

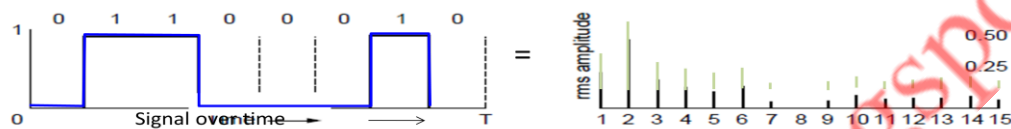
## UNIT -2

### Physical Layer:

### Fourier Analysis

- A time-varying signal can be equivalently represented as a series of frequency components (harmonics) or the sum of sines and cosines:

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



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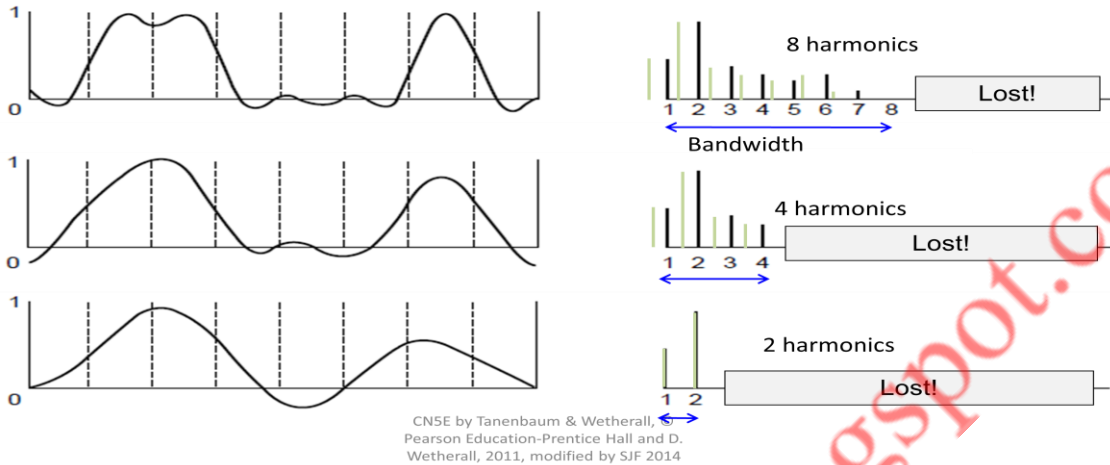
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- Transmitted signals lose some power as they are transmitted.
- For a wire, amplitudes are transmitted mostly undiminished from 0 up to some frequency  $f$ . Frequencies above this frequency  $f$  are attenuated (reduced).
- The width of this frequency range is called the **bandwidth**.
  - Baseband run from 0 to some max frequency
  - Passband- shifted to occupy higher frequencies such as wireless

### Bandwidth

- Bandwidth is a physical property of the transmission medium such as the construction, thickness and length of the wire or fiber.
- Limiting the bandwidth, limits the data rate.
- Goal for digital transmission is to receive a signal with enough fidelity to reconstruct the sequence of bits that was sent.
- Bandwidth – to Electrical Engineers –(analog) means – a quantity measured in Hz ( cycles per second)
- Bandwidth – to Computer Scientists – (digital) means – the maximum data rate of a channel ( bits/second)

## Bandwidth-Limited Signals



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## Maximum Data Rate of a Channel

- Nyquist's theorem relates the data rate to the bandwidth (B) and number of signal levels (V):

$$\text{Max. data rate} = 2B \log_2 V \text{ bits/sec}$$

- Shannon's theorem relates the data rate to the bandwidth (B) and signal strength (S) relative to the noise (N):

$$\text{Max. data rate} = B \log_2 (1 + S/N) \text{ bits/sec}$$

How fast signal  
can change

How many levels  
can be seen

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## Transmission Media

### Transmission Media – Guided

There are several types of cable which are commonly used with LANs. In some cases, a network will utilize only one type of cable, other networks will use a variety of cable types. The type of cable chosen for a network is related to the network's topology, protocol, and size. Understanding the characteristics of different types of cable and how they relate to other aspects of a network is necessary for the development of a successful network.

- Unshielded Twisted Pair (UTP) Cable
- Shielded Twisted Pair (STP) Cable
- Coaxial Cable
- Fiber Optic Cable

### **Unshielded Twisted Pair (UTP) Cable**

Twisted pair cabling comes in two varieties: shielded and unshielded. Unshielded twisted pair (UTP) is the most popular and is generally the best option for school networks.



Figure 2.1 Unshielded Twisted Pair

The quality of UTP may vary from telephone-grade wire to extremely high-speed cable. The cable has four pairs of wires inside the jacket. Each pair is twisted with a different number of twists per inch to help eliminate interference from adjacent pairs and other electrical devices.

The tighter the twisting, the higher the supported transmission rate and the greater the cost per foot. The EIA/TIA (Electronic Industry Association / Telecommunication Industry Association) has established standards of UTP and rated five categories of wire.

Type	Use
Category 1	Voice Only (Telephone Wire)
Category 2	Data to 4 Mbps (LocalTalk)
Category 3	Data to 10 Mbps (Ethernet)
Category 4	Data to 20 Mbps (16 Mbps Token Ring)
Category 5	Data to 100 Mbps (Fast Ethernet)

Table Categories of Unshielded Twisted Pair

## Unshielded Twisted Pair Connector

The standard connector for unshielded twisted pair cabling is an RJ-45 connector. This is a plastic connector that looks like a large telephone-style connector (See fig. 2.2). a slot allows the RJ-45 to be inserted only one way. RJ stands for Registered Jack, implying that the connector follows a standard borrowed from the telephone industry. This standard designates which wire goes with each pin inside the connector.

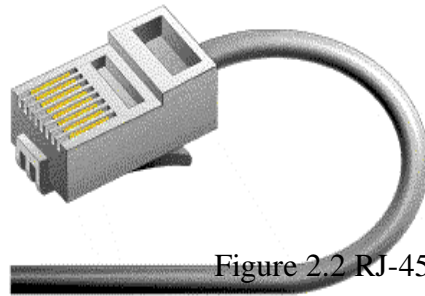


Figure 2.2 RJ-45

## Shielded Twisted Pair (STP) Cable

A disadvantage of UTP is that it may be susceptible to radio and electrical frequency interference. Shielded twisted pair (STP) is suitable for environments with electrical interference; however, the extra shielding can make the cables quite bulky. Shielded twisted pair is often used on networks using Token Ring topology.

## Coaxial Cable

Coaxial cabling has a single copper conductor at its center. A plastic layer provides insulation between the center conductor and the braided metal shield (See fig. 3). The metal shield helps to block any outside interference from fluorescent lights, motors, and other computers.

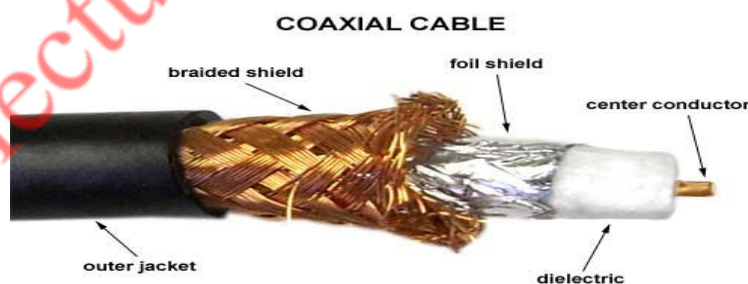


Fig. 2.3 Coaxial cable

Although coaxial cabling is difficult to install, it is highly resistant to signal interference. In addition, it can support greater cable lengths between network devices than twisted pair cable. The two types of coaxial cabling are thick coaxial and thin coaxial.

Thin coaxial cable is also referred to as thinnet. 10base2 refers to the specifications for thin coaxial cable carrying Ethernet signals. The 2 refers to the approximate maximum segment length being 200 meters. In actual fact the maximum segment length is 185 meters. Thin coaxial cable is popular in school networks, especially linear bus networks.

Thick coaxial cable is also referred to as thicknet. 10base5 refers to the specifications for thick coaxial cable carrying Ethernet signals. The 5 refers to the maximum segment length being 500 meters. Thick coaxial cable has an extra protective plastic cover that helps keep moisture away from the center conductor. This makes thick coaxial a great choice when running longer lengths in a linear bus network. One disadvantage of thick coaxial is that it does not bend easily and is difficult to install.

### 2.1.3 Fiber Optic Cable

Fiber optic cabling consists of a center glass core surrounded by several layers of protective materials. It transmits light rather than electronic signals eliminating the problem of electrical interference.

This makes it ideal for certain environments that contain a large amount of electrical interference. It has also made it the standard for connecting networks between buildings, due to its immunity to the effects of moisture and lighting.

Fiber optic cable has the ability to transmit signals over much longer distances than coaxial and twisted pair. It also has made it the standard for connecting networks between buildings, due to its immunity to the effects of moisture and lighting.

Fiber optic cable has the ability to transmit signals over much longer distances than coaxial and twisted pair. It also has the capability to carry information at vastly greater speeds. This capacity broadens communication possibilities to include services such as video conferencing and interactive services. The cost of fiber optic cabling is comparable to copper cabling; however it is more difficult to install and modify. 10BaseF refers to the specifications for fiber optic cable carrying Ethernet signals.

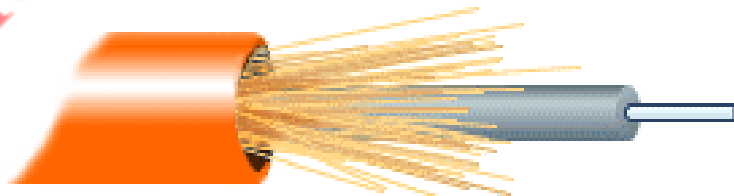


Fig. 2.5 Fiber Optic Cable

Facts about fiber optic cables:

- Outer insulating jacket is made of Teflon or PVC.
- Kevlar fiber helps to strengthen the cable and prevent breakage.
- A plastic coating is used to cushion the fiber center.
- Center (core) is made of glass or plastic fibers.

### **Fiber Optic Connector**

The most common connector used with fiber optic cable is an ST connector. It is barrel shaped, similar to a BNC connector. A newer connector, the SC, is becoming more popular. It has a squared face and is easier to connect in a confined space.

Specification	Cable Type	Maximum length
10BaseT	Unshielded Twisted Pair	100 meters
10Base2	Thin Coaxial	185 meters
10Base5	Thick Coaxial	500 meters
10BaseF	Fiber Optic	2000 meters
100BaseT	Unshielded Twisted Pair	100 meters
100BaseTX	Unshielded Twisted Pair	220 meters

Table 2.2 Ethernet Cable Summary

## **2.2 Transmission Media – Unguided**

Unguided transmission media is data signals that flow through the air. They are not guided or bound to a channel to follow.

Unguided media 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 receiving them. Unguided signals can travel from the source to destination in several ways: ground propagation, sky propagation, and line-of-sight propagation.

In **ground propagation**, radio waves travel through the lowest portion of the atmosphere, hugging the earth. These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the planet. Distance depends on the amount of power in the signal: *The greater the power, the greater the distance*. Ground waves have carrier frequencies up to 2 MHz. AM radio is an example of ground wave propagation.

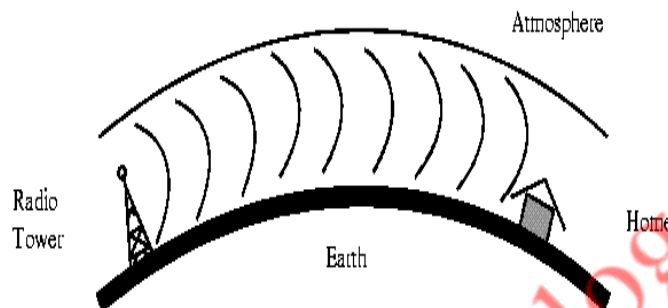


Fig. 2.6 Ground Wave Propagation

In **sky propagation**, higher frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where the particles exist as ions) where they are reflected back to the earth. This type of transmission allows for greater distances with lower output power.

It is sometimes called double hop propagation. It operates in the frequency range of 30 – 85 MHz. Because it depends on the earth's ionosphere, it changes with the weather and time of day. The signal bounces off of the ionosphere and back to the earth. Ham radios operate in this range. Other books called this **ionospheric propagation**.

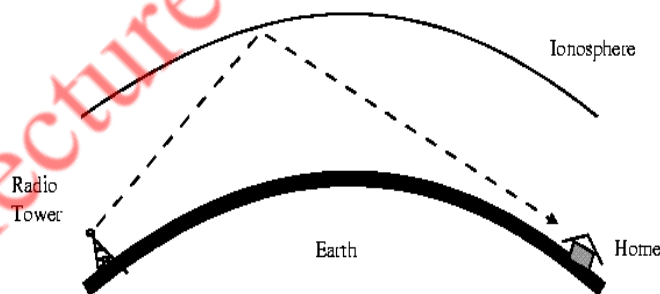


Fig. 2.7 Ionospheric Propagation

In **line-of-sight propagation**, very high-frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other and either tall enough or close enough together not to be affected by the curvature the earth. Line-of-sight propagation is tricky because radio transmission cannot be completely focused.



It is sometimes called space waves or tropospheric propagation. It is limited by the curvature of the earth for ground-based stations (100 km, from horizon to horizon). Reflected waves can cause problems. Examples are: FM radio, microwave and satellite.

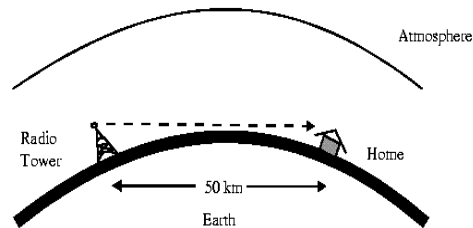


Fig. 2.8 Line-of-sight Propagation

The section of the electromagnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called bands, each regulated by government authorities. These bands are rated from very low frequency (VLF) to extremely high frequency (EHF).

Band	Range	Propagation	Application
VLF (very low frequency)	3-30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30-300 kHz	Ground	Radio beacons and navigation locator
MF (middle frequency)	300 kHz-3 MHz	Sky	AM radio
HF (high frequency)	3-30MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30-300MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz-3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3-30 GHz	Line -of-sight	Satellite communication
EHF (extremely high frequency)	30-300 GHz	Line-of-sight	Radar, satellite

Table 2.3 Bands

We can divide wireless transmission into three broad groups: radio waves, microwaves, and infrared waves.



### **2.2.1 Radio Waves**

Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves.

Radio waves are omnidirectional. When antenna transmits radio waves, they are propagated in all directions. This means that the sending and receiving antennas do not have to be aligned. A sending antenna sends waves that can be received by any receiving antenna.

The omnidirectional property has a disadvantage too. The radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band.

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

### **2.2.2 Microwaves**

Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves.

Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned. The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas. The following describes some characteristics of microwave propagation:

- Microwave propagation is line-of-sight. Since towers with the mounted antennas need to be in direct sight of each other. This also set a limit on the distance between stations depending on the local geography. Towers that are far apart need to be very tall. The curvature of the earth as well as other blocking obstacles does not allow two short towers to communicate by using microwaves. Typically the line of sight due to the Earth's curvature is only 50 km to the horizon. Repeaters are often needed for long-distance communication.
- Very high frequency microwaves cannot penetrate walls. This characteristic can be a disadvantage if receivers are inside the buildings.
- The microwave band is relatively wide, almost 299 GHz. Therefore wider subbands can be assigned, and a high data rate is possible.
- Use of certain portions of the band requires permission from authorities.

### **2.2.3 Infrared Waves**

Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 mm), can be used for short-range communication. Infrared waves, having high frequencies, cannot penetrate walls. This advantageous characteristic prevents interference between one system and another; a short-range communication system in one room cannot be affected by another system in the next room. When we use our infrared remote control, we do not

interfere with the use of the remote of our neighbors. However, this same characteristic makes infrared signals useless for long-range communication. In addition, we cannot use infrared waves outside a building because the sun's rays contain infrared waves that can interfere with the communication.

#### 2.2.4 Satellite

Satellites are transponders (units that receive on one frequency and retransmit on another) that are set in geostationary orbits directly over the equator. These geostationary orbits are 36,000 km from the Earth's surface. At this point, the gravitational pull of the Earth and the centrifugal force of Earth's rotation are balanced and cancel each other out. Centrifugal force is the rotational force placed on the satellite that wants to fling it out into the space.

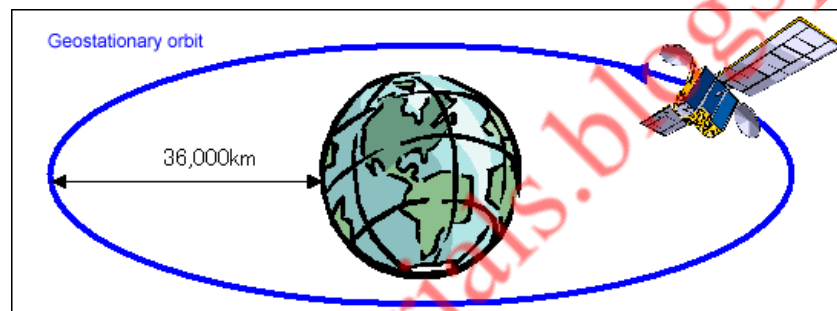


Fig. 2.9 Satellite Communication

The uplink is the transmitter of data to the satellite. The downlink is the receiver of data. Uplinks and downlinks are also called Earth stations because they are located on the Earth. The footprint is the "shadow" that the satellite can transmit to, the shadow being the area that can receive the satellite's transmitted signal.

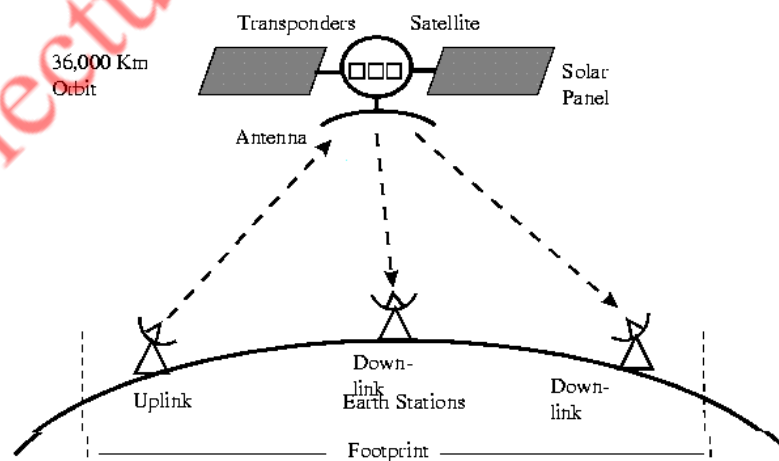


Fig. 2.10 Uplink and Downlink

## Digital Modulation techniques

Digital-to-Analog signals is the next conversion we will discuss in this chapter. These techniques are also called as **Digital Modulation techniques**.

**Digital Modulation** provides more information capacity, high data security, quicker system availability with great quality communication. Hence, digital modulation techniques have a greater demand, for their capacity to convey larger amounts of data than analog modulation techniques.

There are many types of digital modulation techniques and also their combinations, depending upon the need. Of them all, we will discuss the prominent ones.

### ASK – Amplitude Shift Keying

The amplitude of the resultant output depends upon the input data whether it should be a zero level or a variation of positive and negative, depending upon the carrier frequency.

### FSK – Frequency Shift Keying

The frequency of the output signal will be either high or low, depending upon the input data applied.

### PSK – Phase Shift Keying

The phase of the output signal gets shifted depending upon the input. These are mainly of two types, namely Binary Phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK), according to the number of phase shifts. The other one is Differential Phase Shift Keying (DPSK) which changes the phase according to the previous value.

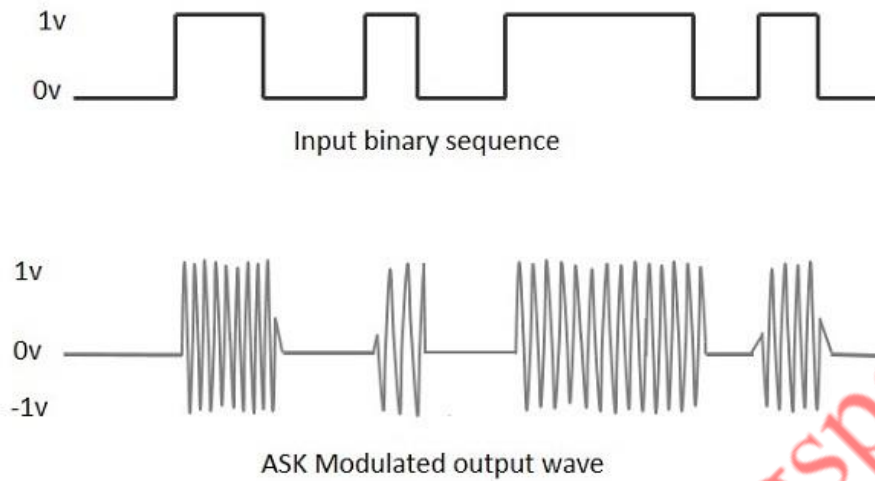
### M-ary Encoding

M-ary Encoding techniques are the methods where more than two bits are made to transmit simultaneously on a single signal. This helps in the reduction of bandwidth.

The types of M-ary techniques are –

- M-ary ASK
- M-ary FSK
- M-ary PSK
- **Amplitude Shift Keying (ASK)** is a type of Amplitude Modulation which represents the binary data in the form of variations in the amplitude of a signal.
- Any modulated signal has a high frequency carrier. The binary signal when ASK modulated, gives a **zero** value for **Low** input while it gives the **carrier output** for **High** input.

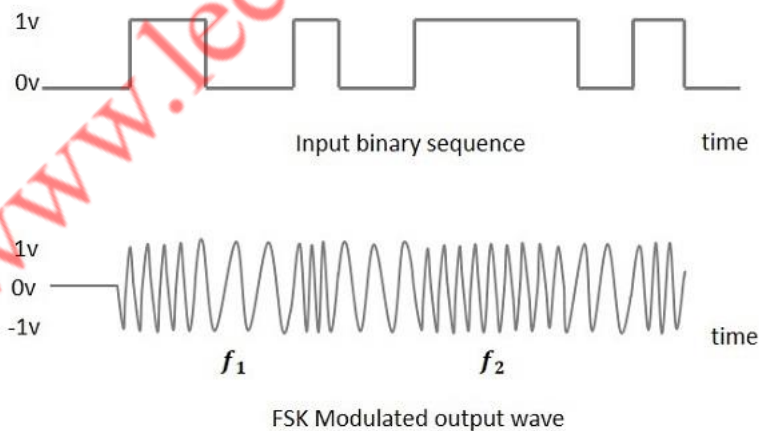
- The following figure represents ASK modulated waveform along with its input.



**Frequency Shift Keying (FSK)** is the digital modulation technique in which the frequency of the carrier signal varies according to the digital signal changes. FSK is a scheme of frequency modulation.

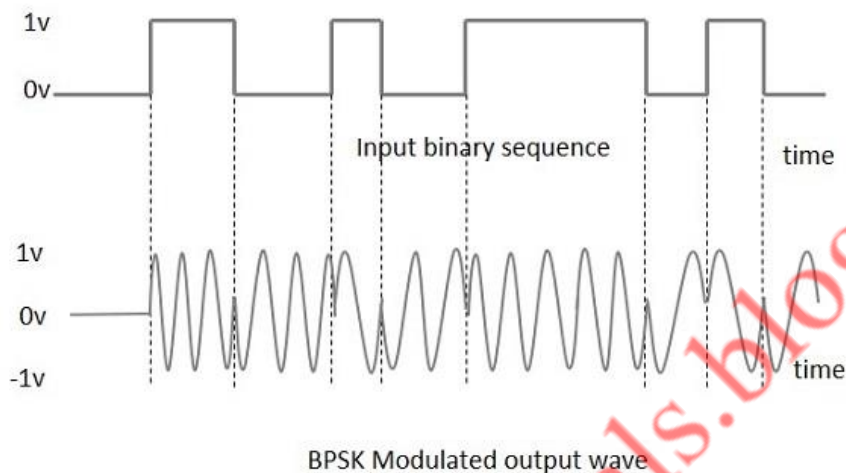
The output of a FSK modulated wave is high in frequency for a binary High input and is low in frequency for a binary Low input. The binary **1s** and **0s** are called Mark and Space frequencies.

The following image is the diagrammatic representation of FSK modulated waveform along with its input.



**Phase Shift Keying (PSK)** is the digital modulation technique in which the phase of the carrier signal is changed by varying the sine and cosine inputs at a particular time. PSK technique is widely used for wireless LANs, bio-metric, contactless operations, along with RFID and Bluetooth communications.

Following is the diagrammatic representation of BPSK Modulated output wave along with its given input.



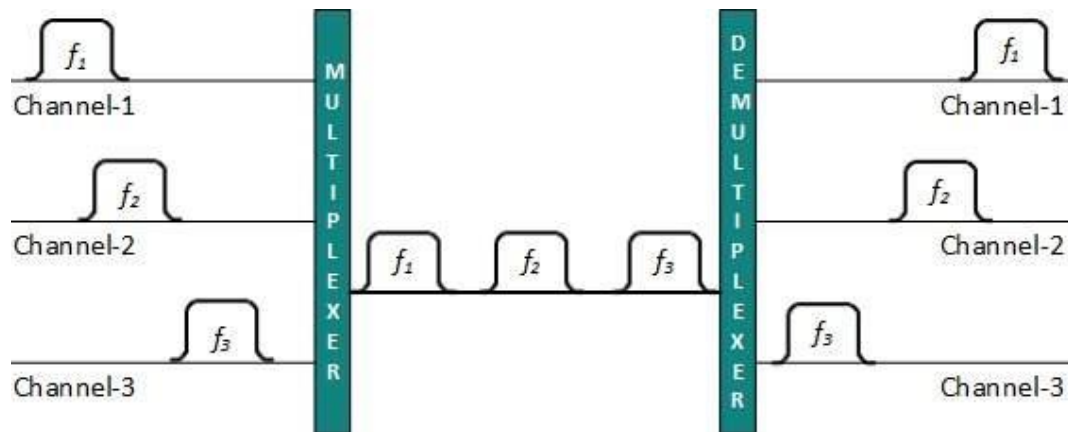
Multiplexing is a technique by which different analog and digital streams of transmission can be simultaneously processed over a shared link. Multiplexing divides the high capacity medium into low capacity logical medium which is then shared by different streams.

Communication is possible over the air (radio frequency), using a physical media (cable), and light (optical fiber). All mediums are capable of multiplexing.

When multiple senders try to send over a single medium, a device called Multiplexer divides the physical channel and allocates one to each. On the other end of communication, a Demultiplexer receives data from a single medium, identifies each, and sends to different receivers.

#### Frequency Division Multiplexing

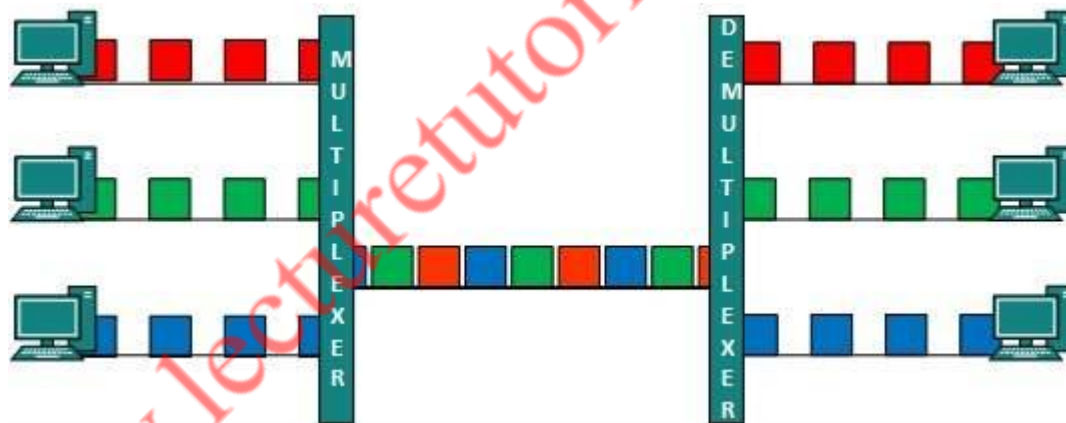
When the carrier is frequency, FDM is used. FDM is an analog technology. FDM divides the spectrum or carrier bandwidth in logical channels and allocates one user to each channel. Each user can use the channel frequency independently and has exclusive access of it. All channels are divided in such a way that they do not overlap with each other. Channels are separated by guard bands. Guard band is a frequency which is not used by either channel.



### Time Division Multiplexing

TDM is applied primarily on digital signals but can be applied on analog signals as well. In TDM the shared channel is divided among its user by means of time slot. Each user can transmit data within the provided time slot only. Digital signals are divided in frames, equivalent to time slot i.e. frame of an optimal size which can be transmitted in given time slot.

TDM works in synchronized mode. Both ends, i.e. Multiplexer and De-multiplexer are timely synchronized and both switch to next channel simultaneously.



When channel A transmits its frame at one end, the De-multiplexer provides media to channel A on the other end. As soon as the channel A's time slot expires, this side switches to channel B. On the other end, the De-multiplexer works in a synchronized manner and provides media to channel B. Signals from different channels travel the path in interleaved manner.

### Code Division Multiplexing

Code division multiplexing (CDM) is a multiplexing technique that uses spread spectrum communication. In spread spectrum communications, a narrowband signal is spread over a



larger band of frequency or across multiple channels via division. It does not constrict bandwidth's digital signals or frequencies. It is less susceptible to interference, thus providing better data communication capability and a more secure private line.

### Code Division Multiple Access

When CDM is used to allow multiple signals from multiple users to share a common communication channel, the technology is called Code Division Multiple Access (CDMA). Each group of users is given a shared code and individual conversations are encoded in a digital sequence. Data is available on the shared channel, but only those users associated with a particular code can access the data.

### Concept

Each communicating station is assigned a unique code. The codes stations have the following properties –

- If code of one station is multiplied by code of another station, it yields 0.
- If code of one station is multiplied by itself, it yields a positive number equal to the number of stations.

The communication technique can be explained by the following example –

Consider that there are four stations w, x, y and z that have been assigned the codes  $c_w$ ,  $c_x$ ,  $c_y$  and  $c_z$  and need to transmit data  $d_w$ ,  $d_x$ ,  $d_y$  and  $d_z$  respectively. Each station multiplies its code with its data and the sum of all the terms is transmitted in the communication channel.

Thus, the data in the communication channel is  $d_w \cdot c_w + d_x \cdot c_x + d_y \cdot c_y + d_z \cdot c_z$

Suppose that at the receiving end, station z wants to receive data sent by station y. In order to retrieve the data, it will multiply the received data by the code of station y which is  $d_y$ .

$$\begin{aligned} \text{data} &= (d_w \cdot c_w + d_x \cdot c_x + d_y \cdot c_y + d_z \cdot c_z) \cdot c_y \\ &= d_w \cdot c_w \cdot c_y + d_x \cdot c_x \cdot c_y + d_y \cdot c_y \cdot c_y + d_z \cdot c_z \cdot c_y \\ c_y &= 0 + 0 + d_y \cdot 4 + 0 = 4d_y \end{aligned}$$



Thus, it can be seen that station z has received data from only station y while neglecting the other codes.

## Orthogonal Sequences

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The codes assigned to the stations are carefully generated codes called chip sequences or more popularly orthogonal sequences. The sequences are comprised of +1 or -1. They hold certain properties so as to enable communication.

The properties are –

A sequence has  $m$  elements, where  $m$  is the number of stations.

- If a sequence is multiplied by a number, all elements are multiplied by that number.
- For multiplying two sequences, the corresponding positional elements are multiplied and summed to give the result.
- If a sequence is multiplied by itself, the result is  $m$ , i.e. the number of stations.
- If a sequence is multiplied by another sequence, the result is 0.
- For adding two sequences, we add the corresponding positional elements.

Let us ascertain the above properties through an example.

Consider the following chip sequences for the four stations w, x, y and z –

[+1 -1 -1 +1], [+1 +1 -1 -1], [+1 -1 +1 -1] and [+1 +1 +1 +1]

- Each sequence has four elements.
- If [+1 -1 -1 +1] is multiplied by 6, we get [+6 -6 -6 +6].
- If [+1 -1 -1 +1] is multiplied by itself, i.e. [+1 -1 -1 +1]. [+1 -1 -1 +1], we get +1+1+1+1 = 4, which is equal to the number of stations.
- If [+1 -1 -1 +1] is multiplied by [+1 +1 -1 -1], we get +1-1+1-1 = 0
- If [+1 -1 -1 +1] is added to [+1 +1 -1 -1], we get [+2 0 -2 0].

The commonly used orthogonal codes are **Walsh codes**.