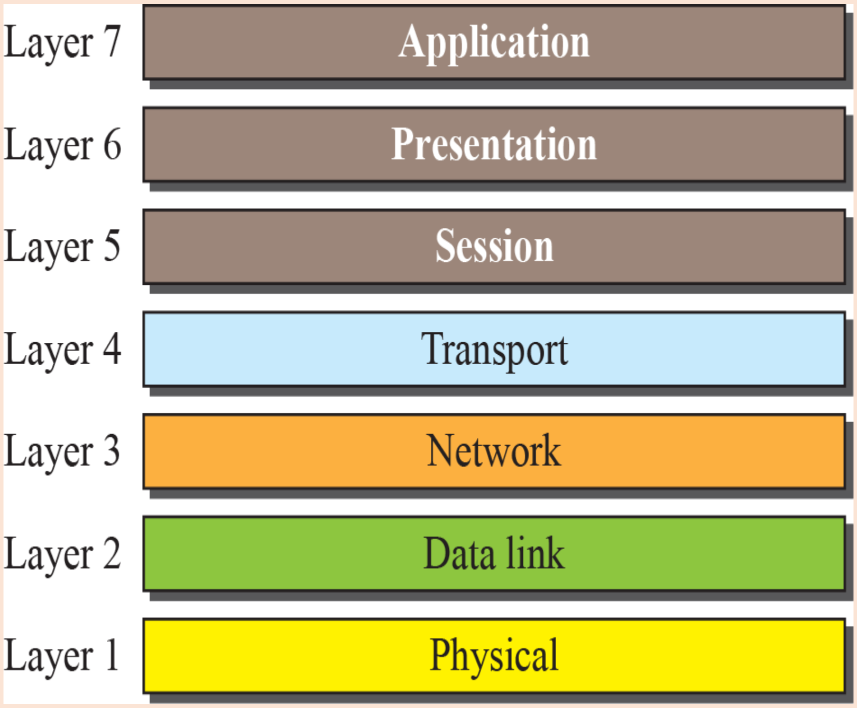

OSI Model vs TCP/IP Protocol suite

- **Two Layers of OSI missing from TCP/IP**
- **Application (TCP/IP) = Application + Presentation + Session (OSI)**

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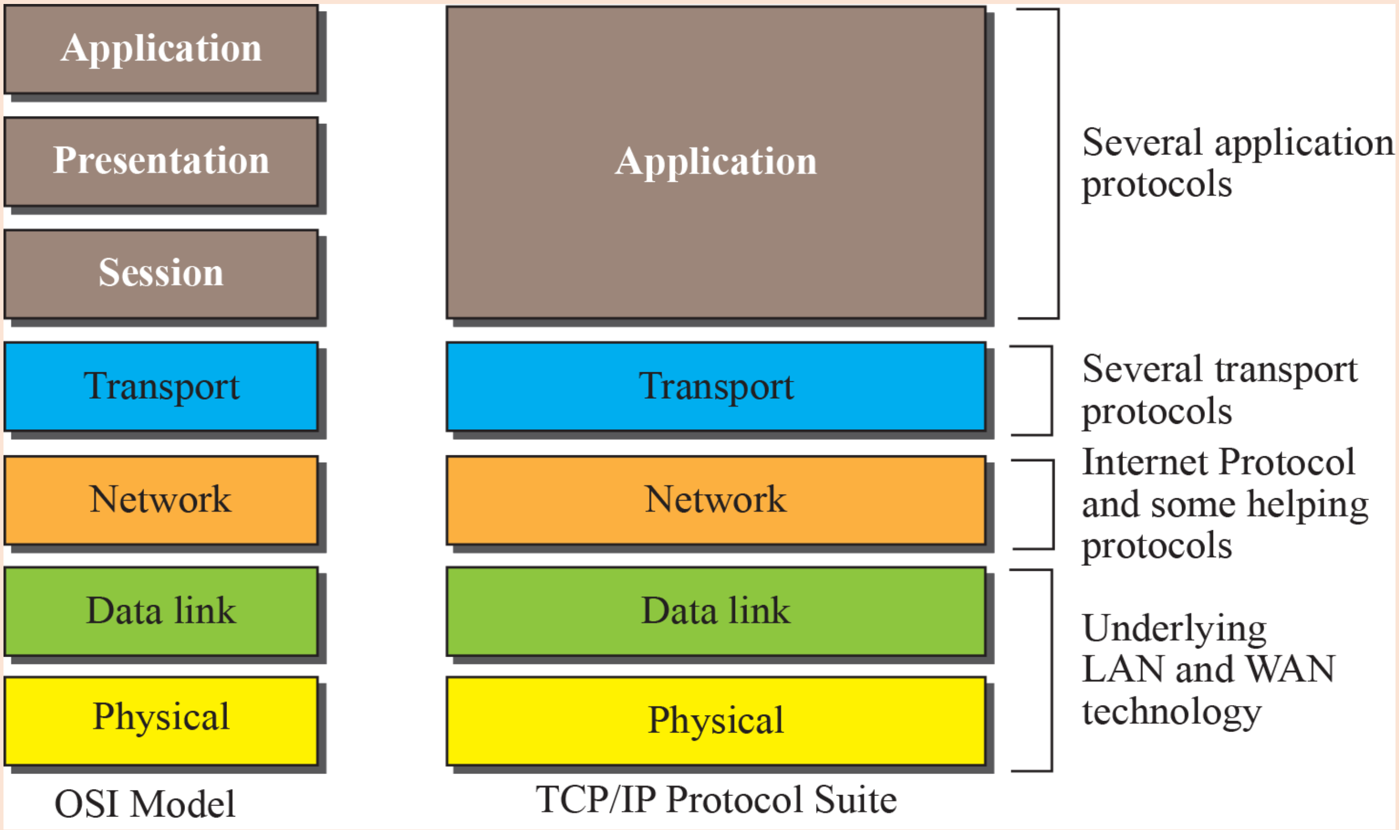
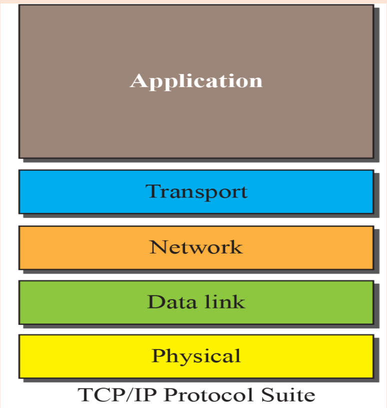


Lack of OSI Model's Success

- **Three reasons OSI did not replace TCP/IP:**
  - ✓ **OSI was completed when TCP/IP was fully in place**
  - ✓ **Some layers in OSI not fully defined**
  - ✓ **Performance of TCP/IP better than that of OSI**

Topic # 28:

Data Communication versus Computer Networks



Analog & Digital Transmission

Transmission Media

Switching

Error Detection and Correction

Media Access and Data Link Control

Wired and Wireless LANs

Topic # 29

Communication at Physical Layer

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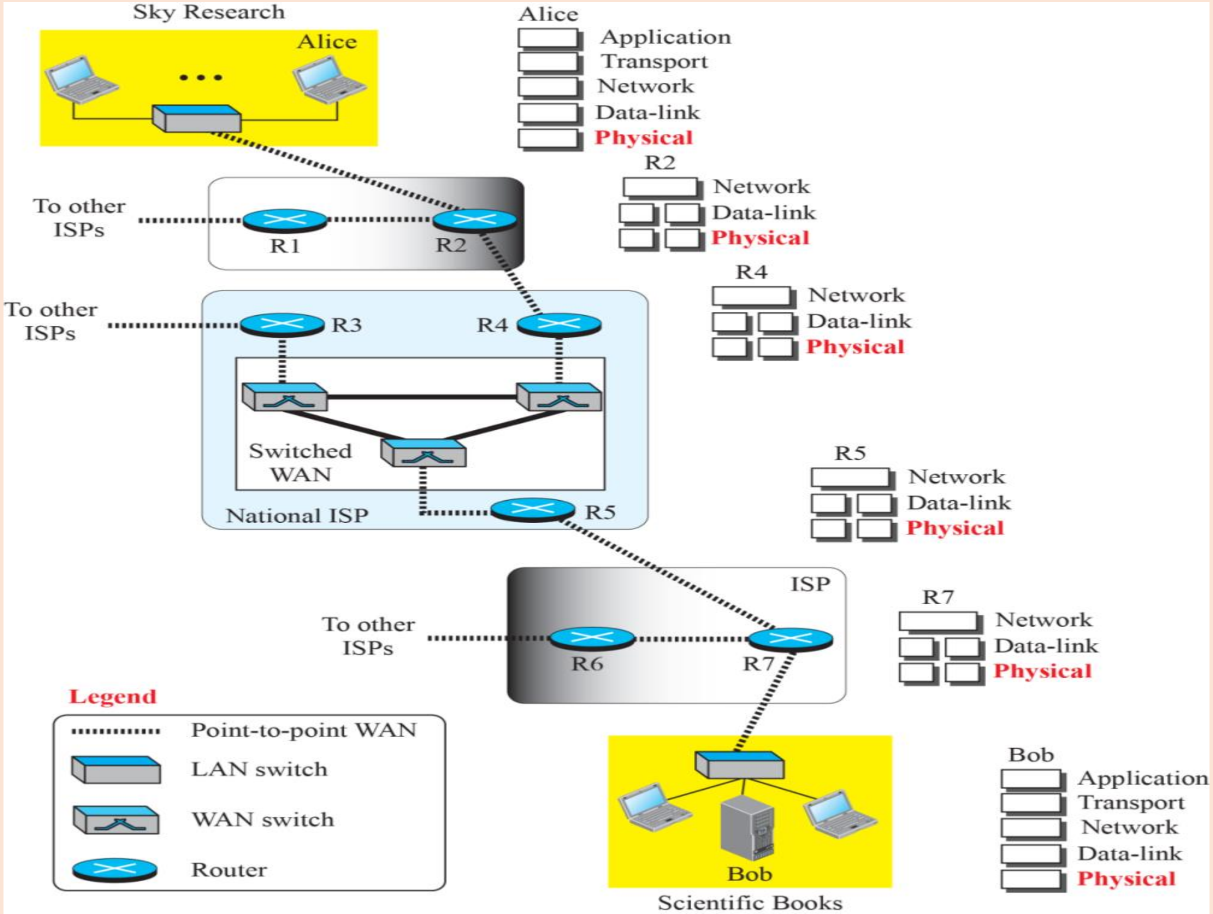


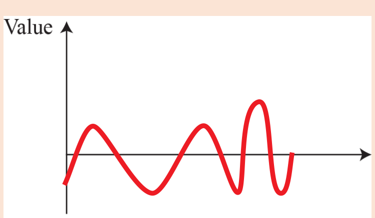
Analog & Digital Data

- **Data → Analog or Digital**
- **Analog Data → Continuous**
- **Digital Data → Discrete**
- **Examples: Analog Clock vs. Digital Clock**
- **Human voice vs. Data in Computer**

Topic # 30:

- **Analog & Digital Signals**

- **Signals represent Data**
- **Signals → Analog or Digital**
- **Analog Signal → Infinite Levels of Intensity over time**
- **Digital Signal → Limited number of defined values**



a. Analog signal

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Periodic & Non-periodic Signals

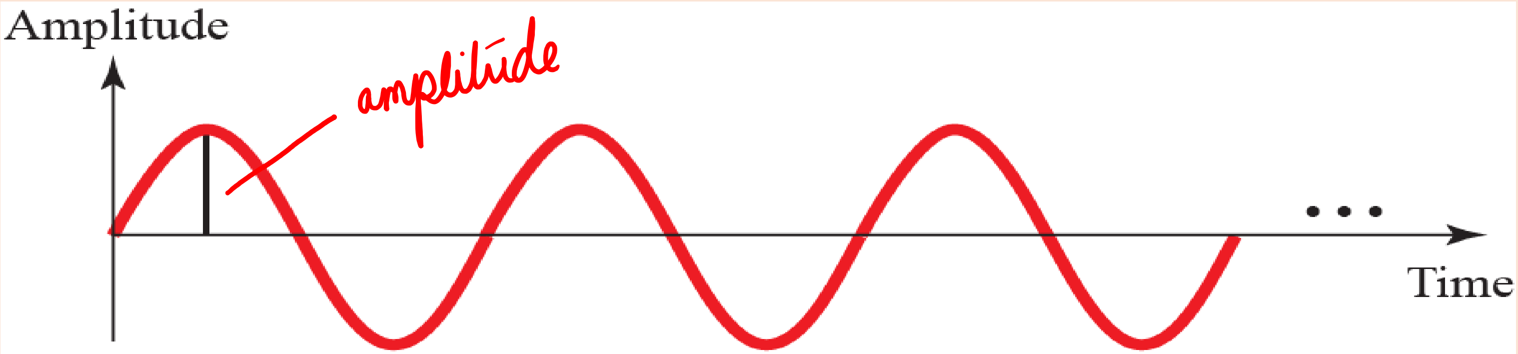
- **Analog/Digital Signal → Periodic or Non-periodic**
- **Periodic Signal → Pattern**
- **Period and Cycle**
- **Non-Periodic → No Pattern**
- **Periodic ANALOG Signals and Non-periodic DIGITAL Signals**

Topic # 31

Periodic Analog Signals

- **Periodic Analog Signals → Simple or Composite**
- **Simple Periodic Analog signal→ Sine wave**
- **Composite Periodic Analog signal→ Composed of multiple sine waves**

Sine Wave – Peak Amplitude



a. A signal with high peak amplitude

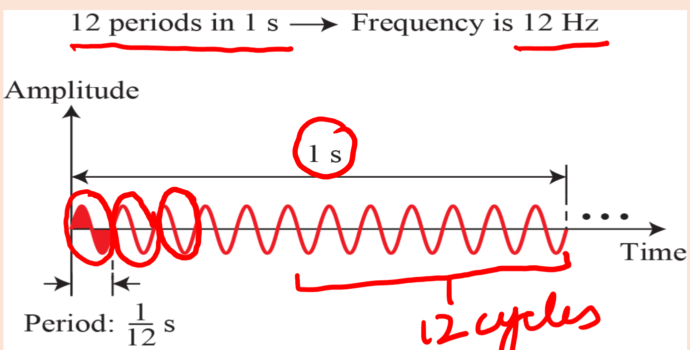
Topic # 32

Sine Wave –Frequency

- **Period (T) → Amount of time required to complete 1 cycle**
- **Frequency (f) → No. of Periods in 1 sec**
- **f = 1/T or T = 1/f**

If you want to defined frequency then you are allowed to use f=1/T (Period)

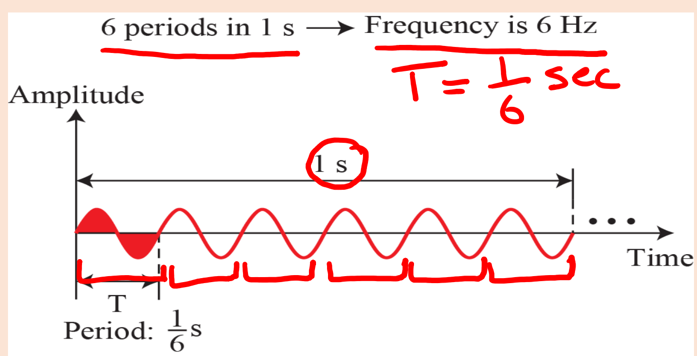
If you want to defined period then you are allowed to use T=1/F (Frequency)



a. A signal with a frequency of 12 Hz

Hz = cycles/sec

$T = \frac{1}{f} = \frac{1}{12}$ sec



b. A signal with a frequency of 6 Hz

Topic # 33

Period		*Frequency*	
Unit	*Equivalent*	*Unit*	*Equivalent*
Seconds (s) ✓	1 s	Hertz (Hz) ✓	1 Hz
Milliseconds (ms)	10^{-3} s ✓	Kilohertz (kHz)	10^{3} Hz ✓
Microseconds (μs)	10^{-6} s ✓	Megahertz (MHz)	10^{6} Hz ✓
Nanoseconds (ns)	10^{-9} s ✓	Gigahertz (GHz)	10^{9} Hz ✓

The power we use at home has a frequency of 60 Hz. The period of this sine wave can be determined as follows:

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166 \text{ sec}$$

$$= 16.6 \text{ msec}$$

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

$$T = 100\text{ms} \Rightarrow 100 \times 10^{-3} \text{sec} = 10^{-1} \text{sec}$$

$$f = \frac{1}{T} = \frac{1}{10^{-1}} = 10 \text{ Hz}$$

$$10 \times 10^{-3} \text{ kHz}$$

$$= 10^{-2} \text{ kHz}$$

Topic# 34

Phase (or Phase Shift)

- **Position of waveform relative to time 0**
- **Phase describes the amount of shift of the wave**

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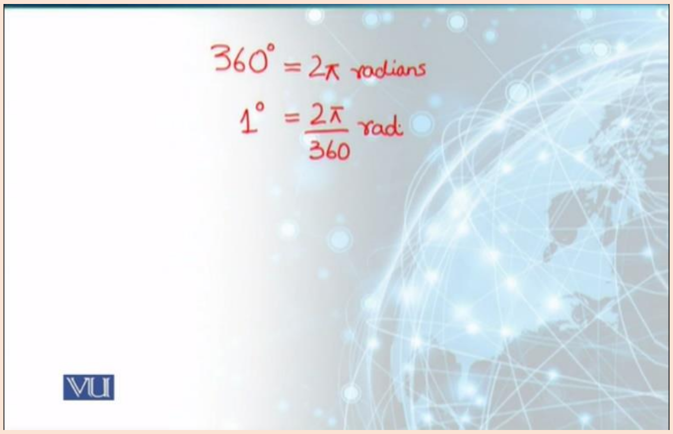
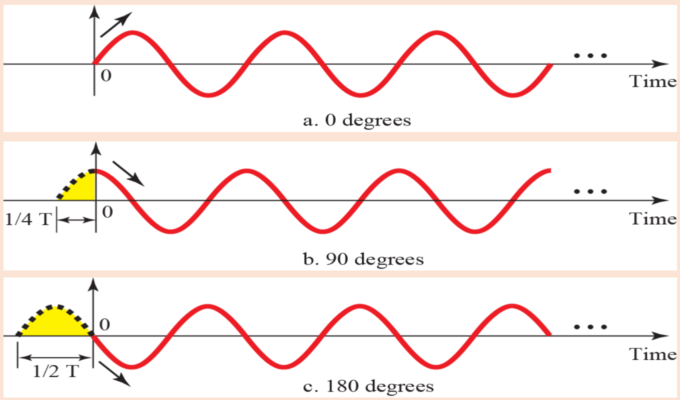
- **Indicates start of the first cycle**



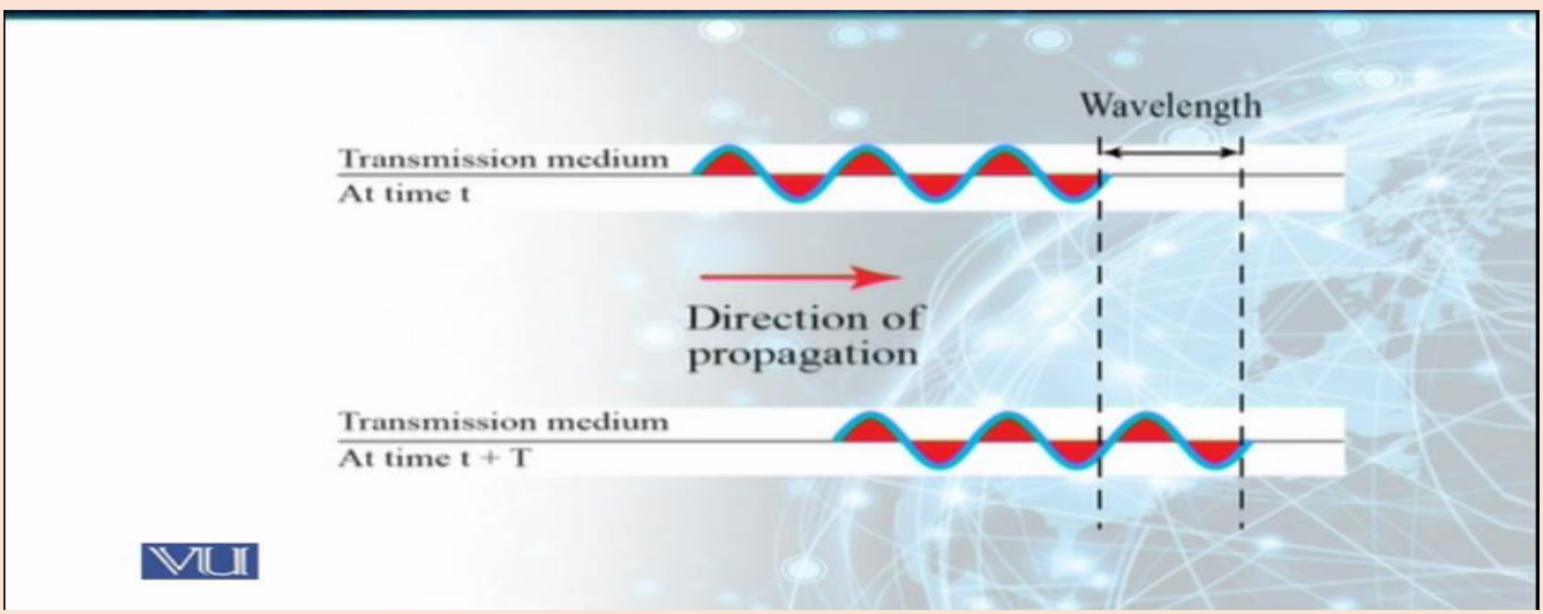


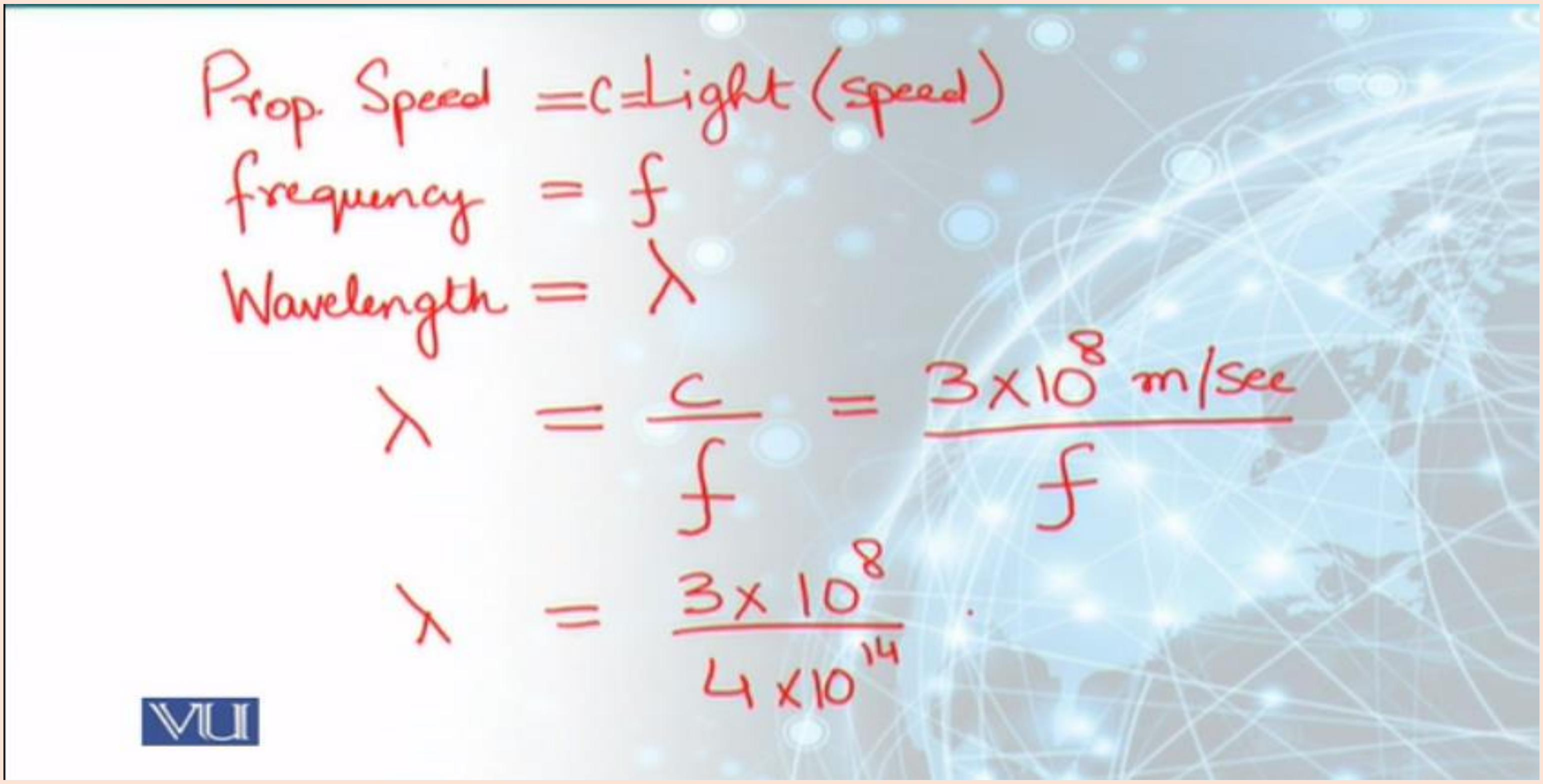
Topics # 35

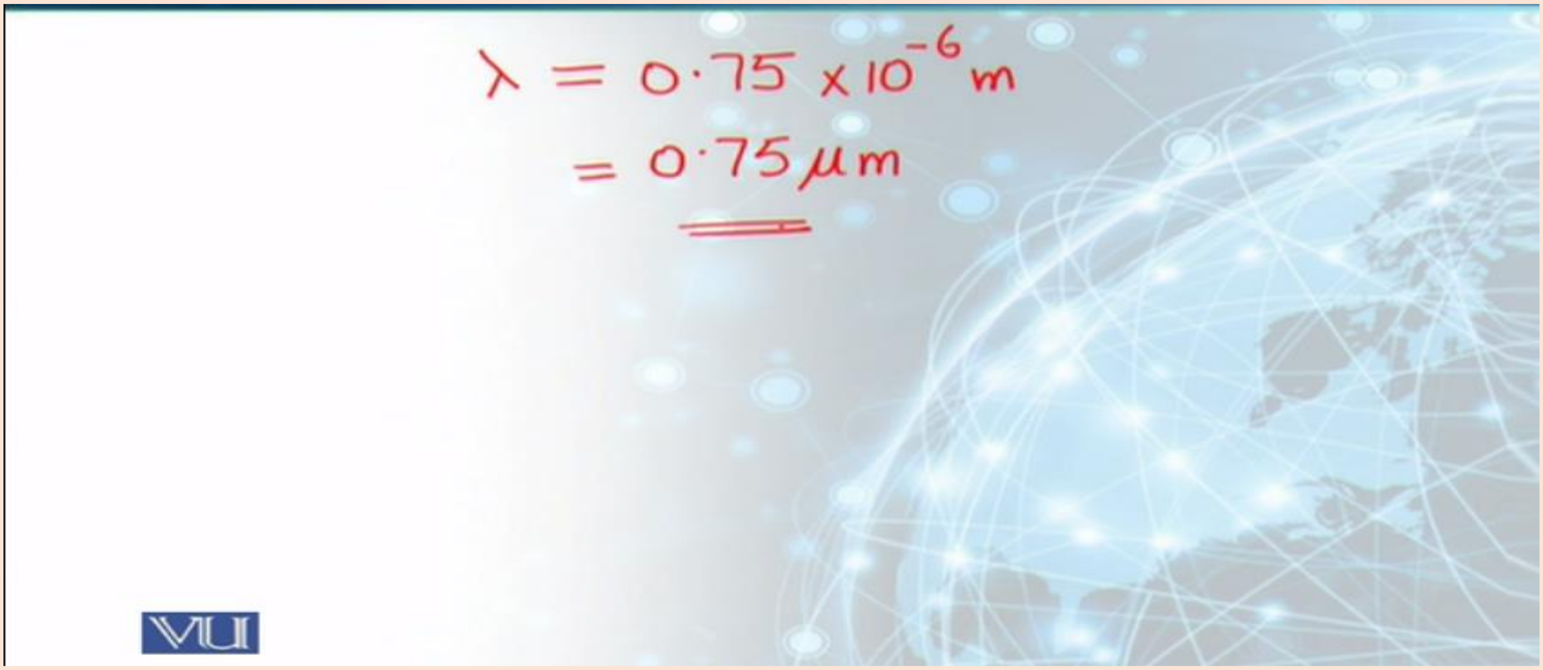
Wavelength

Wavelength is another characteristic of a signal traveling through a transmission medium.

Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium (see Figure 3.7).





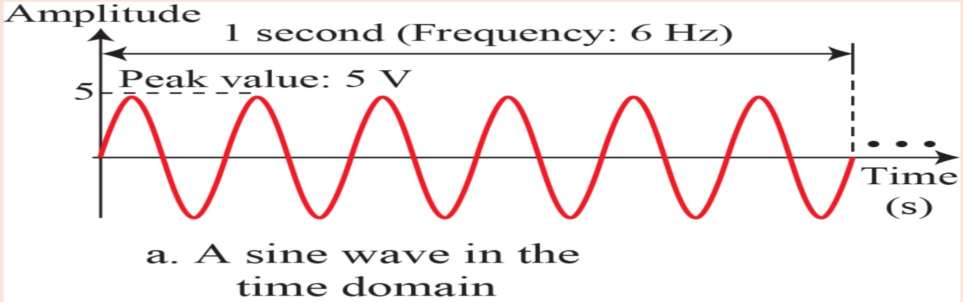


Topic # 36

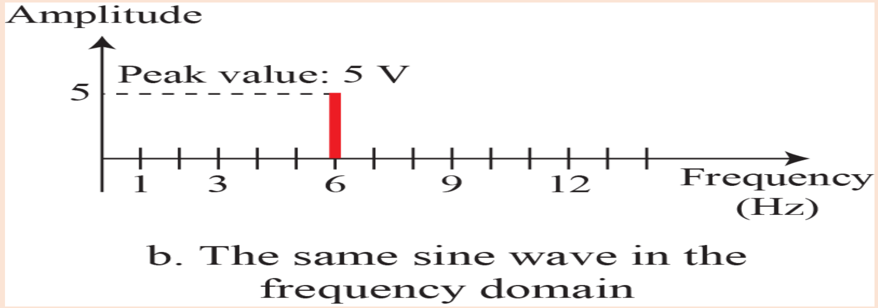
Time & Frequency Domains

Put simply, a **time-domain** graph shows how a signal changes over **time**, whereas a **frequency-domain** graph shows how much of the signal lies within each given **frequency** band over a range of **frequencies**.

A sine wave is comprehensively defined by its amplitude, frequency, and phase. We have been showing a sine wave by using what is called a time domain plot. The time-domain plot shows changes in signal amplitude with respect to time (it is an amplitude-versus-time plot). Phase is not explicitly shown on a time-domain plot.



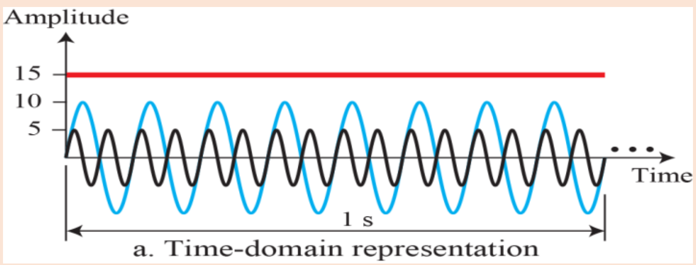
a. A sine wave in the time domain



b. The same sine wave in the frequency domain

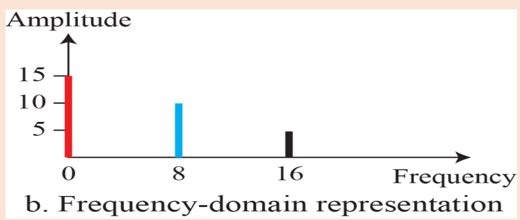
Example 3.7

The frequency domain is more compact and useful when we are dealing with more than one sine wave. For example, Figure 3.9 shows three sine waves, each with different amplitude and frequency. All can be represented by three spikes in the frequency domain.



a. Time-domain representation

Figure



b. Frequency-domain representation

Topic # 37

Composite Signals

So far, we have focused on simple sine waves. Simple sine waves have many applications in daily life. We can send a single sine wave to carry electric energy from one place to another. For example, the power company sends a single sine wave with a frequency of 60 Hz to distribute electric energy to houses and businesses.

- **Single Sine Wave can only carry limited information**
- **Composite Signal is made up of multiple simple sine waves**
- **Can be periodic or non-periodic**

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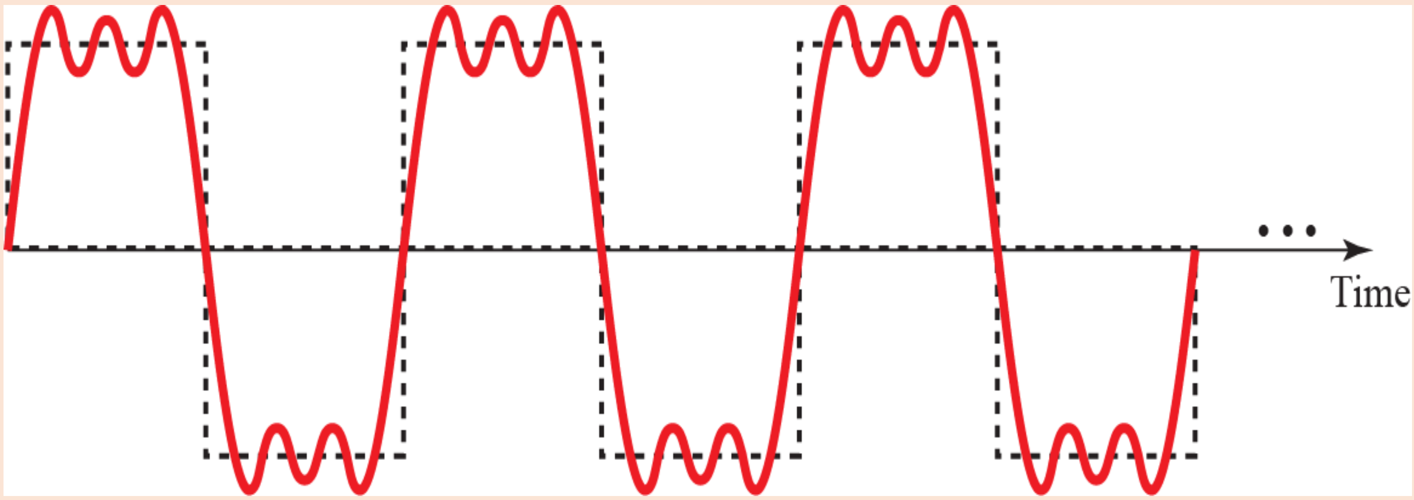
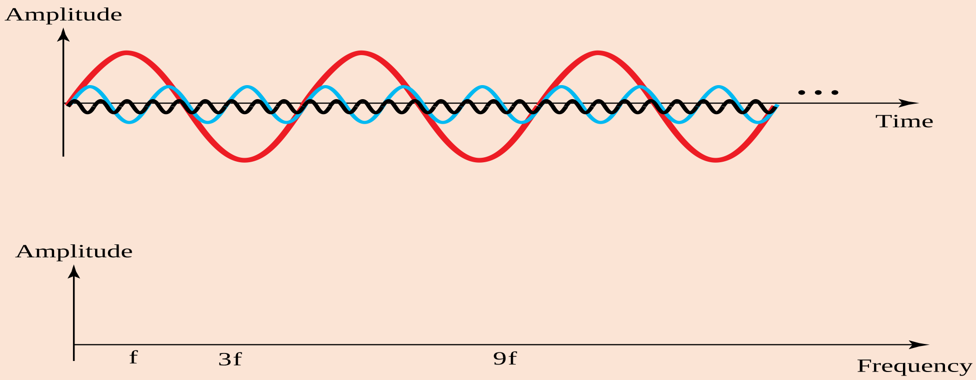
- **A Composite Periodic Signal**



Decomposition of Composite Periodic Signal

If the **composite signal** is **periodic**, the **decomposition** gives a series of **signals** with discrete frequencies. If the **composite signal** is nonperiodic, the **decomposition** gives a combination of sine waves with continuous frequencies.

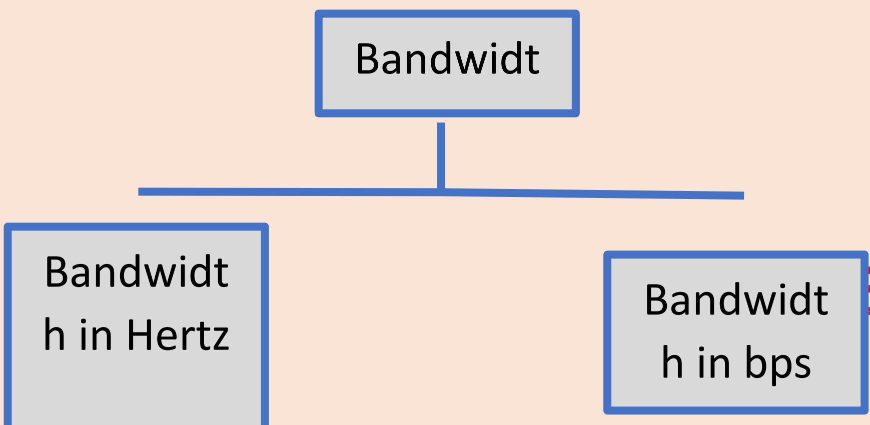


b. Frequency-domain decomposition of the composite signal

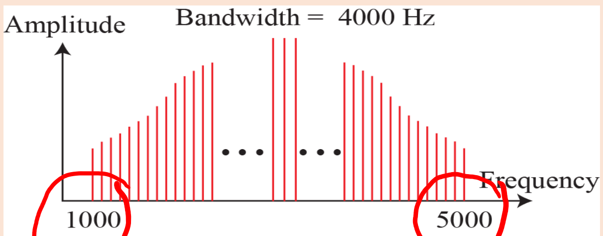
Topic # 38

Bandwidth

- **An important characteristic that measures Network Performance**
- **Bandwidth can be used in two different contexts with two different measuring values:**
    - **Bandwidth in Hertz**
    - **Bandwidth in bits per second**



- **Range of frequencies contained in a Composite Signal**
- **The bandwidth is normally a difference between two frequencies (the highest and the lowest)**

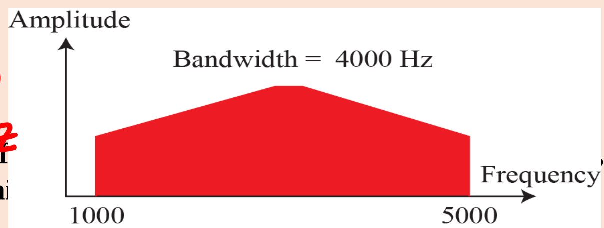


a. Bandwidth of a periodic signal

$B = f_h - f_l$

$= 5000 - 1000$

$= 4000\,Hz$



b. Bandwidth of a nonperiodic signal

$5000 - 1000$

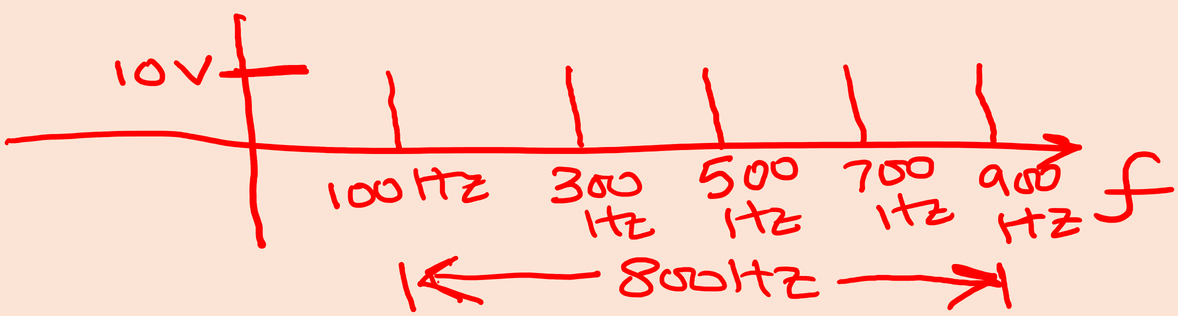
$B = 4000\,Hz$

If a periodic signal is decomposed into f... , 700, and 900 Hz, what is its bandwidth? Draw the spectrum, assumi... of 10 V.

$B = f_h - f_l$

$= 900 - 100$

$B = 800\,Hz$



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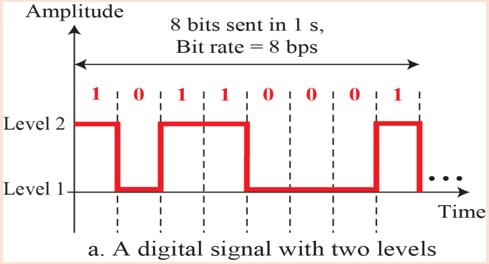
Topic # 39

Digital Signals

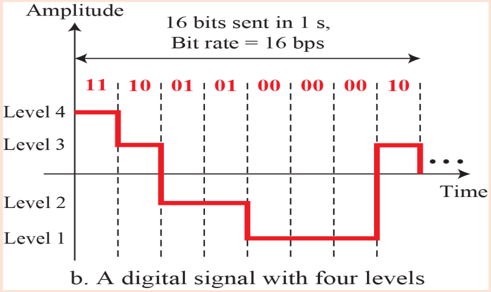
In addition to being represented by an analog signal, information can also be represented by a digital signal. For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage.
A digital signal can have more than two levels.

- **Information can also be represented by a digital signal**
- **For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage**
- **A digital signal can have more than two levels so that we can send more than one bit for each level**



a. A digital signal with two levels

In general, if a signal has L levels, each



b. A digital signal with four levels

$\log_2 4 = 2$ bits

TOPIC # 40

In this case, we can send more than 1 bit for each level. Figure 3.17 shows two signals, one with two levels and the other with four.

A digital signal has eight levels. How many bits are needed per level? We calculate the number of bits from the following formula. Each signal level is represented by 3 bits.

Number of bits per level

$$= \log_2 8 = 3$$

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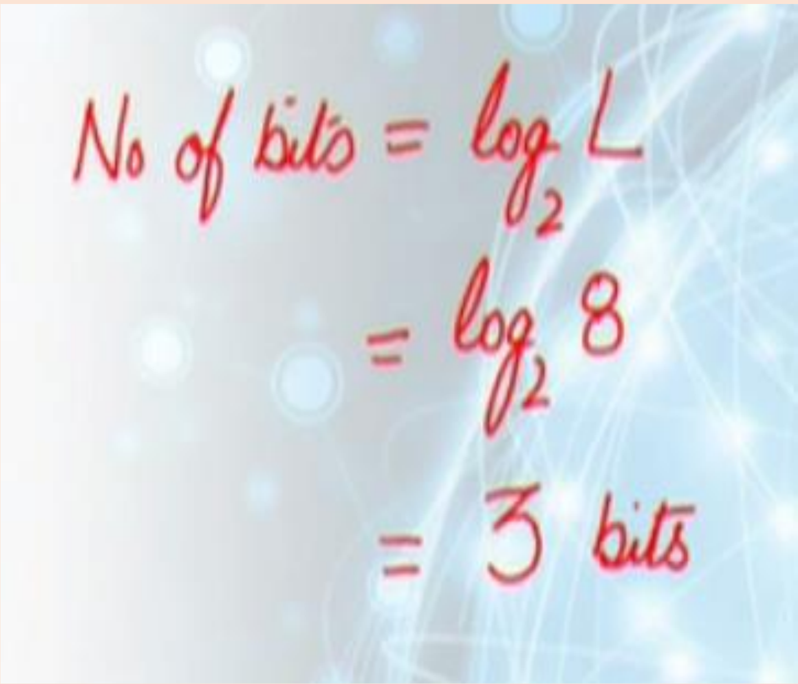
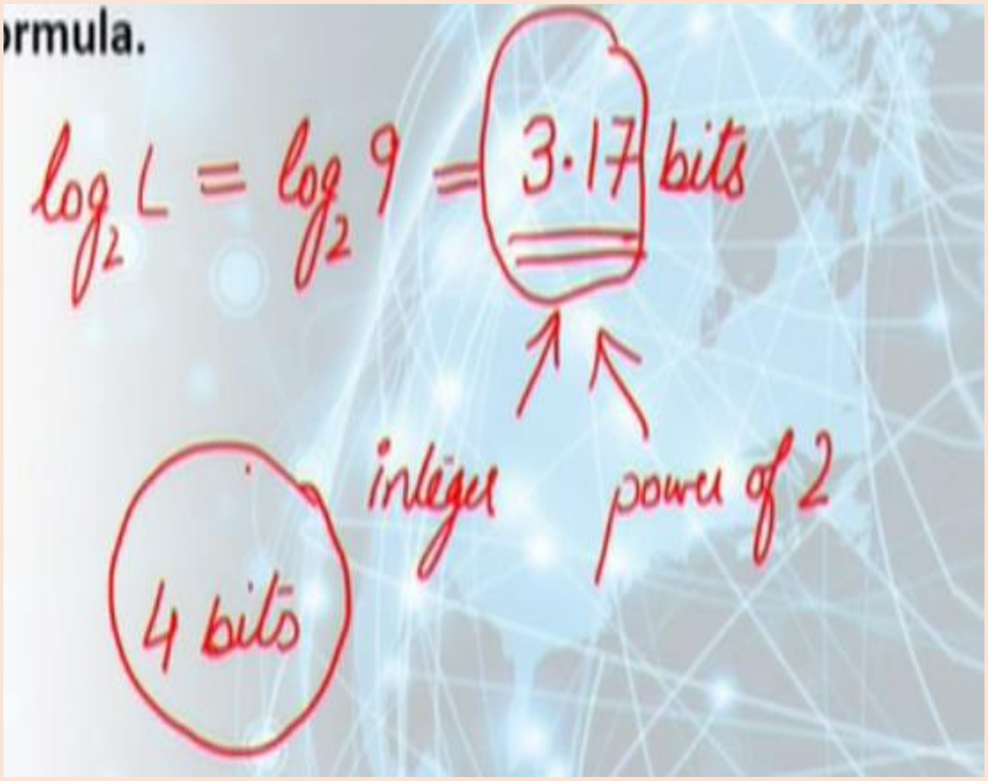
A digital signal has eight levels. How many bits are needed per level?



Example 3.17

A digital signal has nine levels. How many bits are needed per level? We calculate the number of bits by using the formula. Each signal level is represented by 3.17 bits. However, this answer is not realistic. The number of bits sent per level needs to be an integer as well as a power of 2. For this example, 4 bits can represent one level.

A digital signal has nine levels. How many bits are needed per level? We calculate the number of bits by using the formula.



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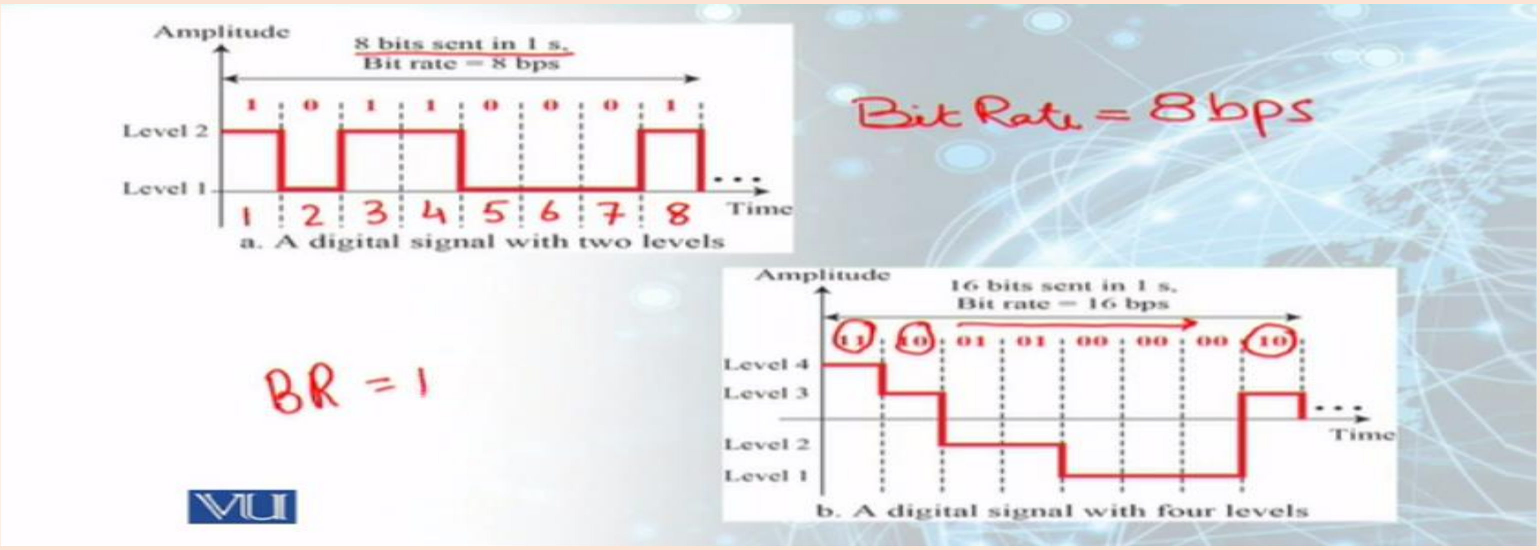
Bit Rate

- Number of bits sent in 1 second
- Bit Rate is expressed in bits per second (bps)
- Most digital signals are non-periodic, and thus period and frequency are not appropriate characteristics



Topic # 41

Bit Rate

Most digital signals are nonperiodic, and thus period and frequency are not appropriate characteristics. Another term—bit rate (instead of frequency)—is used to describe digital signals. The bit rate is the number of bits sent in 1s, expressed in bits per second (bps). Figure 3.17 shows the bit rate for two signals.

- Number of bits sent in 1 second
- Bit Rate is expressed in bits per second (bps)
- Most digital signals are non-periodic, and thus period and frequency are not appropriate characteristics

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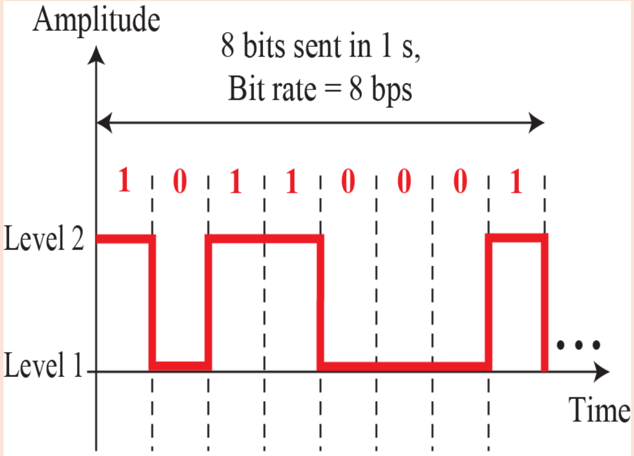
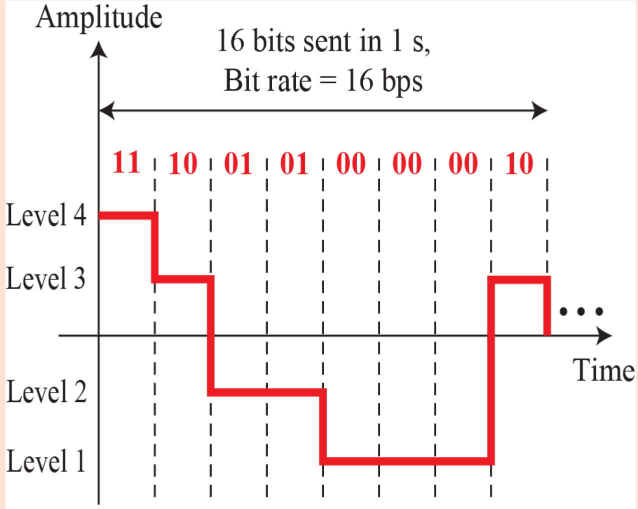


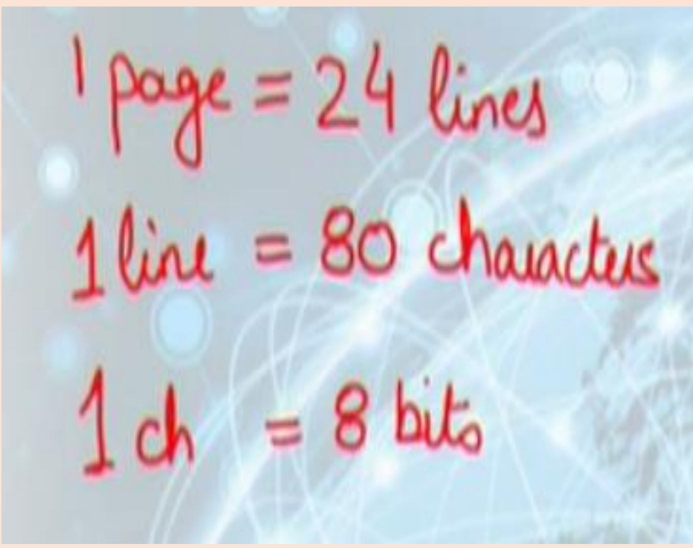
a. A digital signal with two levels

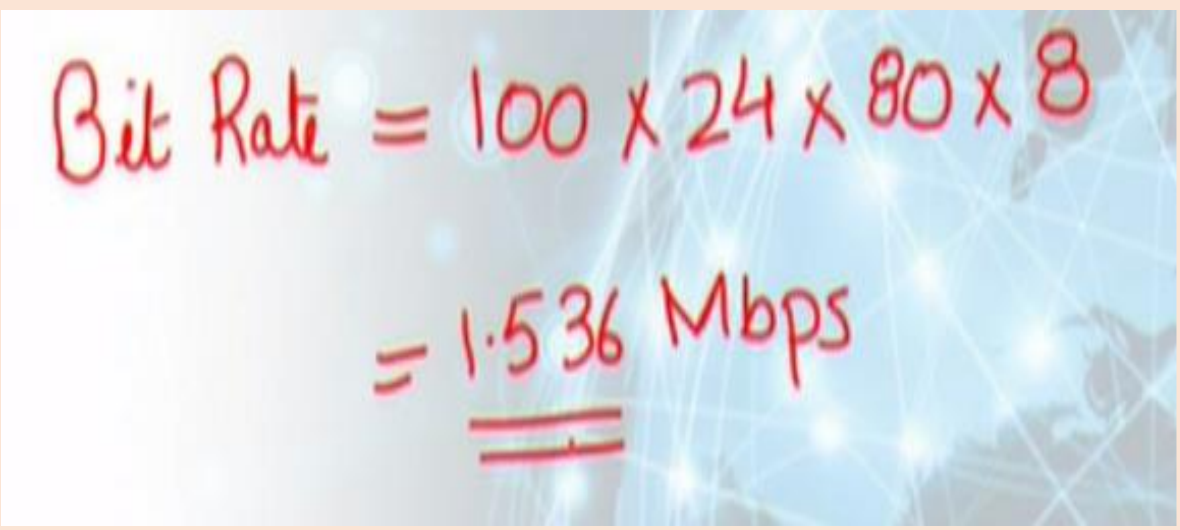


b. A digital signal with four levels

Example

Assume we need to download text documents at the rate of 100 pages per second. What is the required bit rate of the channel?





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Example 3.18

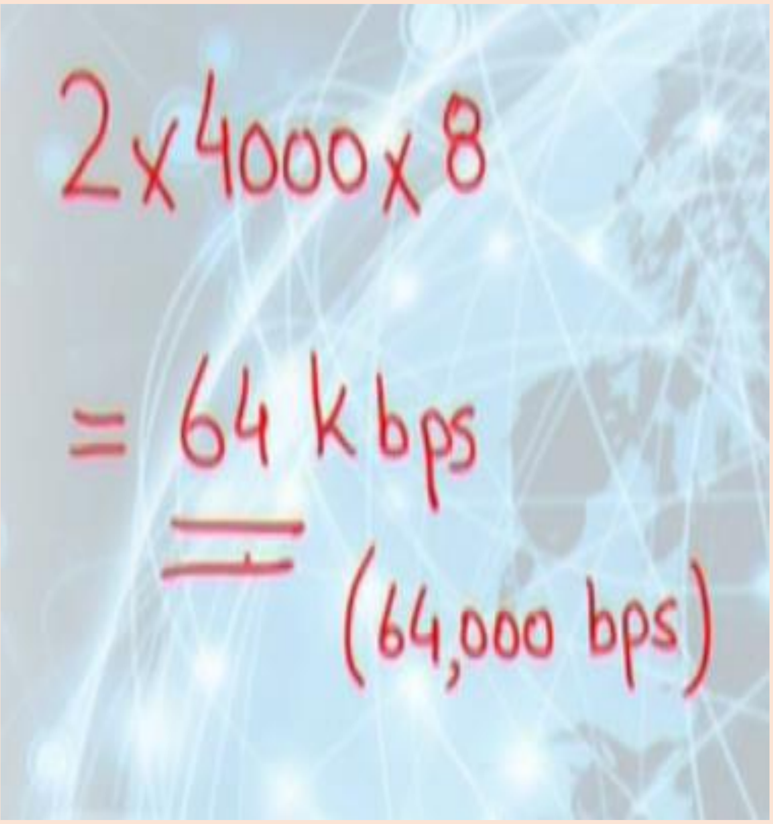
Solution

From Table 3.1 we find the equivalents of 1 ms (1 ms is 10–3 s) and 1 s (1 s is 106 μs). We make the following substitutions:

$$100 \times 24 \times 80 \times 8 = 1{,}536{,}000 \text{ bps}$$

$$= 1.536 \text{ Mbps}$$

A digitized voice channel is made by digitizing a 4-kHz bandwidth analog voice signal. We need to sample the signal at twice the highest frequency (two samples per hertz). We assume that each sample requires 8 bits. What is the required bit rate?



Example 3.19

Solution

A page is an average of 24 lines with 80 characters in each line. If we assume that one character requires 8 bits, the bit rate is

$$2 \times 4000 \times 8 = 64{,}000 \text{ bps}$$

$$= 64 \text{ kbps}$$

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BIT LENGTH:

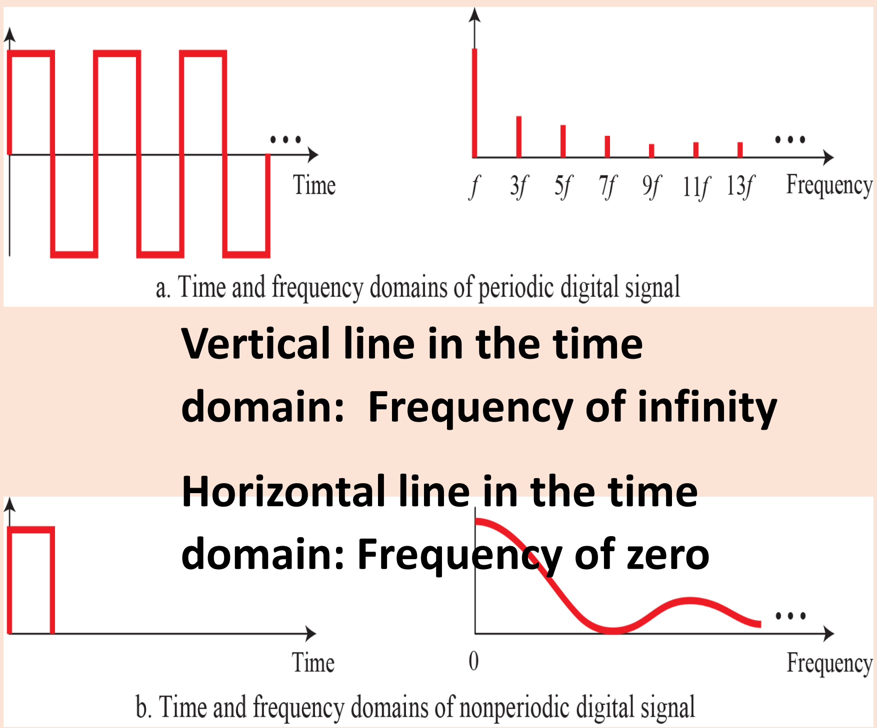
We discussed the concept of the wavelength for an analog signal: the distance one cycle occupies on the transmission medium. We can define something similar for a digital signal: the bit length. The bit length is the distance one bit occupies on the transmission medium.

$$\text{Bit length} = \text{propagation speed} \times \text{bit duration}$$

Topic # 42

Digital Signal as Composite Analog Signal

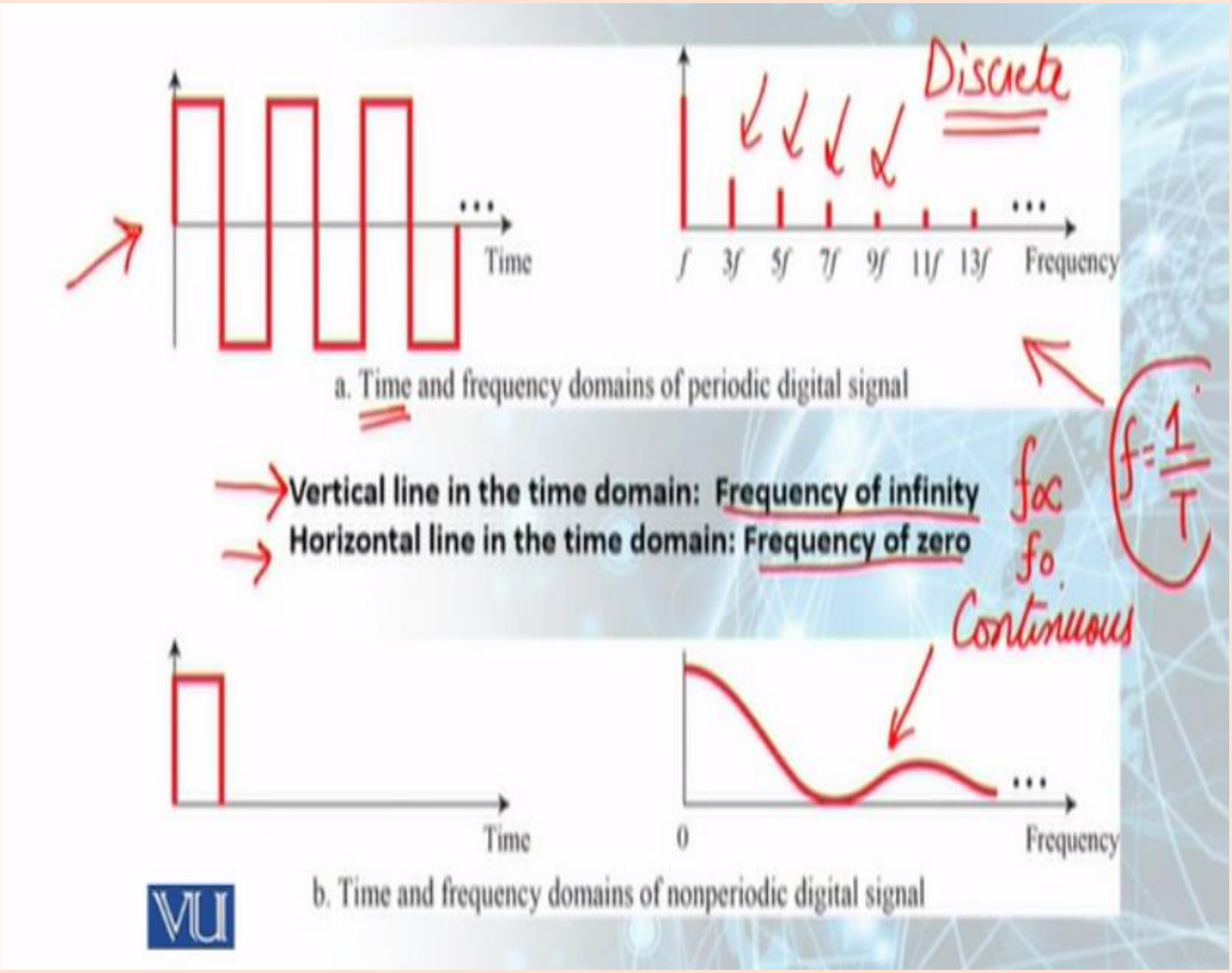
- **Based on Fourier analysis, a digital signal is a composite analog signal**
- **A digital signal, in the time domain, comprises connected vertical and horizontal line segments**
- **Infinite Bandwidth**



a. Time and frequency domains of periodic digital signal

b. Time and frequency domains of nonperiodic digital signal

- **A vertical line in the time domain means a frequency of infinity: a horizontal line in the time domain means a frequency of zero. Going from a frequency of zero to a frequency of infinity implies all frequencies in between are part of the domain.**



- **A vertical line in the time domain means a frequency of infinity: a horizontal line in the time domain means a frequency of zero. Going from a frequency of zero to a frequency of infinity implies all frequencies in between are**
- **part of the domain.**

Topic # 43:

Transmission of Digital Signals

- **Digital signal, periodic or non-periodic, is a composite analog signal with frequencies between zero and infinity (Infinite Bandwidth)**
- **Two approaches for transmission:**
  - ✓ **Baseband Transmission**
  - ✓ **Broadband Transmission**

Baseband Transmission is a signaling technology that sends digital signals over a single frequency as discrete electrical pulses. The entire bandwidth of a **baseband** system carries only one data **signal** and is generally less than the amount of bandwidth available on a broadband **transmission** system.

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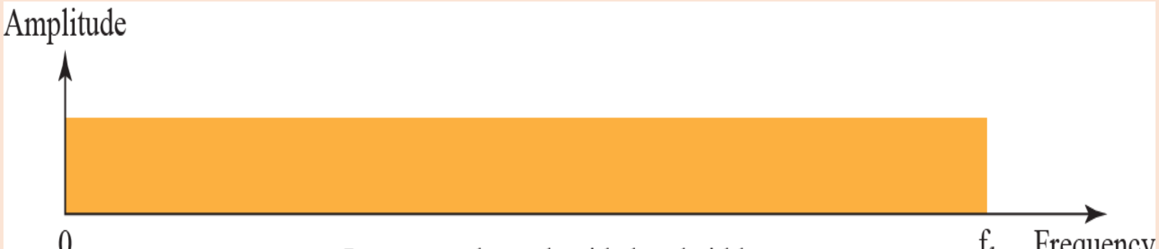
Broadband Transmission is a signaling technology that sends signals simultaneously over a range of different frequencies as electromagnetic waves. The bandwidth of a **broadband** system can usually carry multiple, simultaneous data signals.

- ✓ **Baseband Transmission**

Low Pass Channel

Sending a **Digital Signal** without changing it to an **Analog Signal**

Transmission of Digital Signals



a. Low-pass channel, wide bandwidth

b. Low-pass channel, narrow bandwidth

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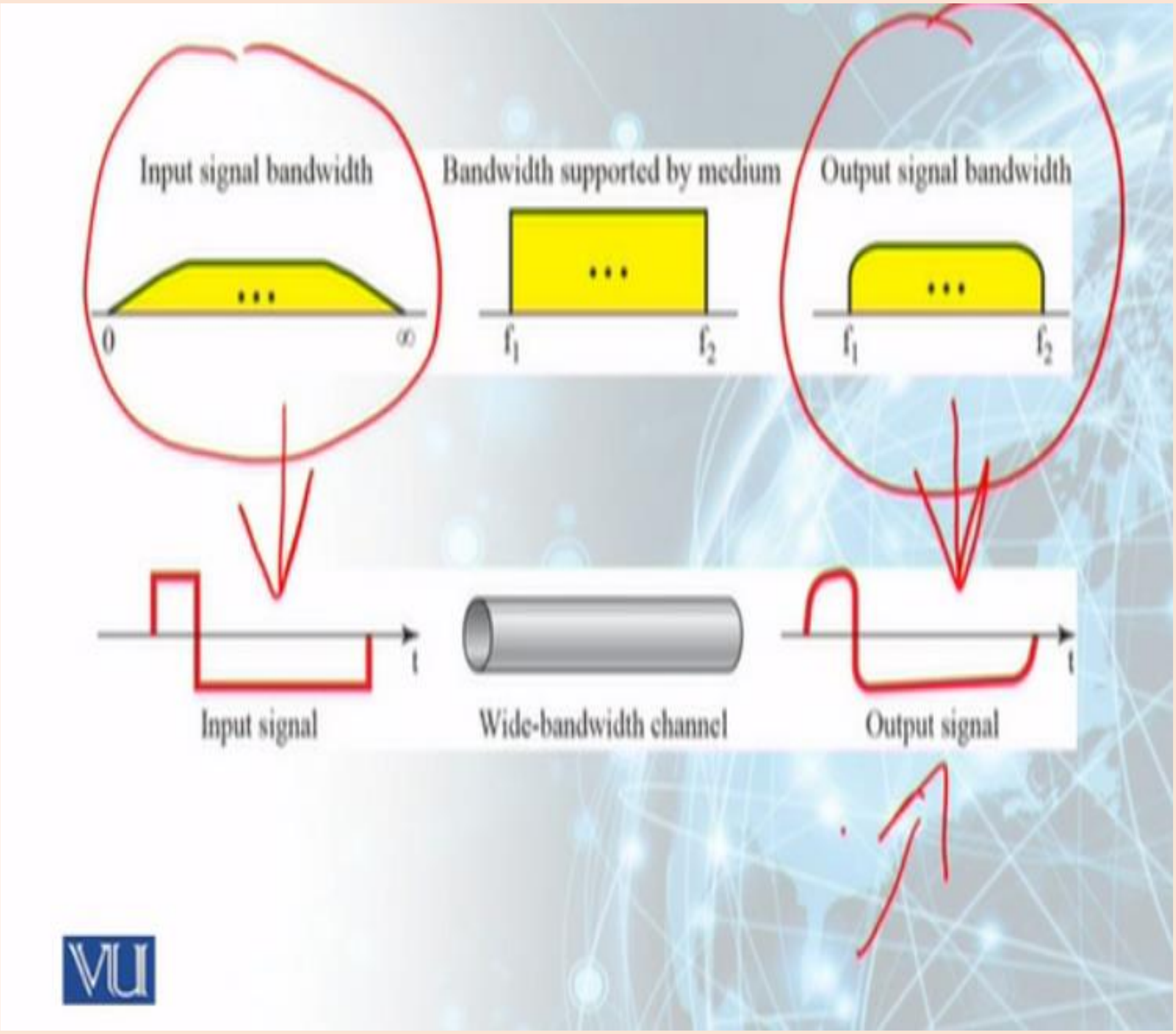

Topic # 44

Broadband Transmission (Modulation)

- **Changing the Digital signal to an Analog signal for transmission**
- **Modulation allows us to use a bandpass channel—a channel with a bandwidth that does not start from zero**
- **More available than a low-pass channel**

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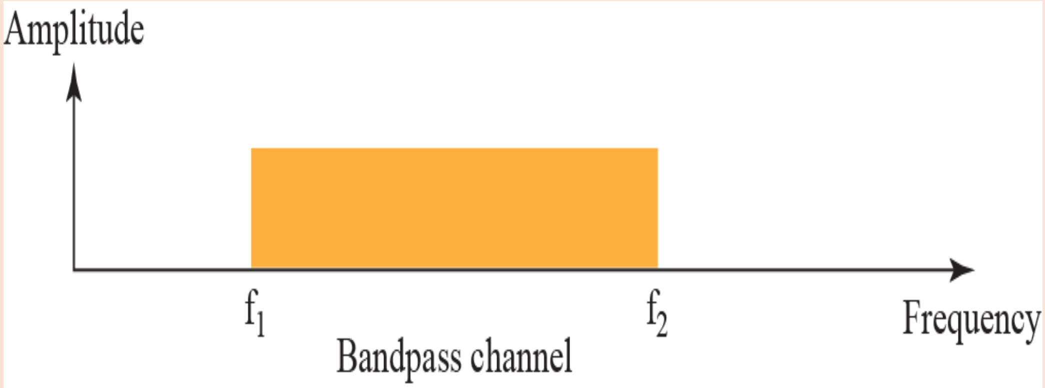

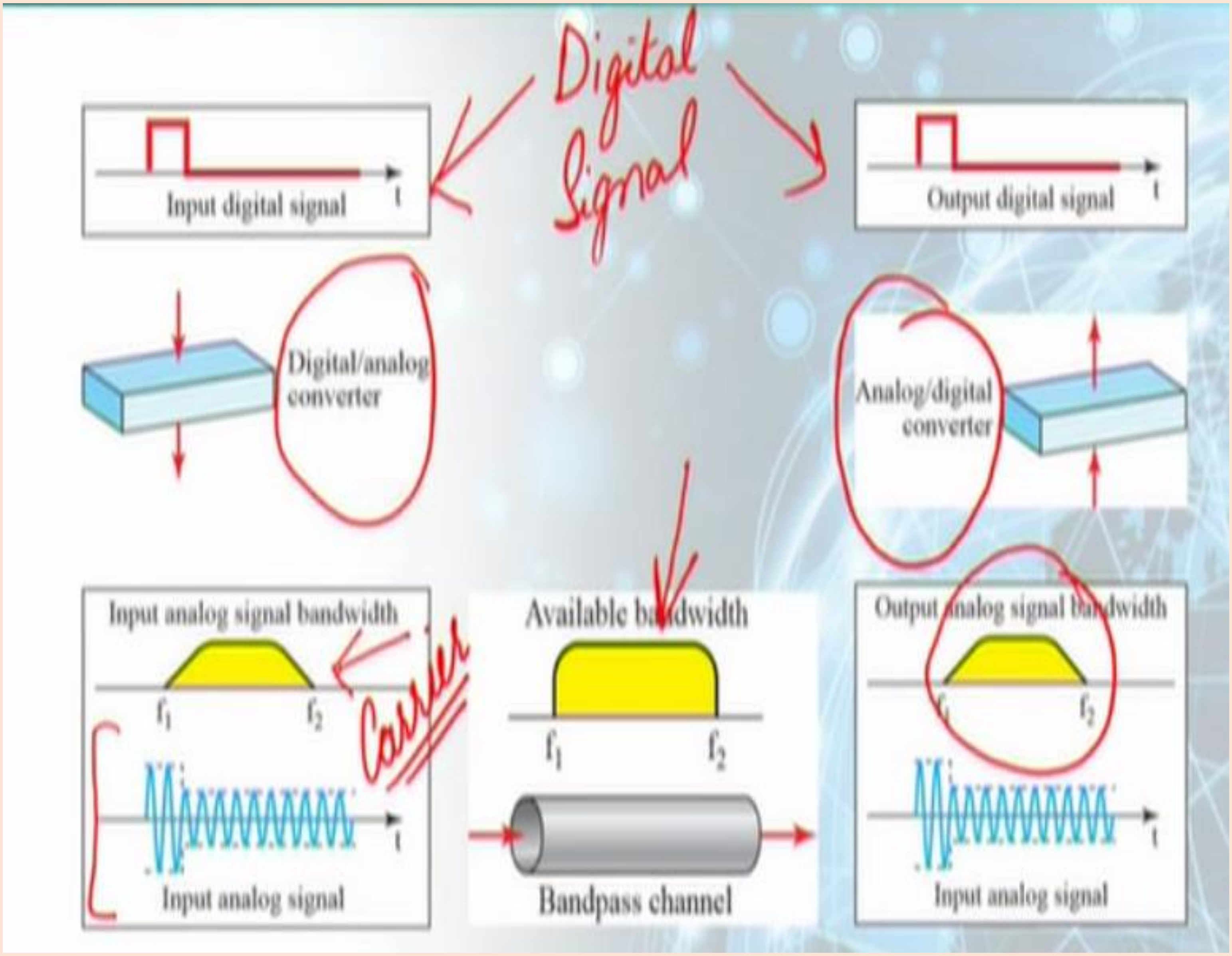

Topic # 45

Transmission Impairments

- **Transmission media are not perfect**
- **Cause Signal impairments**

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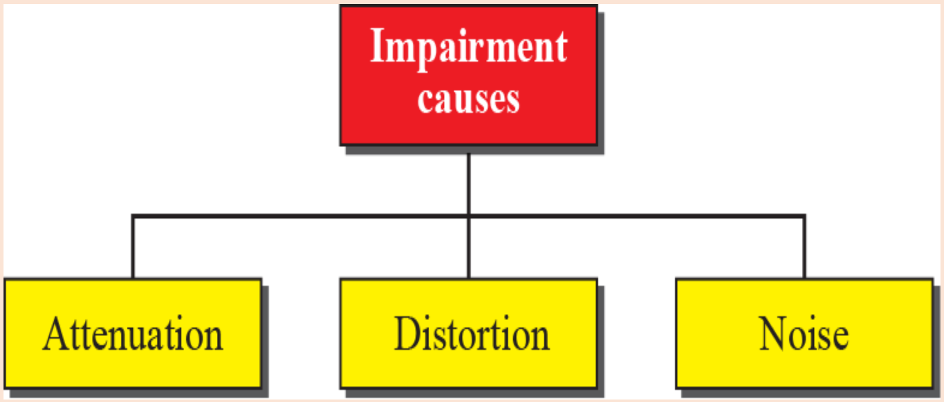
- **Signal sent is not the same as the signal received**



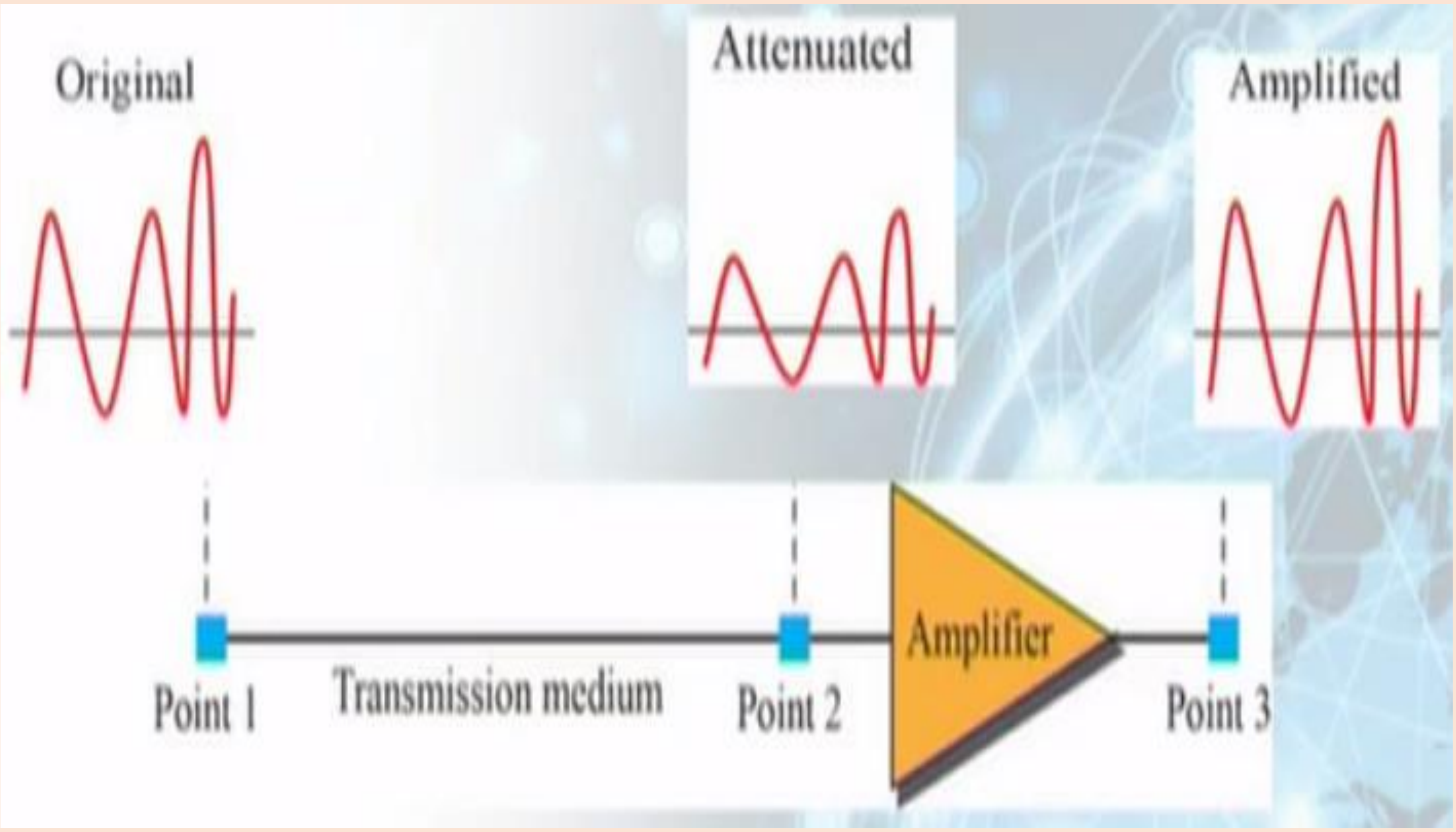
What is sent is not what is received. Three causes of impairment are attenuation, distortion, and noise (see Figure 3.26).

Signals travel through transmission media, which are not perfect. The imperfection causes signal impairment. This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium.

Attenuation:

Attenuation means a loss of energy. When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium. That is why a wire carrying electric signals gets warm, if not hot, after a while. Some of the electrical energy in the signal is converted to heat.

To compensate for this loss, amplifiers are used to amplify the signal. Figure 3.27 shows the effect of attenuation and amplification.



Topic # 46

Attenuation and Amplification - Decibel

- **Unit of Signal strength is Decibel or dB**

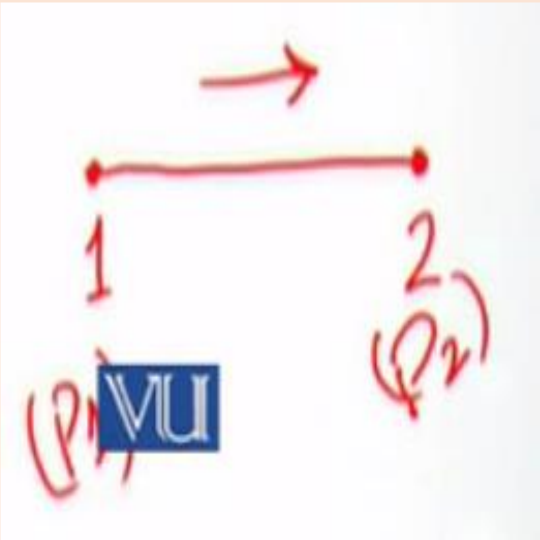
- **Decibel (dB) measures the relative strengths of two signals or one signal at two different points**

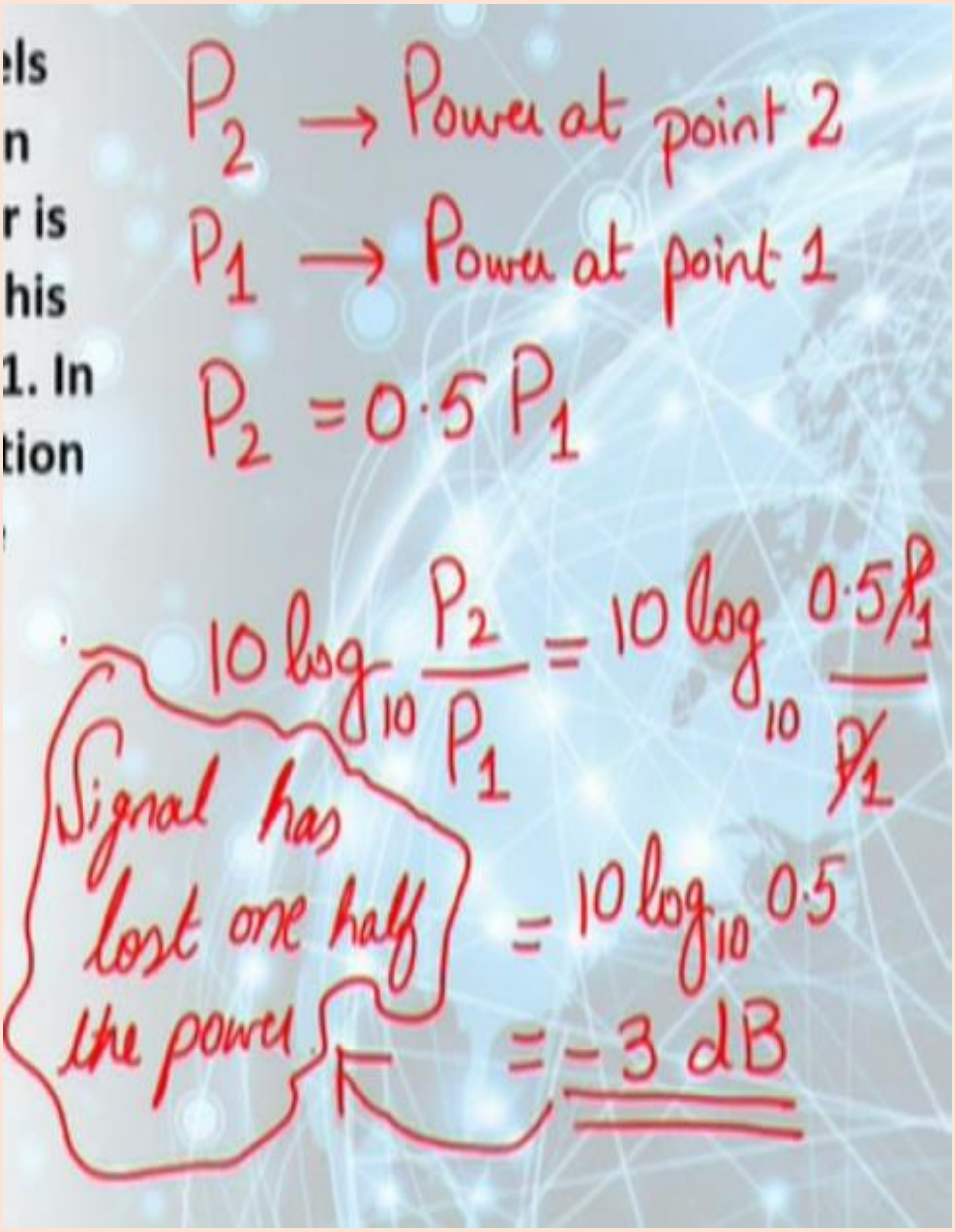
$$10 \log_{10} P_2/P_1$$

- **Decibel is negative if a signal is attenuated and positive if signal is amplified.**

Example:

- **Suppose a signal travels through a transmission medium and its power is reduced to one half. This means that P2 = 0.5 P1. In this case, the attenuation (loss of power) can be calculated as**





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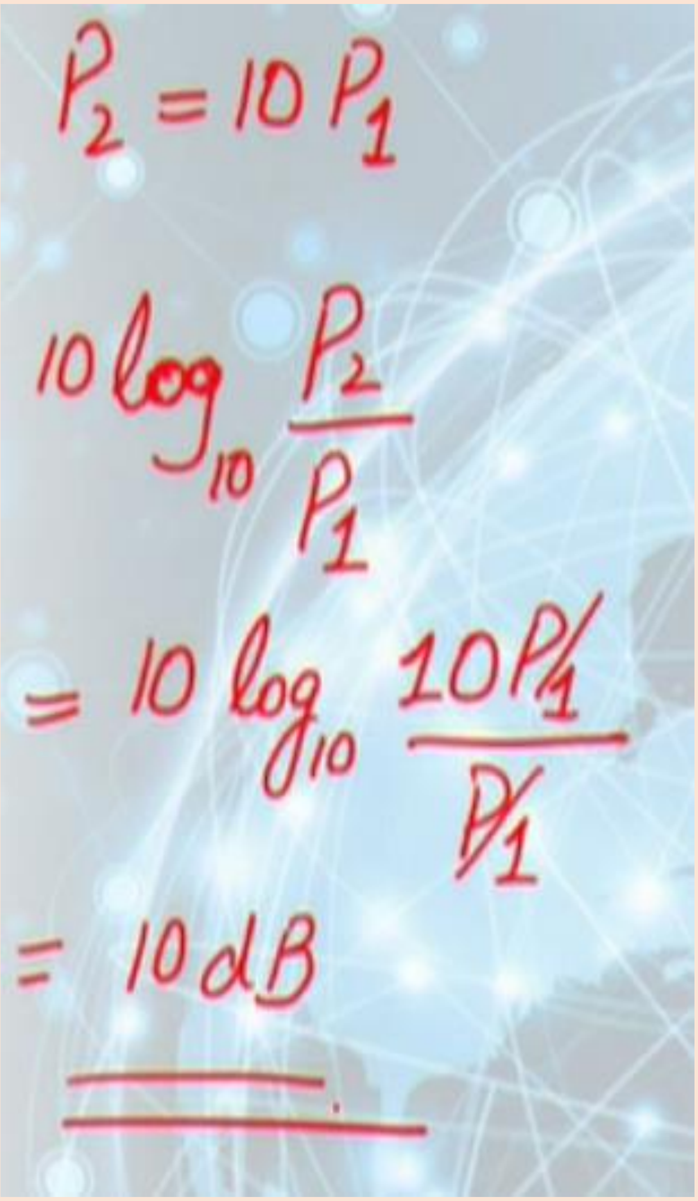
Example:

A signal travels through an amplifier, and its power is increased 10 times. This means that $P_2 = 10P1$. In this case, the amplification (gain of power) can be calculated as



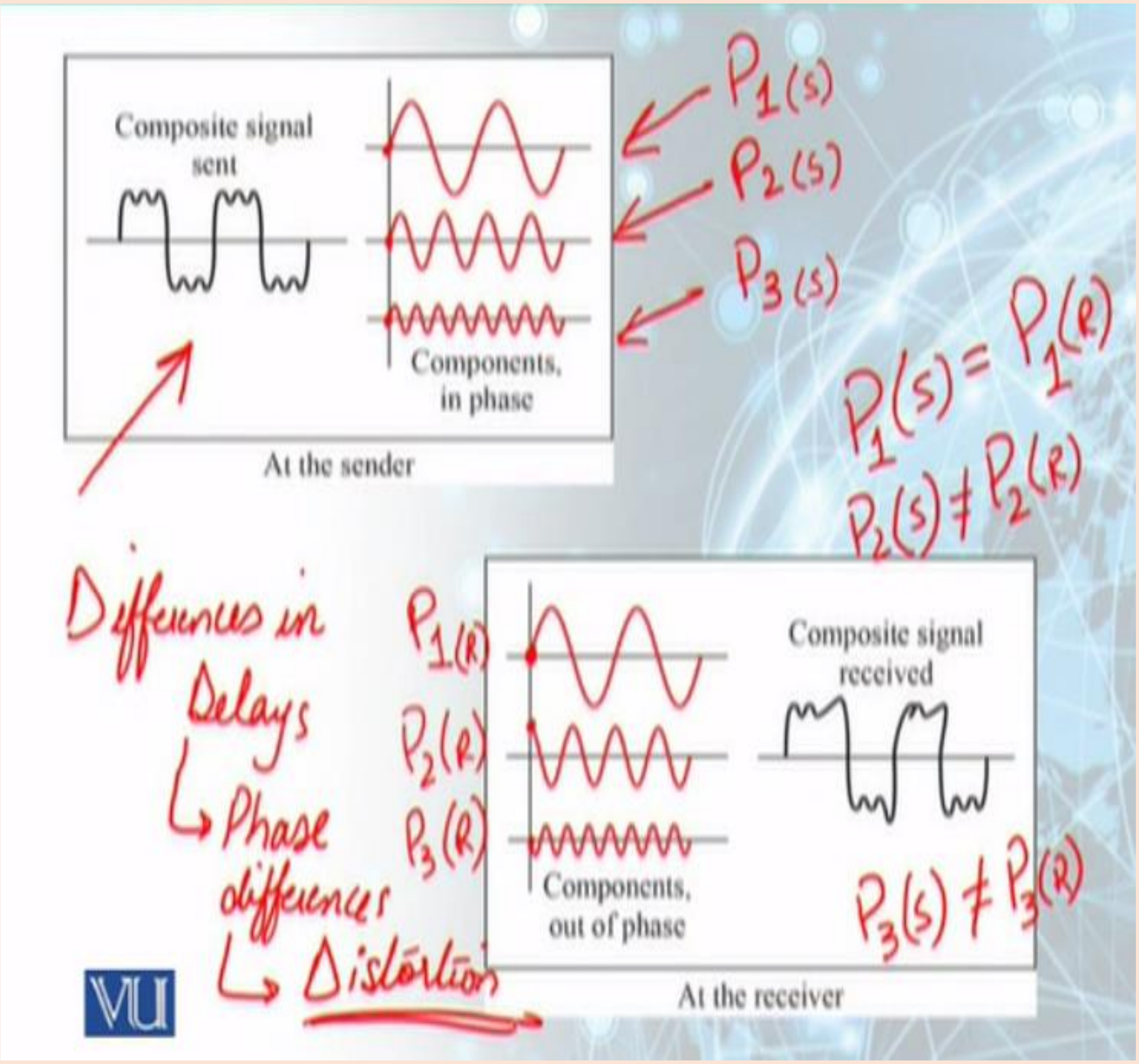
Topic # 47:

Distortion

Distortion – It means changes in the form or shape of the signal. This is generally seen in composite signals made up with different frequencies. Each frequency component has its own propagation speed travelling through a medium

- **Distortion means that the signal changes its form or shape.**
- **Distortion can occur in a composite signal made of different frequencies.**
- **Each signal component has its own propagation speed (see the next section) through a medium and, therefore, its own delay in arriving at the final destination.**

- **Differences in delay may create a difference in phase if the delay is not exactly the same as the period duration.**
- **Figure 3.29**



Topic # 48

Noise

Noise is unwanted electrical or electromagnetic energy that degrades the quality of signals and **data**. **Noise** occurs in digital and analog systems, and can affect files and **communications** of all types, including text, programs, images, audio, and telemetry. ... Normally this **noise** is of little or no consequence.

- **Noise is another cause of impairment.**
- **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 not originally sent by the transmitter.**

- **Induced noise comes from sources such as motors.**
- **Crosstalk is the effect of one wire on the other.**

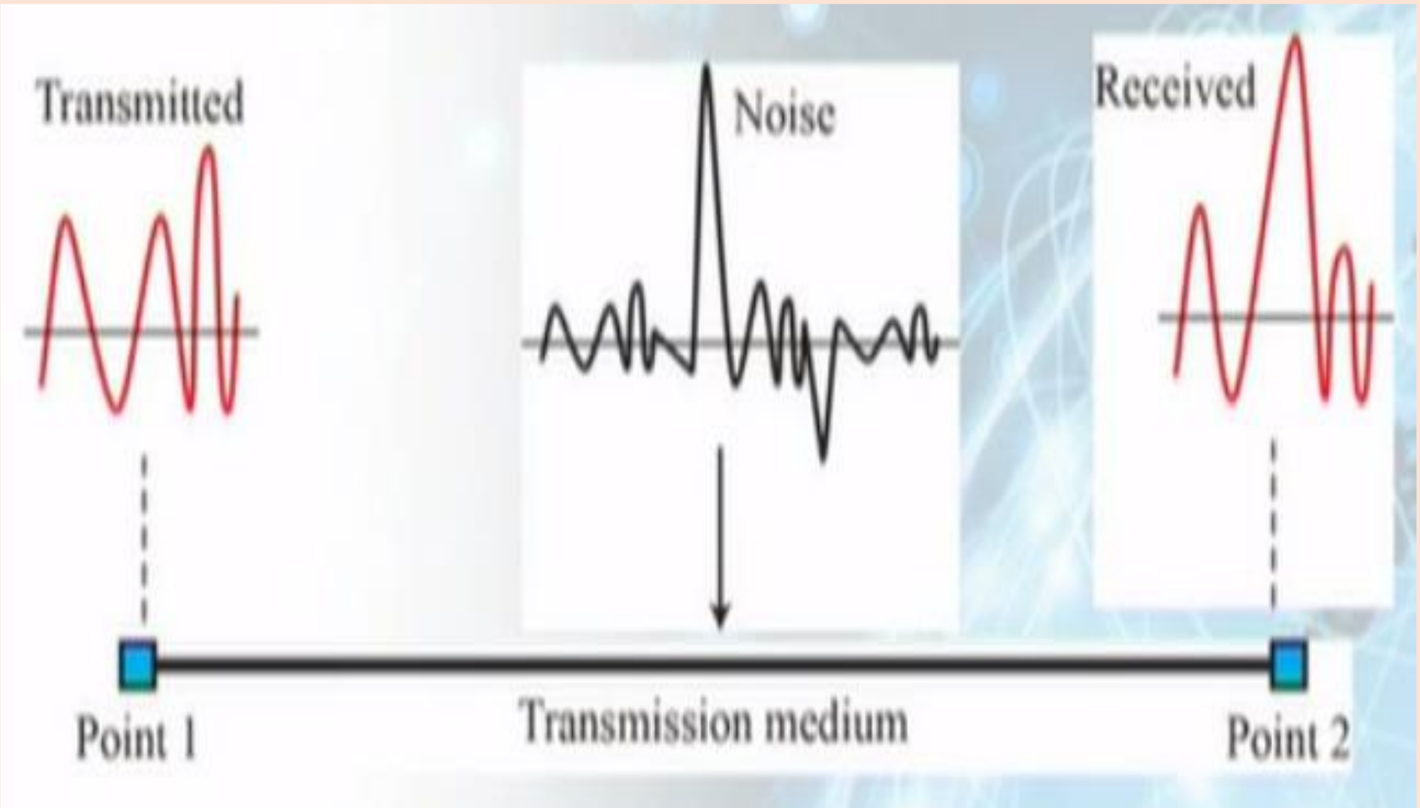
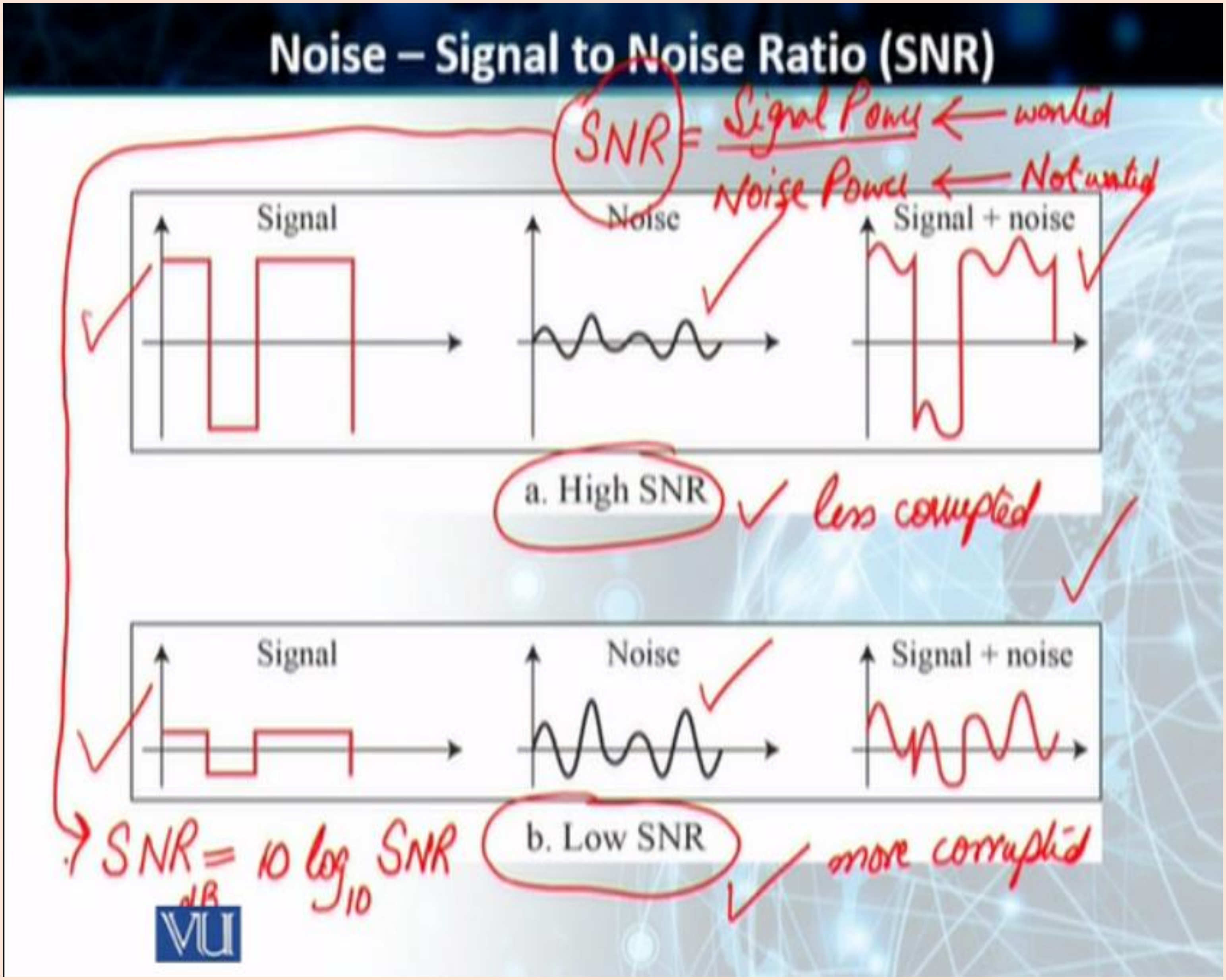


Figure 3.31

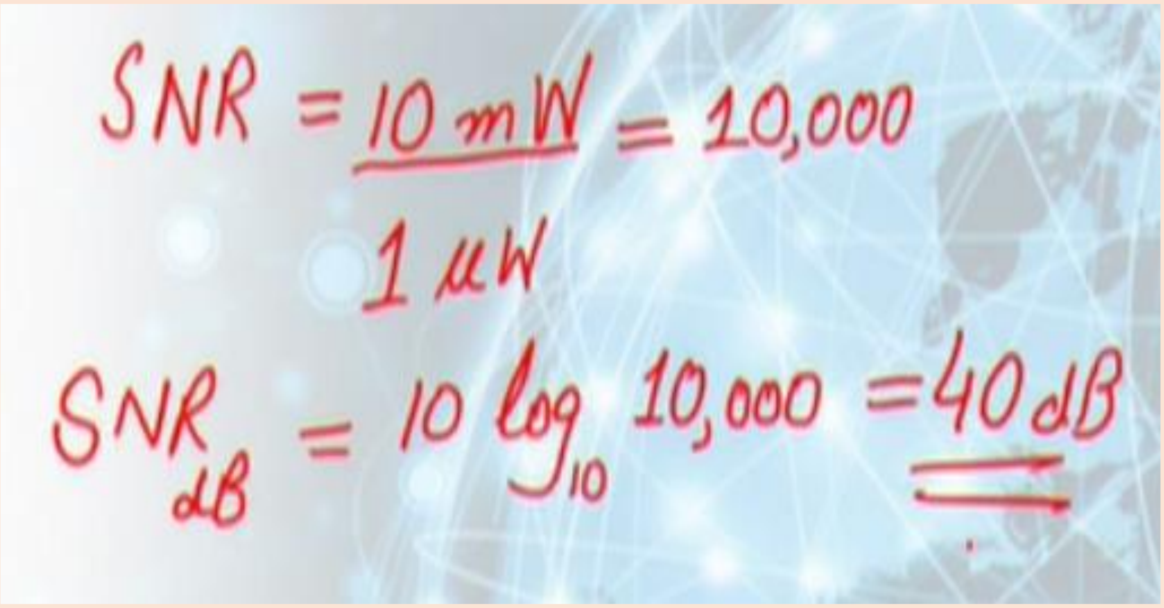
Noise – Signal to Noise Ratio (SNR)

- **Signal to Noise Ratio (SNR) is used to find the theoretical bit rate limit of a signal**

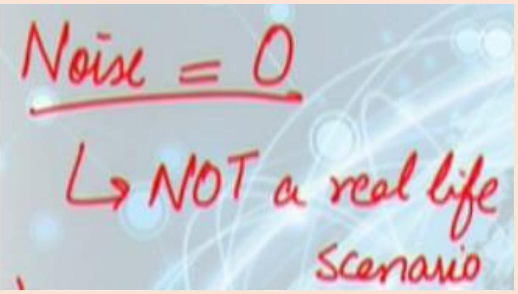
$$SNR = \frac{\text{average signal power}}{\text{average noise power}}$$

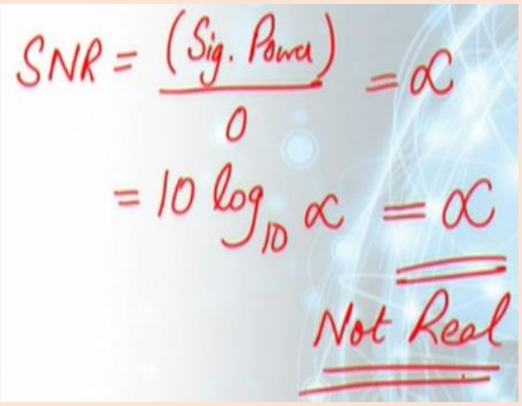


The power of a signal is 10 mW and the power of the noise is 1 μW; what are the values of SNR and SNR_{dB}



The values of SNR and SNR_{dB} for a noiseless channel are calculated as





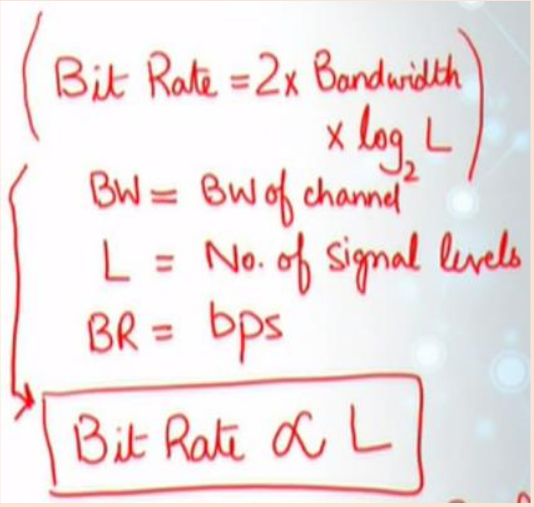
Topic # 49:

Data Rate Limits

A very important consideration in **data** communications is how fast we can send **data**, in bits per second, over a channel. **Data rate** depends on three factors: The **bandwidth** available.

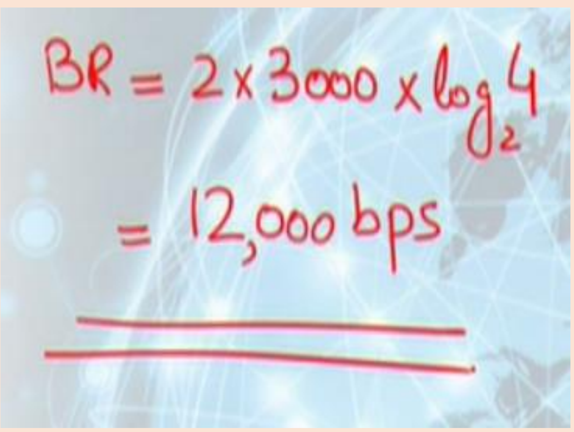
- **How fast we can send data, in bits per second, over a channel?**
- **Data Rate depends on 3 factors:**
  - ✓ **The Bandwidth available**
  - ✓ **The level of the signals we use**
  - ✓ **The level of noise**
- **Two theoretical formulas developed to calculate the data rate:**
  - ✓ **one by Nyquist for a noiseless channel**
  - ✓ **another by Shannon for a noisy channel**
- ✓ **For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate**
- ✓ **Finding balance between Bit rate and System Reliability**

Noiseless Channel: Nyquist Rate



Example

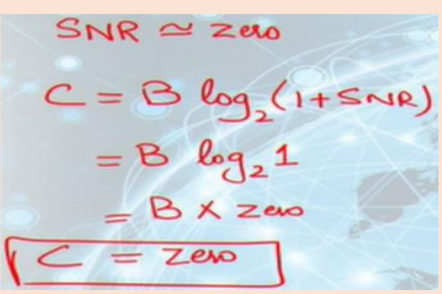
Consider the same noiseless channel transmitting a signal with four signal levels (for each level, we send 2 bits). The maximum bit rate can be calculated as



Topic # 50

Noisy Channel : Shannon Capacity:

- **In reality, we cannot have a noiseless channel; the channel is always noisy**
- **In 1944, Claude Shannon introduced a formula, to determine the theoretical highest data rate for a noisy channel:**
- **Example:**
- **Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as**



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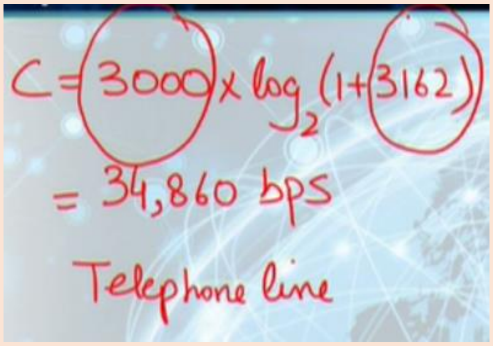
Example:

Theoretical highest bit rate of a Telephone line with a Bandwidth of 3000 Hz assigned for data communication. SNR is usually 3162. The capacity is calculated as:



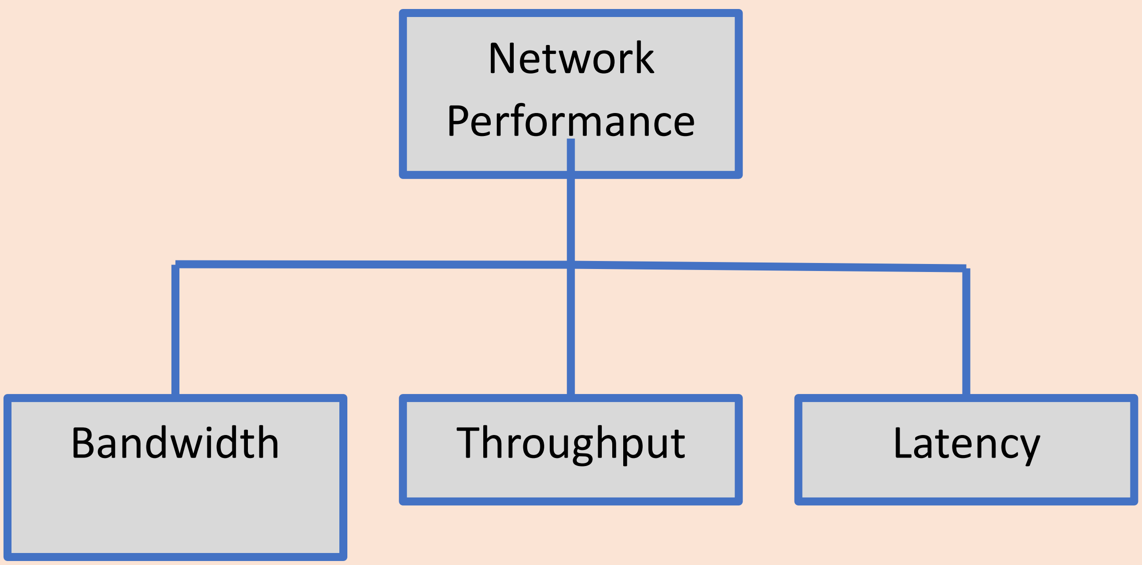
Using Both Limits

- **In practice, we need to use both methods to find the limits and signal levels**
- **Shannon's formula gives us the upper limit while the Nyquist formula gives us the signal levels**

Topic # 51

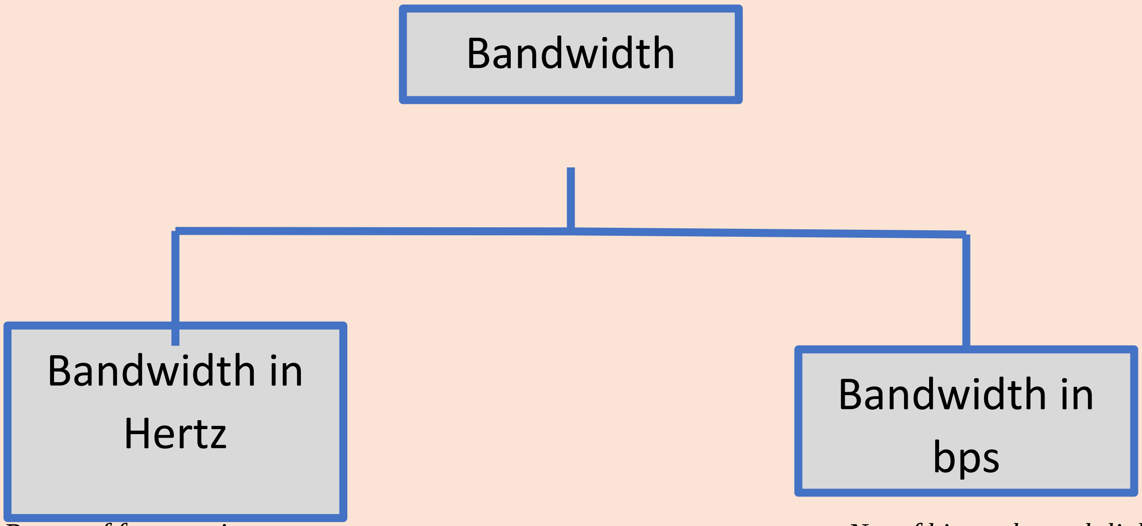
Network Performance

- **Data transmission (in form of Signal) over a network and how network behaves is important**
- **More important is the performance of the network**
- **How good is our network?**



- **There are 3 characteristics of network performance**
- **Bandwidth:**
- **Bandwidth** is measured as the amount of **data** that can be transferred from one point to another within a network in a specific amount of time. Typically, **bandwidth** is expressed as a bitrate and measured in bits per second (bps).

- **An important characteristic that measures Network Performance**
- **Bandwidth can be used in two different contexts with two different measuring values:**
    - **Bandwidth in Hertz**
    - **Bandwidth in bits per second**
- **Example 3.42**
- **The bandwidth of a subscriber line is 4 kHz for voice or data. The bandwidth of this line for data transmission**
- **can be up to 56,000 bps using a sophisticated modem to change the digital signal to analog.**
- **If the telephone company improves the quality of the line and increases the bandwidth to 8 kHz, we can send 112,000 bps by using the same technology as mentioned in Example 3.42.**



Range of frequencies

or network can transmit

No. of bits a channel, link

in a composite signal

Throughput

- **Measure of how fast we can actually send data through a network.**
- **Bandwidth is not the same as Throughput**
- **A link may have a bandwidth of B bps, but we can only send T bps through this link with T always less than B**
- **A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?**

$$T = \frac{(12{,}000 \times 10{,}000)}{60}$$

$$= 2\,\text{Mbps}$$

The throughput is a measure of how fast we can actually send data through a network. Although, at first glance, bandwidth in bits per second and throughput seem the same, they are different. A link may have a bandwidth of B bps, but we can only send T bps through this link with T always less than B.

The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.

We can say that latency is made of four components: propagation time, transmission time, queuing time and processing delay.

Latency = propagation time + transmission time + queuing time + processing delay

Example 3.44

Solution

We can calculate the throughput as

Throughput =

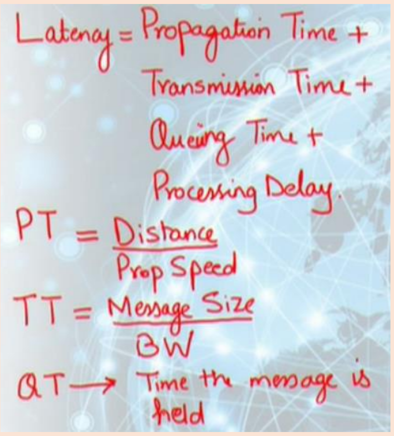
(12,000X10,000)/60 = 2Mbps

The throughput is almost one-fifth of the bandwidth in this case.

Topic # 52:

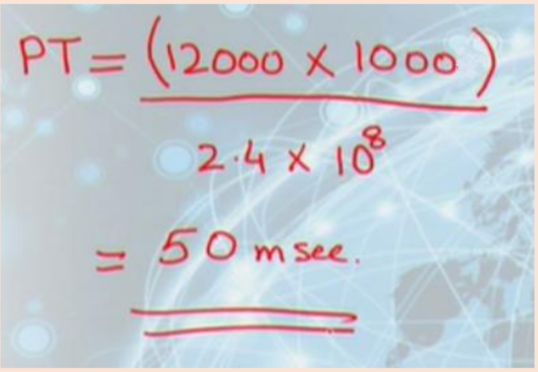
Latency or Delay

- Latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source



Example

What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be 2.4 × 10^8 m/s in cable.

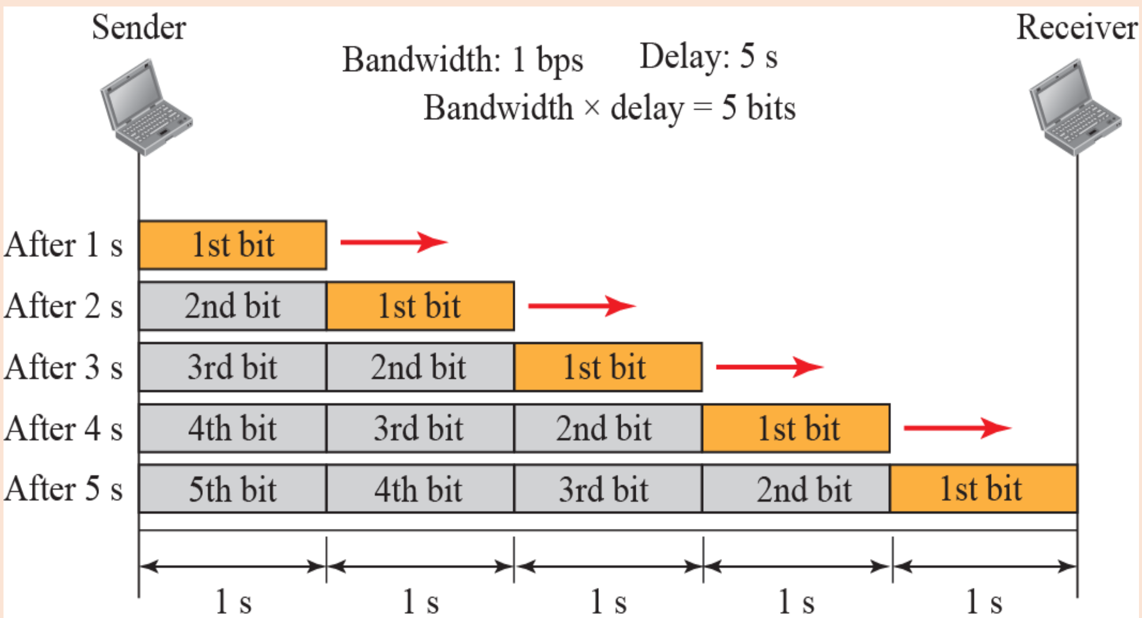


Topic # 53

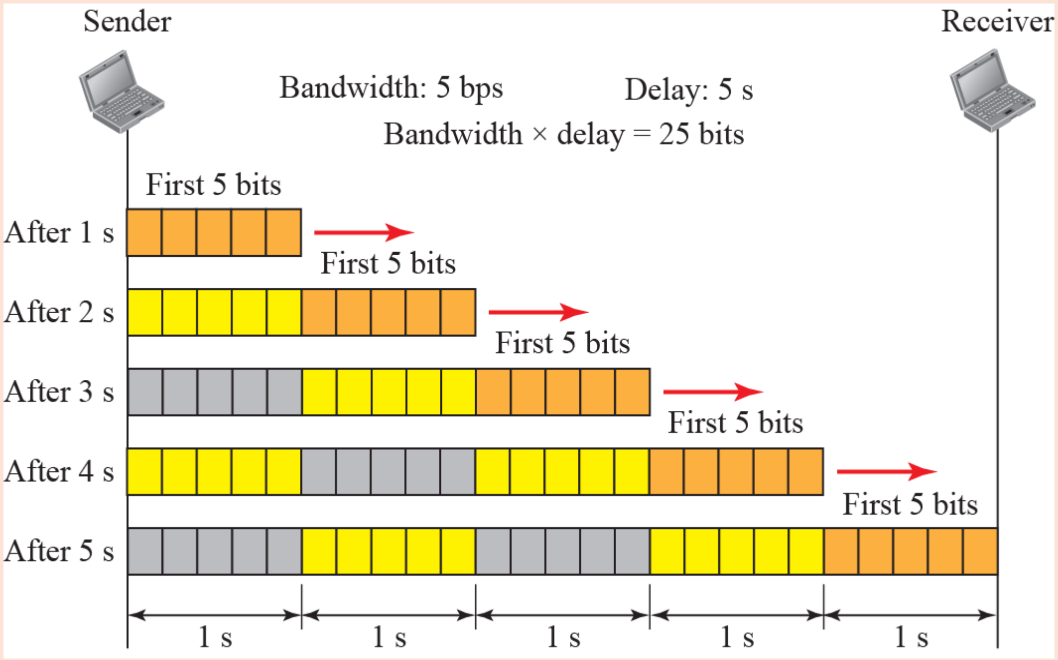
Delay – Bandwidth Delay Product

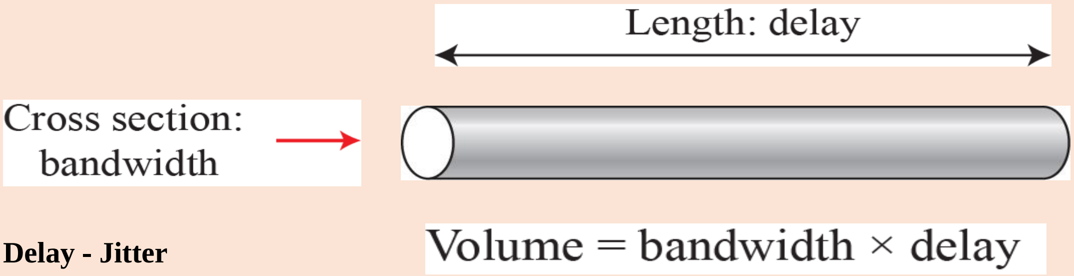
- **Bandwidth and delay are two performance metrics of a link**
- **Product of the two, The Bandwidth-Delay Product defines the number of bits that can fill a link**
- **Bandwidth-Delay Product**

Case 1



Case 2





Delay - Jitter

- **Jitter is a problem if different packets of data encounter different delays and the application using the data at the receiver site is time-sensitive (audio and video data, for example)**
- **Delay for first packet is 20 ms for the second is 45 ms, and for the third is 40 ms, then the real-time application that uses the packets endures jitter.**

Topic # 54

Digital-to-digital Conversion

- **Data → Analog or Digital**
- **Signals → Analog or Digital**
- **Digital Transmission**
- **Analog Transmission**
- **Digital Transmission**

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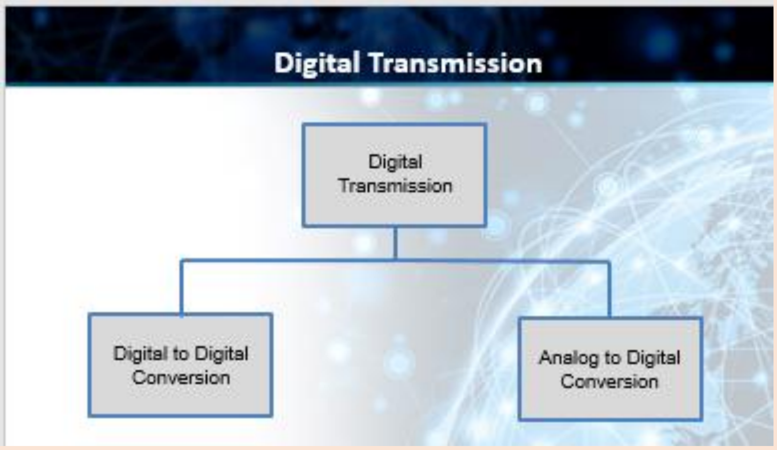

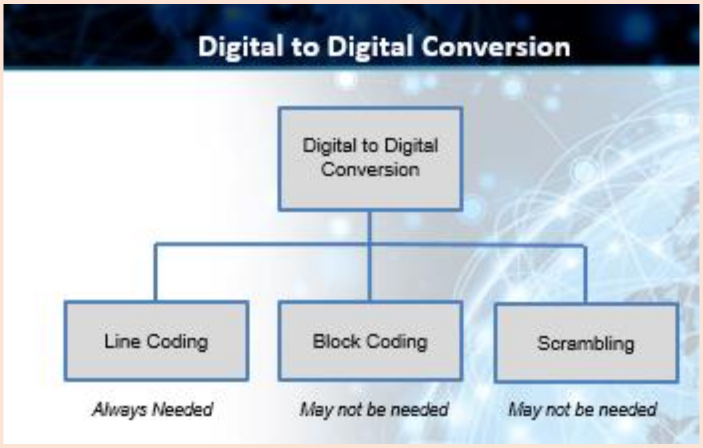

Signal Elément versus Data Elément

"A **data element** is the smallest entity that can represent a piece of information (a bit). A **signal element** is the shortest unit of a digital **signal**. **Data elements** are what we need to send; **signal elements** are what we can send. **Data elements** are being carried; **signal elements** are the carriers."

- **A Data element is the smallest entity that can represent a piece of information → Bit**
- **A Signal element is the shortest unit of a digital signal**
- **Data Elements: Carried**
- **Signal Elements: Carriers**

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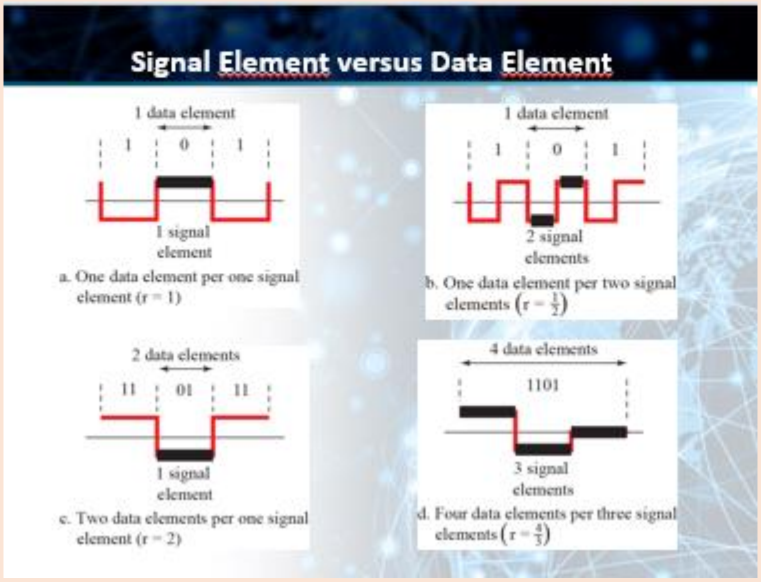


Topic # 55

Data rate and **Signal rate**:

Data rate – Number of **data** elements transmitted per second. **Signal rate** – Number of **signal** elements transmitted per second.

- **Data Rate is number of data elements sent in 1 sec (bps)**
- **Signal Rate is number of signal elements sent in 1 sec (baud)**
- **Data Rate → Bit Rate**
- **Signal Rate → Pulse Rate, Modulation Rate or Baud Rate**

S → Signal Rate
D → Data Rate
r → No. of data elements carried by signal element

$$S = \frac{D}{r}$$

Example:

A signal has a signal rate of 100 bauds. What is the Data rate if one data element is carried per signal element?

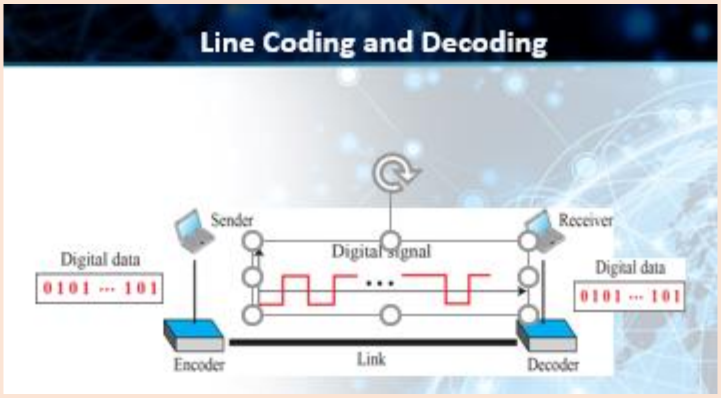
Topic # 56

Line Coding

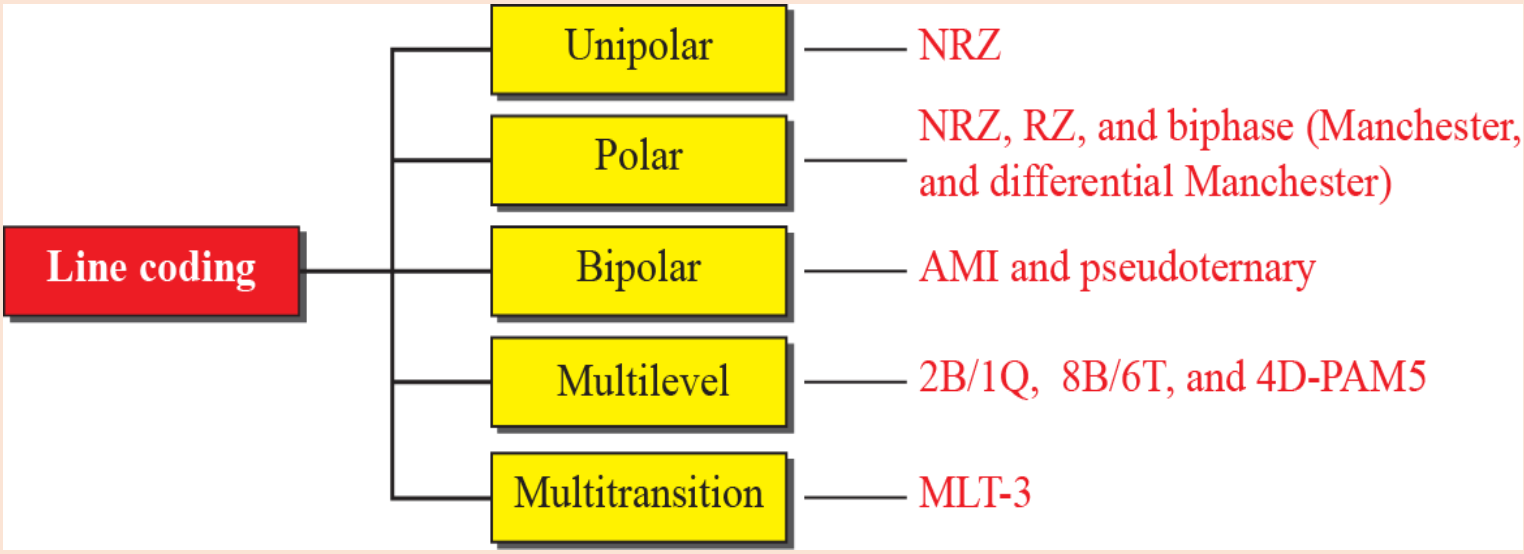
Line coding is the process of converting digital data to digital signals. By this **technique** we convert a sequence of bits to a digital signal. At the sender side digital data are encoded into a digital signal and at the receiver side the digital data are recreated by decoding the digital signal

- **Digital data to Digital signals**

- **Data (Text, Numbers, Pictures, Audio, or Video) is stored in computer memory as sequences of bits**
- **Line coding converts a sequence of Bits to a Digital Signal**
- **Line Coding and Decoding**



Line Coding Schemes



Line Coding Schemes

- **We can roughly divide line coding schemes into five broad categories**

Unipolar NRZ scheme(non-return-to-zero**)**

Unipolar encoding is a line code. A positive voltage represents a binary 1, and zero volts indicates a binary 0. ... It is called **NRZ** because the signal does not return to zero at the middle of the bit, as instead happens in other line coding schemes, such as Manchester code.

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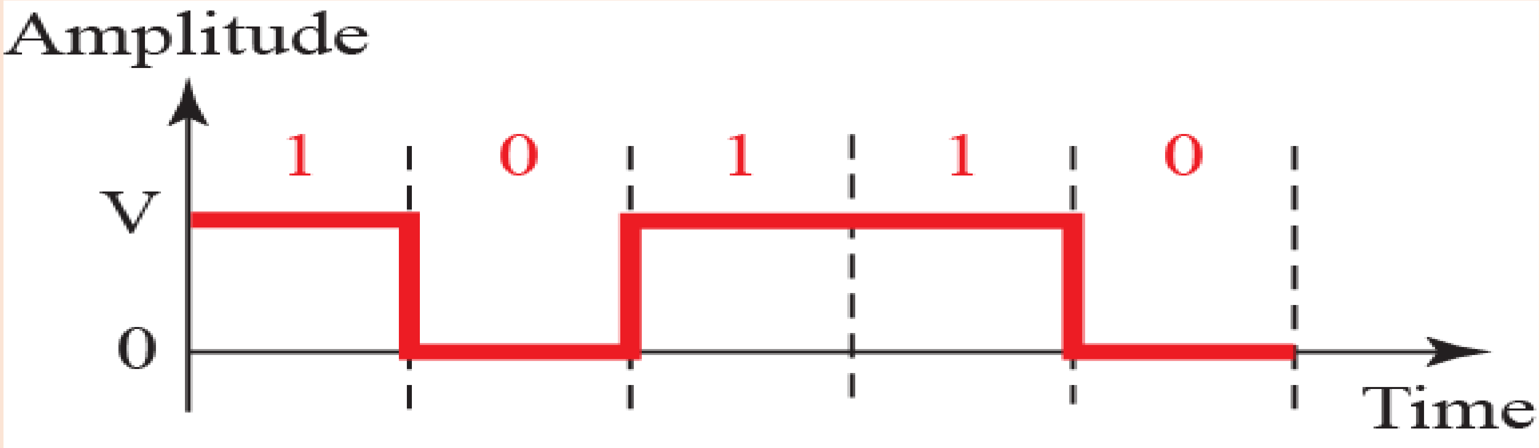
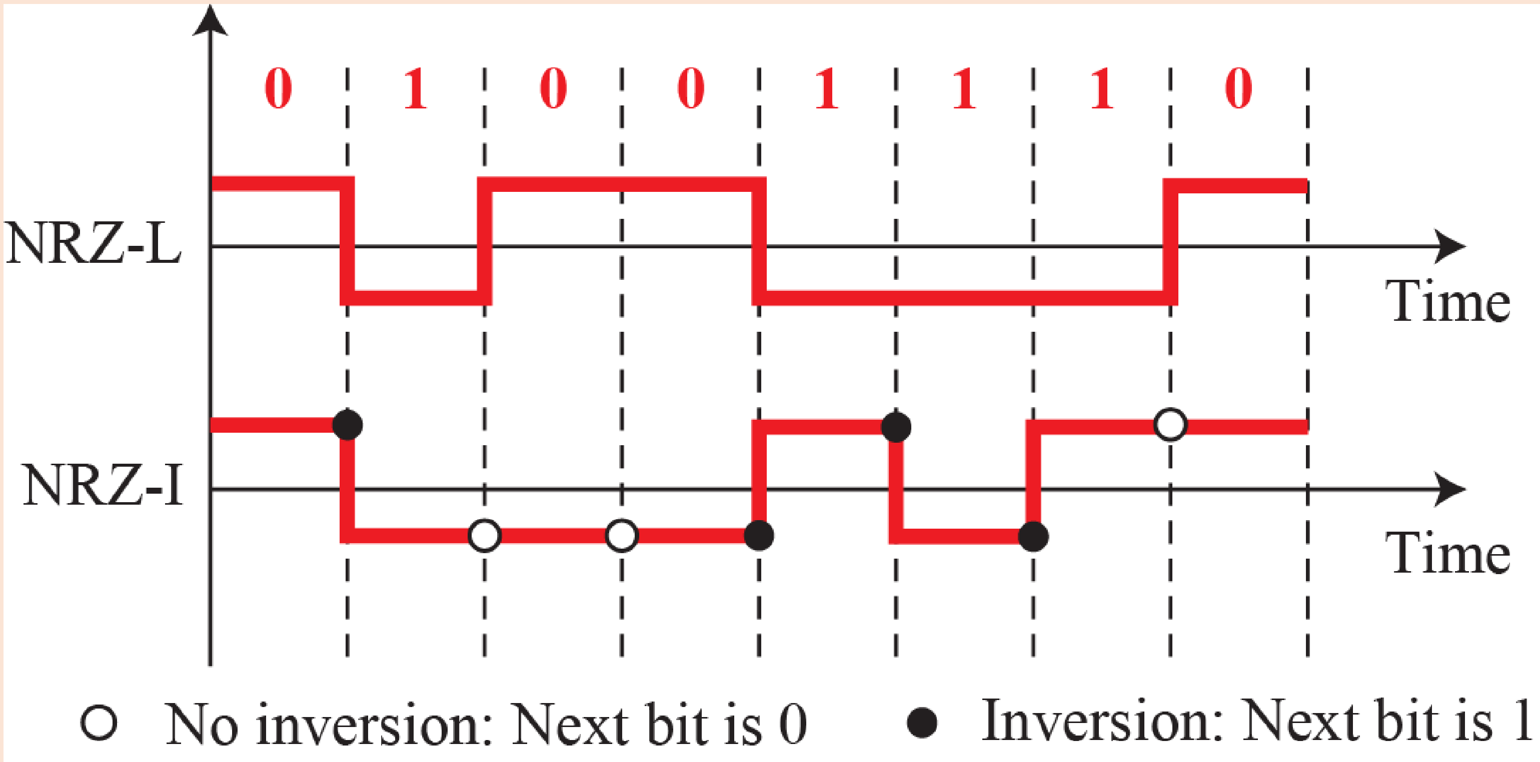


Polar schemes (NRZ):

Polar NRZ. In this type of **Polar** signaling, a High in data is represented by a positive pulse, while a Low in data is represented by a negative pulse.



Topic # 58:

Polar RZ

Polar RZ. In this type of **Polar** signaling, a High in data, though represented by a Mark pulse, its duration T_0 is less than the symbol bit duration. Half of the bit duration remains high but it immediately returns to zero and shows the absence of pulse during the remaining half of the bit duration.

Polar schemes (RZ)(return-to-zero**)**

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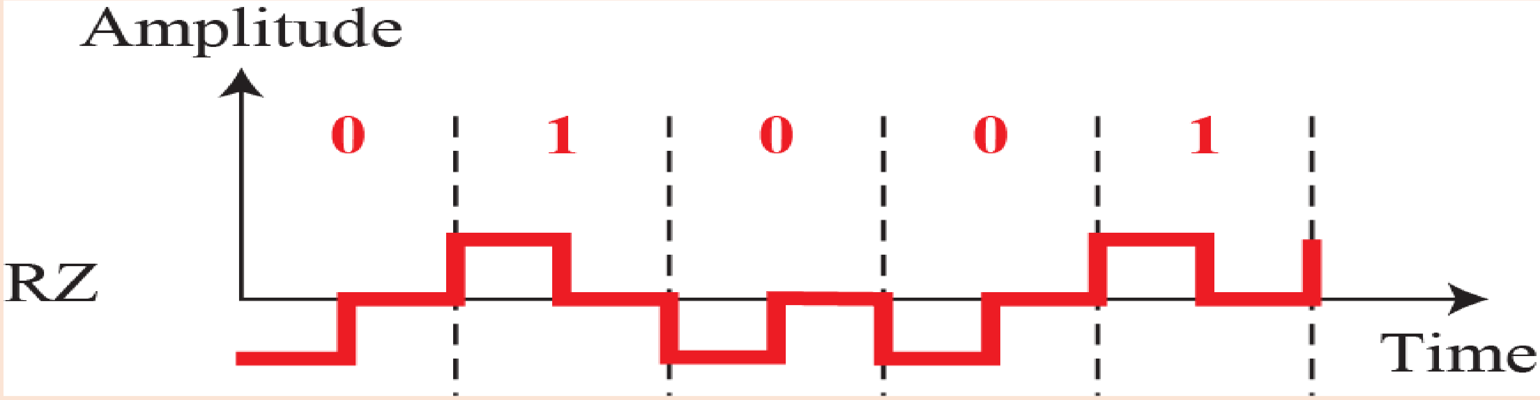
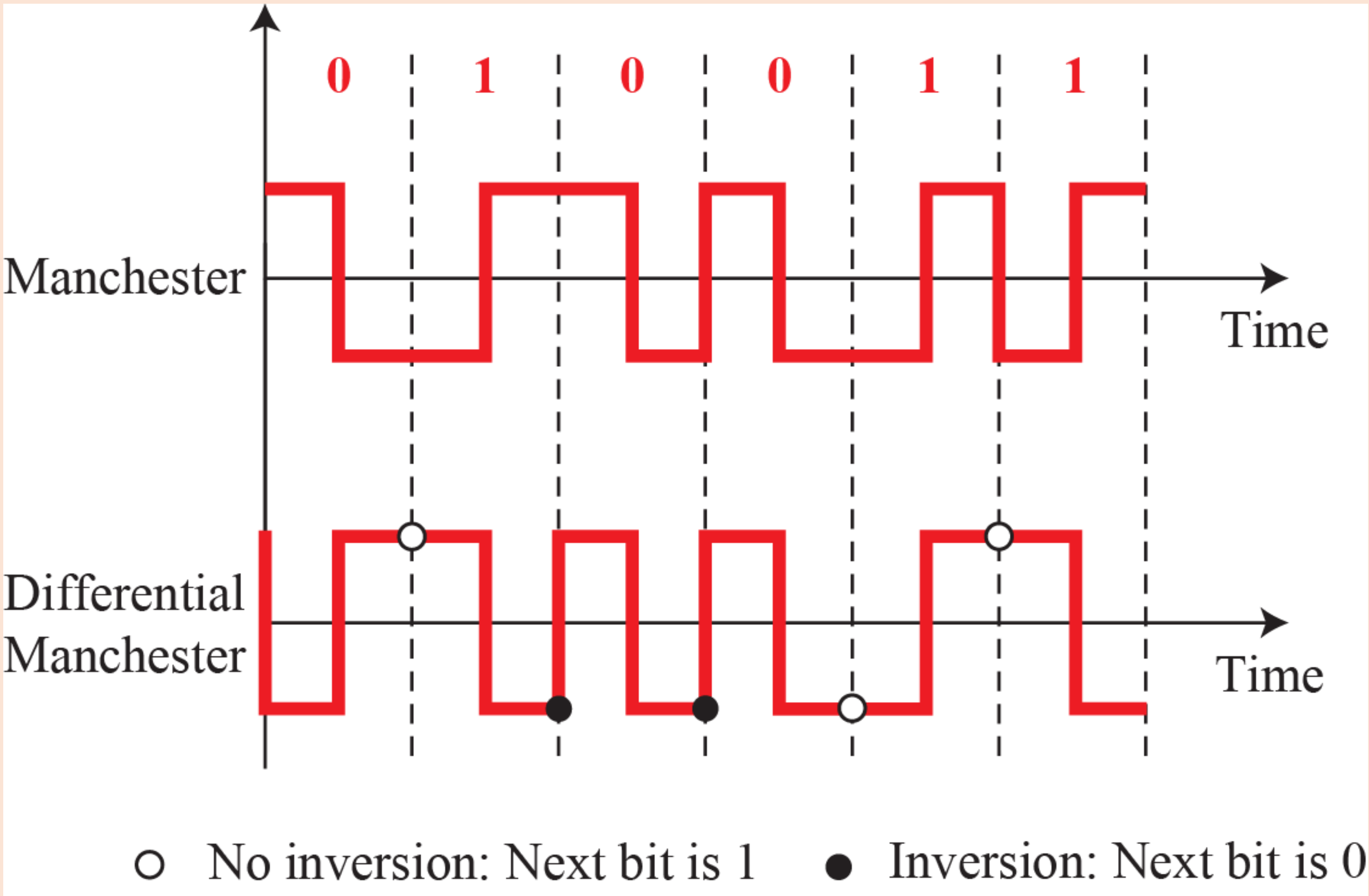


Topic # 59:

Line Coding Schemes

- **We can roughly divide line coding schemes into five broad categories**
- **Polar BiPhase:**

Biphase encoding: It has following characteristics: Modulation rate twice that of NRZ and bandwidth correspondingly greater. ... Since there can be transition at the beginning as well as in the middle of the bit interval the clock operates at twice the data transfer rate.



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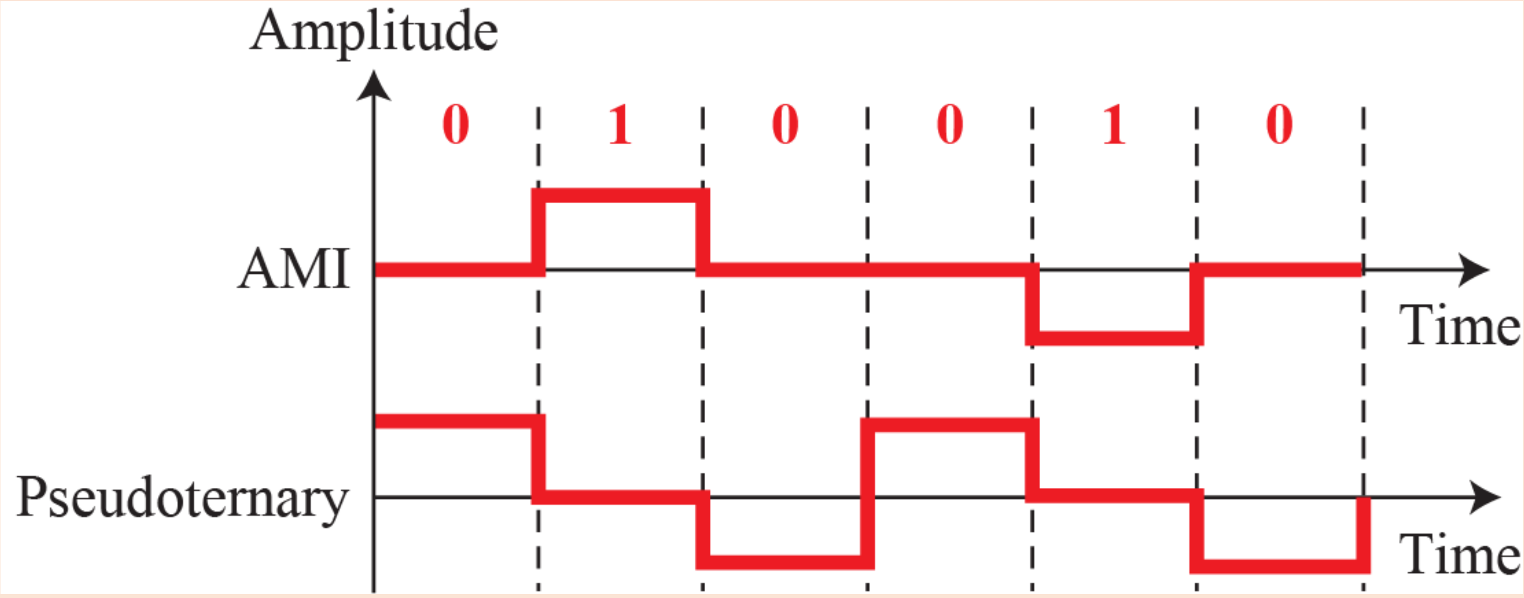
Topic # 60

Bipolar schemes: AMI & Pseudoternary

Alternate Mark Inversion (**AMI**) – A neutral zero voltage represents binary 0. ... **Pseudoternary** – Bit 1 is encoded as a zero voltage and the bit 0 is encoded as alternating positive and negative voltages i.e., opposite of **AMI scheme**. Example: Data = 010010. The **bipolar scheme** is an alternative to NRZ.



Multilevel: 2B1Q:

Multilevel: 2B1Q scheme 10.2.5. Multiline Transmission NRZ-I and differential Manchester are classified as differential encoding but use two transition rules to encode binary data (no inversion, inversion). If we have a signal with
2 Binary 1 Quinary

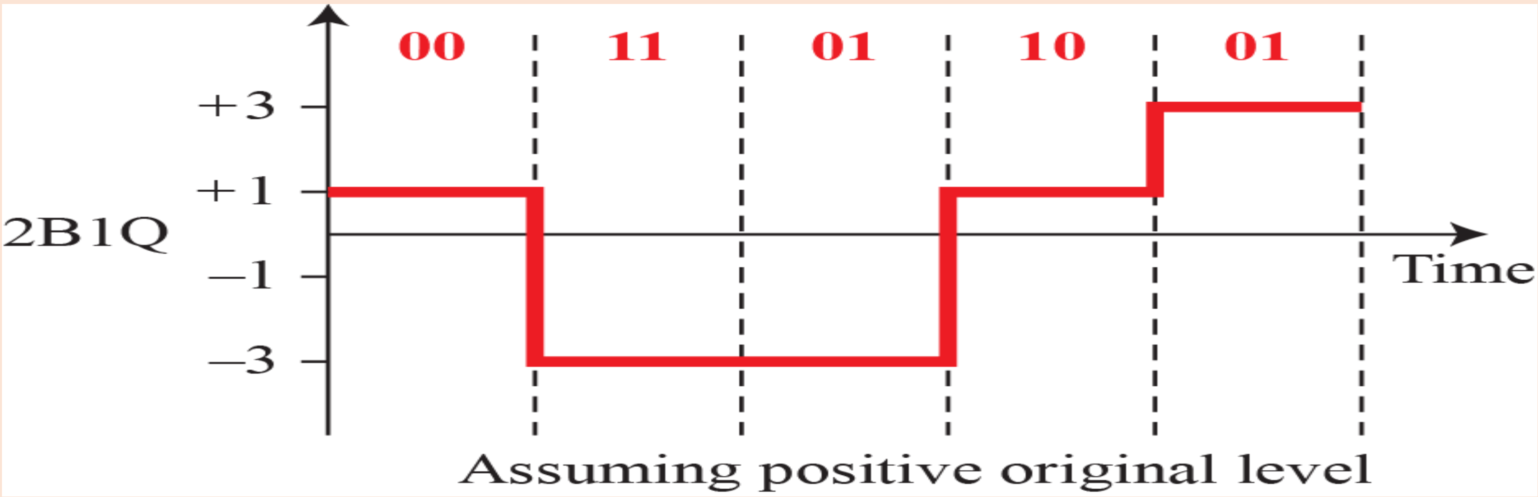


Table 4.1: Summary of line coding schemes

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Category	Scheme	Bandwidth (average)	Characteristics
Unipolar	NRZ	$B = N/2$	Costly, no self-synchronization if long 0s or 1s, DC
Polar	NRZ-L	$B = N/2$	No self-synchronization if long 0s or 1s, DC
	NRZ-I	$B = N/2$	No self-synchronization for long 0s, DC
	Biphase	$B = N$	Self-synchronization, no DC, high bandwidth
Bipolar	AMI	$B = N/2$	No self-synchronization for long 0s, DC
Multilevel	2B1Q	$B = N/4$	No self-synchronization for long same double bits
	8B6T	$B = 3N/4$	Self-synchronization, no DC
	4D-PAM5	$B = N/8$	Self-synchronization, no DC
Multitransition	MLT-3	$B = N/3$	No self-synchronization for long 0s

Topic # 61

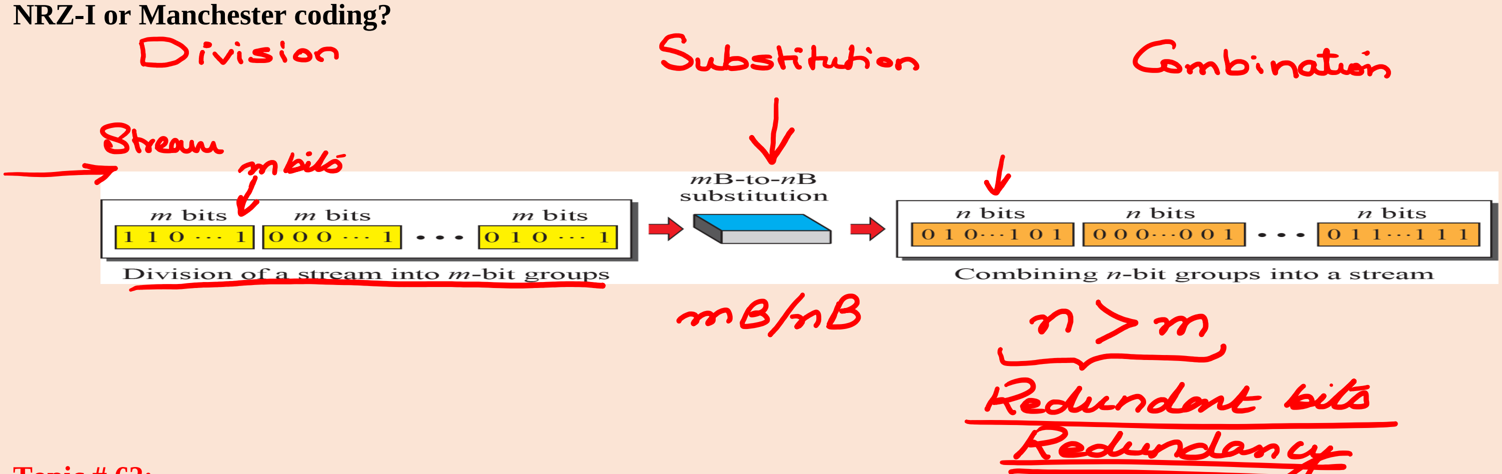
Block Coding

Block coding refers to the technique of adding extra bits to a digital word in order to improve the reliability of **transmission**. The word consists of the message bits (often called information, or **data**) plus **code** bits. ... A **block code** adds bits to existing message bits, or **blocks**, independently of adjacent **blocks** 1

- **Block coding changes a block of 'm' bits into a block of 'n' bits (n>m)**
- **mB/nB encoding technique**
- **We need Redundancy to ensure Synchronization**
- **Block coding gives us redundancy and improves line coding performance**

Example:

We need to send data at a 1-Mbps rate. What is the minimum required bandwidth, using a combination of 4B/5B and NRZ-I or Manchester coding?

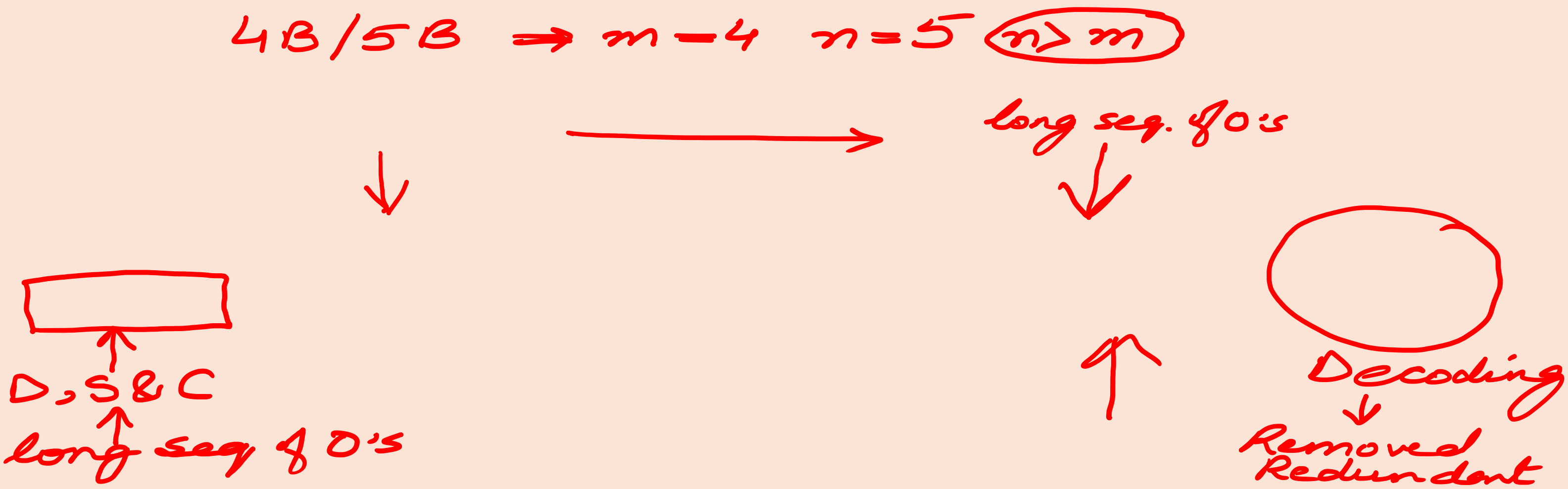


Topic # 62:

Block Coding

- **Block coding changes a block of ‘m’ bits into a block of ‘n’ bits (n>m)**
- **mB/nB encoding technique**
- **We need Redundancy to ensure Synchronization**
- **Block coding gives us redundancy and improves line coding performance**

Example:



- **Block coding changes a block of ‘m’ bits into a block of ‘n’ bits (n>m)**
- **mB/nB encoding technique**
- **We need Redundancy to ensure Synchronization**
- **Block coding gives us redundancy and improves line coding performance**

$2^4 = 16$ $2^5 = 32$ groups

Data Sequence	*Encoded Sequence*	*Control Sequence*	*Encoded Sequence*
0000	11110	Q (Quiet)	00000
0001	01001	I (Idle)	11111
0010	10100	H (Halt)	00100
0011	10101	J (Start delimiter)	11000
0100	01010	K (Start delimiter)	10001
0101	01011	T (End delimiter)	01101
0110	01110	S (Set)	11001
0111	01111	R (Reset)	00111
1000	10010		
1001	10011		
1010	10110		
1011	10111		
1100	11010		
1101	11011		
1110	11100		
1111	11101		

Topic # 63:

- **Block coding changes a block of 'm' bits into a block of 'n' bits (n>m)**
- **mB/nB encoding technique**
- **We need Redundancy to ensure Synchronization**
- **Block coding gives us redundancy and improves line coding performance**

Example

- **We need to send data at a 1-Mbps rate. What is the minimum required bandwidth, using a combination of 4B/5B and NRZ-I or Manchester coding?**
- What is the minimum required bandwidth, using a combination of **4B/5B and NRZ-I or Manchester coding**?
  First **4B/5B** block **coding** increases the bit rate to 1.25 Mbps. The minimum bandwidth using **NRZ-I** is N/2 or 625 kHz. The **Manchester** scheme needs a minimum bandwidth of 1 MHz.

Data Rate = 1 Mbps

4B/5B Block Coding

↳ 4 bit group ⇔ 5 bit group

Data Rate = 1.25 Mbps

Signal Rate ↑

$NRZ\text{-}I = \frac{N}{2} = \frac{1.25\text{ Mbps}}{2}$

= 625 kHz

Manchester ⇒ 1 MHz

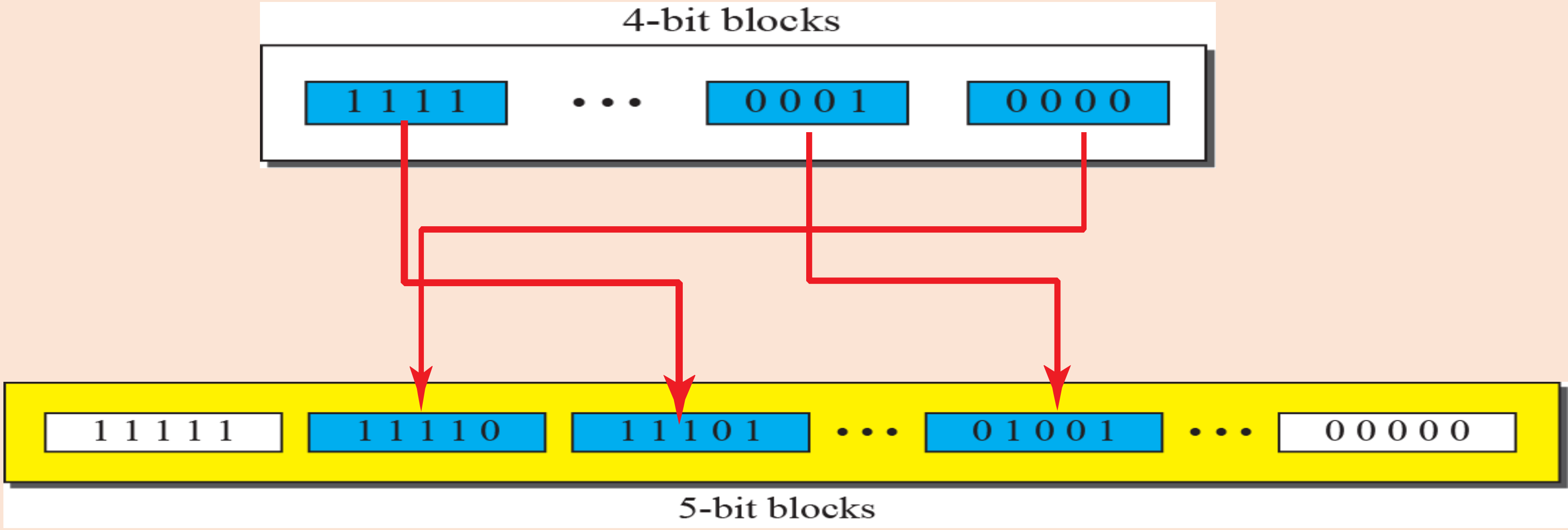
Synchronisation ⇒ ✓

Signal Rate ↑ ⇒ BW ↑ ✓

$BW_{NRZ\text{-}I} < BW_{Manchester}$

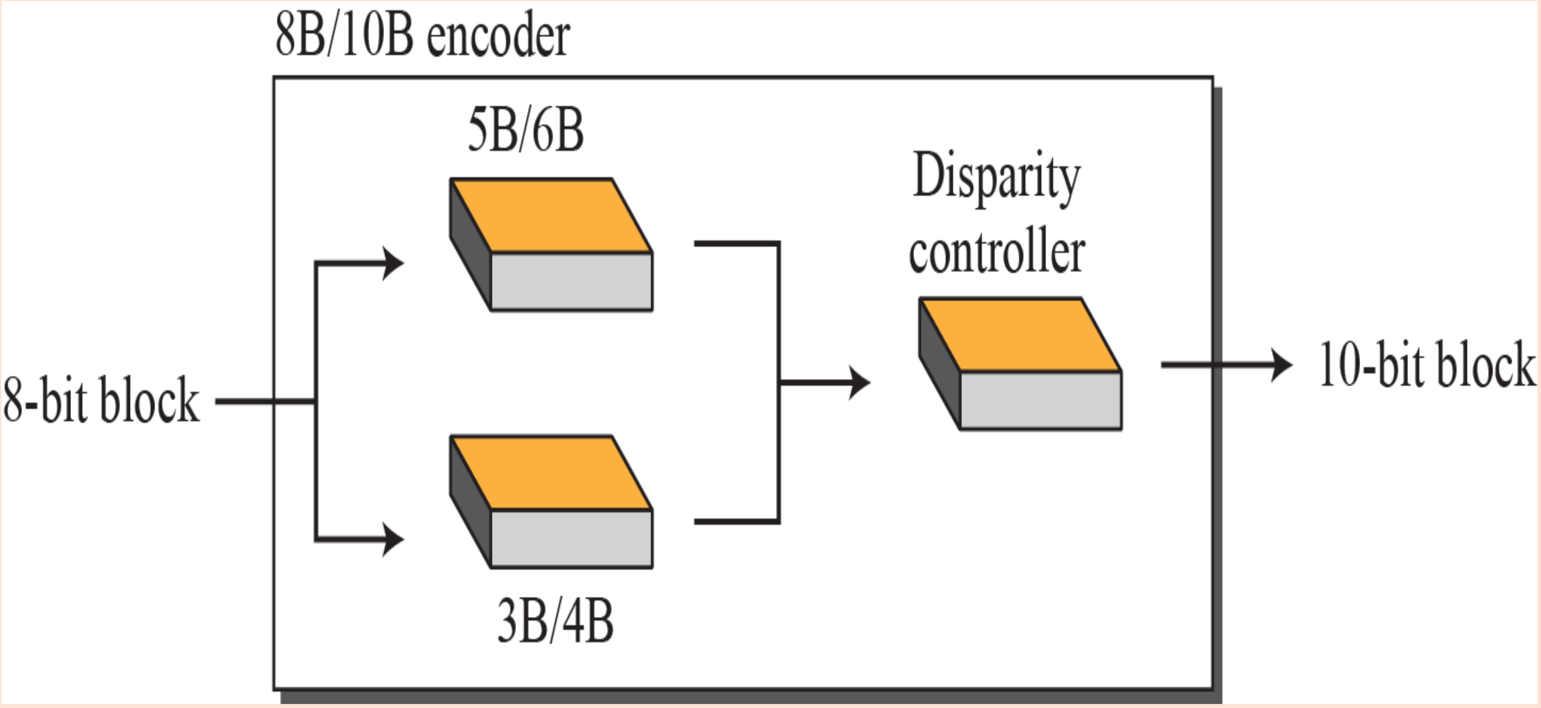
DC - component X

Example:



8B/10B block encoding:

8b/10b coding is DC-free, meaning that the long-term ratio of ones and zeros transmitted is exactly 50%. To achieve this, the difference between the number of ones transmitted and the number of zeros transmitted is always limited to ±2, and at the end of each symbol, it is either +1 or −1.



Topic # 64

Scrambling

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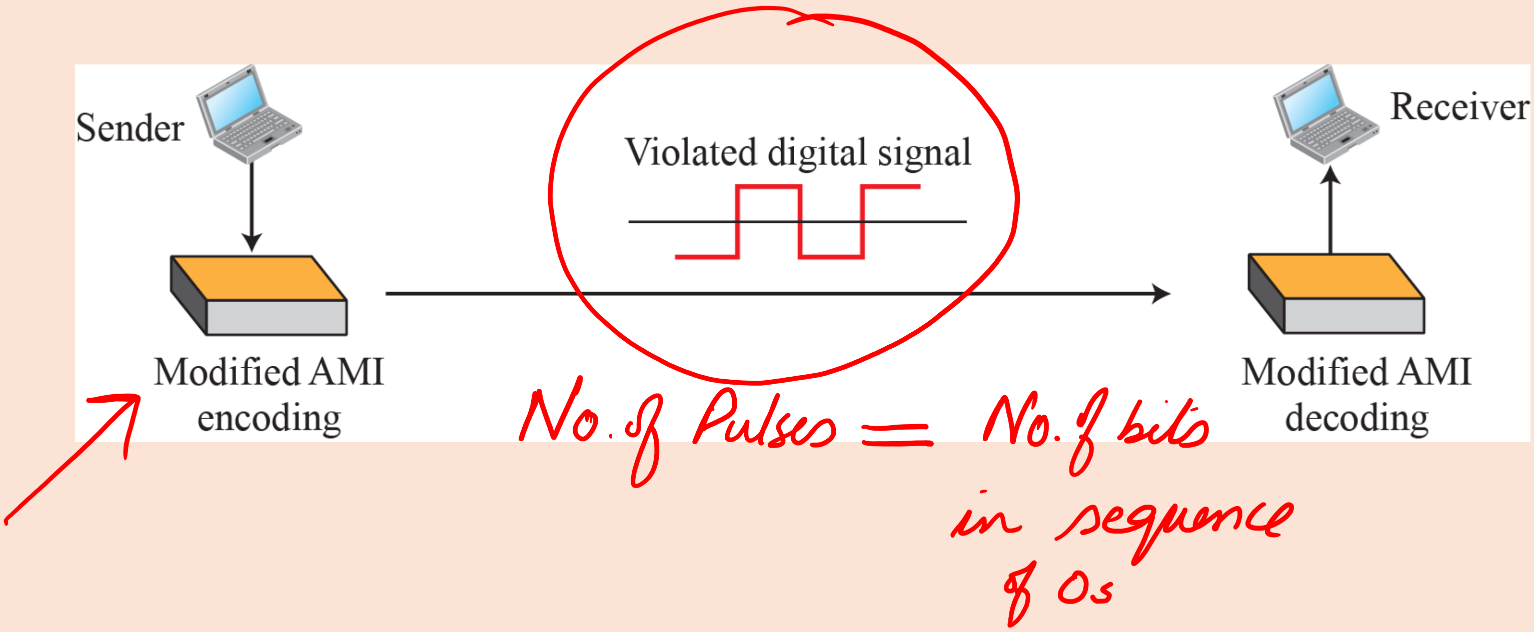
In telecommunications and recording, a scrambler (also referred to as a randomizer) is a device that manipulates a **data** stream before transmitting. The manipulations are reversed by a descrambler at the receiving side. **Scrambling** is widely used in satellite, radio relay **communications** and PSTN modems.

- **Biphase schemes suitable for LAN but not for Long Distance**
- **Block Coding + NRZ-I solves synch issue but has DC component**
- **Bipolar AMI has a narrow bandwidth (no DC Component) but synch issue (long series of 0s)**
- **The system needs to insert the required pulses based on the defined scrambling rules**

AMI used with scrambling:

This **means** that the signal cannot be corrupted, it is stronger than error detection. ... Alternate Mark Inversion (**AMI**) **used with scrambling**



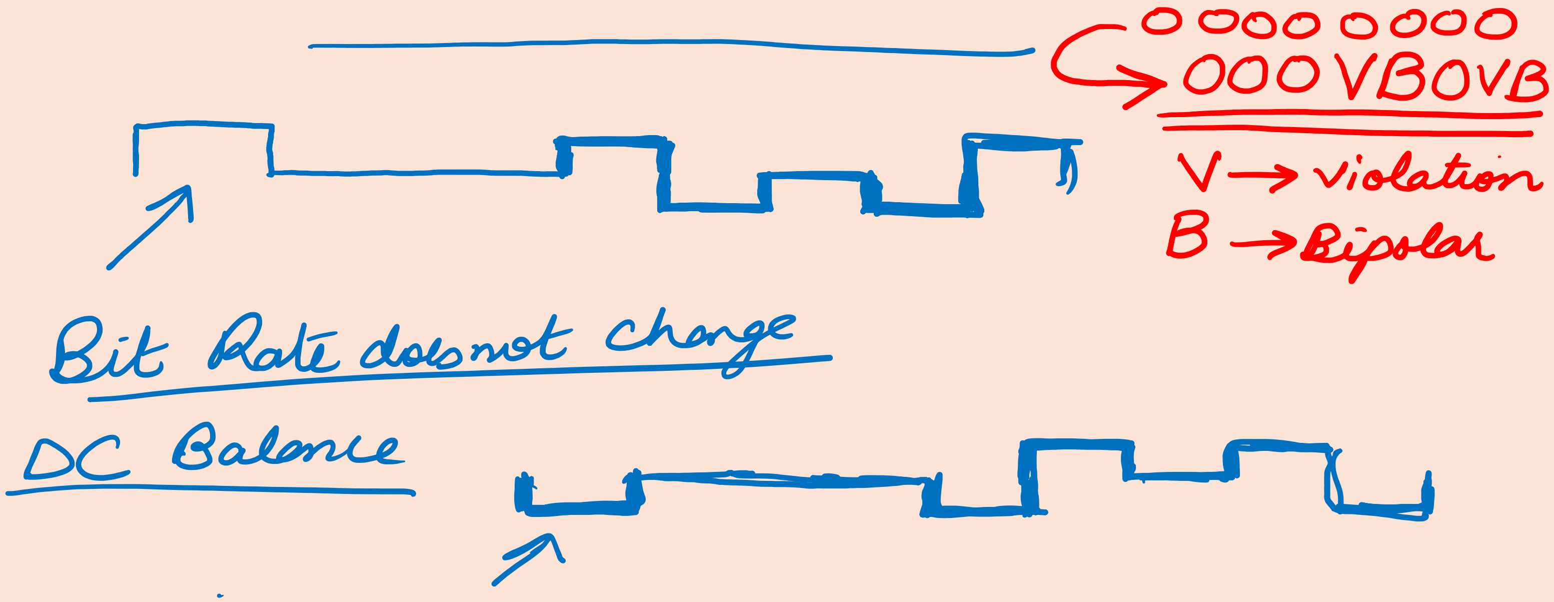
Topic # 65:

Types of Scrambling Techniques

Scrambling is a digital encoding **technique** that is used in modern data communication schemes and can principally provide aid in retrieving information from received data enhancing synchronization between the transmitter and the receiver.

- **Two common scrambling techniques are B8ZS and HDB3**
- **Bipolar with 8-Zero Substitution (B8ZS)**
- **High-density bipolar 3-zero (HDB3)**

Two cases of B8ZS scrambling technique:



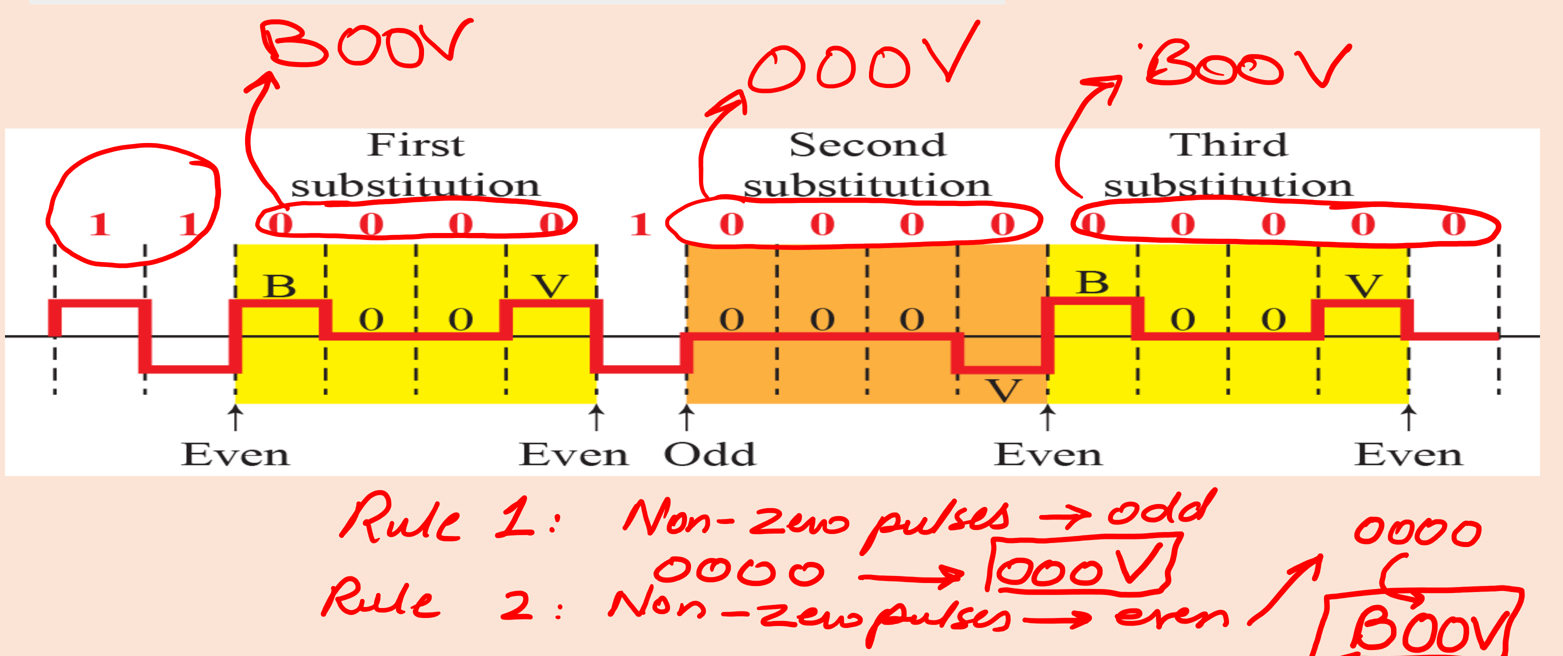
Topic # 66

Different situations in HDB3 scrambling technique

High-Density Bipolar-3 Zeros × Based on bipolar-AMI × String of four zeros is replaced with sequences containing one or two pulses. B. HDB3 Number of Bipolar Pulses since last substitution Polarity of Preceding Pulse Odd Even - 000- +00+ + 000+ -00-

HDB3 substitutes four consecutive zeros with 000V or B00V depending on the number of nonzero pulses after the last substitution. × If no of non-zero pulses are even the substitution is B00V to make total non-zero pulse even. × If no of non-zero pulses are odd the substitution is 000V to make total non-zero pulses even. × Example 1 of HDB3 encoding the pattern of bits " 1 0 0 0 0 1 1 0 “encoded in HDB3 is " + 0 0 0 V - + 0 " (the corresponding encoding using AMI is " + 0 0 0 0 - + "). Different situations in HDB3 scrambling technique

Example 2 of HDB3 encoding the pattern of bits " 1 0 1 0 0 0 0 0 1 1 0 0 0 0 1 1 0 0 0 0 0 0 " encoded in HDB3 is " + 0 - 0 0 0 V 0 + - B 0 0 V - + B 0 0 V 0 0 " which is: " + 0 - 0 0 0 - 0 + - + 0 0 + - + - 0 0 - 0 0 "



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Topic # 67

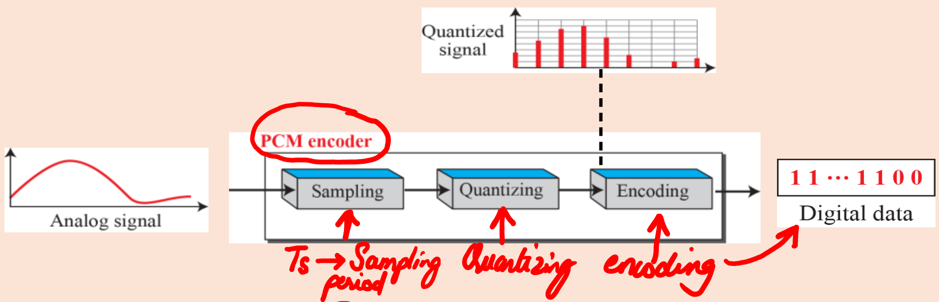
Analog-to-digital Conversion

1. In electronics, an **analog**-to-**digital converter** (ADC, A/D, or A-to-D) is a system that converts an **analog** signal, such as a sound picked up by a microphone or light entering a **digital** camera, into a **digital** signal. ...
2. There are several ADC architectures.

- **Analog Data to Digital Data**
- **Process of Digitization**
- **Two techniques:**
  - ✓ **Pulse Code Modulation (PCM)**
  - ✓ **Delta Modulation (DM)**

Pulse Code Modulation (PCM):

Pulse-code modulation (**PCM**) is used to digitally represent sampled analog signals. It is the standard form of digital audio in computers, CDs, digital telephony and other digital audio applications.

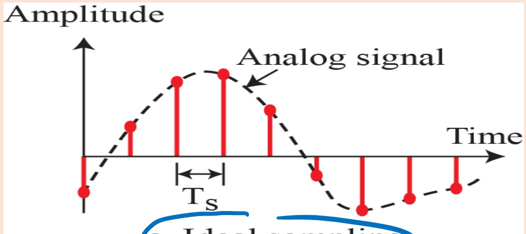


- **Sampling**
- **Quantization**
- **Encoding**

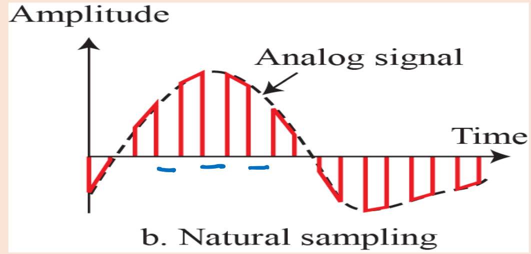
Sampling:

In signal processing, **sampling** is the reduction of a continuous-time signal to a discrete-time ... Audio **sampling**[edit]. Digital audio uses **pulse-code modulation** (**PCM**) and digital signals for sound reproduction. This includes analog-to-digital.

PCM (**Pulse Code Modulation**) is a standardized method used in the telephone network (POTS) to change an analog signal to a digital one. The analog signal is first **sampled** at a 8-kHz **sampling** rate. Then each **sample** is quantized into 1 of 256 levels and then encoded into digital eight-bit words.



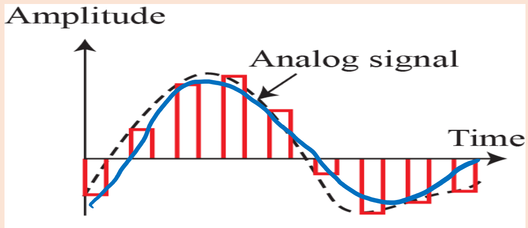
a. Ideal sampling



b. Natural sampling

Sampling
↳ Pulse Amplitude Modulation

T_S → Sampled interval or Sample period

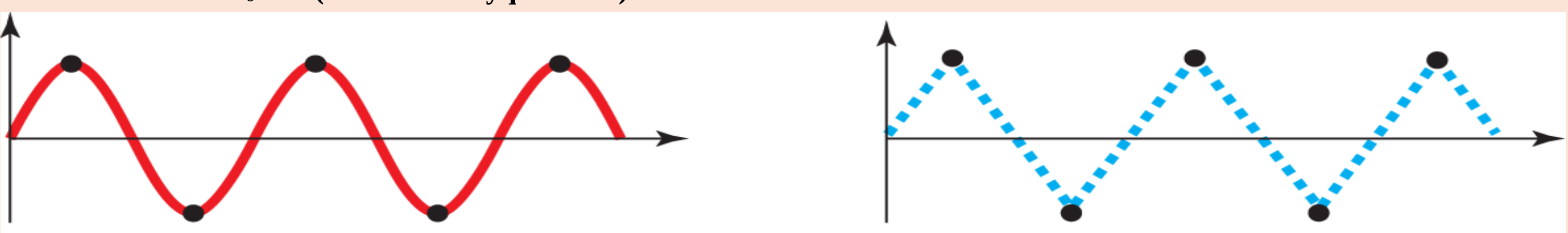


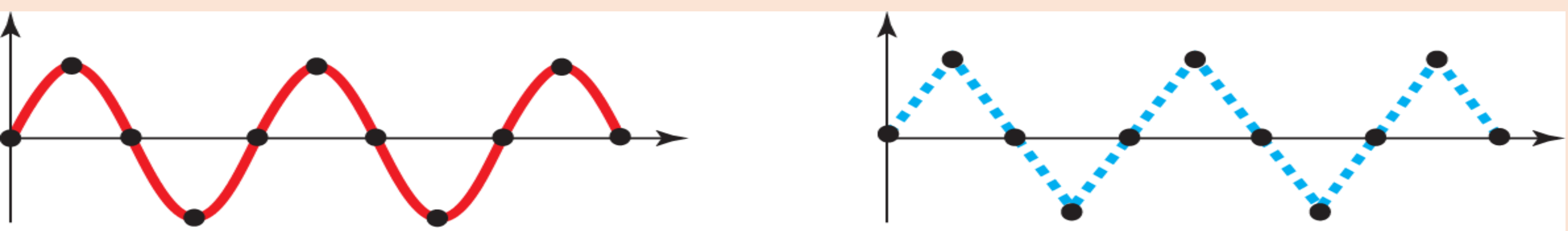
c. Flat-top sampling

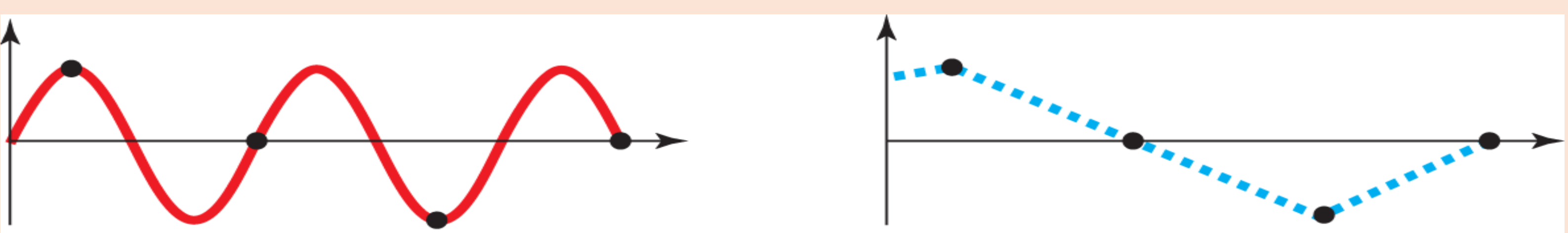
Sample and Hold

Nyquist Sampling Rate

- **Nyquist → fs = 2fh**
- **Sampling sine wave at three sampling rates:**
  - ✓ **f_s = 4f (2 times the Nyquist rate)**


a. Nyquist rate sampling: $f_s = 2\,f$


b. Oversampling: $f_s = 4\,f$

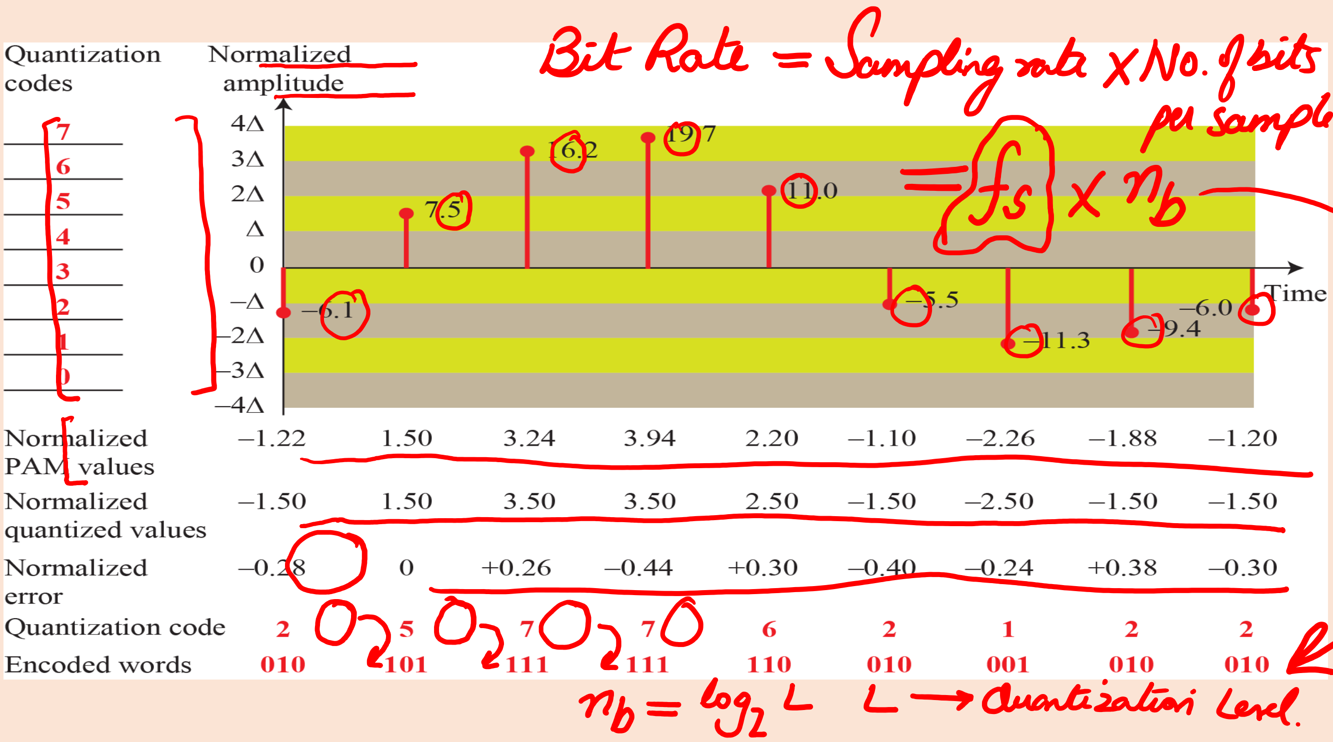

c. Undersampling: $f_s = f$

Topic # 69:

Quantization & encoding of a sampled signal:

Quantization is the process of changing a continuous-amplitude signal into on with discrete amplitudes. To communicate sampled values, we send a sequence of bits that represents the **quantized** value. For 16 **quantization** levels, 4 bits are required. **PCM** can use a binary representation of value.

- **Sampling → Series of pulses with amplitude values between min and max signal amplitude**
- **Infinite set with non-integral values not suitable for encoding**
- **We quantize the sampling output into certain levels based on range of amplitudes and how much accuracy is needed**
- **PCM encoding**. The input to the **PCM ENCODER** module is an analog message. This must be constrained to a defined bandwidth and amplitude range. The maximum allowable message bandwidth will depend upon the sampling rate to be used.



Topic # 70

Decoding

Just for explanation:

(The voltage at Vout of the decoder is identical with s(t) above. The decoder itself has introduced no distortion of the received signal. But s(t) is already an inexact version of the sample-and-hold operation at the encoder. This will give rise to quantization distortion as well as the sampling distortion already mentioned. You should read about these phenomena in a Text book.

extracts a frame synchronization signal FS from the data itself (from the embedded alternate ones and zeros in the LSB position), or uses an FS signal stolen from the transmitter (see above).

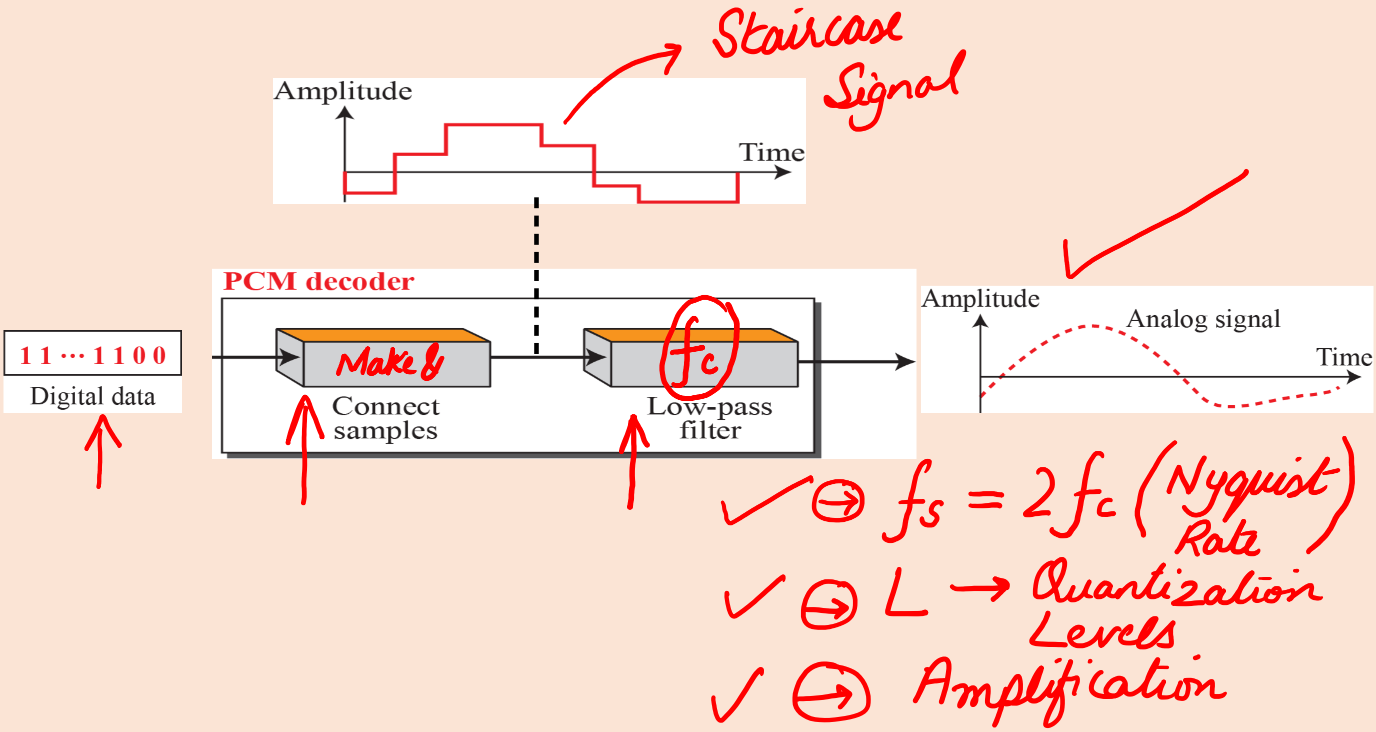
2. extracts the binary number, which is the coded (and quantized) amplitude of the sample from which it was derived, from the frame.

3. identifies the quantization level which this number represents.

4. generates a voltage proportional to this amplitude level.

5. presents this voltage to the output Vout. The voltage appears at Vout for the duration of the frame under examination.

6. message reconstruction can be achieved, albeit with some distortion, by lowpass filtering. A built-in reconstruction filter is provided in the module.)



Topic # 71:

Analog-to-digital Conversion

- **Analog Data to Digital Data**
- **Process of Digitization**
- **Two techniques:**
    - ✓ **Pulse Code Modulation (PCM)**
    - ✓ **Delta Modulation (DM)**

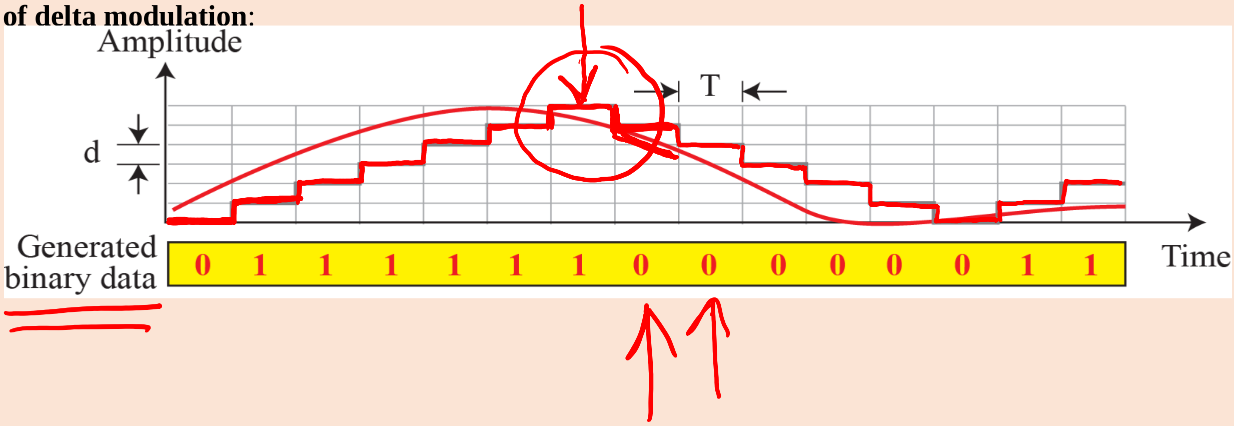
Delta Modulation (DM)

A **delta modulation** (**DM** or **Δ-modulation**) is an analog-to-digital and digital-to-analog signal conversion technique used for transmission of voice information where quality is not of primary importance. The analog signal is approximated with a series of segments.

- **PCM is a very complex technique**
- **Delta modulation is a simpler technique**

- **PCM finds the value of the signal amplitude for each sample; DM finds the change from the previous sample**
- **No code words**

The process of delta modulation:

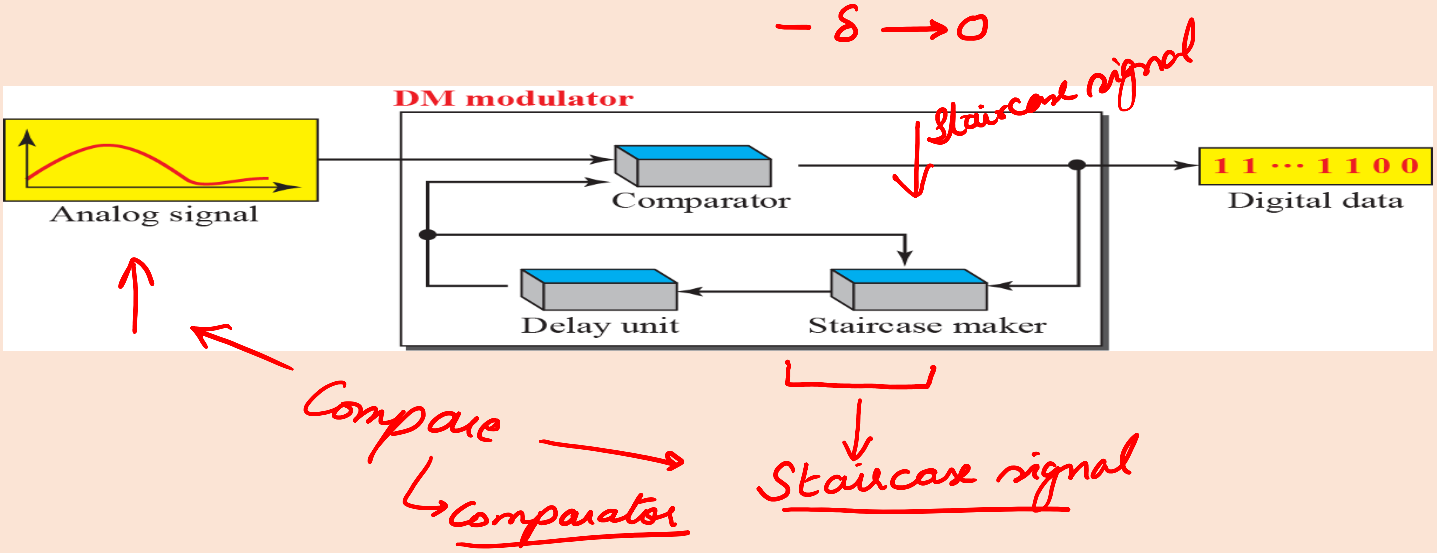


Topic # 72:

Delta Modulation Components

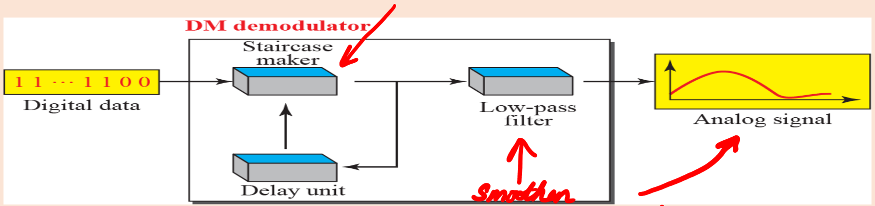
- **Delta modulation is a simpler technique**
- **DM finds the change from the previous sample**
- **No code words**

Delta → δ   +δ → 1
−δ → 0



Delta Modulation Components

Adaptive DM → δ is not fixed → Performance ↑



Smoothen staircase signal

Quantization Error (QE)

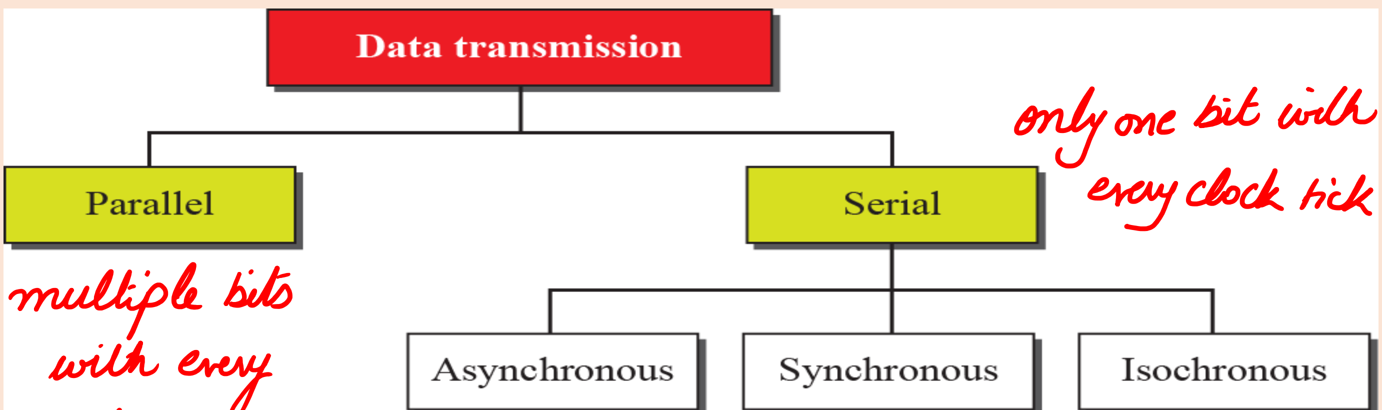
$QE_{DM} < QE_{PCM}$.

Topic # 73:

Transmission Modes

Transmission mode refers to the mechanism of transferring of data between two devices connected over a network. It is also called Communication **Mode**. These **modes** direct the direction of flow of information.

- **Transmission of Data:**
  - ✓ **Wiring**
    - ➢ **Data Stream**
  - ✓ **Do we send 1 bit at a time; or do we group bits into larger groups and, if so, how?**
- **Parallel or Serial Transmission**



Parallel Transmission

When data is sent using **parallel** data **transmission**, multiple data bits are **transmitted** over multiple channels at the same time. This means that data can be sent much faster than using serial **transmission** methods.

- **Binary data (1s ad 0s) organized in groups of ‘n’ bits**
- **We send ‘n’ bits at a time instead of just one**
- **‘n’ wires required to send ‘n’ bits at one time**

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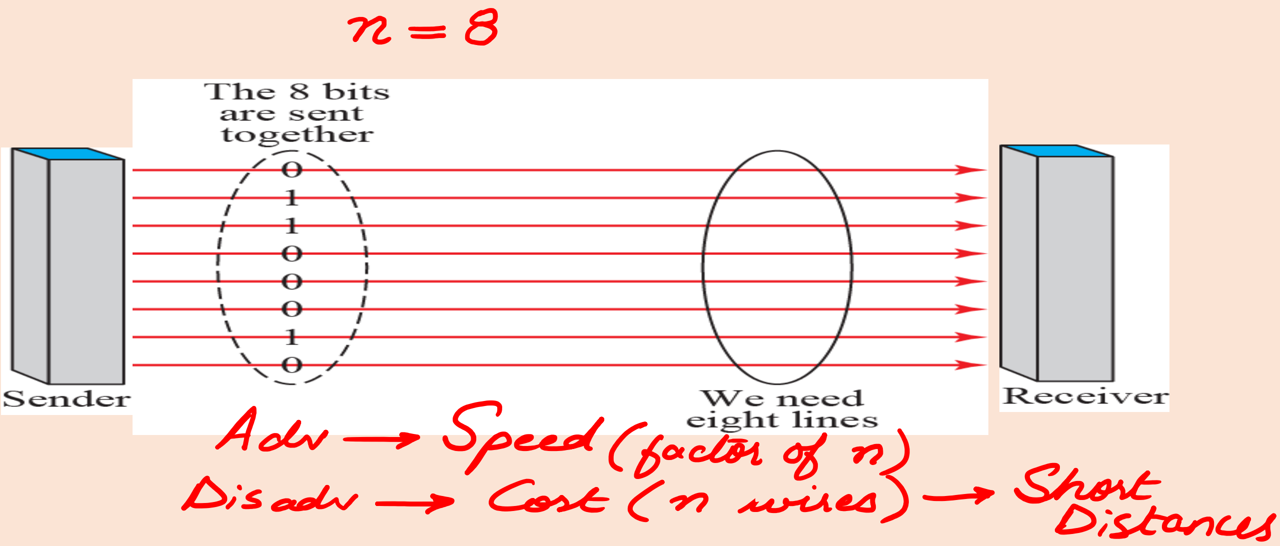


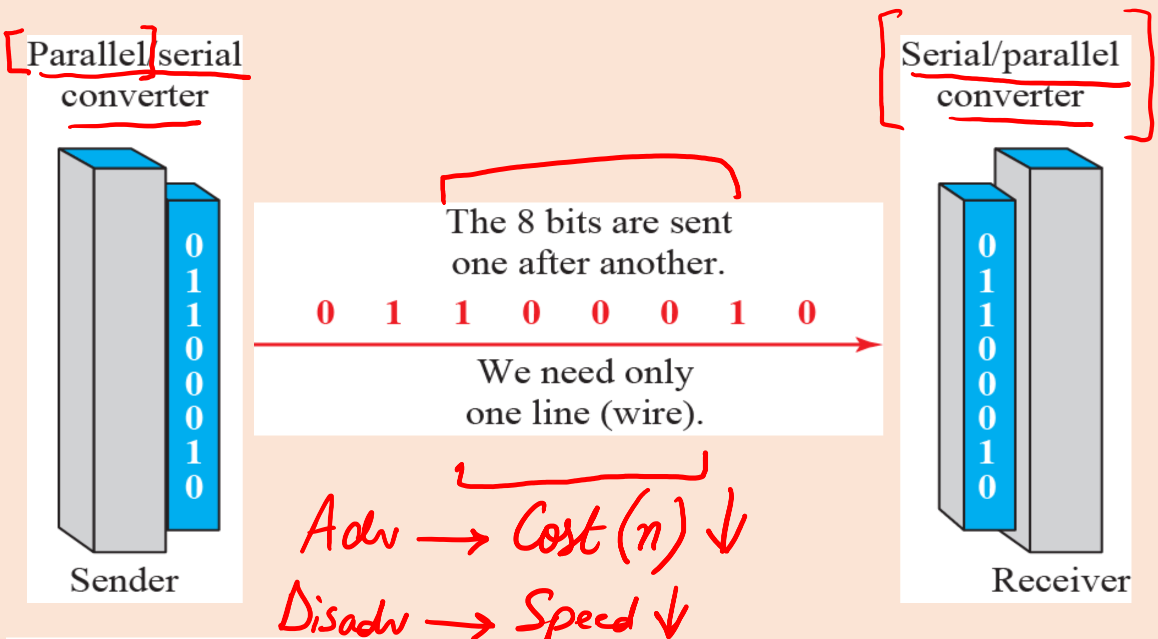
Topic # 74

Serial Transmission

When data is sent or received using **serial** data **transmission**, the data bits are organized in a specific order, since they can only be sent one after another. The order of the data bits is important as it dictates how the **transmission** is organized when it is received.

- **In serial transmission one bit follows another**
- **Only one communication channel rather than 'n' to transmit data**

Serial Transmission



Asynchronous Transmission

Asynchronous Transmission is a mode of serial **transmission** for modems and other telecommunication devices in which the data is **transmitted** as a continuous stream of bytes separated by start and stop bits.

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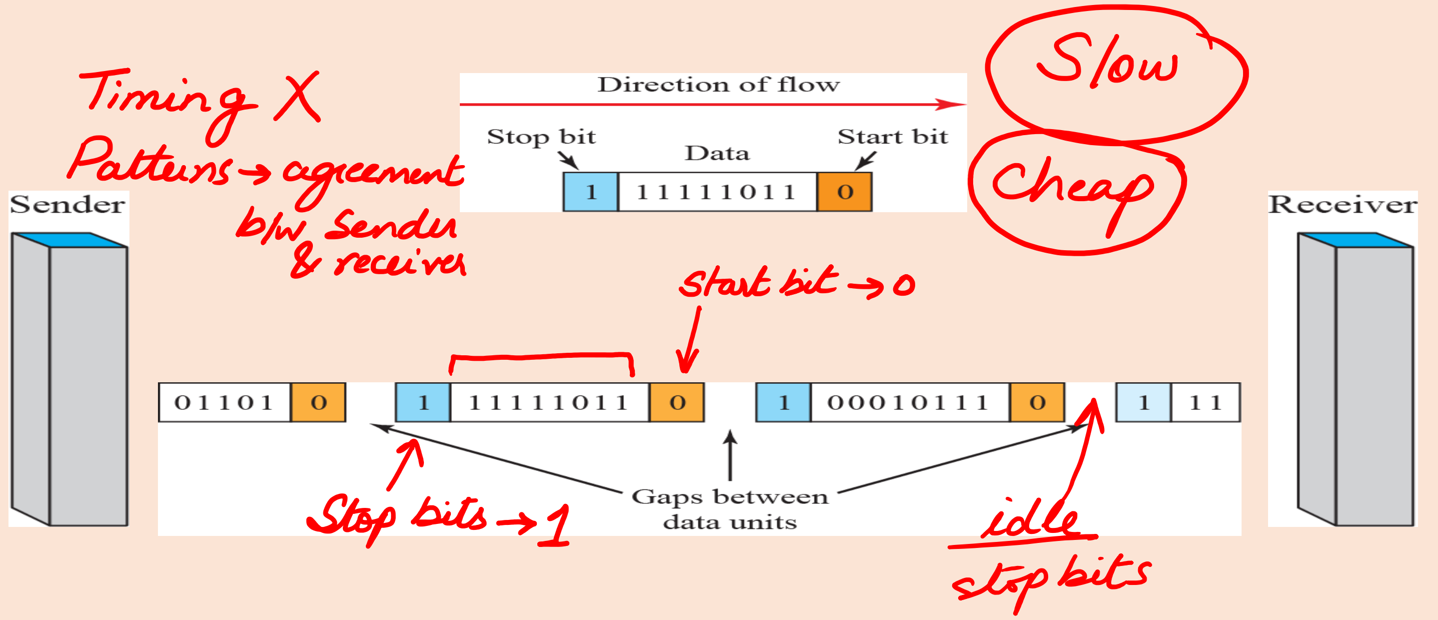
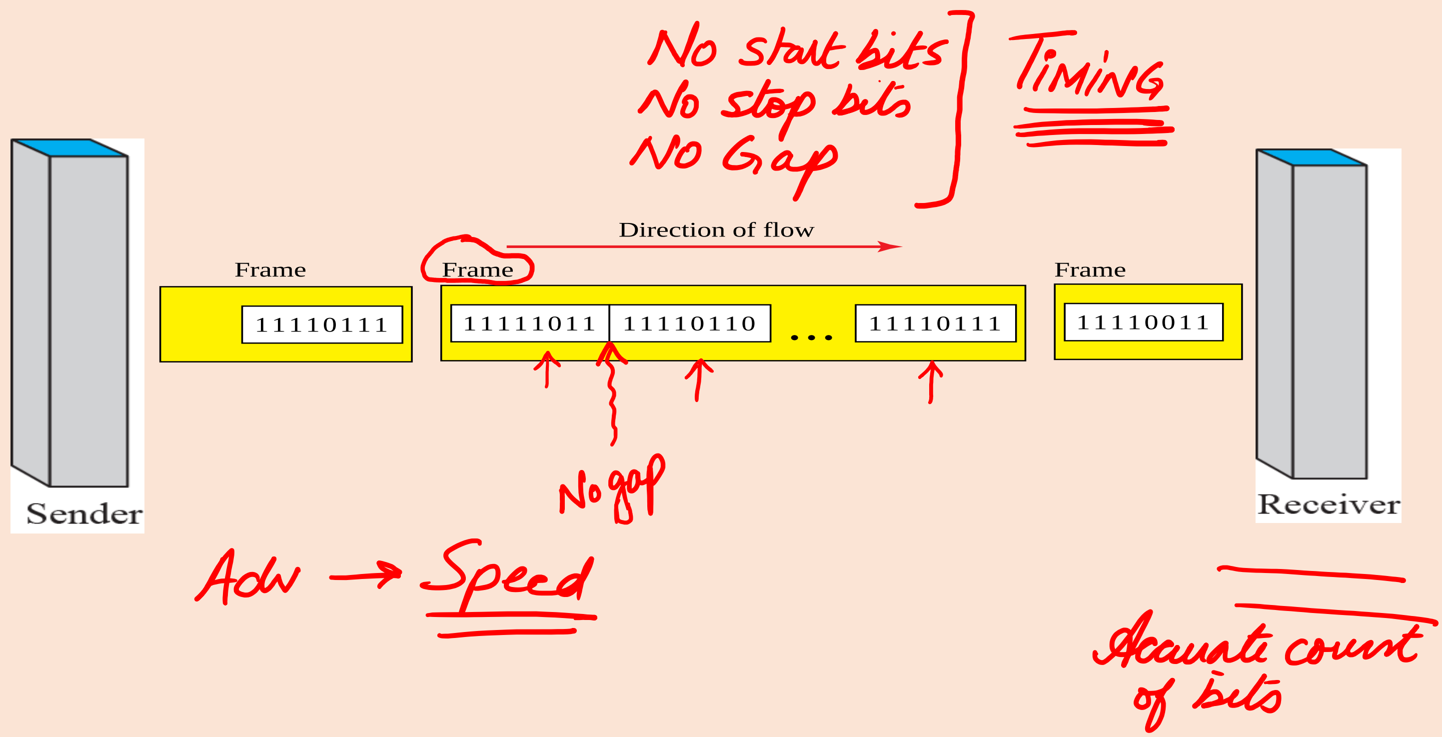


Topic # 75

Serial Transmission

- **In serial transmission one bit follows another**
- **Only one communication channel rather than 'n' to transmit data**



Isochronous Transmission

The **ISOCHRONOUS** (ISOC) format for data **transmission** is a procedure or protocol in which each information CHARACTER or BYTE is individually synchronized or FRAMED by the use of Start and Stop Elements, also referred to as START BITS and STOP BITS.

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- **Real time Audio and Video**
- **Synchronization between characters is not enough**
- **Entire stream should be synchronized**
- **Isochronous guarantees fixed rate data**

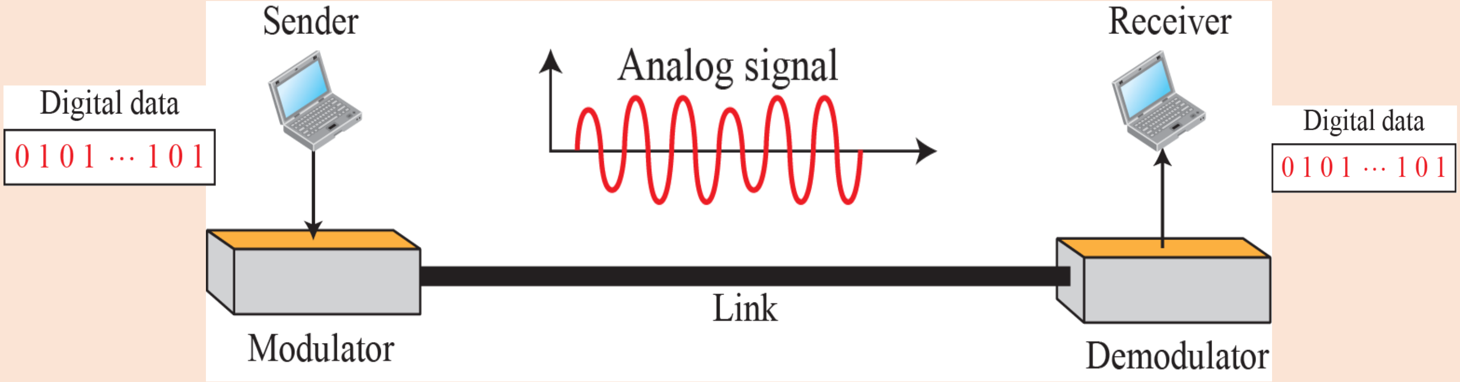
Topic # 76

Digital-to-Analog Conversion

- **Process of changing one of the characteristics of analog signal based on the information in digital data**
- **A sine wave is defined by 3 characteristics:**
  - ✓ **Amplitude**
  - ✓ **Frequency**
  - ✓ **Phase**
  - ✓ **By changing one of these characteristics, we can use it to represent a digital signal**

Digital-to-Analog Conversion

Digital-to-**analog conversion** (DAC), Process by which **digital** signals (which have a binary state) are **converted** to **analog** signals (which theoretically have an infinite number of states). For example, a modem converts computer **digital** data to **analog** audio-frequency signals that can be transmitted over telephone lines.



Types of Digital to Analog Conversion

There are mainly two **types** of methods that are commonly used for **digital to analog conversions**. The Weighted Resistor method, the R-2R Ladder Network Method along with The Serial **Digital to Analog Converter**, BCD **Digital to Analog Converter** and the Bipolar **Digital to Analog Converter**.

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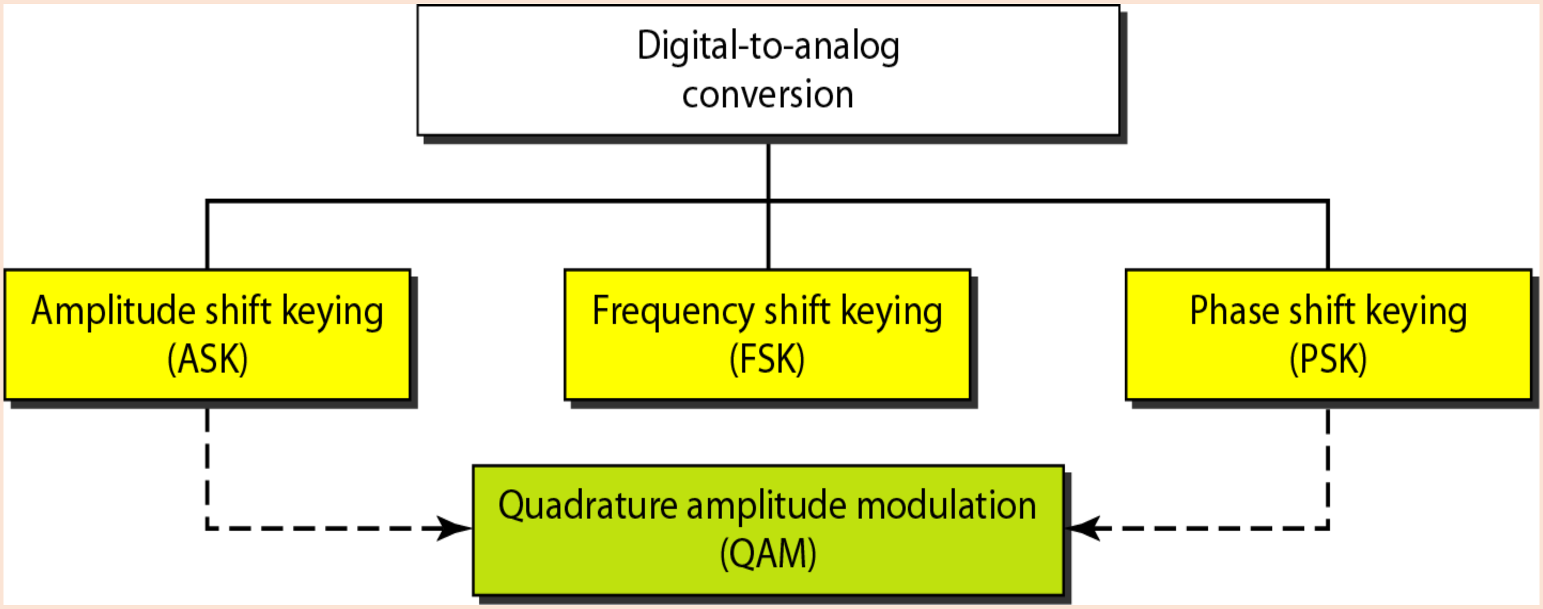


Topic # 77

Aspects of Digital to Analog Conversion

- **Before we discuss specific methods of digital-to-analog modulation, two basic issues must be reviewed:**
    - ✓ **Bit and Baud rates and**
    - ✓ **The Carrier Signal**

Aspects of Digital to Analog Conversion

- **In Analog Transmission of Digital Data, Baud Rate is less than or equal to the Bit Rate**
    - ✓ **Data Element vs. Signal Element**
    - ✓ **Data Rate vs. Signal Rate**
- **Bandwidth Required ∝ Signal Rate (except FSK)**
- **Carrier Signal**

Data Element → bit
Signal Element → smallest unit of signal (constant)

$S = \frac{N}{r} \Rightarrow r = \log_2 L$

Carrier Signal

Sender → high freq. signal
↳ base of information signal

Modulation (Shift Keying)

Aspects of Digital to Analog Conversion

- **Before we discuss specific methods of digital-to-analog modulation, two basic issues must be reviewed:**
  - ✓ **Bit and Baud rates and**
  - ✓ **The Carrier Signal**

Topic # 78

Aspects of Digital to Analog Conversion

- **Before we discuss specific methods of digital-to-analog modulation, two basic issues must be reviewed:**
  - ✓ **Bit and Baud rates and**
  - ✓ **The Carrier Signal**

- **Example**
- **An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate?**

$r = 4 \quad S = 1000$

$N = ?$

$S = \frac{N}{r} \Rightarrow N = S \times r$

$N = 1000 \times 4$

$= 4000 \text{ bps}$

- **Example**

An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

$N = 8000 \text{ bps}$

$S = 1000 \text{ baud}$

$L = ?$

$r = ?$

$S = \frac{N}{r} \Rightarrow r = \frac{N \text{ (bits)}}{S \text{ (bauds)}}$

→ $r = 8 \text{ bits/baud}$

$r = \log_2 L$

→ $L = 2^r = 2^8 = 256$

Topic # 79

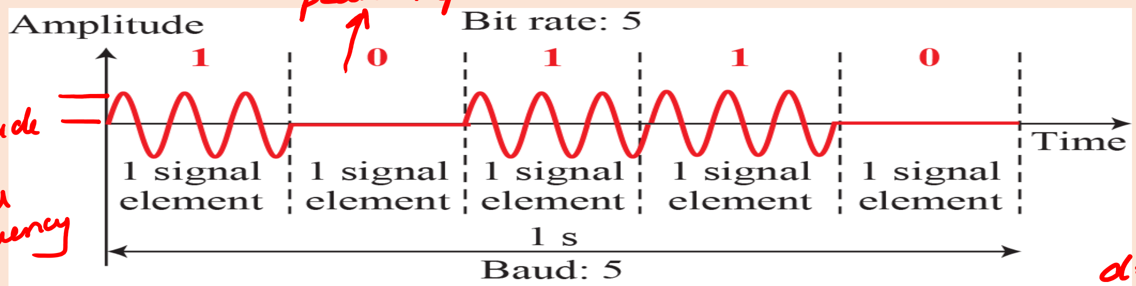
Amplitude Shift Keying (ASK)

Amplitude-shift keying is a form of amplitude modulation that represents digital data as variations in the amplitude of a carrier wave. In an ASK system, the binary symbol d-amplitude carrier wave and fixed frequency for a bit duration of T seconds.

- **The amplitude of the carrier signal is varied to create signal elements**
- **Both frequency and phase remain constant while the amplitude changes**
- **Binary ASK or On-Off Keying (OOK)**

peak amplitude is zero

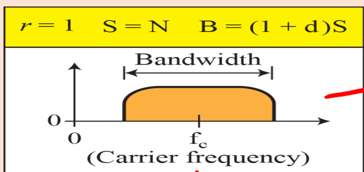
Same amplitude as carrier frequency



d=0 → min
d=1 → max

$B=(1+d)S$

d → modulation & filtering process (0 → 1)



non periodic composite signal

BW ∝ Signal Rate

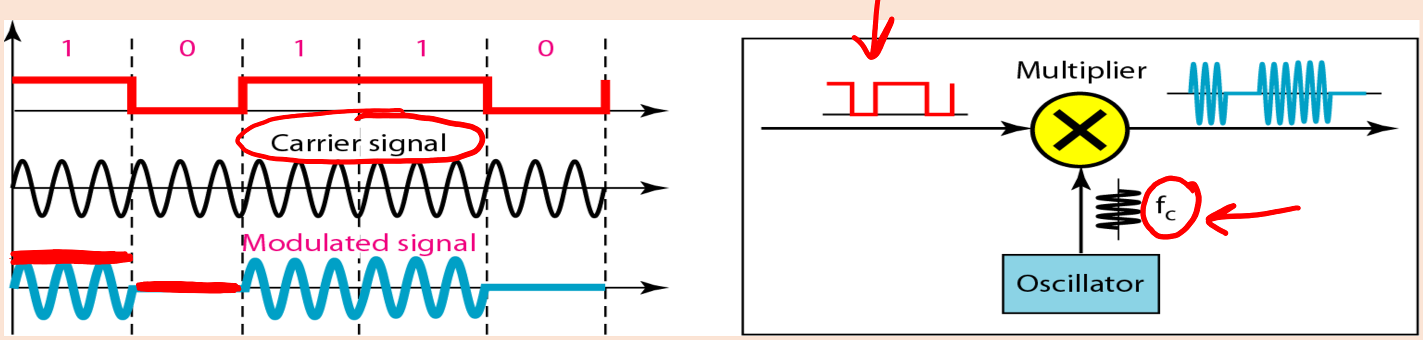
Topic # 80

Amplitude Shift Keying (ASK)

- **The amplitude of the carrier signal is varied to create signal elements**
- **Both frequency and phase remain constant while the amplitude changes**
- **Binary ASK or On-Off Keying (OOK)**

Unipolar NRZ → HV = 1
LV = 0

U NRZ



1 → maintaining amplitude of carrier

0 → zero amplitude

Example:

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate if we modulated our data by using ASK with d = 1?

$f_c = 250\,kHz$

$B = (1+d)S$

$B = (1+1)S$

$B = 2S$

$r = 1$

$B = 2\left(\frac{N}{r}\right)$

$B = 2N \quad (r=1)$

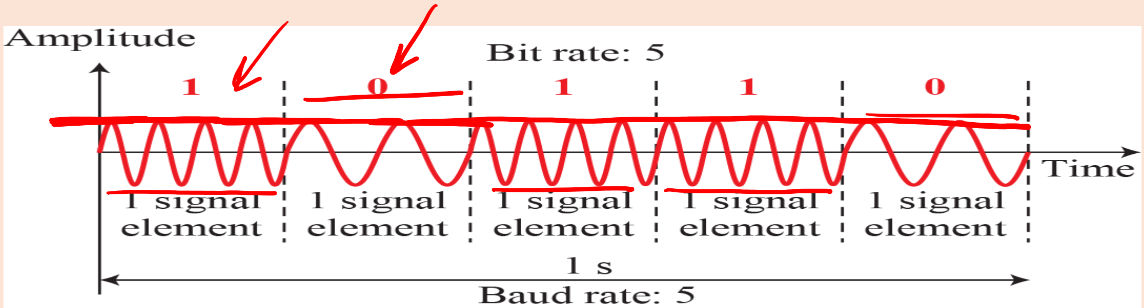
$N = \frac{B}{2} = \frac{100\,kHz}{2} = 50\,kbps$

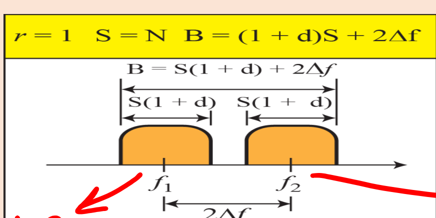
Topic # 81

Frequency Shift Keying (FSK)

Frequency-shift keying (**FSK**) is a **frequency** modulation scheme in which digital information is transmitted through discrete **frequency** changes of a carrier signal. The simplest **FSK** is binary **FSK** (BFSK). BFSK uses a pair of discrete **frequencies** to transmit binary (0s and 1s) information.

- **The frequency of the carrier signal is varied to represent data**
- **The frequency of the modulated signal is constant for the duration of one signal element, but changes for the next signal element if the data element changes**
- **Both peak amplitude and phase remain constant**
- **The frequency of the carrier signal is varied to represent data**
- **Both peak amplitude and phase remain constant**





zero — one

$f_2 - f_1 = 2\Delta f$

$B = (1+d)S + 2\Delta f$

$B \propto S$

Topic # 82

Example

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?

$$B = (1+d) \times S + 2\Delta f$$

$$\Delta f = 50 kHz$$

$$B = 2S + 50$$

$$2S + 50 = 100$$

$$2S = 50 kHz$$

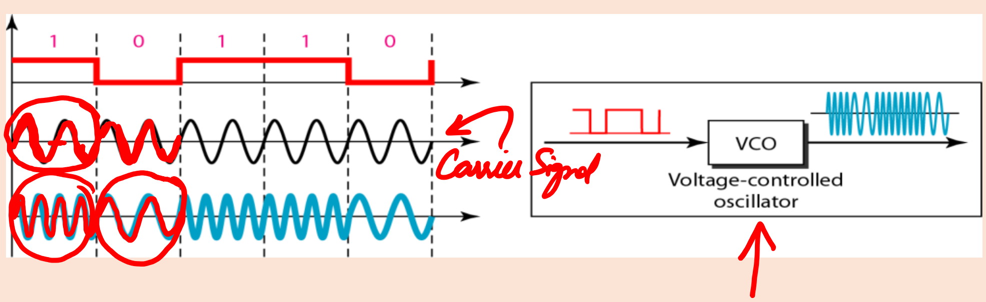
$$S = 25 kbaud$$

$$N = S$$

$$N = 25 kbps$$

Implementation of BFSK

Unipolar NRZ



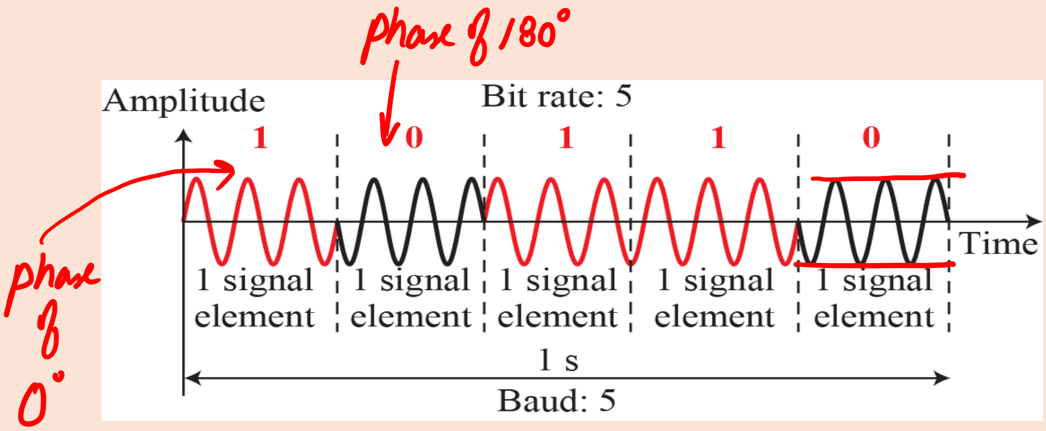
Topic # 83

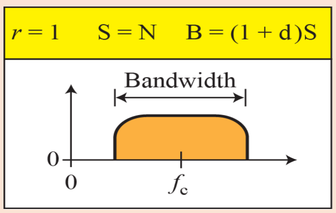
Phase Shift Keying (PSK)

Phase-shift keying (**PSK**) is a digital modulation process which conveys data by changing (modulating) the **phase** of a constant frequency reference signal (the carrier wave). The modulation is accomplished by varying the sine and cosine inputs at a precise time.

- **The phase of the carrier is varied to represent two or more different signal elements**
- **Both peak amplitude and frequency remain constant**

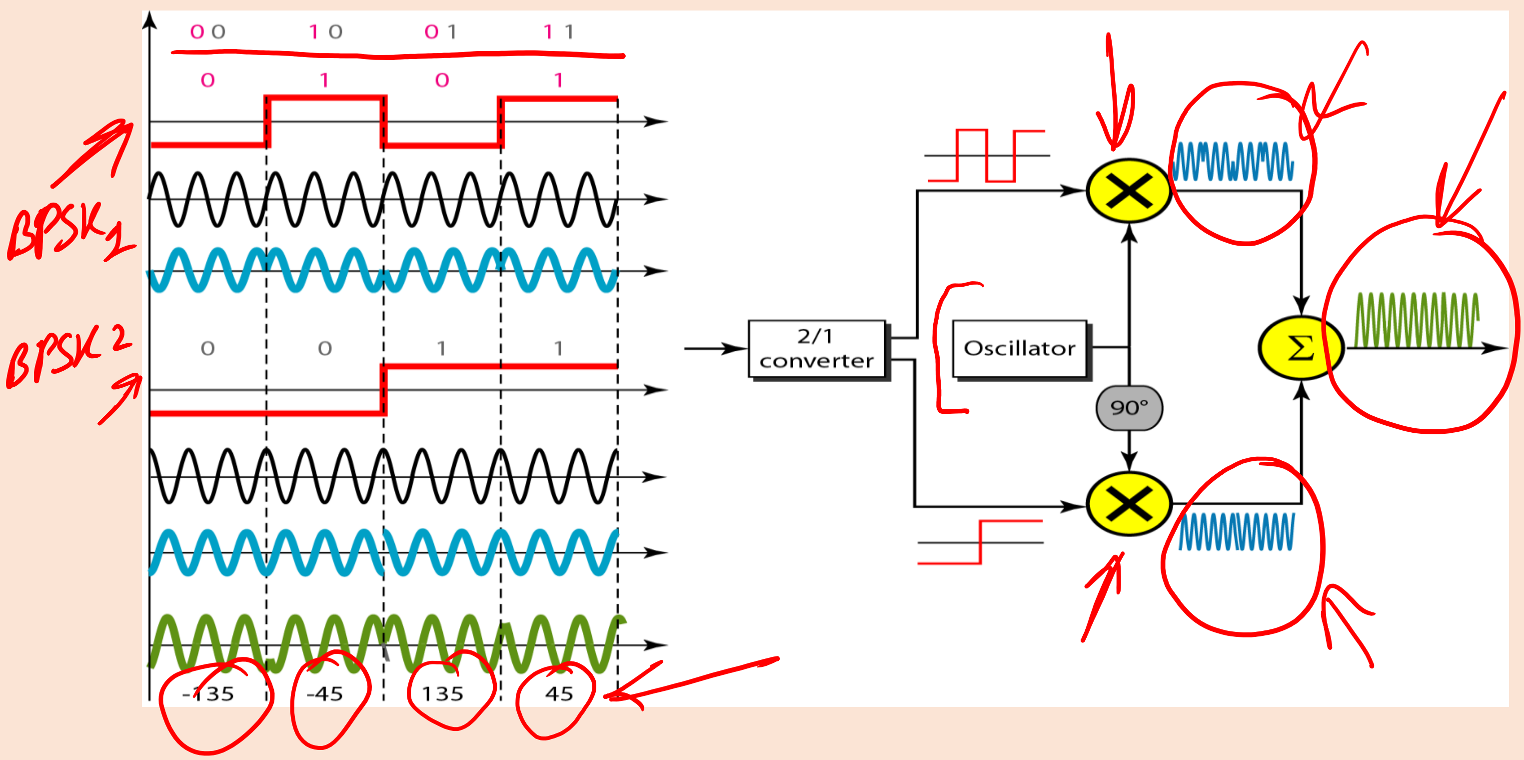
- **PSK is relatively common than ASK or FSK**





$B = (1+d)S$

$B_{PSK} = B_{ASK}$



Example:

Find the bandwidth for a signal transmitting at 12 Mbps for QPSK. The value of d = 0.

$r = 2$

$S = \frac{N}{r}$

$= \frac{12 Mbps}{2}$

$= 6 M baud.$

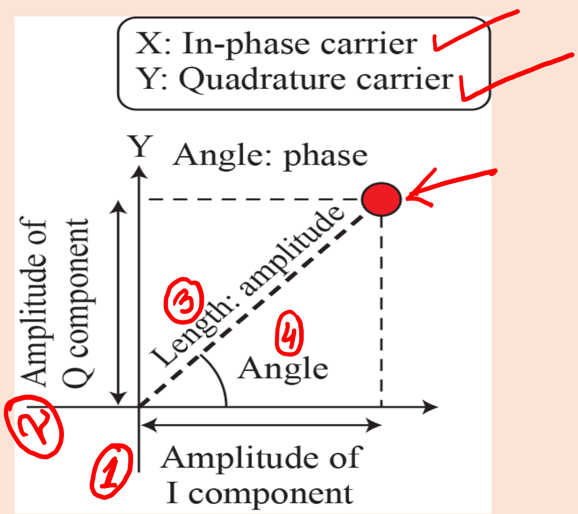
$d = 0 \longrightarrow B = S = 6 MHz$

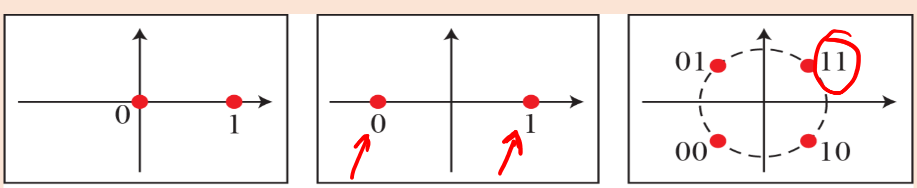
Topic # 84

Constellation Diagram

A **constellation diagram** is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase-shift keying. It displays the signal as a two-dimensional xy-plane scatter **diagram** in the complex plane at symbol sampling instants.

- **Helps us define the phase and amplitude of a signal element when we are using two carriers (one in phase and other in quadrature)**
- **Signal element is represented as a dot**





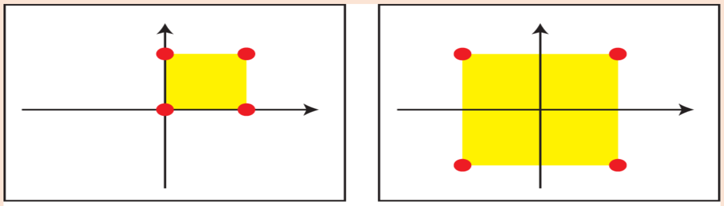
a. BASK (OOK) b. BPSK c. QPSK

Topic# 85

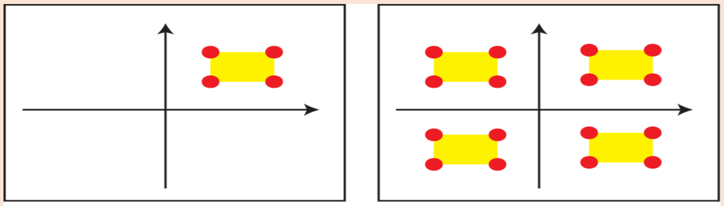
Quadrature Amplitude Modulation (QAM)

Quadrature amplitude modulation is the name of a family of digital modulation methods and a related family of analog modulation methods widely used in modern telecommunications to transmit information.

- **PSK is limited by the ability of the equipment to distinguish small differences in phase which limits its potential bit rate**
- **We have been altering only one of the three characteristics of a sine wave at a time; but what if we alter two?**
- **Why not combine ASK and PSK?**



a. 4-QAM b. 4-QAM



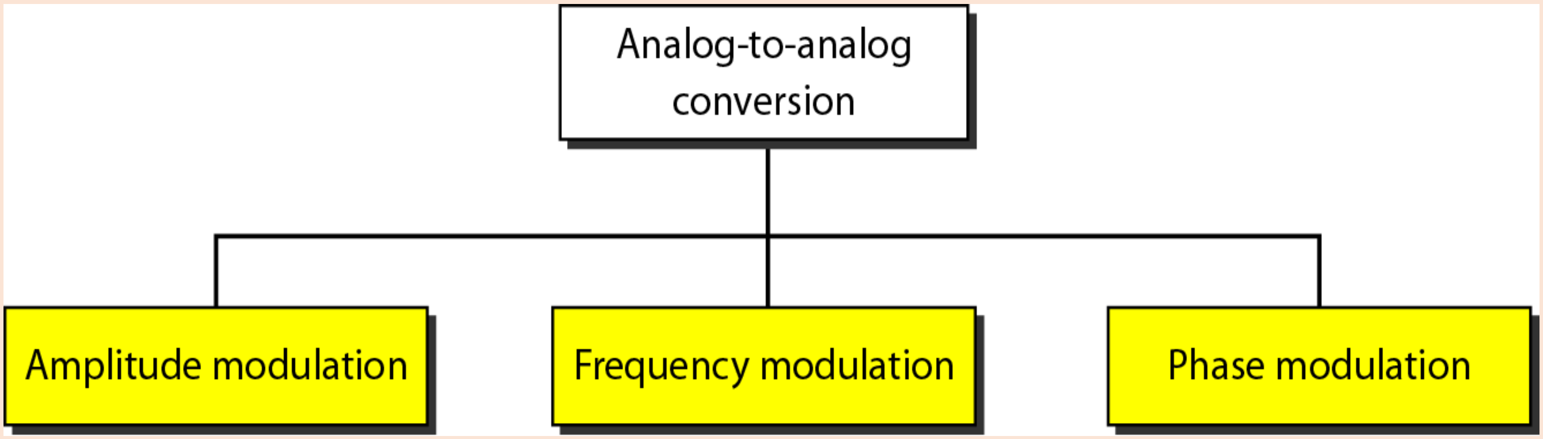
c. 4-QAM d. 16-QAM

Analog-to-Analog Conversion

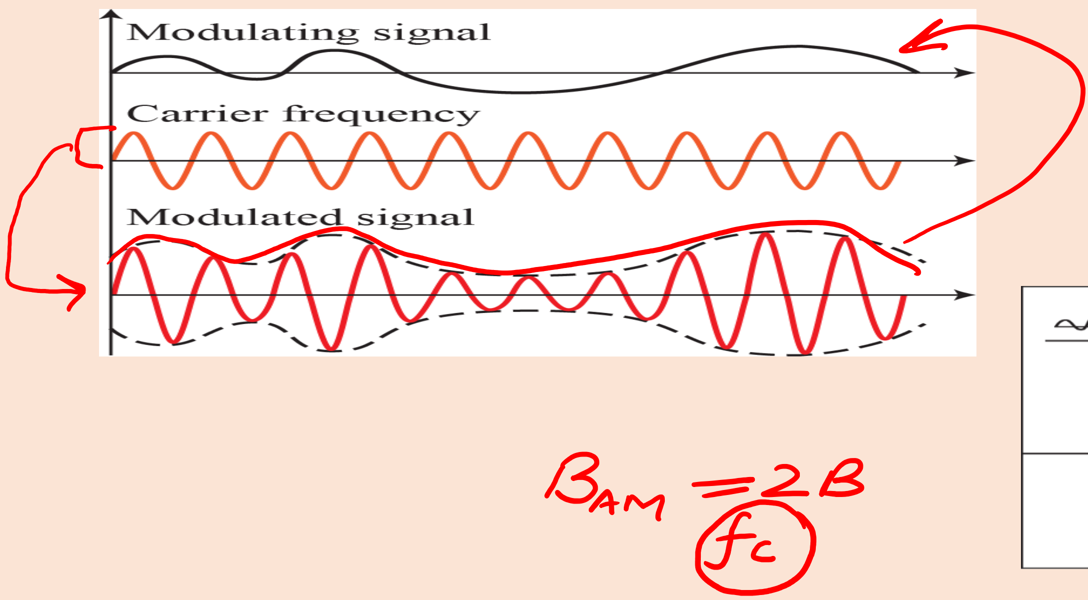
Analog-to-**analog conversion**, or modulation, is the representation of **analog** information by an **analog** signal. It is a process by virtue of which a characteristic of carrier wave is varied according to the instantaneous amplitude of the modulating signal

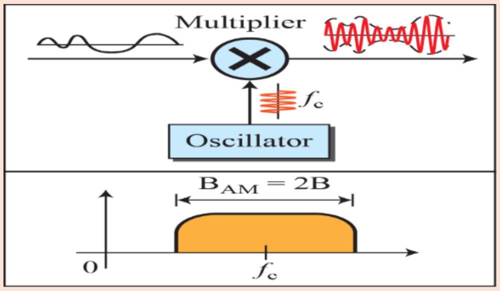
- **Representation of Analog information by an Analog signal**
- **Amplitude Modulation (AM)**
- **Frequency Modulation (FM)**
- **Phase Modulation (PM)**

Types of Analog-to-Analog Modulation



Topic#87





Topic#88

Analog-to-Analog Conversion

- **Representation of Analog information by an Analog signal**
- **Amplitude Modulation (AM)**
- **Frequency Modulation (FM)**
- **Phase Modulation (PM)**

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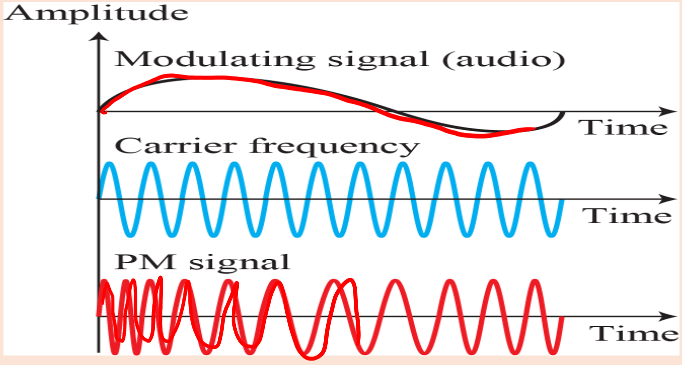
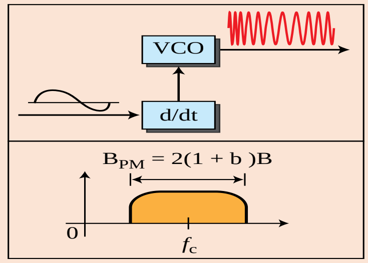


$B_{PM} = 2(1+\beta)B$

$\beta = 1$ narrowband
$\beta = 3$ wideband

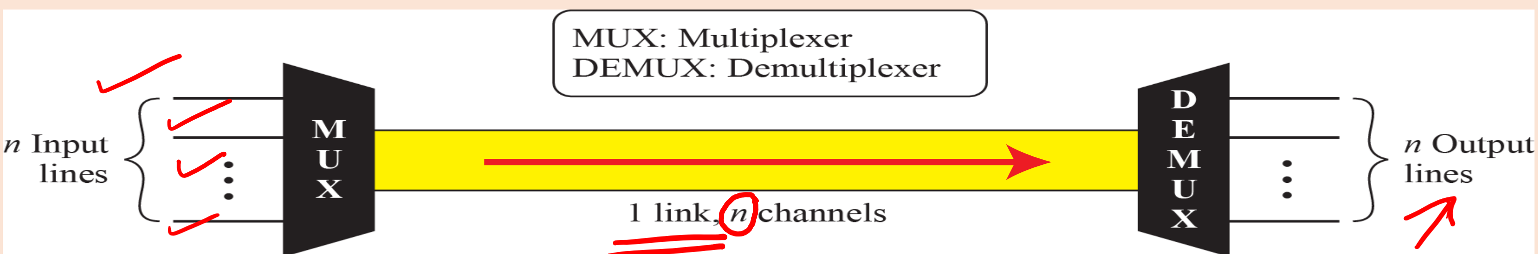


Topic#89

Multiplexing

- **Simultaneous transmission of multiple signals across a single data link**
- **As data & telecom use increases, so does traffic**
  - ✓ **Add individual links each time a new channel is needed**
  - ✓ **Install higher-bandwidth links and use each to carry multiple signals**

In telecommunications and computer networks, multiplexing is a method by which multiple analog or digital signals are combined into one signal over a shared medium. The aim is to share a scarce resource. For example, in telecommunications, several telephone calls may be carried using one wire.



Multiplexer (many to one)

Demultiplexer (one to many)

Topic#90

Multiplexing

- **Simultaneous transmission of multiple signals across a single data link**

Categories of Multiplexing

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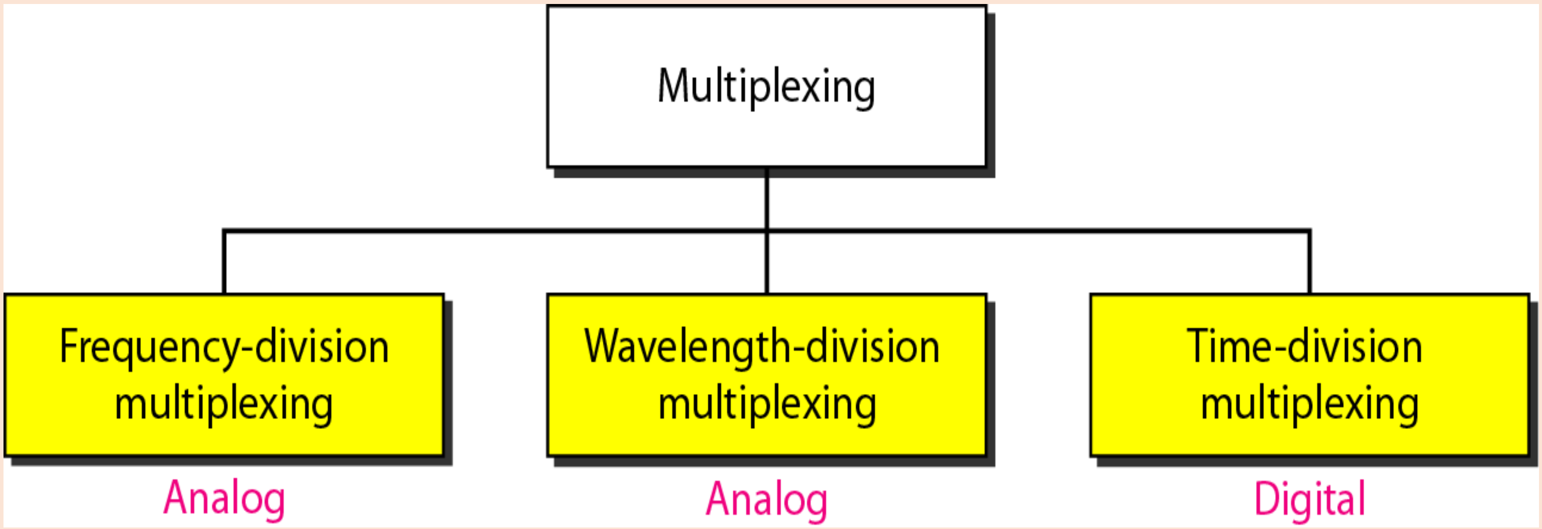
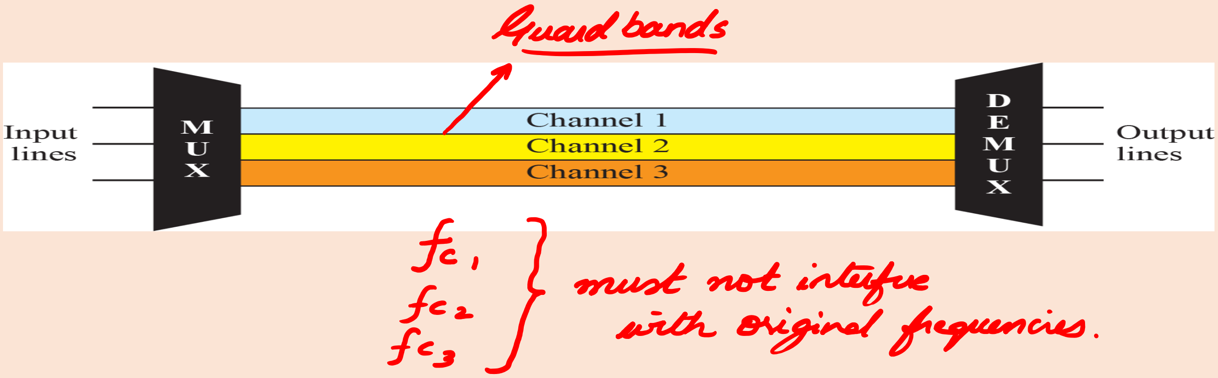


Frequency-Division Multiplexing:

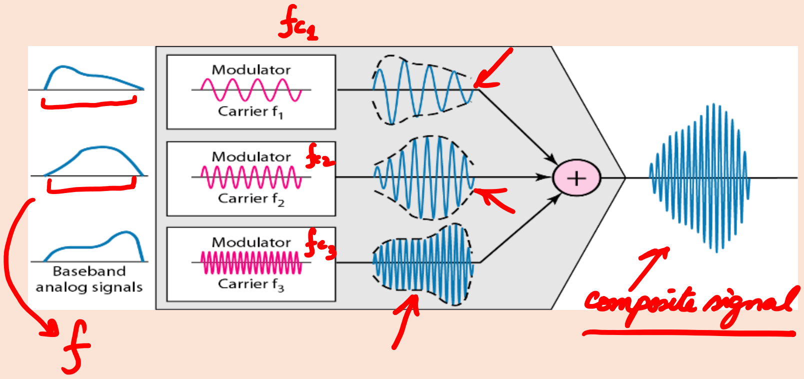
Frequency division multiplexing (FDM) is a technique of **multiplexing** which means combining more than one signal over a shared medium. In FDM, signals of different **frequencies** are combined for concurrent transmission.

- **An analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted**
- **Signals generated by each sending device modulate different carrier frequencies**
- **These modulated signals are then combined into a single composite signal that can be transported by the link**



Topic#91

- **These modulated signals are then combined into a single composite signal that can be transported by the link**
- **An analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted**



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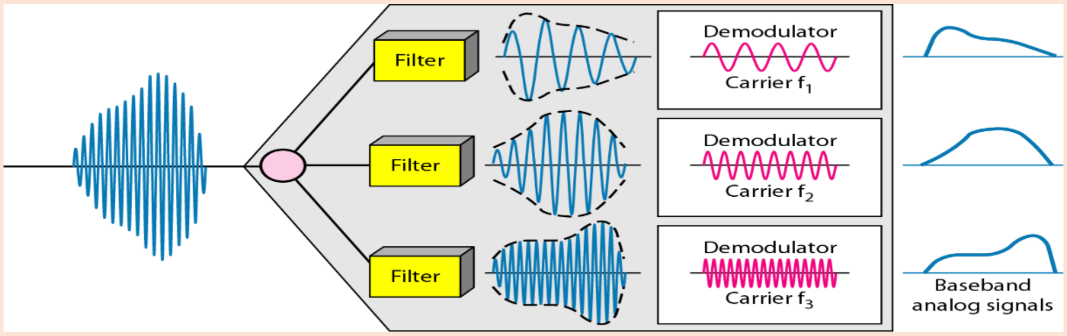
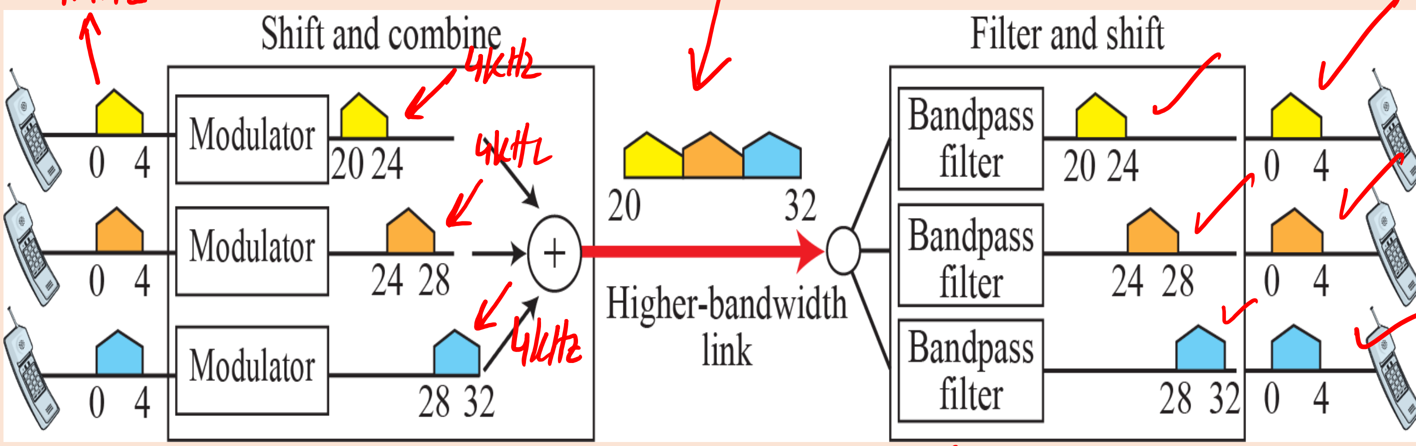


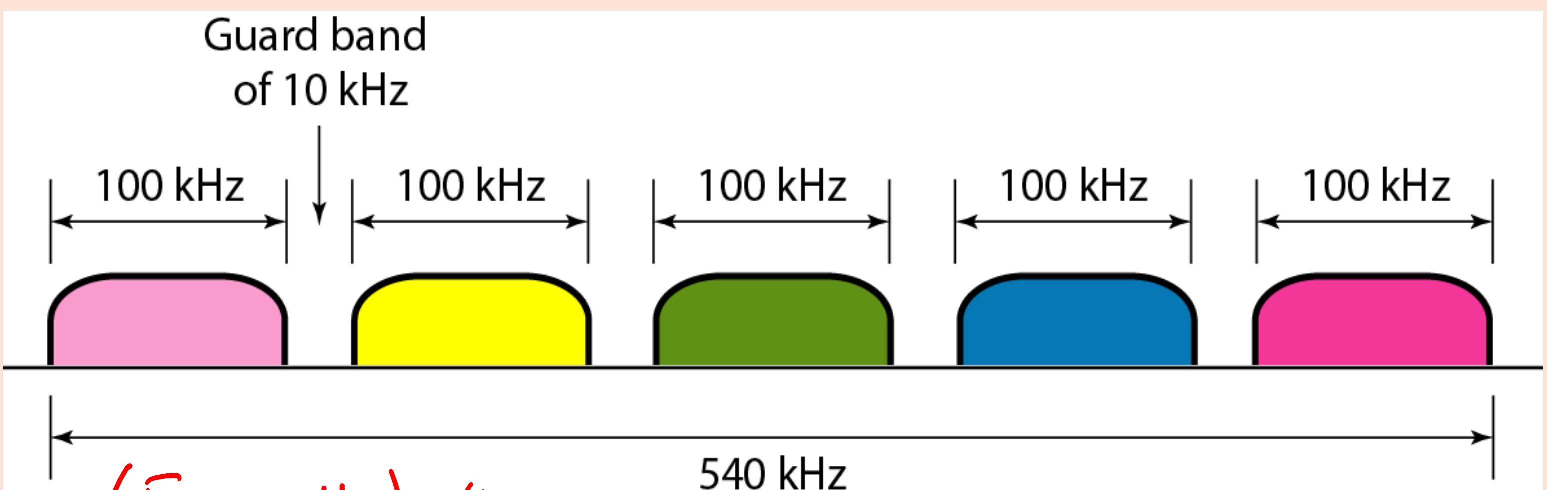
Example

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



Example:

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



(5x1 Hz)+(4x kHz)

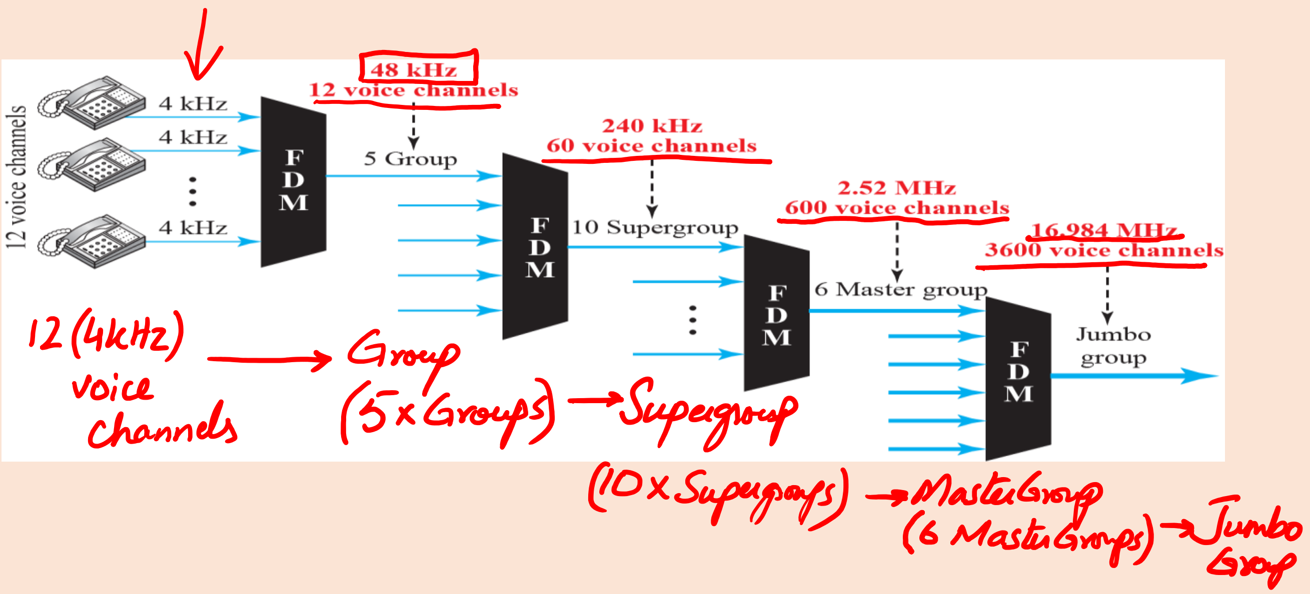
Topic#92

The Analog Carrier System

The electronic mechanisms that implemented FDM are called **analog carrier systems**. The carrier in **an analog carrier system** is a signal ...

Multiplex Level: No. of Voice Circuits
Group: 12
Voice channel: 1
Jumbo group: 3,600

- **Telephone companies multiplex signals from lower-bandwidth lines on to higher-bandwidth lines**
- **For Analog, FDM is used**

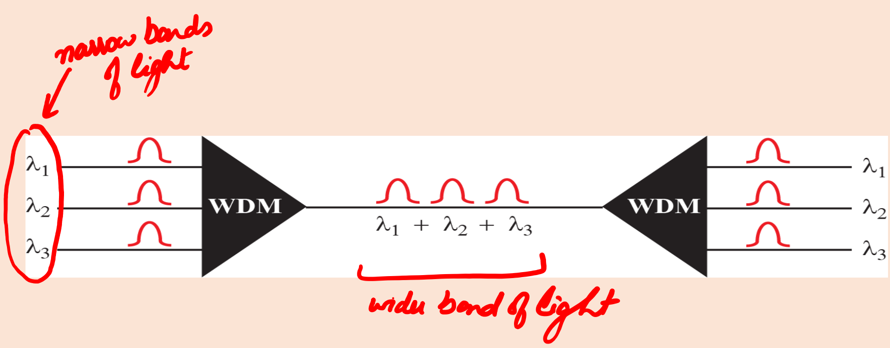


Topic#93

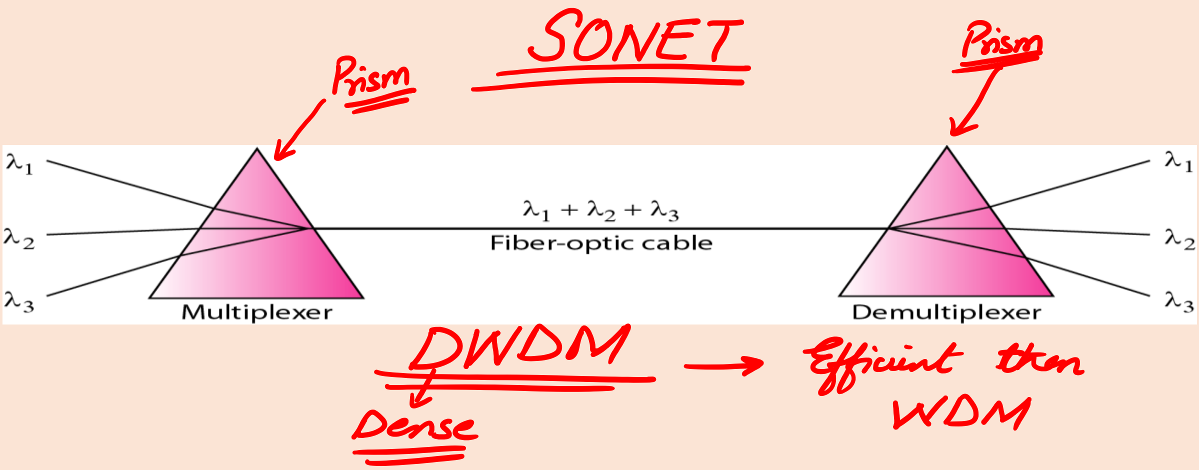
Wavelength-Division Multiplexing

In fiber-optic communications, **wavelength-division multiplexing** (**WDM**) is a technology which multiplexes a number of optical carrier signals onto a single optical.

- **Designed to use the high-data-rate capability of fiber-optic cable**
- **Fiber data rate is higher than the data rate of metallic transmission cable**
- **Using a fiber-optic cable for a single line wastes the available bandwidth**
- **Multiplexing allows us to combine several lines into one**



Prisms in Wave-Length Division Multiplexing



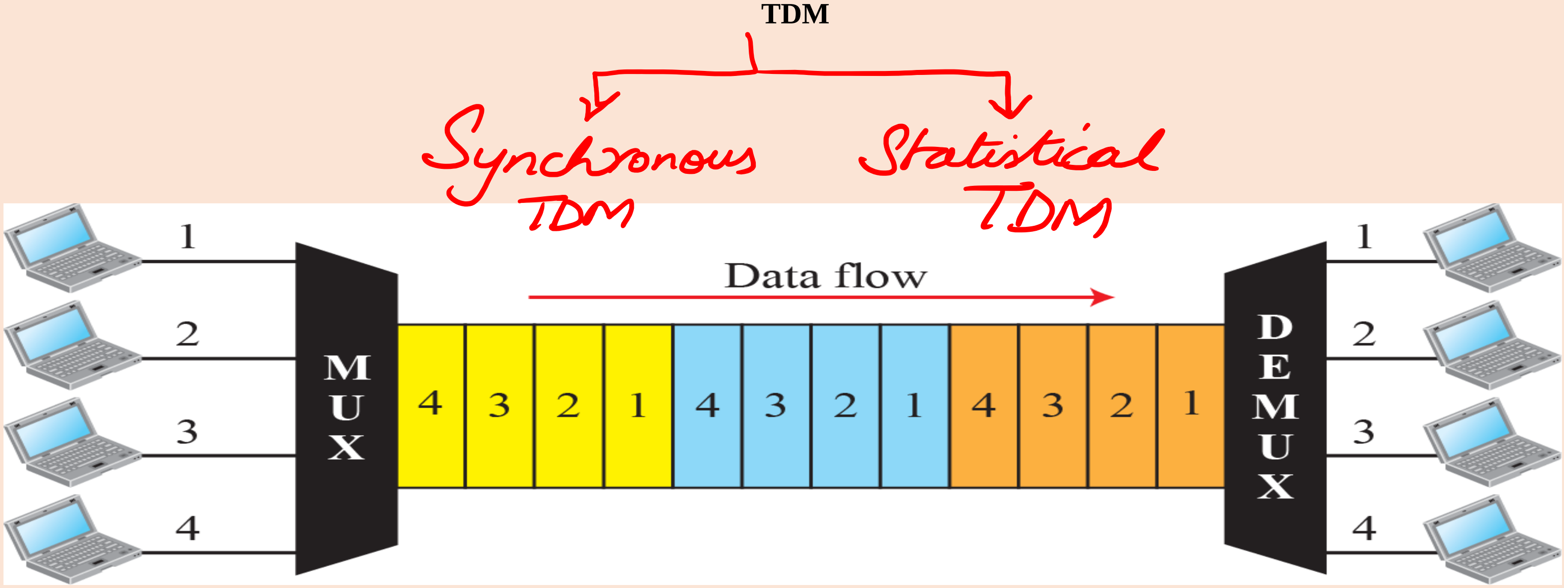
Topic#94

Time-Division Multiplexing

Time-division multiplexing (**TDM**) is a method of transmitting and receiving independent signals over a common signal path by means of synchronized switches at each end of the transmission line so that each signal appears on the line only a fraction of **time** in an alternating pattern.

- **Digital process that allows several connections to share the high bandwidth of a link**
- **Time is shared i.e.; each connection occupies a portion of time in the link**

TDM



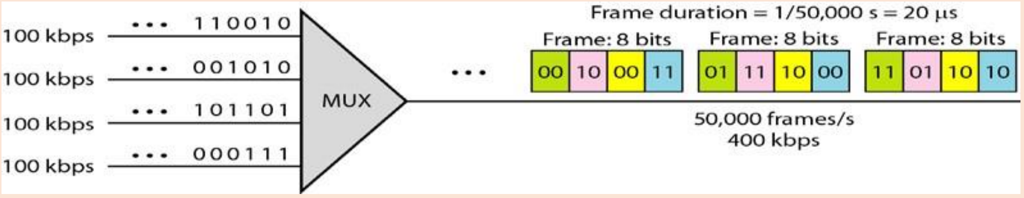
Topic # 95

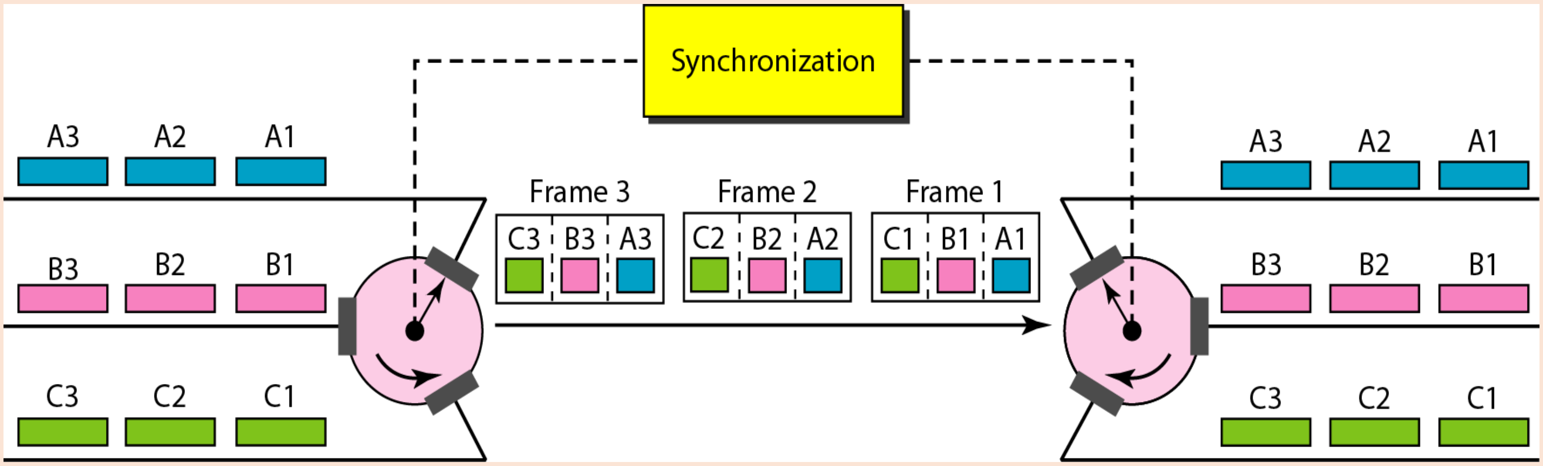
Time-Division Multiplexing

- **Digital process that allows several connections to share the high bandwidth of a link**
- **Time is shared i.e. each connection occupies a portion of time in the link**

In Figure the data rate for each input connection is 1 kbps. If 1 bit at a time is multiplexed (a unit is 1 bit), what is the duration of

- **each input slot,**
- **each output slot, and**
- **each frame?**





Topic#96

Time-Division Multiplexing

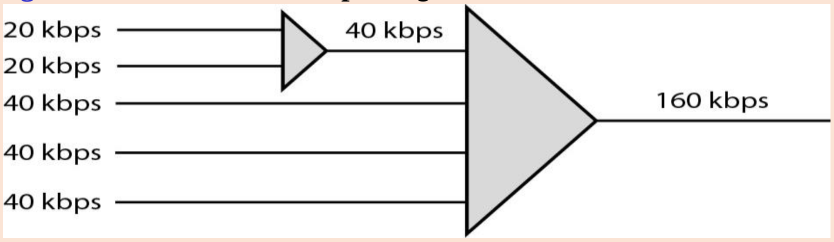
- **Digital process that allows several connections to share the high bandwidth of a link**
- **Time is shared i.e.; each connection occupies a portion of time in the link**

Multilevel Multiplexing

Multilevel Multiplexing Multilevel multiplexing is a technique used when the data rate of an input line is a multiple of others. ... The first two input lines can be multi- plexed together to provide a data rate equal to the last three. A second level of multi- plexing can create an output of 160 kbps.

Multilevel Muxing:
When some of the input lines have half the rate of the others.

Figure 6.19 ***Multilevel multiplexing***



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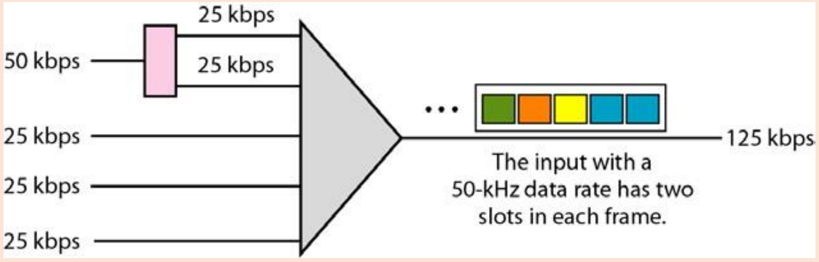
Multiple Slot Allocation:

When an input line has multiple rates of the others.

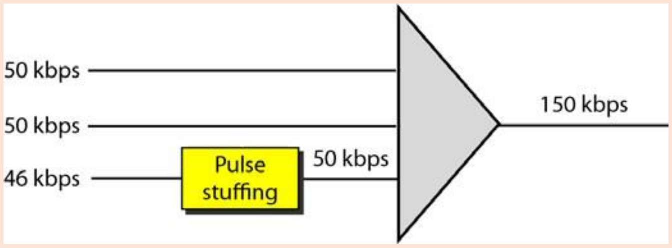
Multiple-slot multiplexing



Pulse Stuffing: (bit padding)

When the bit rates of the input lines are not multiple integers of each other.

Pulse stuffing

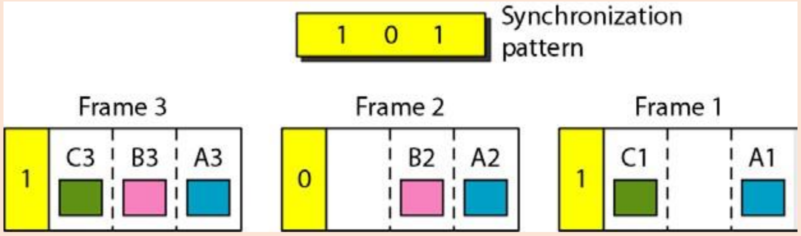


Pulse Stuffing: insertion of **dummy** bit (in the line with lower data rate).

Frame Synchronization

Mux-Demex synchronization is very important maintain the integrity of the frames exchange between source and destination.

Framing bits



A “framing bit” is added at the beginning of a frame, alternating 0,1,0,1… between frames.

Topic#97

Digital Signal Service Hierarchy (DS-N)

Telephone companies use TDM via DS_*n* digital hierarchy.

Figure 6.23 Digital *hierarchy*

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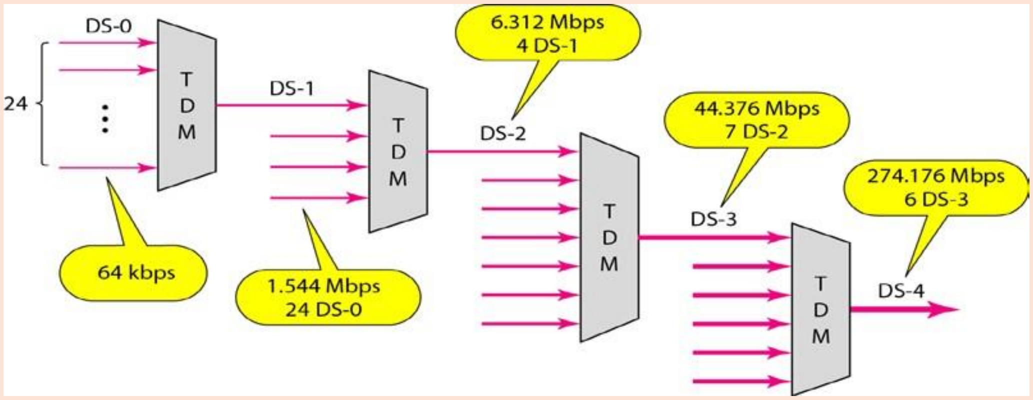


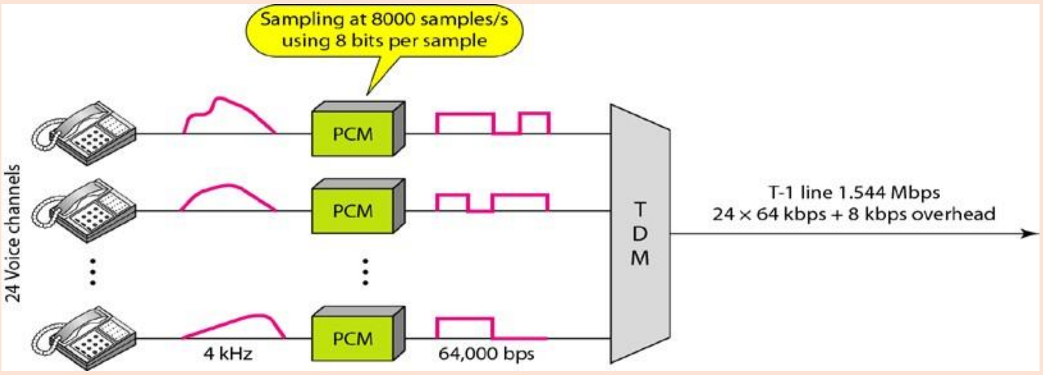
• T lines implements (carry) the above DS-n services: T-1 carries DS-1 up to T-5 carries DS-5.

T-1 line data rate: 24 PCM channels 24 X 8 bits + 1 (framing) = 193 bits to be transmitted every sample time **125 micro sec/sample** (why?)

yielding a data rate of (193/125) X 10^6 = 1.544 M b/s

Notice that the sampling rate is **8000 sample/sec**, since the TP line BW is 4 KHz and by ***Nyquist*** we sample twice the channel BW (**8000** sample/sec), hence **1/8000 = 125 micro sec/sample**

Figure 6.24 ***T-1 line for multiplexing telephone lines***



6.47

• T_n are digital lines to carry digital data from digital or analog sources (in this case after using Delta Code Modulation, DCM).

Topic # 98

II) *Statistical* TDM (STDM):

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- TDM is inefficient in case of a user not using its assigned time slot (wasting BW).
- In STDM, slots are allocated based on data availability (***dynamic***), instead of ***static*** assignment of time slots, one per user, i.e., instead of having **one local queue** per user's station, as done in TDM, we will have one ***global system queue*** to feed the Mux every Δt (original time slot of TDM) in the **STDM**. In **STDM,** the global queue will be served via the ***n*** time slots (***n***servers), instead of the *single* local queue *single* time slot server at each station in the TDM.

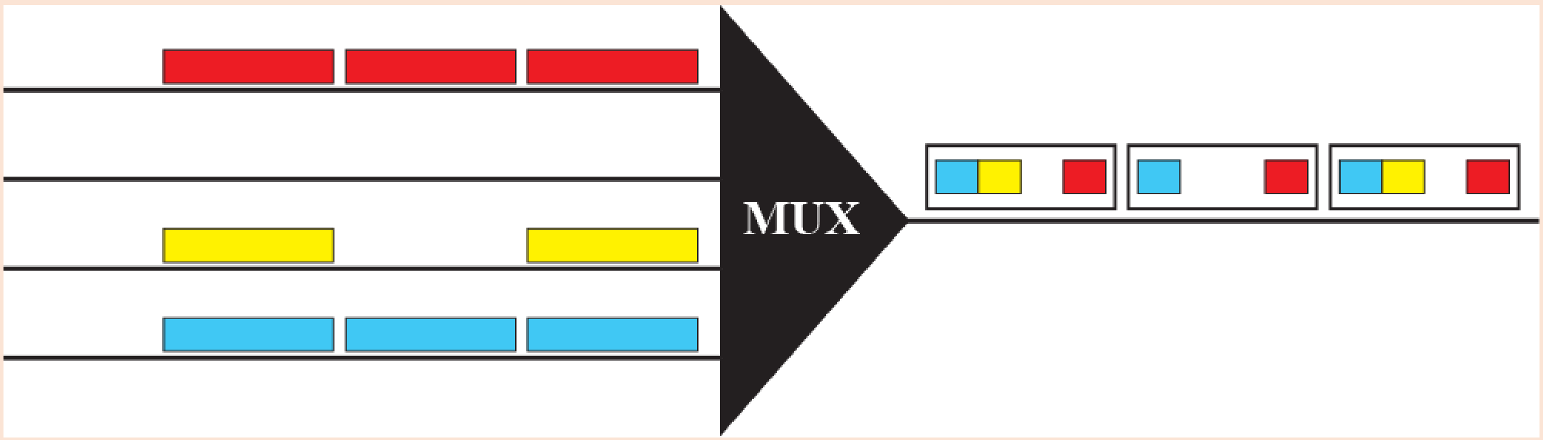
Problem? Yes, at the destination "Demux", directing the frames to the correct destination?

Solution □ add address to each Muxed frame with its corresponding destination user.

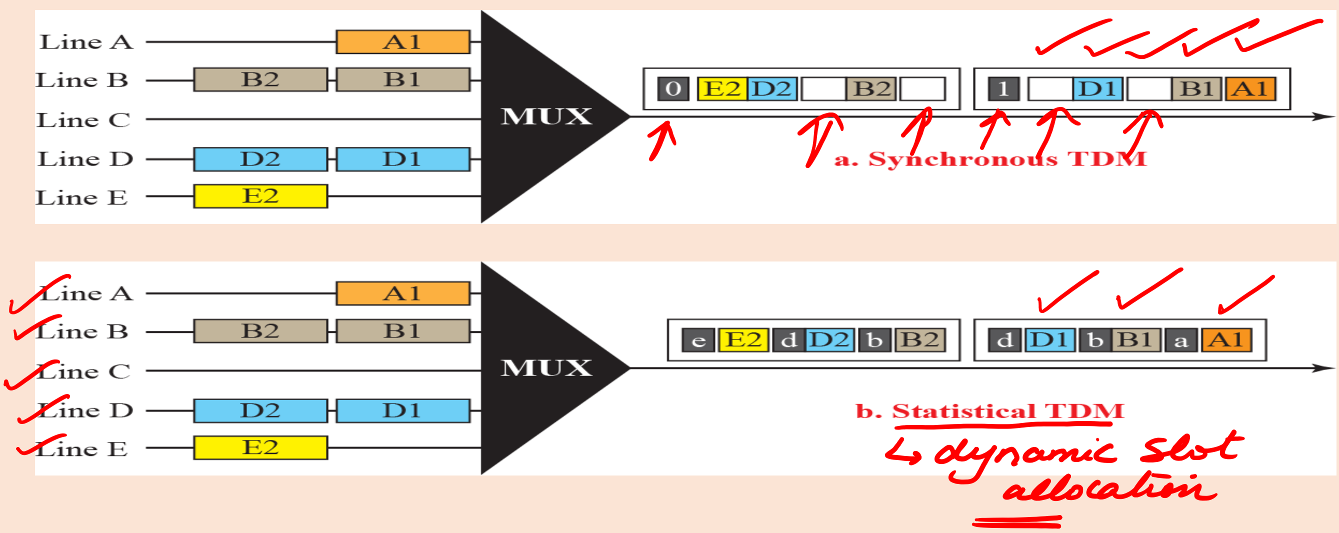
Time-Division Multiplexing

- **Synchronous TDM**
- **Statistical TDM**

- **Empty slots**



Statistical TDM



) *Statistical* TDM (STDM):

- TDM is inefficient in case of a user not using its assigned time slot (wasting BW).

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- In STDM, slots are allocated based on data availability (***dynamic***), instead of ***static*** assignment of time slots, one per user, i.e., instead of having **one** **local queue** per user's station, as done in TDM, we will have one ***global*** ***system queue*** to feed the Mux every Δt (original time slot of TDM) in the **STDM**. In **STDM,** the global queue will be served via the ***n*** time slots (***n***servers), instead of the *single* local queue *single* time slot server at each station in the TDM.

Problem? Yes, at the destination "Demux", directing the frames to the correct destination?

Solution add address to each Muxed frame with its corresponding destination user.

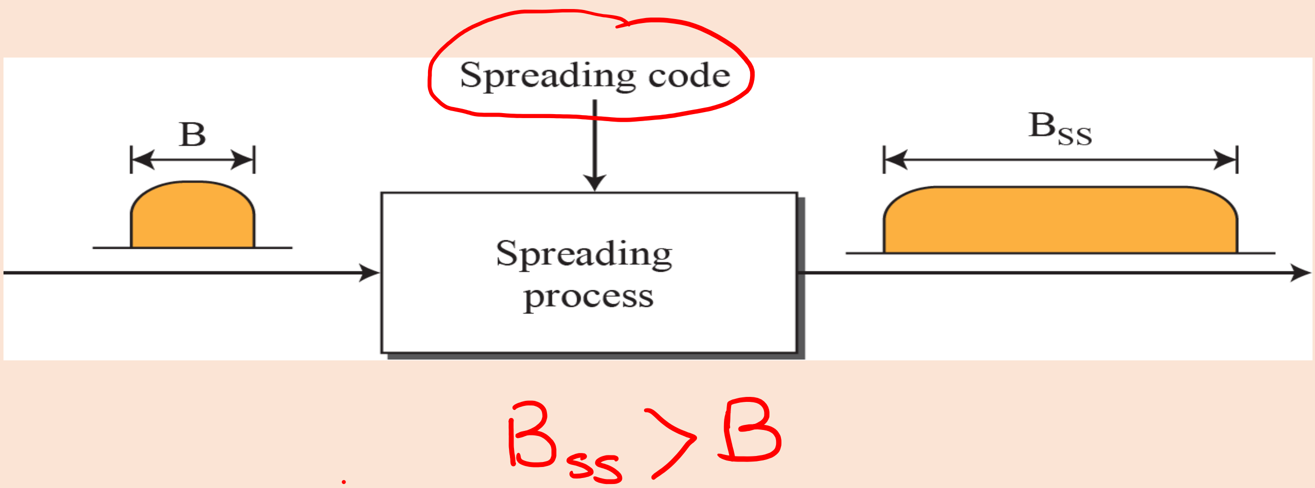
Topic#99

SPREAD SPECTRUM

In telecommunication and radio communication, spread-spectrum techniques are methods by which a signal generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth.

- **In wireless applications, stations must be able to share the medium without interception by an eavesdropper and without being subject to jamming from a malicious intruder**
- **To achieve these goals, spread spectrum adds redundancy and spread original spectrum needed for each station**
- **SPREAD SPECTRUM - Principles**

The core principle of spread spectrum is the use of noise-like carrier waves, and, as the name implies, bandwidths much wider than that required for simple point-to-point **communication** at the same data rate. **Resistance** to jamming (interference).



Topic#100

SPREAD SPECTRUM TECHNIQUES

In telecommunication and radio communication, spread-spectrum techniques are methods by which a signal (e.g., an electrical, electromagnetic, or acoustic signal) generated with a particular bandwidth is deliberately spread in the **frequency** domain, resulting in a signal with a wider bandwidth.

- **Frequency Hopping Spread Spectrum (FHSS)**

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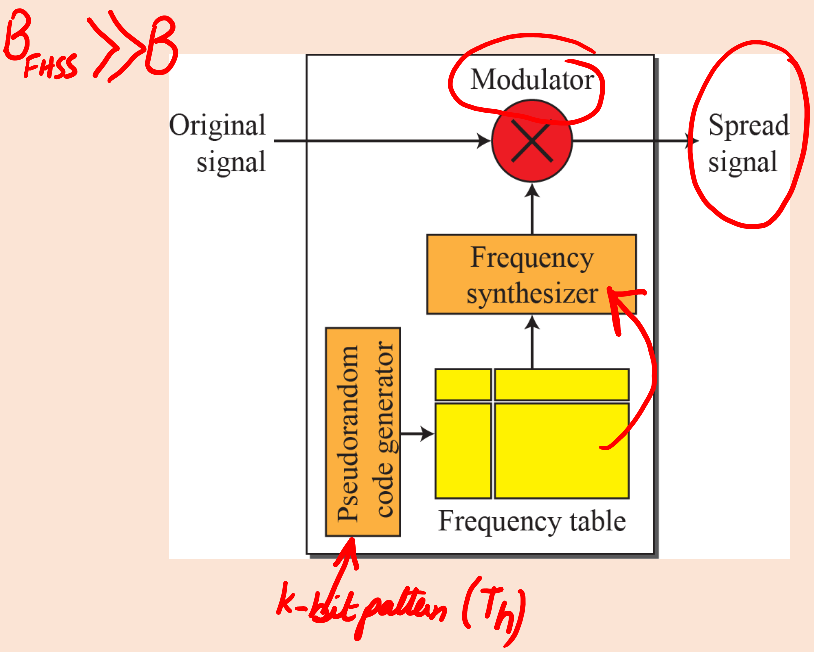
- **Direct Sequence Spread Spectrum (DSSS)**

Frequency Hopping Spread Spectrum (FHSS)

- **'M' different carrier frequencies that are modulated by the source signal**
- **At one moment, signal modulates one carrier frequency and at next moment, it modulates another**

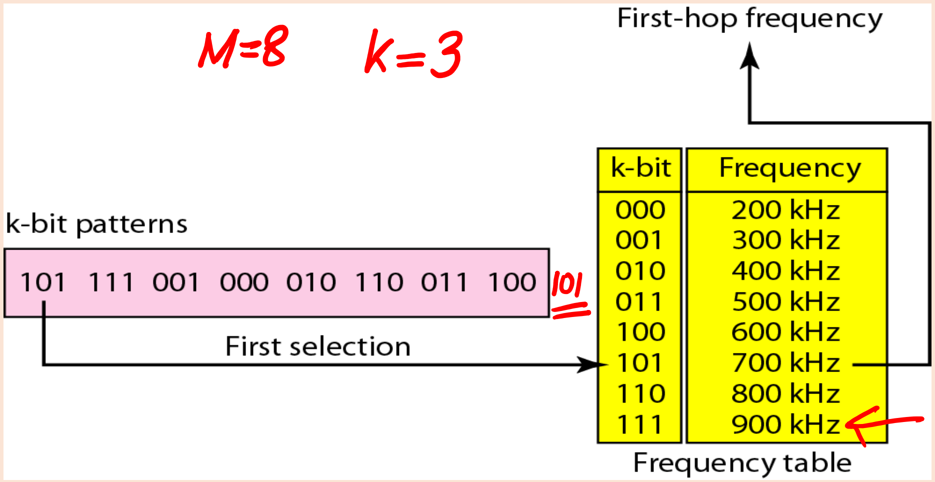
Frequency Hopping Spread Spectrum (FHSS):

Frequency-hopping spread spectrum (**FHSS**) is a method of transmitting radio signals by rapidly changing the carrier **frequency** among many distinct **frequencies** occupying a large **spectral** band. ... **FHSS** is used to avoid interference, to prevent eavesdropping, and to enable code-division multiple access (CDMA) communications.



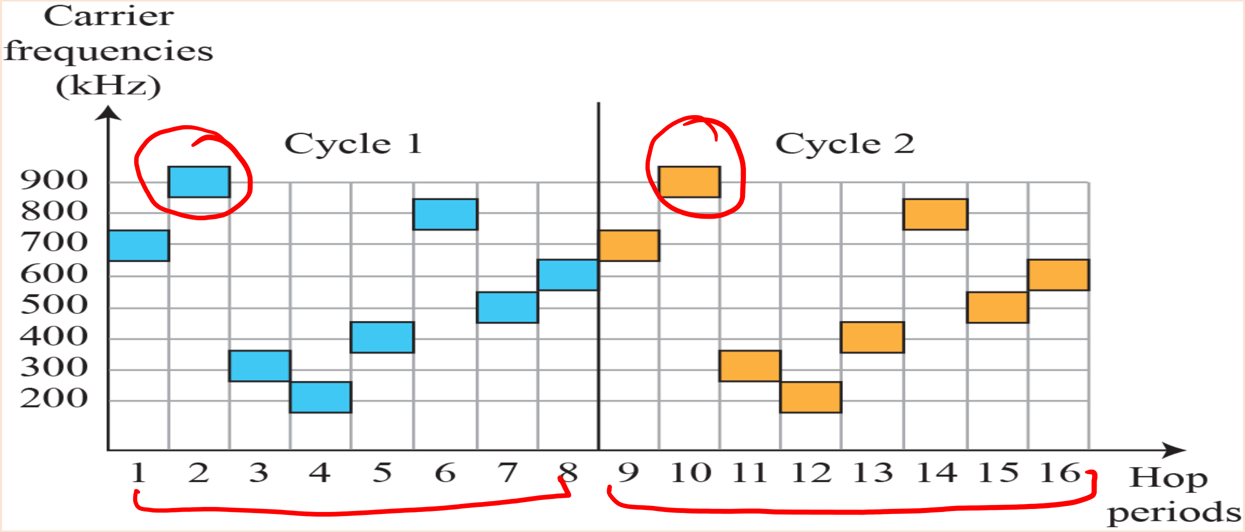
Frequency Selection in FHSS:

In **FHSS** the message signal is transmitted by rapidly switching among many **frequency** channels, using a pseudorandom sequence known to both transmitter and receiver. **FHSS** divides the available **frequency** band into sub-bands or channels, and hops among them in a predetermined order.



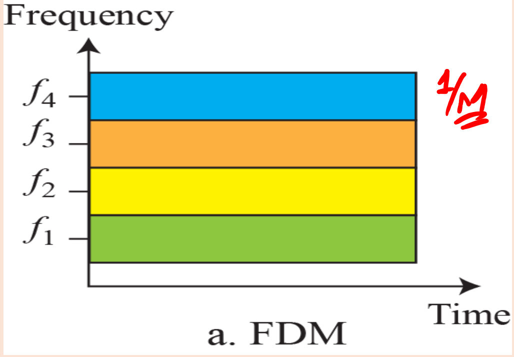
FHSS Cycles:

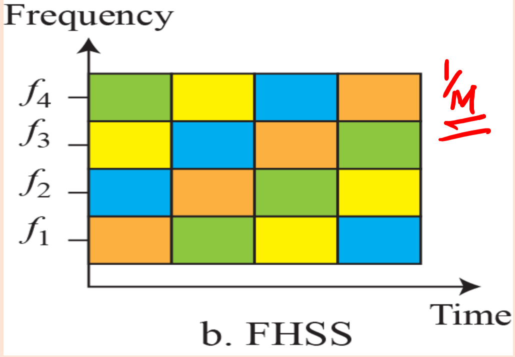
Frequency-hopping spread spectrum (**FHSS**) is a method of transmitting radio signals by rapidly changing the carrier frequency among many distinct frequencies occupying a large spectral band. The changes are controlled by a code known to both transmitter and receiver. FHSS is used to avoid interference, to prevent eavesdropping, and to enable code-division multiple access (CDMA) communications.



Bandwidth Sharing:

Shared and Dedicated **Bandwidth**. **Shared** Plans involves a set **bandwidth shared** among users, On a **shared** Internet connection, all **bandwidth** (5 Mbps, 10 Mbps, etc.) is split among all users and devices. Download and upload speeds on a **shared** package are "up to" a particular limit.





DSSS:

In telecommunications, direct-sequence spread spectrum (**DSSS**) is a spread-spectrum modulation technique primarily used to reduce overall signal interference. The direct-sequence modulation makes the transmitted signal wider in bandwidth than the information bandwidth.

- **DSSS also expands the bandwidth of the original signal, but the process is different**
- **We replace each data bit with 'n' bits using a spreading code**
- **Each bit is assigned a code of 'n' bits, called chips, where the chip rate is 'n' times that of the data bit**

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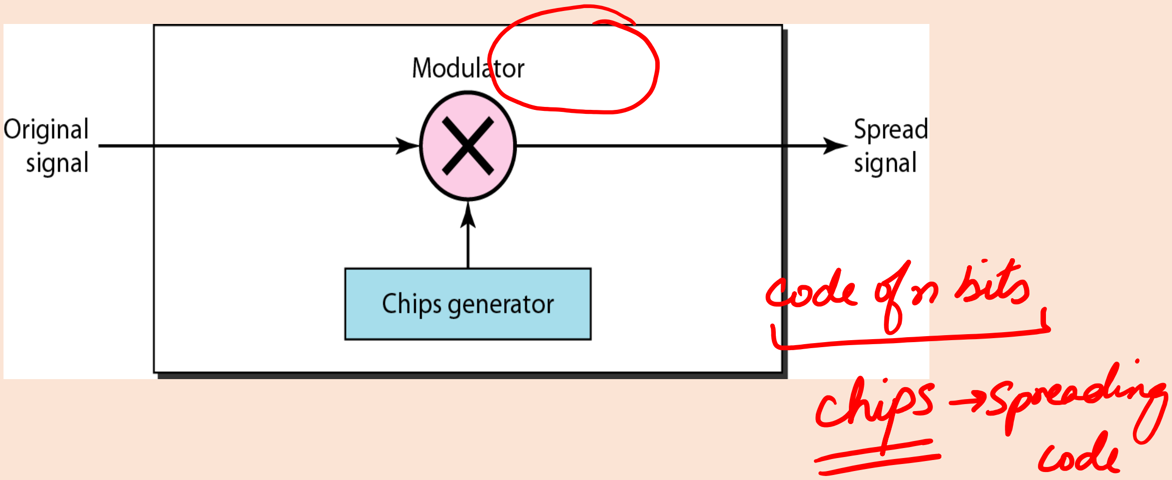


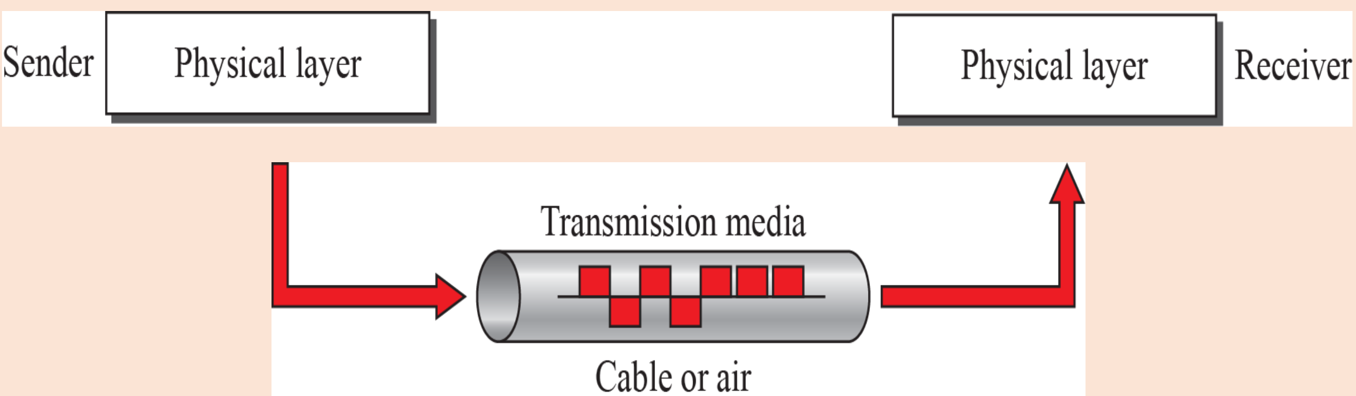
Topic#101:

Transmission Media

The **transmission medium** can be defined as a pathway that can transmit information from a sender to a receiver. **Transmission media** are located below the physical layer and are controlled by the physical layer. **Transmission media** are also called

- **Located below the physical layer and are directly controlled by the physical layer**
- **Belong to layer zero**
- **Metallic Media i.e. Twisted pair and Coaxial Cable**
- **Optical Fiber Cable**
- **Free Space i.e. Air, Vaccum**

Transmission Media & Physical Payer

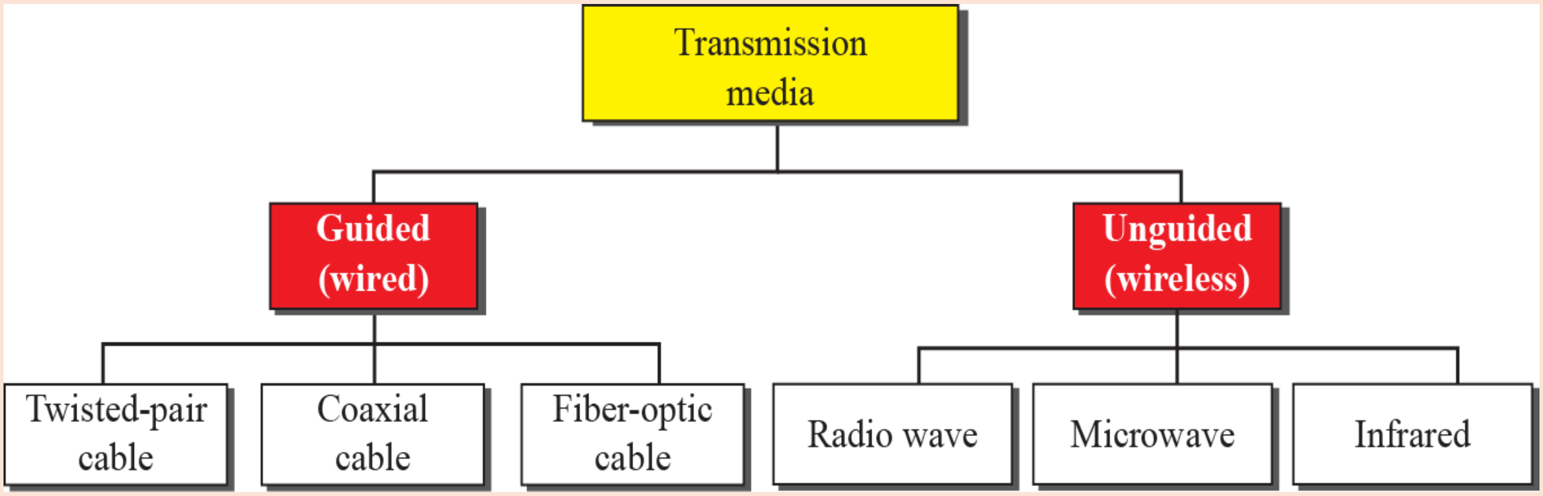


Topic#102:

Transmission Media

- **Located below the physical layer and are directly controlled by the physical layer**
- **Belong to layer zero**
- **Metallic Media i.e. Twisted pair and Coaxial Cable**
- **Optical Fiber Cable**

- **Free Space i.e. Air, Vacuum**
- **Classes of Transmission Media**



Guided Media:

Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable. **Guided** Transmission **Media** uses a "cabling" system that guides the data signals along a specific path.

- **Media that provides a conduit from one device to another**
- **Twisted-pair cable, coaxial cable, and fiber-optic cable**
- **Signal traveling along any of these media is directed and contained by the physical limits of the medium**

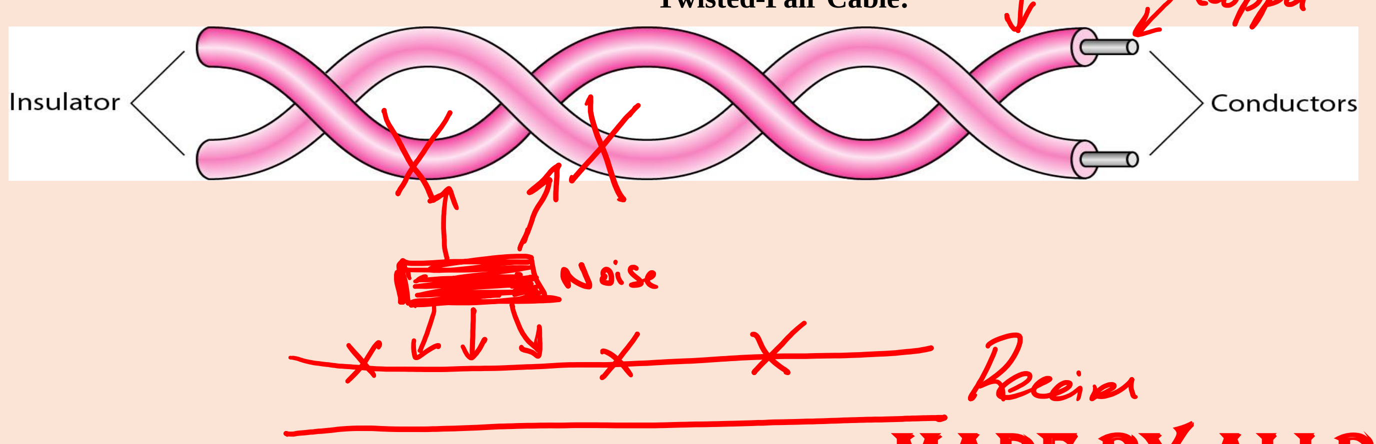
Twisted-Pair Cable:

Twisted pair cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purposes of improving electromagnetic compatibility

- **Consists of 2 copper conductors, each with its own plastic insulation, twisted together**
- **One wire carries signals and other is ground reference**
- **Receiver uses difference between the two**
- **Interference (Noise) & Crosstalk**

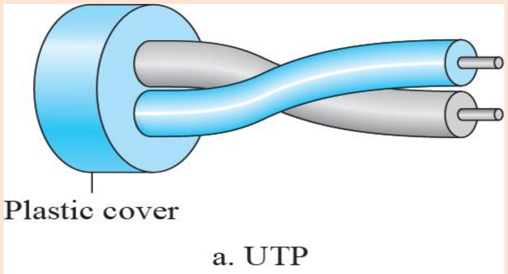
Topic #103:

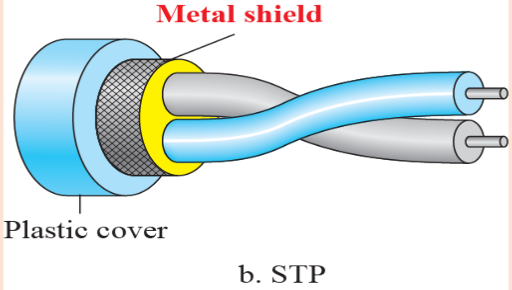
Twisted-Pair Cable:



Twisted-Pair Cable

- **UTP**
- **STP**





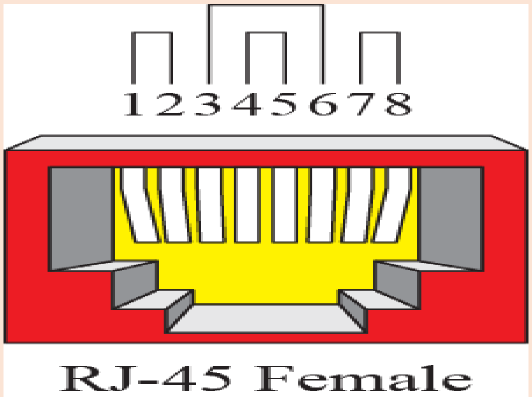
Topic # 104

Categories of Unshielded Twisted-Pair Cables

Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called *SSTP (shielded screen twisted-pair)*. Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs

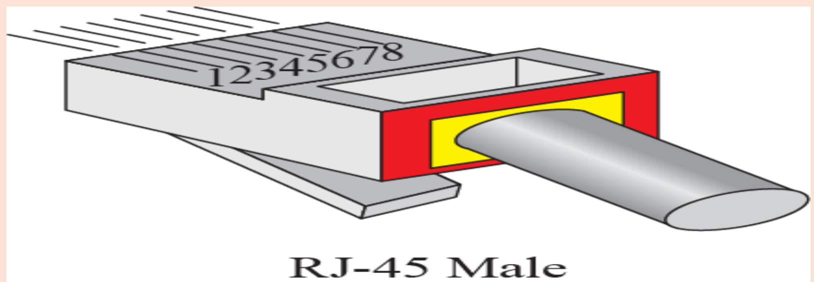
UTP Connectors:

As UTP is a balanced transmission line, a balun is needed to connect to unbalanced equipment, for example any using BNC connectors and designed for coaxial cable. **Unshielded twisted pair** is the most common kind of copper telephone wiring.

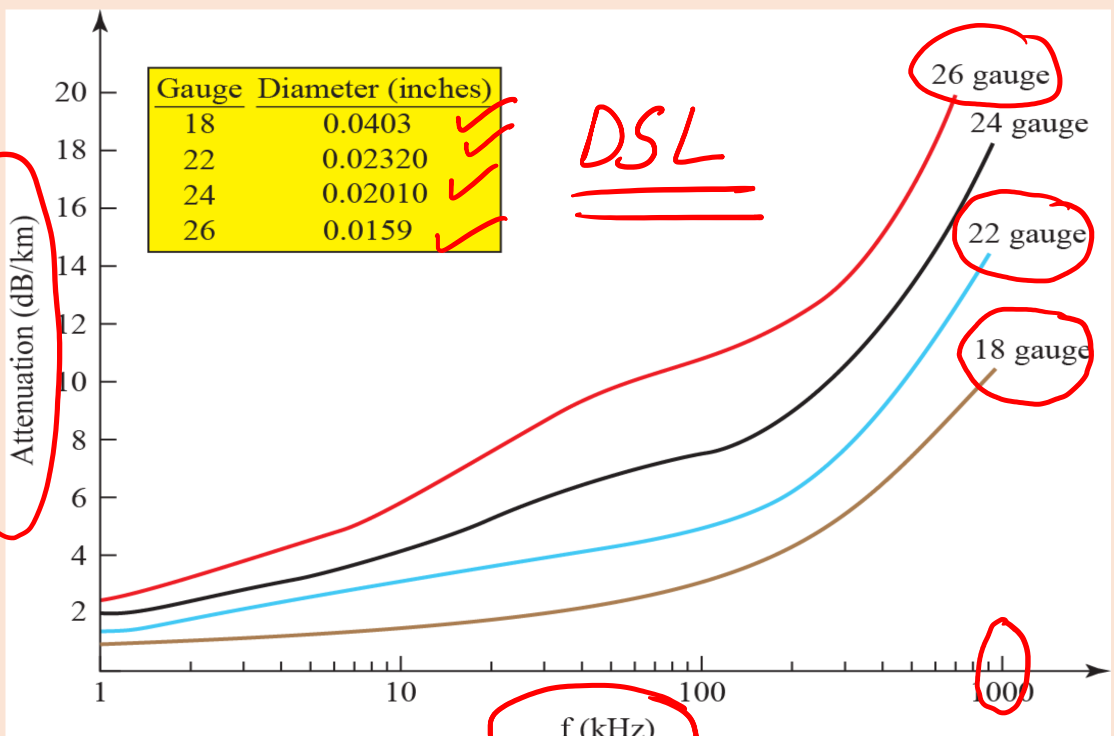


Registered Jack

Keyed



UTP Connectors:

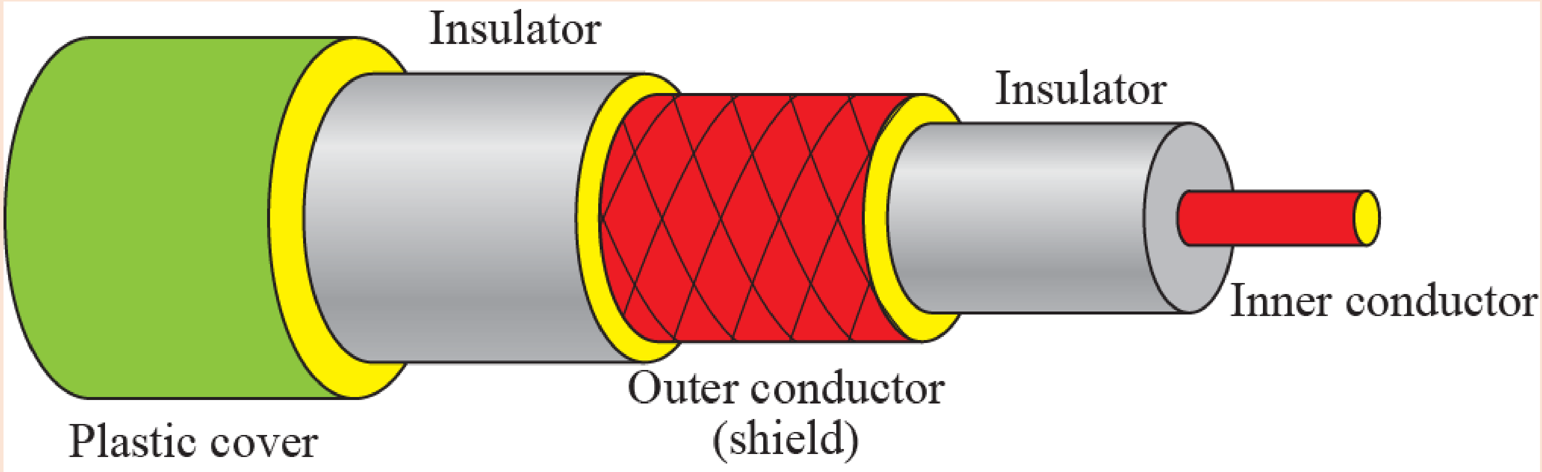


Topic#105

Coaxial Cable

Coaxial cable, or coax is a type of electrical cable consisting of an inner conductor surrounded by a concentric conducting shield, with the two separated by a dielectric; many coaxial cables also have a protective outer sheath or jacket

- **Carries signals of higher frequency ranges than those in twisted pair cable**



Categories of Coaxial Cables

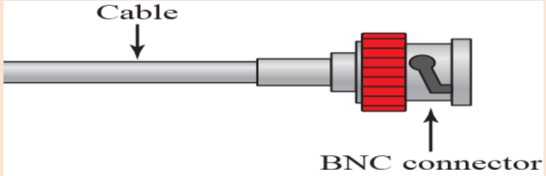
Category	*Impedance*	*Use*
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

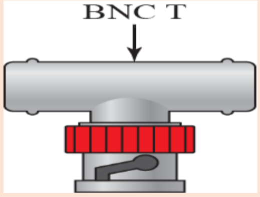
Topic#106

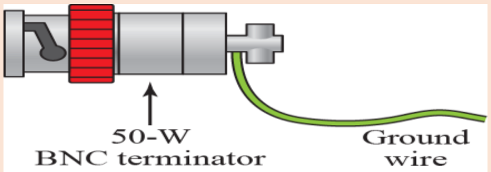
Coaxial Cable

- **Carries signals of higher frequency ranges than those in twisted pair cable**

The BNC connector is a miniature quick connect/disconnect radio frequency connector used for coaxial cable.







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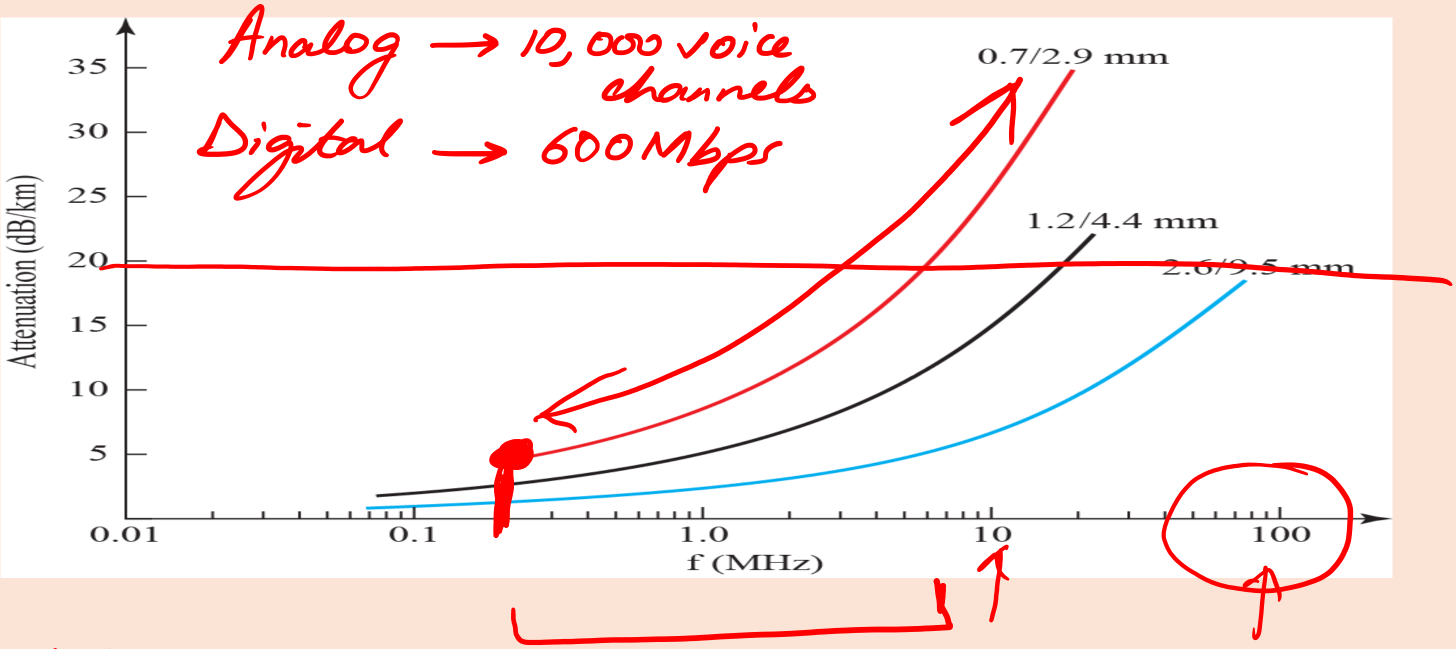


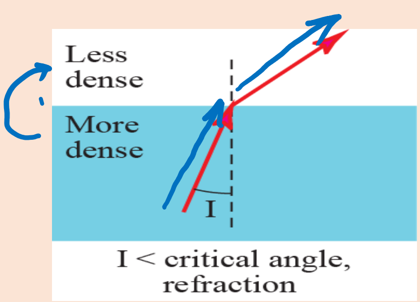
Topic#107:

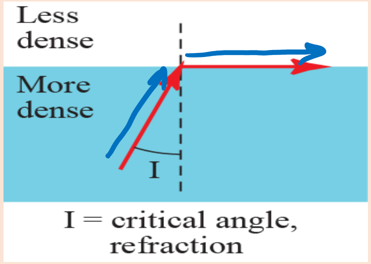
Fiber-Optic Cable

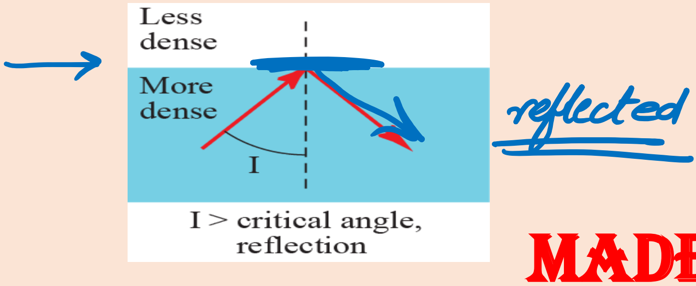
A fiber-optic cable, also known as an optical-fiber cable, is an assembly similar to an electrical cable, but containing one or more optical fibers that are used to carry light.

- **Made of glass or plastic and transmits signals in the form 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**

A ray of light being refracted in a plastic block. In physics, refraction is the change in direction of a wave passing from one medium to another or from a gradual change in the medium. Refraction of light is the most commonly observed phenomenon, but other ... This is due to the **bending of light rays** as they move from the water to the air.



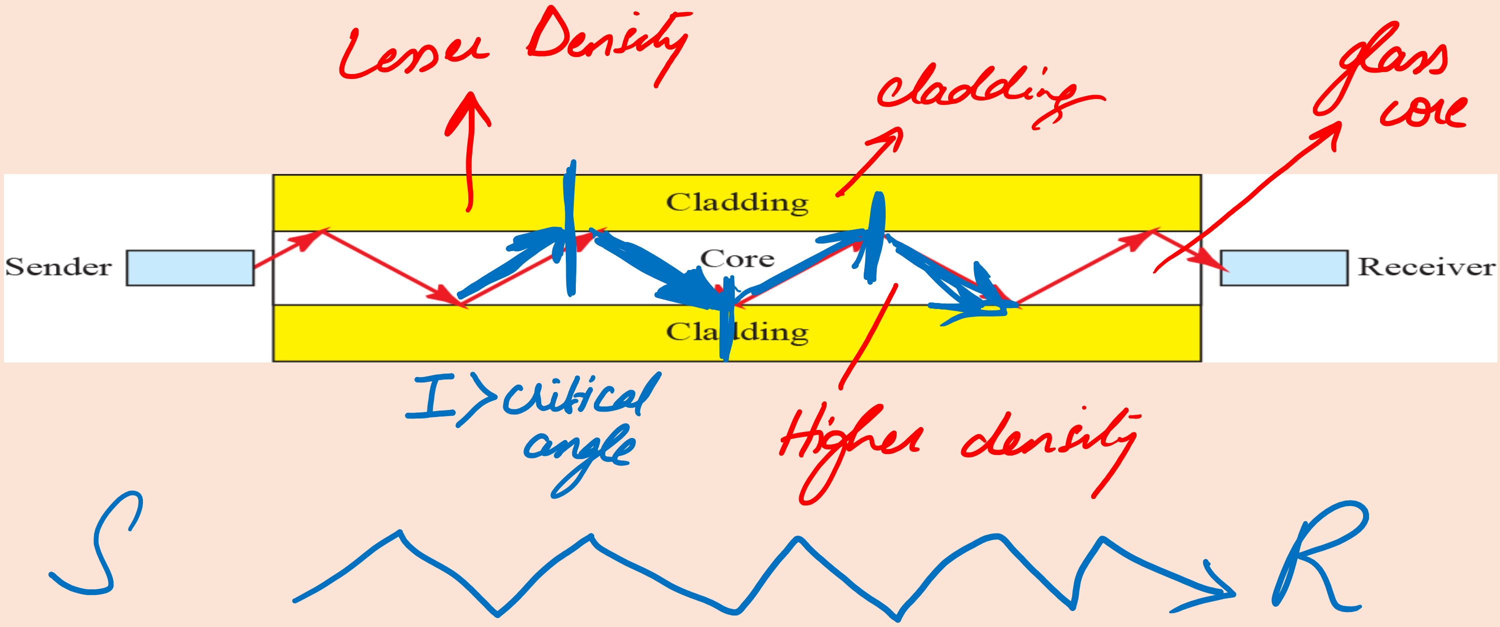




Topic#108

Fiber-Optic Cable

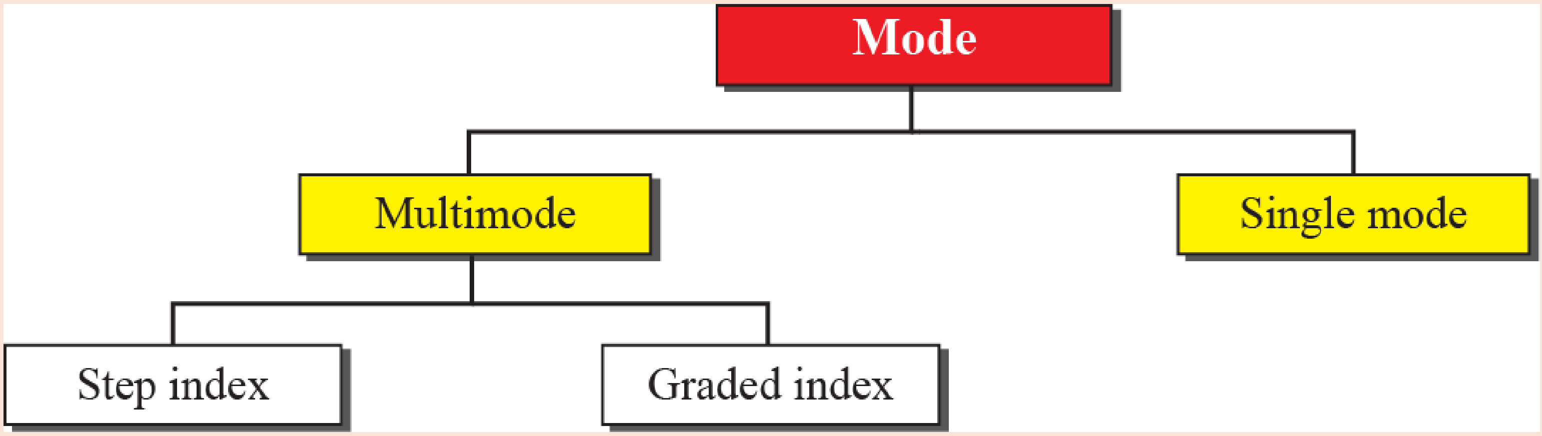
- **Made of glass or plastic and transmits signals in the form of light**
- **Optical Fiber**



Fiber-Optic Cable

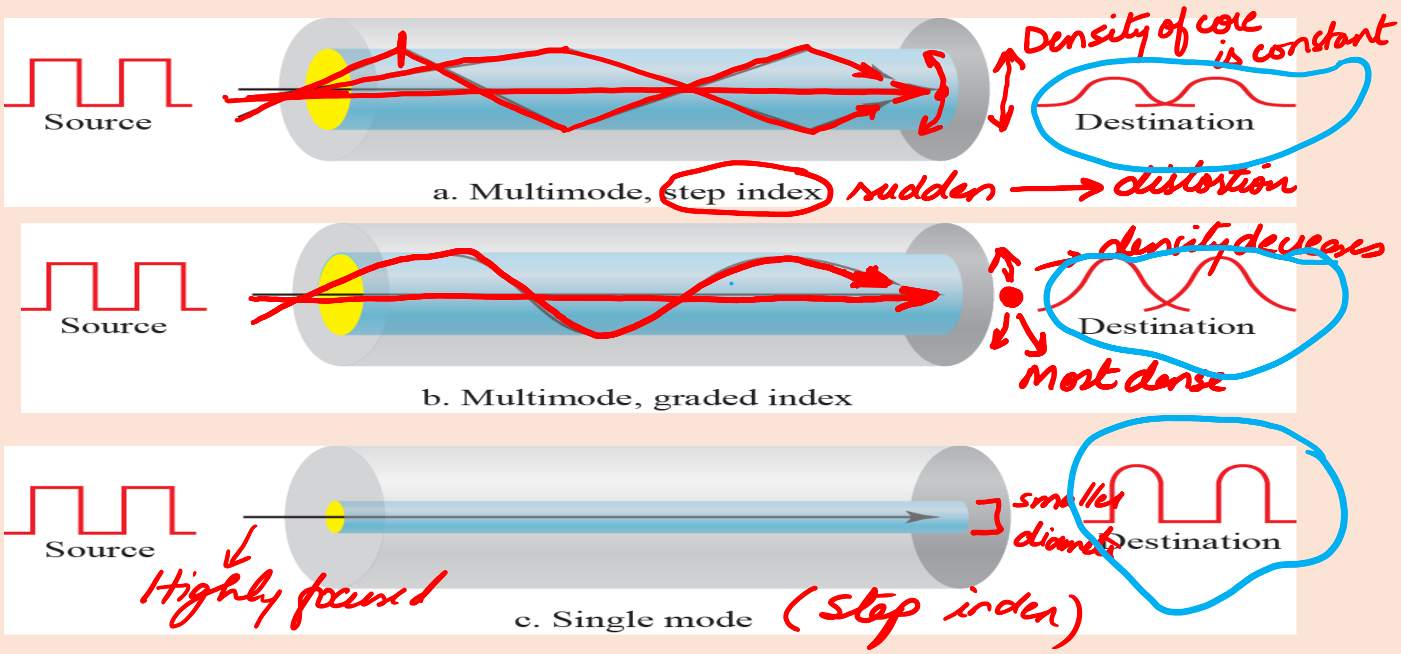
- **Made of glass or plastic and transmits signals in the form of light**

Propagation Modes



Topic#109

Modes



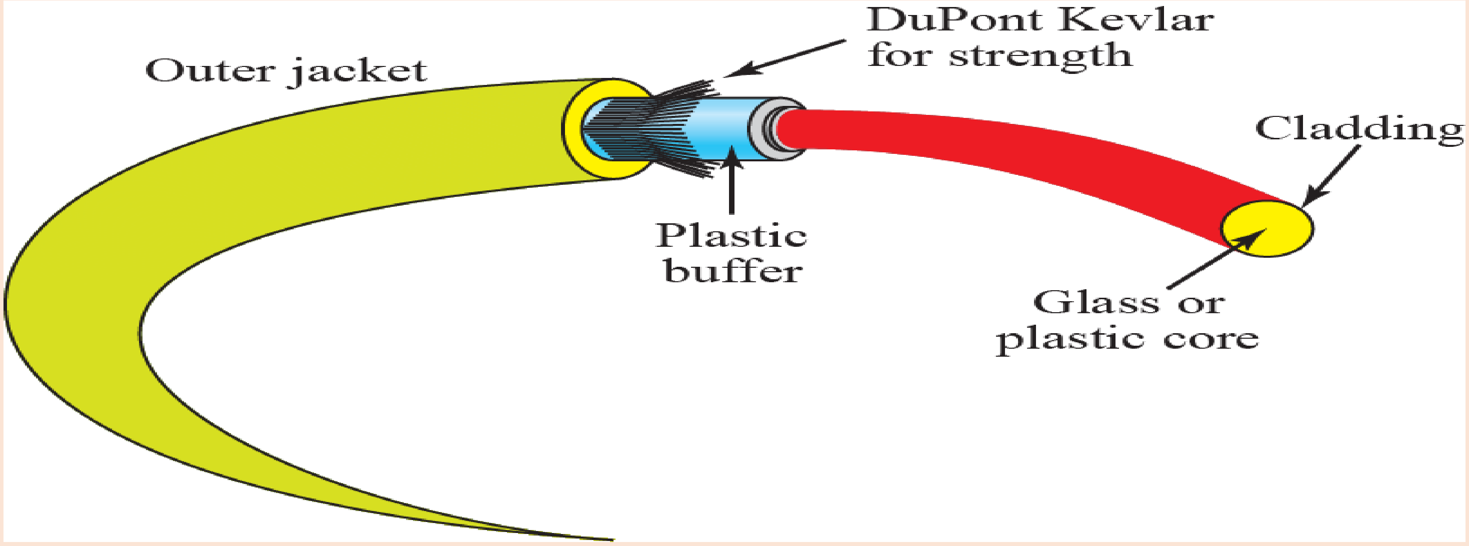
Topic#110

Fiber Types

Type	Core (µm)	Cladding (µm)	Mode
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

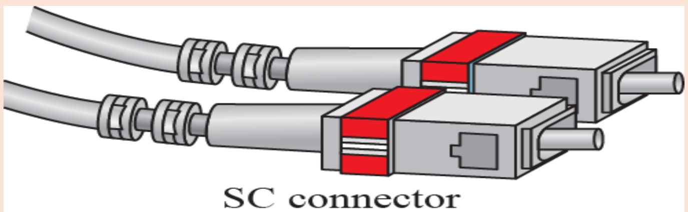
Fiber Composition

A single **fiber** itself is a composite material consisting of cellulose, hemicelluloses, and lignin, with minor amounts of sugars, starch proteins, etc, — it is a three-dimensional biopolymer. The performance of a natural **fiber** depends on several factors, such as its chemical **composition** and physical properties [8]

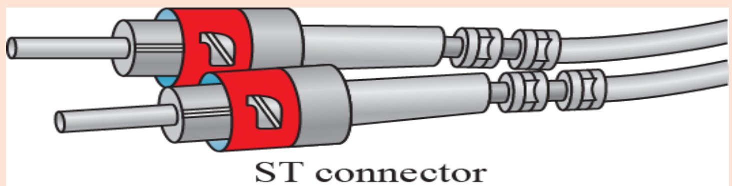


Fiber-Optic Cable Connector:

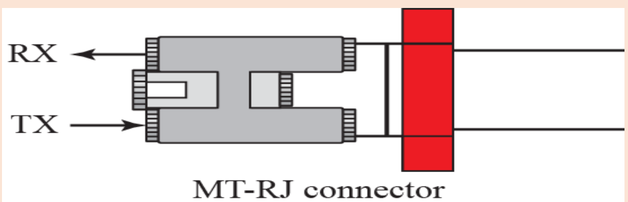
An optical fiber connector terminates the end of an optical fiber, and enables quicker connection and disconnection than splicing. The connectors mechanically couple and align the cores of fibers so light can pass. Better connectors lose very little light due to reflection or misalignment of the fibers.



Cable TV



Networking Routers



Optical Fiber Performance

As a beam of light, that holds signals, travels through the central region of the **fiber optic**, the light's power decreases. ... Therefore, the connection strength becomes more diminished. This decrease in light energy is commonly known as **fiber optic** loss or attenuation.

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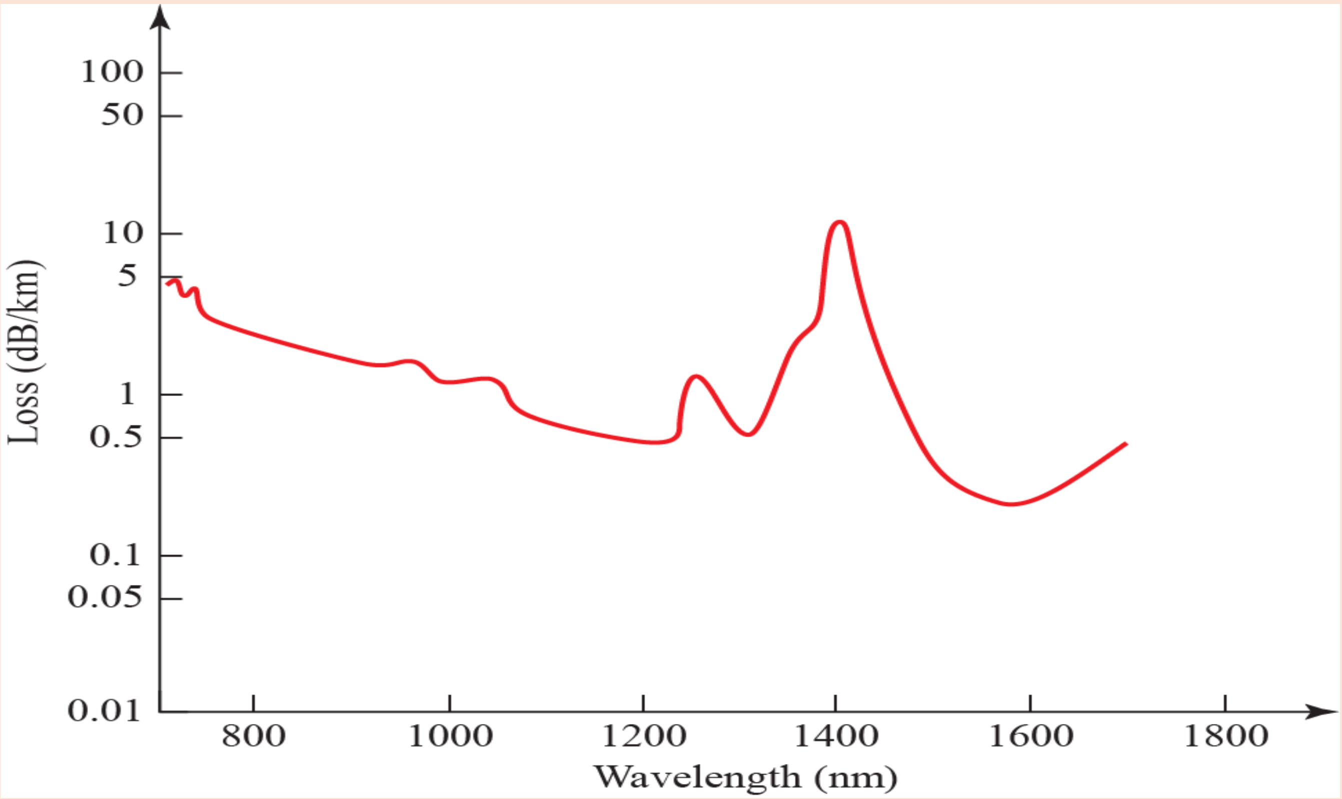

Advantages & Disadvantages

- **Higher Bandwidth**
- **Less Attenuation**
- **Less EM Interference**
- **Light Weight**
- **Less corrosive than copper**
- **Installation/Maintenance**
- **Unidirectional**
- **Cost**

Topic# 111

Unguided Media

Unguided medium transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication. Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them.

- **Unguided medium transport waves without using a physical conductor**
- **Often referred to wireless communication**

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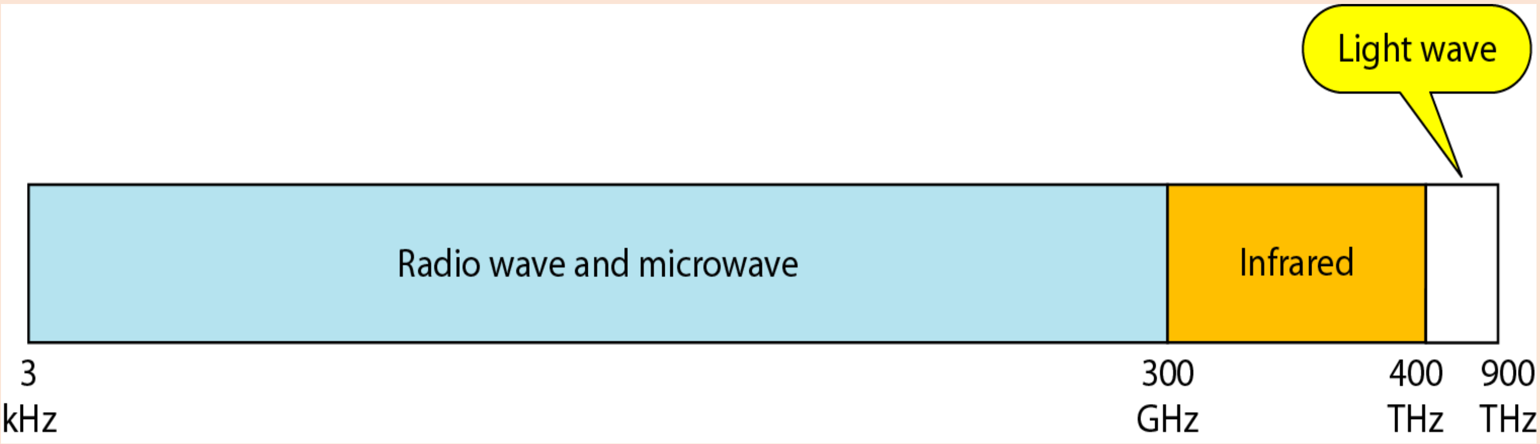
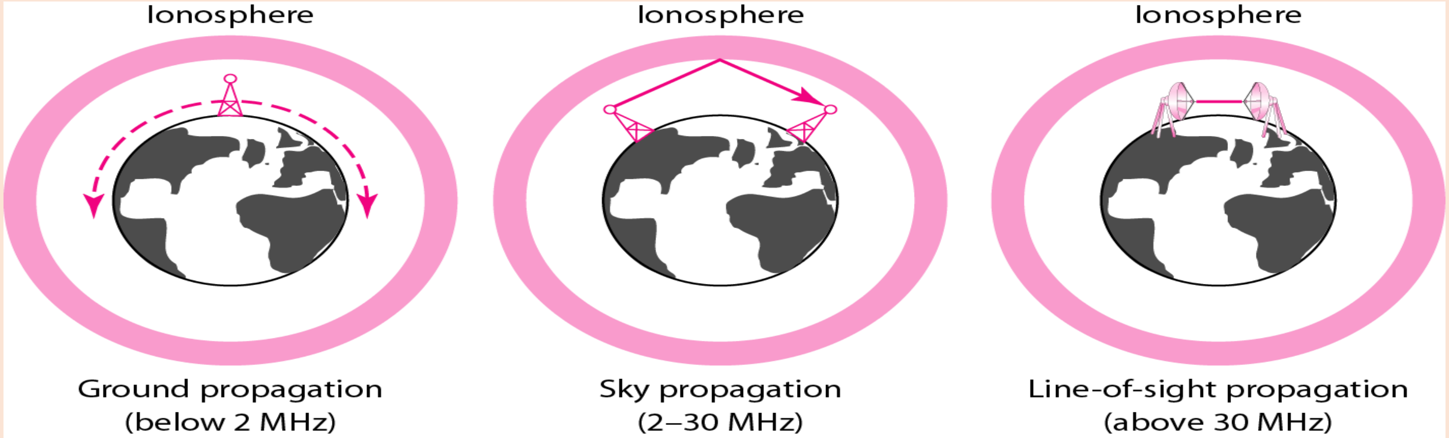
- **Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them**

Electromagnetic Spectrum



The **Electromagnetic Spectrum**. The **electromagnetic** (**EM**) **spectrum** is the range of all types of **EM** radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of **electromagnetic** radiation.



Bands

middle frequency (MF)	300 kHz–3 MHz	Sky	AM radio
high frequency (HF)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft
very high frequency (VHF)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
ultrahigh frequency (UHF)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
superhigh frequency (SF)	3–30 GHz	Line-of-sight	Satellite
extremely high frequency (EHF)	30–300 GHz	Line-of-sight	Radar, satellite

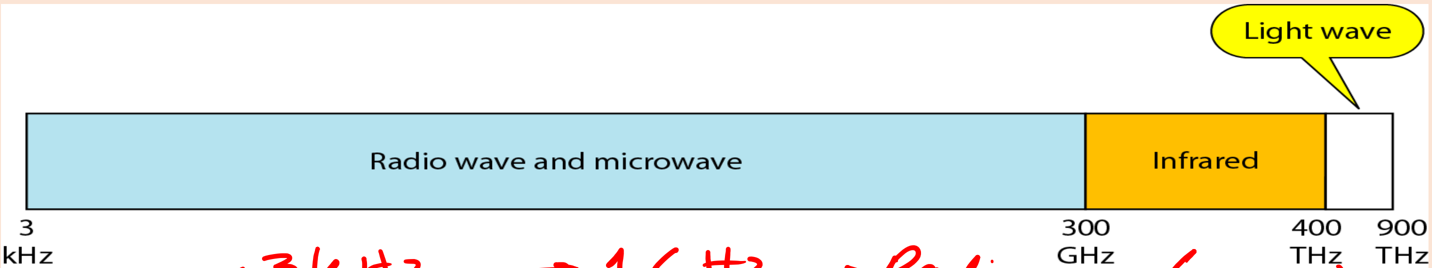
Topic #112

Radio waves are a type of electromagnetic radiation best-known for their use in communication technologies, such as television, mobile phones and radios. These devices receive **radio waves** and convert them to mechanical vibrations in the speaker to create sound **waves**.

- **Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves**
- **Electromagnetic waves ranging in frequencies between 1 and 300 GHz are called microwaves**

Electromagnetic Spectrum

The **Electromagnetic Spectrum**. The **electromagnetic** (**EM**) **spectrum** is the range of all types of **EM** radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of **electromagnetic** radiation.



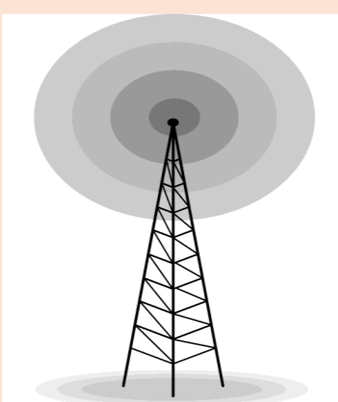
3KHz → 1GHz → Radio waves (narrow)

Sub-bands

1GHz → 3GHz → Microwaves

Omnidirectional Antenna

In radio communication, an **omnidirectional antenna** is a class of **antenna** which radiates equal radio power in all directions perpendicular to an axis (azimuthal directions), with power varying with angle to the axis (elevation angle), declining to zero on the axis.



AM
FM } Radio
TV
cordless phones, pagers

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Topic# 113

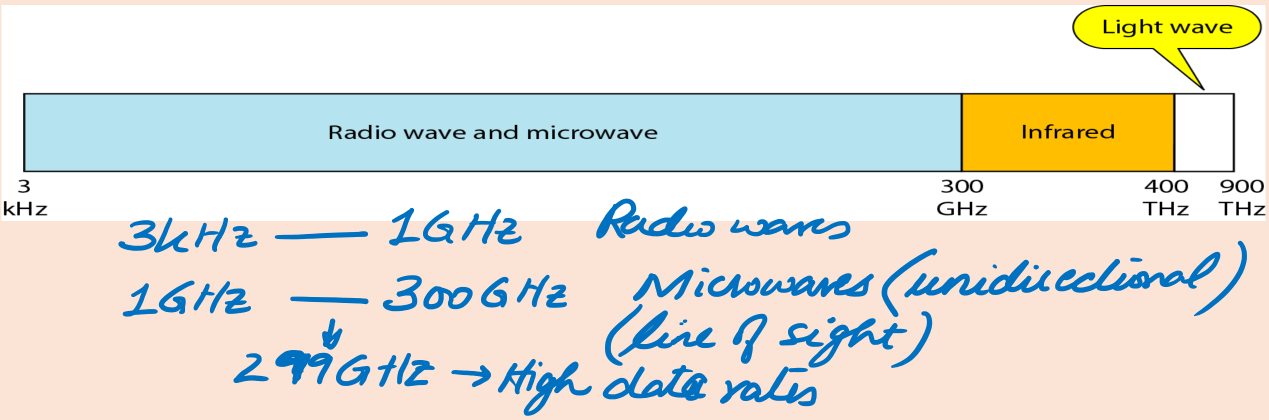
Microwaves

Microwave is a form of electromagnetic radiation with wavelengths ranging from about one meter to one millimeter; with frequencies between 300 MHz (1 m) and 300 GHz (1 mm). Different sources define different frequency ranges as **microwaves**; the above broad definition includes both UHF and EHF (millimeter wave) bands.

- **Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves**
- **Microwaves are unidirectional**
- **When an antenna transmits microwaves, they can be narrowly focused**

Electromagnetic Spectrum

The **Electromagnetic Spectrum**. The **electromagnetic** (**EM**) **spectrum** is the range of all types of **EM** radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of **electromagnetic** radiation.



Unidirectional Antennas

A **unidirectional antenna** focuses the radiofrequency (RF) energy in one or two directions which lowers the **beamwidth** and overall area covered, but increases the strength of the signal and distance covered in that direction. In fact, an indoor 14dBi directional antenna can reach up to 3.2km indoors and 6.4km outdoors! However, for these antennas to work optimally they have to be pointed directly at the receivers so that the signal can be detected – this can make installation a difficult process.

Infrared

Infrared radiation (IR), or **infrared** light, is a type of radiant energy that's invisible to human eyes but that we can feel as heat. All objects in the universe emit some level of IR radiation, but two of the most obvious sources are the sun and fire.

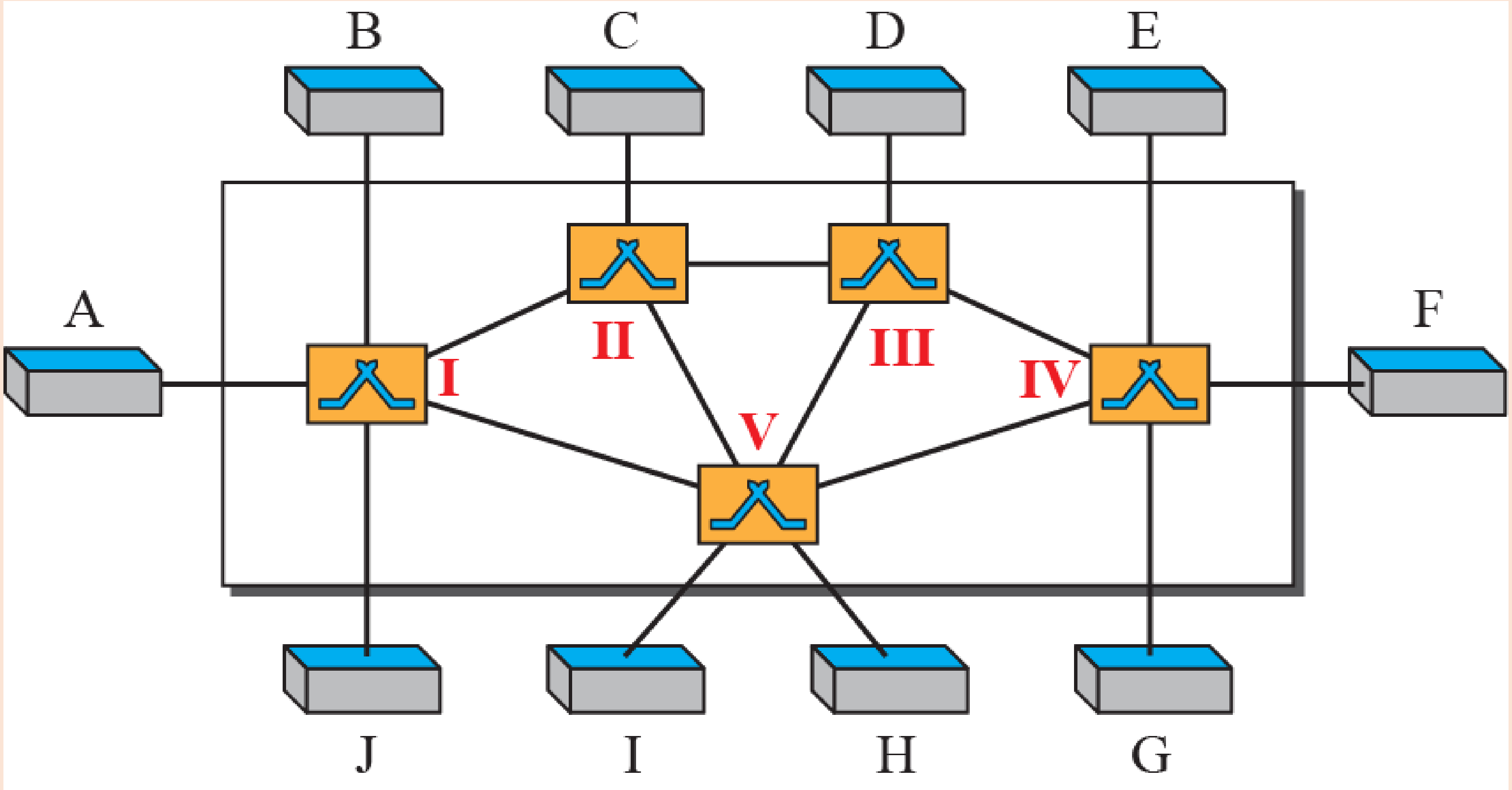
- **Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication**
- **Infrared waves, having high frequencies, cannot penetrate walls**
- **Prevents interference between one system and another**

Topic# 114

Switching

Switching is process to forward packets coming in from one port to a port leading towards the destination. When data comes on a port it is called ingress, and when data leaves a port or goes out it is called egress. A communication system may include number of **switches** and nodes.

Switched Network



Three Methods of Switching

- **Three Methods:**
  - ✓ **Circuit Switching**
  - ✓ **Packet Switching**
  - ✓ **Message switching**
- **The first two are commonly used today**
- **The third has been phased out in general communications**

Topic# 115

Three Methods of Switching

- **Three Methods:**
  - ✓ **Circuit Switching**
  - ✓ **Packet Switching**

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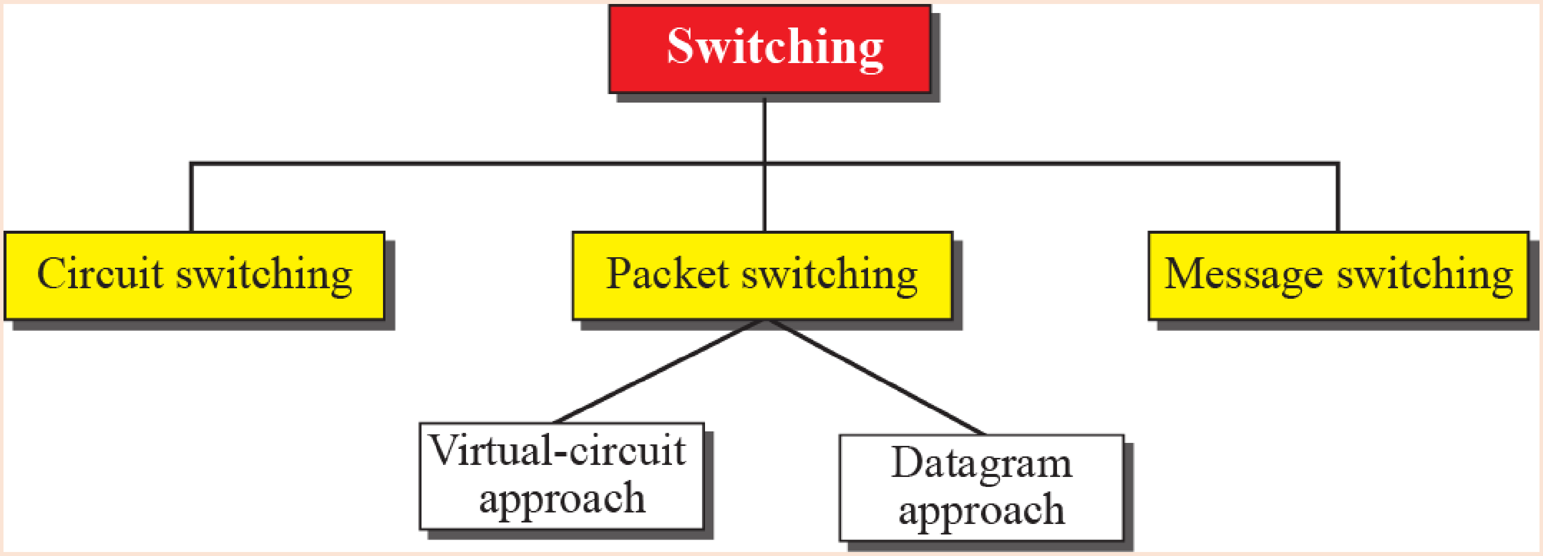
✓ Message switching

- The first two are commonly used today
- The third has been phased out in general communications

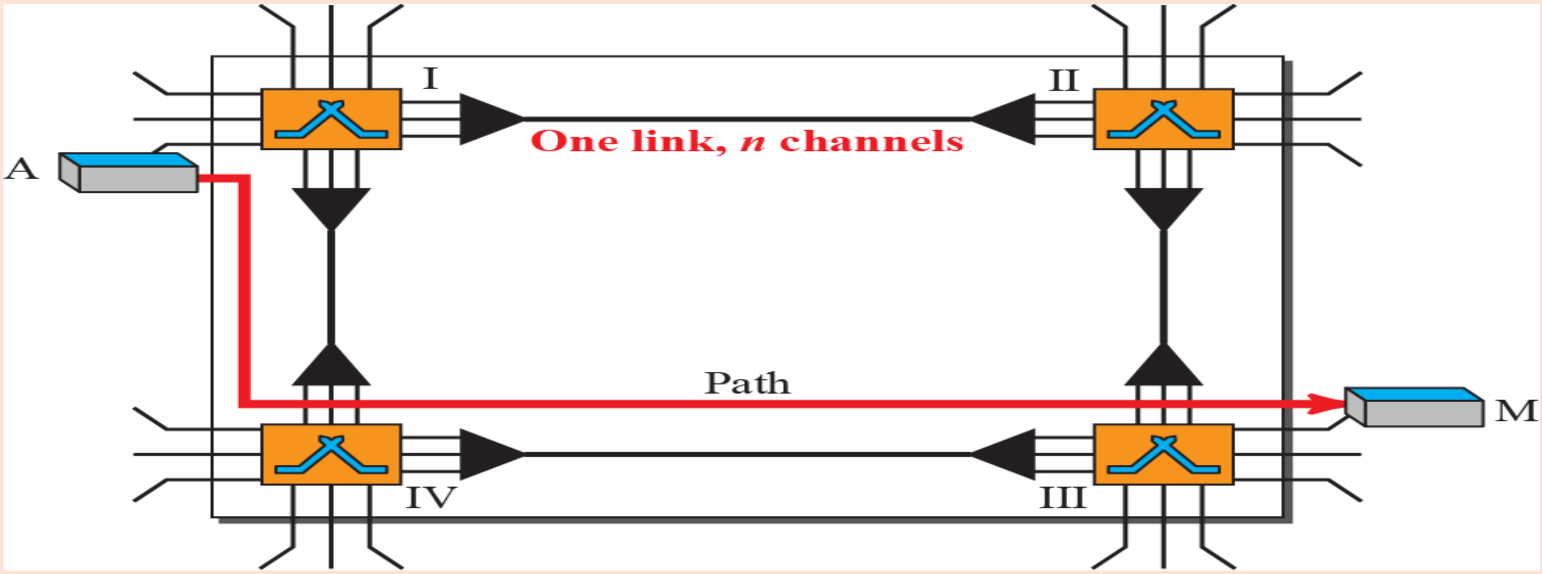
Taxonomy of Switched Networks



Circuit-switched Networks

- A set of switches connected by physical links
- A connection between two stations is a dedicated path made of one or more links
- Each connection uses only one dedicated channel on each link
- Each link is normally divided into n channels by using FDM or TDM
- A set of switches connected by physical links

A Circuit-Switched Network



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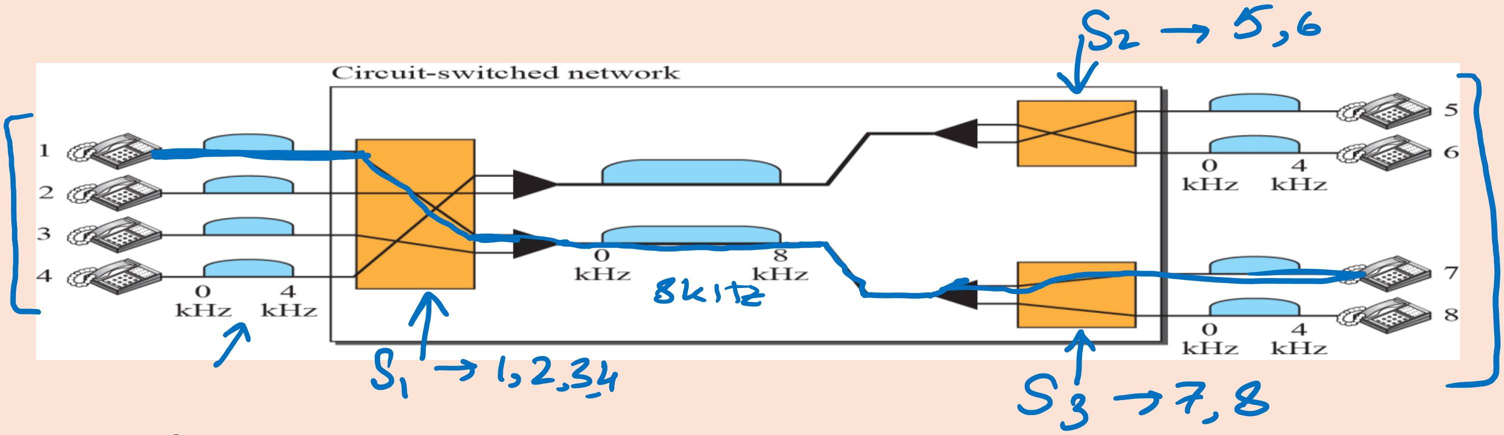
Topic# 116

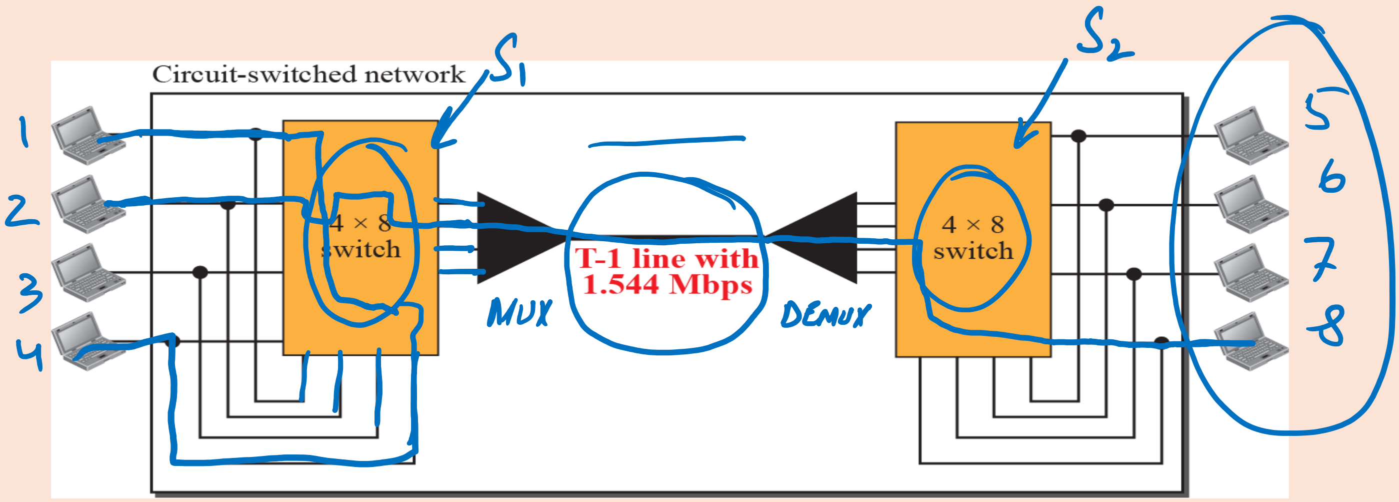
Example:

As a trivial example, let us use a circuit-switched network to connect eight telephones in a small area. Communication is through 4-kHz voice channels. We assume that each link uses FDM to connect a maximum of two voice channels. The bandwidth of each link is then 8 kHz.



Example:

As another example, consider a circuit-switched network that connects computers in two remote offices of a private company. The offices are connected using a T-1 line leased from a communication service provider. There are two 4 × 8 (4 inputs and 8 outputs) switches in this network.

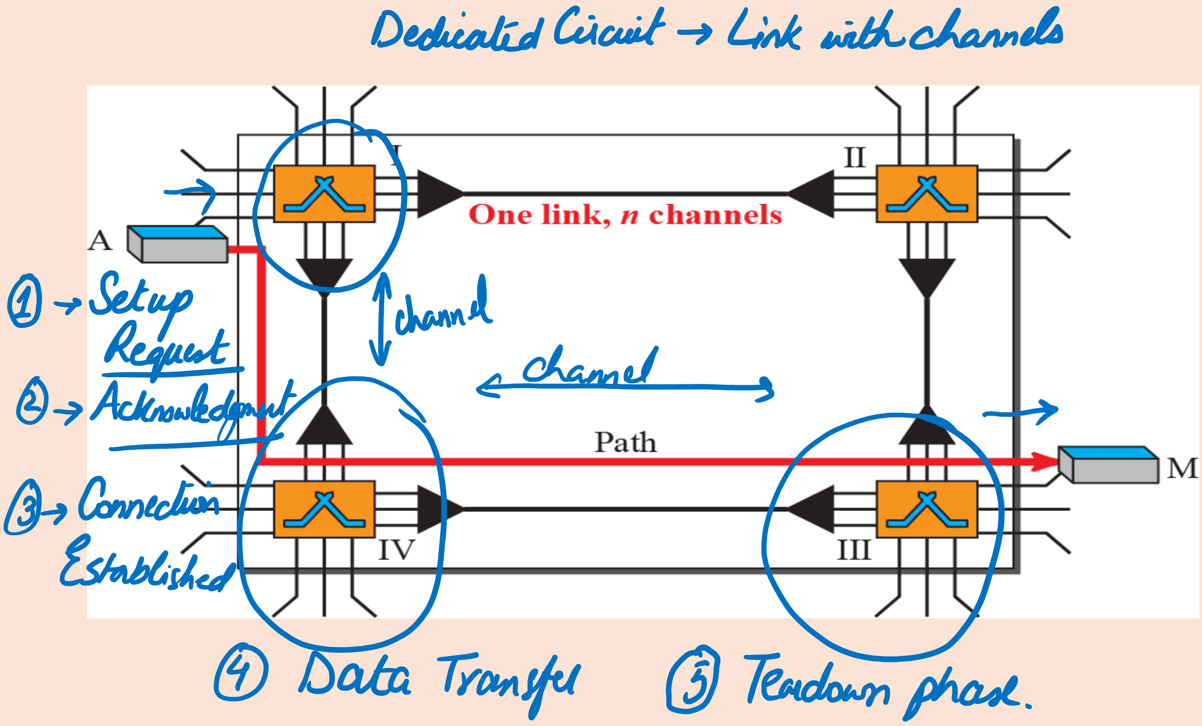


Topic# 117

Three Phases in a Circuit Switched Network

- **The actual communication in a circuit-switched network requires 3 phases:**
  - ✓ **Connection Setup**
  - ✓ **Data Transfer**
  - ✓ **Connection Teardown**

Three Phases in a Circuit Switched Network



Topic#118:

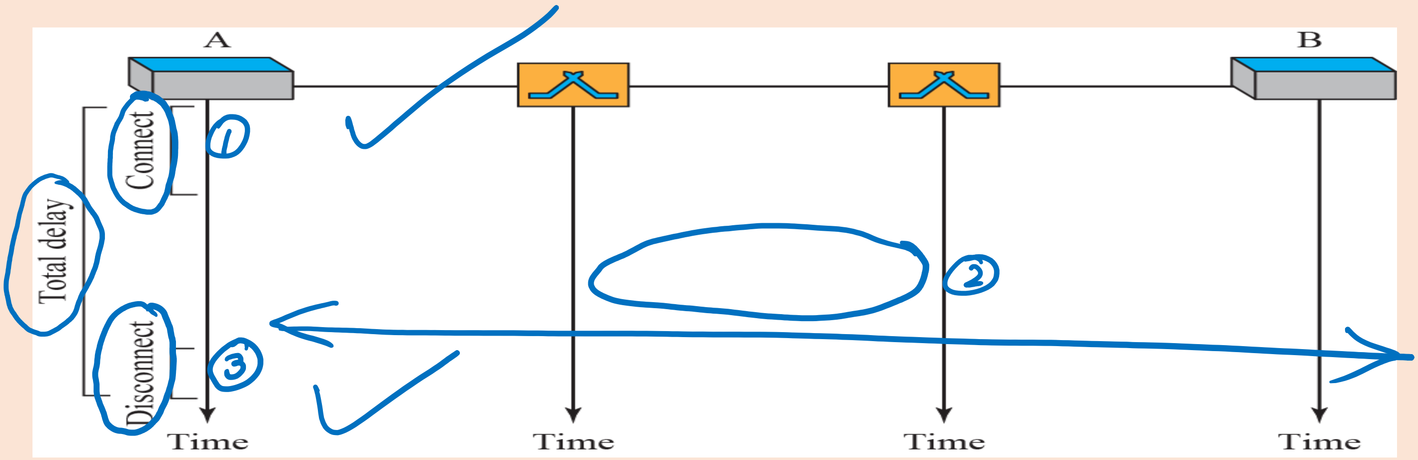
Efficiency of a Circuit-Switched Network

- **Not as efficient as packet switching because resources are allocated during the entire duration of the connection and these resources are unavailable to other connections**
- **In a telephone network, people normally terminate the communication when they have finished their conversation**
- **Data Network is an issue**

Delay in a Circuit-Switched Network

- **Circuit switched networks have low efficiency but minimal delay**
- **Data is not delayed at each switch; the resources are allocated for the duration of the connection**

Delay in a Circuit-Switched Network



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Topic # 119

Packet Switching

Packet switching is the transfer of small pieces of data across various networks. These data chunks or “**packets**” allow for faster, more efficient data transfer. Often, when a user sends a file across a network, it gets transferred in smaller data **packets**, not in one piece.

- **If the message is going to pass through a packet-switched network, it needs to be divided into packets of fixed or variable size**
- **The size of the packet is determined by the network and the governing protocol**

Datagram Networks

Datagram networks

Featured snippet from the web

A **datagram** is a basic transfer unit associated with a packet-switched **network**. ... **Datagrams** provide a connectionless communication service across a packet-switched **network**. The delivery, arrival time, and order of arrival of **datagrams** need not be guaranteed by the **network**.

- **Each packet is treated independently of all others.**
- **Even if a packet is part of a multi-packet transmission, the network treats it as though it existed alone**
- **Packets are referred to as datagrams**

Virtual-Circuit Networks

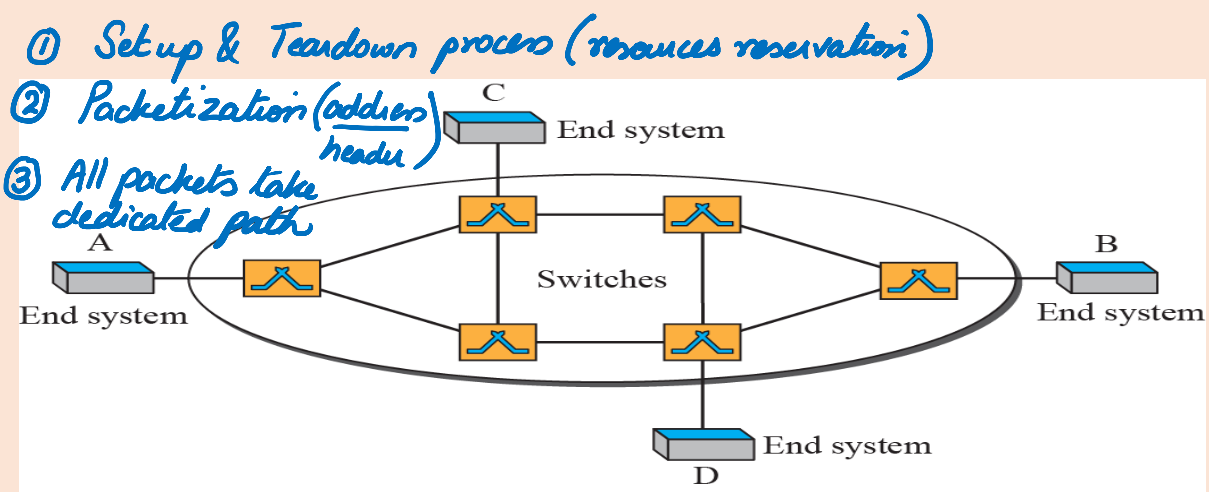
A **virtual circuit** (VC) is a means of transporting data over a packet-switched **network** in such a way that it appears as though there is a dedicated physical link between the source and destination end systems of this data. The term **virtual circuit** is synonymous with **virtual** connection.

- **A virtual-circuit network is a cross between a circuit-switched network and a datagram network**

Topic # 120

Virtual-Circuit Networks

- **A virtual-circuit network is a cross between a circuit-switched network and a datagram network**



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Topic # 121

Virtual-Circuit Networks

A virtual-circuit network is a cross between a circuit-switched network and a datagram network

Physical → Circuit Switching (Set up, Transfer & Teardown)

Data Link Layer → Virtual Circuit Approach (Set up, Transfer & Teardown Packets (Frames))

Network Layer → Datagram Switching (Independent Datagrams or Packets)

Topic # 122

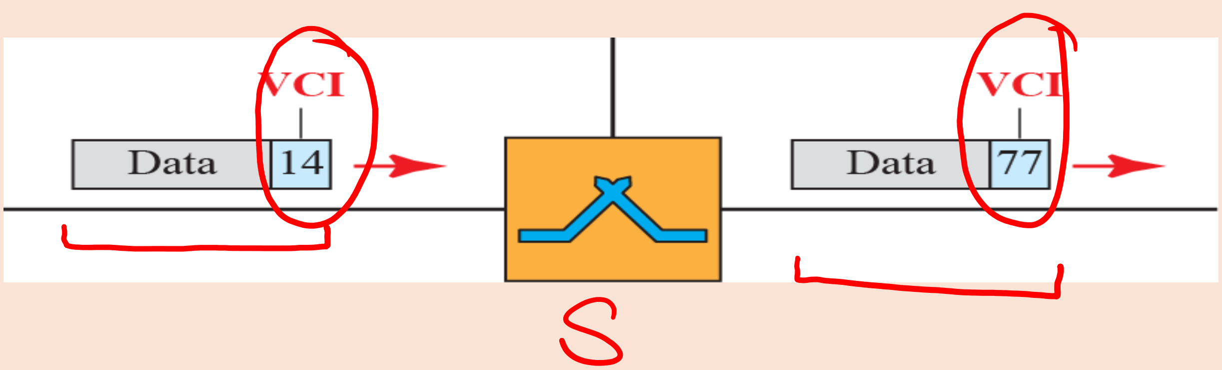
Virtual-Circuit Networks

A virtual-circuit network is a cross between a circuit-switched network and a datagram network

Virtual-Circuit Identifier

A **virtual circuit identifier** (VCID) is a type of numeric **identifier** used to distinguish between different **virtual circuits** in a connection-oriented **circuit**-switched telecommunication network. It enables a **circuit**-switched network to identify different **virtual circuits**/channels involved in a device's data communication.

VCI (label) → local switch scope



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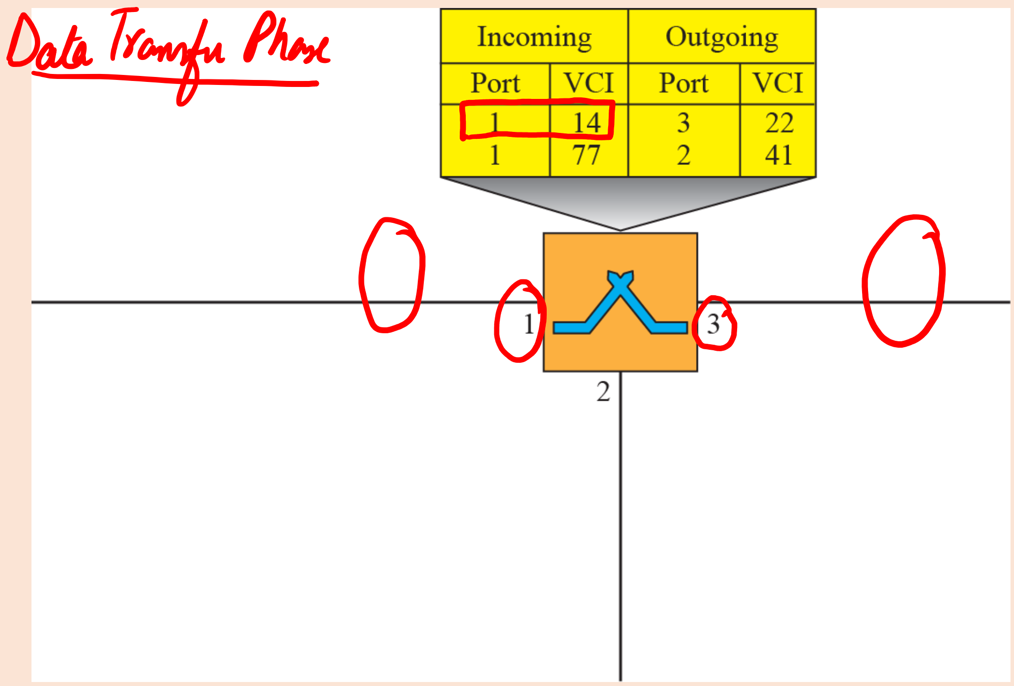
Switch & table for a virtual-circuit network

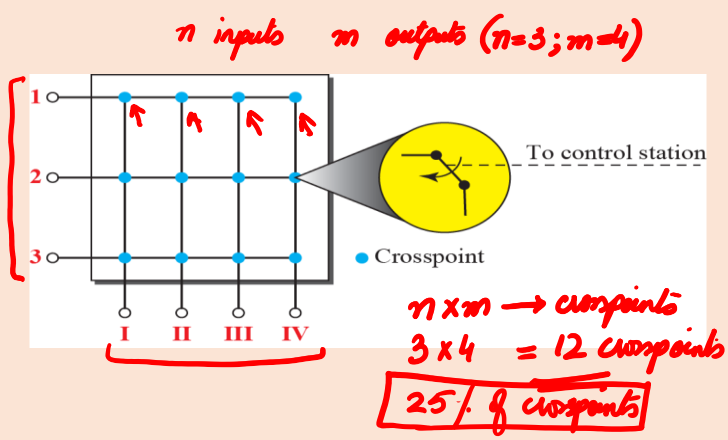


Topic# 123

Structure of A Circuit Switch

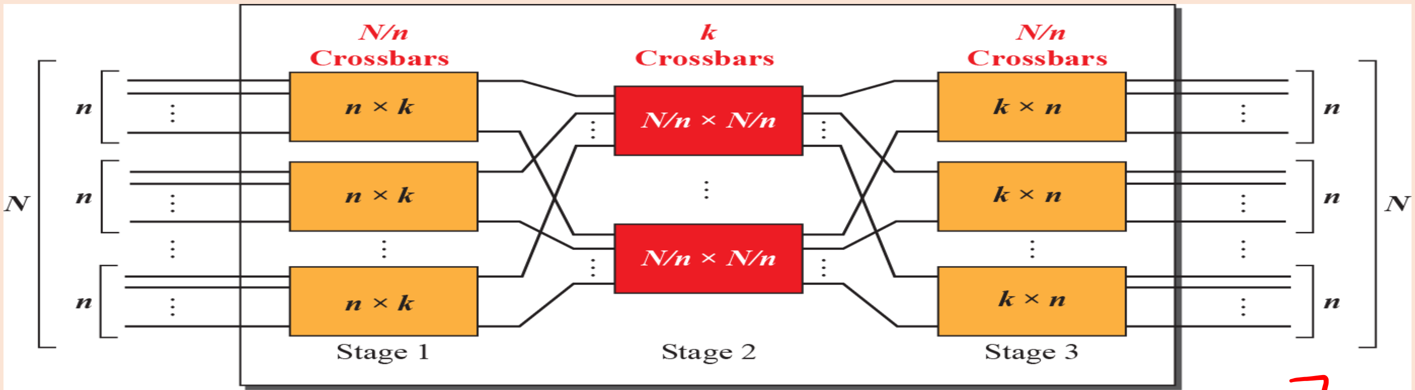
- **Circuit switching today can use either of two technologies:**
    - ✓ **The Space-Division switch**
    - ✓ **The Time-Division switch**

Crossbar switch with 3 inputs & 4 outputs



Multistage Switch

$N \times N$ crosspoints

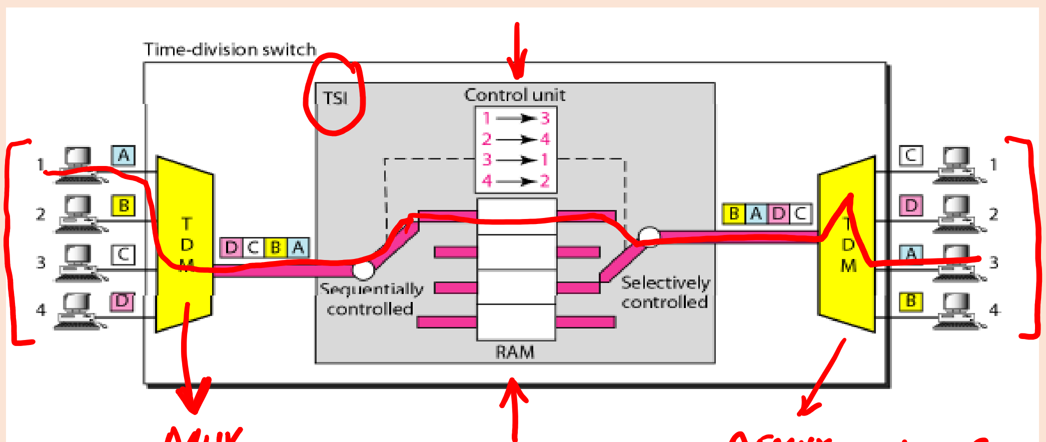


No. of crosspoints $\Rightarrow 2kN + k\left(\frac{N}{n}\right)^2$ → lesser

" " " $\Rightarrow N^2$

Time-Division Switch

- **Uses TDM inside a switch**
- **Most popular technology is Time-Slot Interchange (TSI)**



memory locations ↕ time slots

1 → 3
2 → 4
3 → 1
4 — 2

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If you have any question

then contact on this email:

Ar8758451@gmail.com

Thank You

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