Investigates how digital data is encoded using signal elements

Competency Level 6.3

Learning Outcomes:

- graphically represents encoding of digital data using two voltage levels as well as Manchester encoding
- describes the possibility of using the changes in frequency and phase as signal elements
- Explains the need for synchronization and describes the problems that arise when the
- Transmitter and the receiver are not synchronized
- Describes how the parity bit enables detecting a bit error

Agreeing on signal elements to represent data (a protocol)

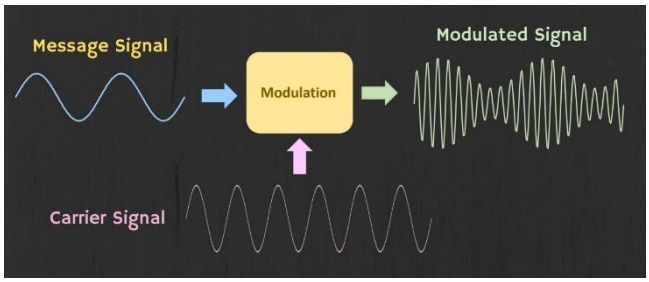
Basic modulation techniques

What is carrier waves?

- Carrier wave is a wave that flows through a transmission media and which is used to carry data.
- Data is available inside a source as an electronic wave.
- This wave should be connected to carrier wave.

What is Modulation?

- To connect carrier wave, high frequency must be created by changing the frequency, amplitude and phase of the carrier wave this is call Modulation
- Modulation is the process of converting data into radio waves by adding information to an electronic or optical carrier signal
- It is all so the method of combining an audio frequency signal with a radio frequency carrier wave.
- Modulation is usually applied to electromagnetic signals: radio waves, lasers/optics and computer networks.
- The audio frequency is also known as modulating wave and the resultant wave produced is called as **modulated wave**.
- Throughout the modulation, some characteristics of the carrier wave are varied in time with the modulating signal and are accomplished by combining the two.

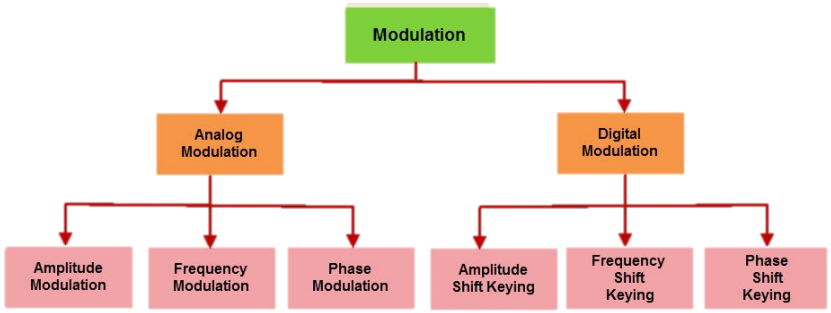


Why use modulation?

- Multiple carriers of different frequencies can often be transmitted over a single media, with each carrier being modulated by an independent signal. For example, Wi-Fi uses individual channels to simultaneously transmit data to and from multiple clients
- Baseband signals are incompatible for direct transmission. For such a signal, to travel longer distances, its strength has to be increased by modulating with a high frequency carrier wave, which doesn't affect the parameters of the modulating signal.

Types of modulation

The modulation is of following two types:



Analog modulation

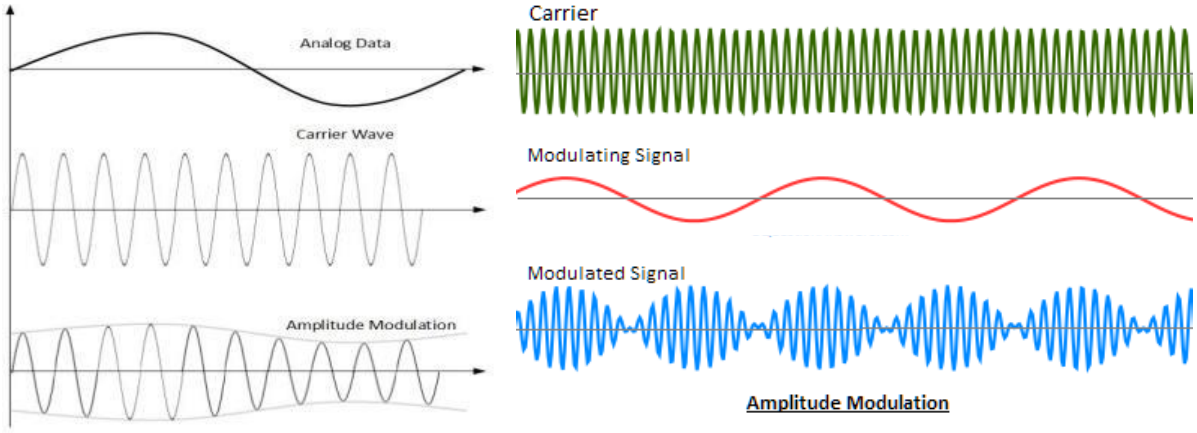
- It is the process of transferring analog low frequency baseband signal, like an audio or TV signal over a higher frequency carrier signal such as a radio frequency band.
- Baseband signal is always analog for this modulation.

There are three properties of a carrier signal amplitude, frequency and phase thus there are three basic types of analog modulations.

1. Amplitude Modulation (AM)
2. Frequency Modulation (FM)
3. Phase modulation (PM)

1. Amplitude Modulation (AM)

- It is a form of modulation used for radio transmissions for broadcasting and two way radio communication applications.
- Amplitude of carrier signal varies according to the amplitude of modulating signal. The frequency or phase of the carrier signal remains unchanged
- Mainly used for long, medium and short wave broadcasting and for some aeronautical point to point communications.
- The first amplitude modulated signal was transmitted in 1901 by a Canadian engineer named Reginald Fessenden.
- Amplitude modulation is used in a variety of applications
    - ***Broadcast transmissions:*** AM is still widely used for broadcasting on the long, medium and short wave bands.
    - ***Air band radio:*** VHF transmissions for many airborne applications still use AM. . It is used for ground to air radio communications as well as two way radio links for ground staff as well.
    - ***Single sideband:*** Amplitude modulation in the form of single sideband used for HF radio links.
    - ***Quadrature amplitude modulation:*** AM is widely used for the transmission of data in everything from short range wireless links such as Wi-Fi to cellular telecommunications and much more.



Advantages

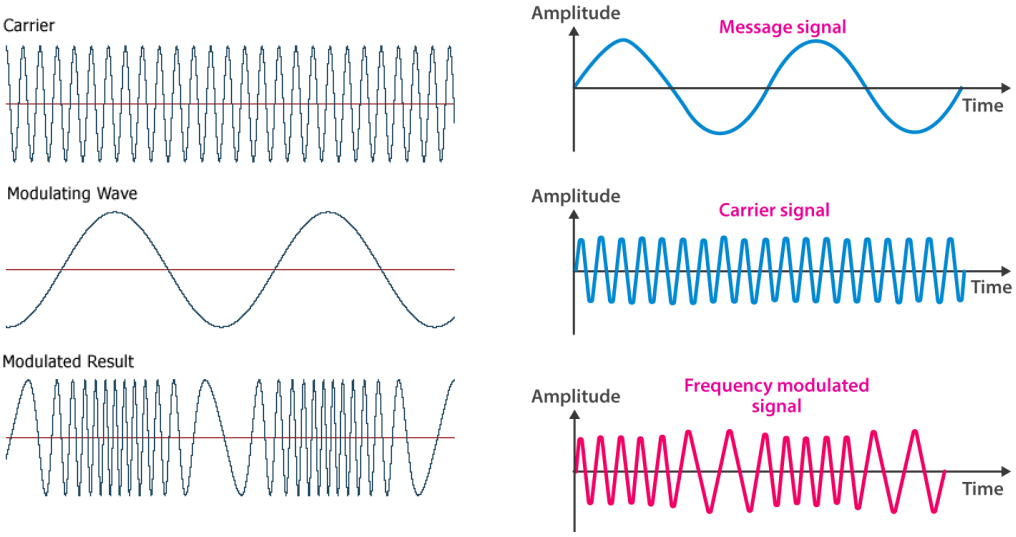
- It is simple to implement
- it can be demodulated using a circuit consisting of very few components
- AM receivers are very cheap as no specialized components are needed.

Disadvantages

- It is not efficient in terms of its power usage
- It is not efficient in terms of its use of bandwidth, requiring a bandwidth equal to twice that of the highest audio frequency
- It is prone to high levels of noise because most noise is amplitude based and obviously AM detectors are sensitive to it.

2. Frequency Modulation (FM)

- It is the modulation method to transmit information over a carrier wave by increasing the amount of waves (frequency).
- The feature includes the transmission of the high quality voice, and comparatively less noise.
- The carrier signal frequency changes according to the frequency of the Modulating signal
- An American engineer named Edwin Armstrong was investigating this issue and whether frequency modulation, rather than amplitude modulation might provide an advantage.
- Around 1928, Armstrong started to develop the concept of using FM, and rather than reducing the bandwidth, he increased it.
- Armstrong launched his own radio station in 1939 to demonstrate the effectiveness of FM

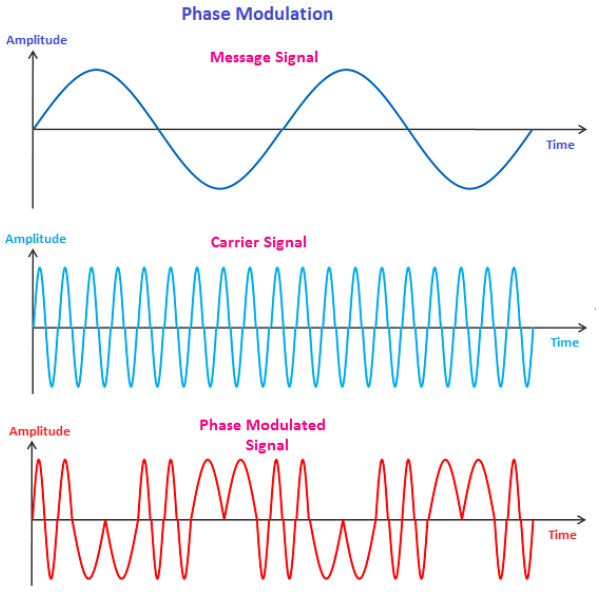


Advantages and Disadvantages of Frequency Modulation

Advantages	Disadvantages
• Less interference and noise.	• Equipment cost is higher. Has a large bandwidth.
• Power Consumption is less as compared to AM.	• The receiving are of FM signal is small.
• Adjacent FM channels are separated by guard bands.	• The antennas for FM systems should be kept close for better communication.

3. Phase modulation (PM)

- The phase of a carrier signal is modulated in order to reflect the changes in voltage (Amplitude) of an analog data signal
- Phase modulation is a type of modulation where the phase of the carrier signal varies as per amplitude variations of the message signal Or the process of transmitting information over a carrier wave by varying its phase in accordance with the amplitude of the message signal.
- In phase modulation, the phase of the carrier signal is varied whereas the amplitude of the carrier signal remains constant.



Advantage

- Modulation and demodulation does not catch any channel noise.

Disadvange:

- Circuit needed for PM modulation and demodulation is bit complicated than AM and FM

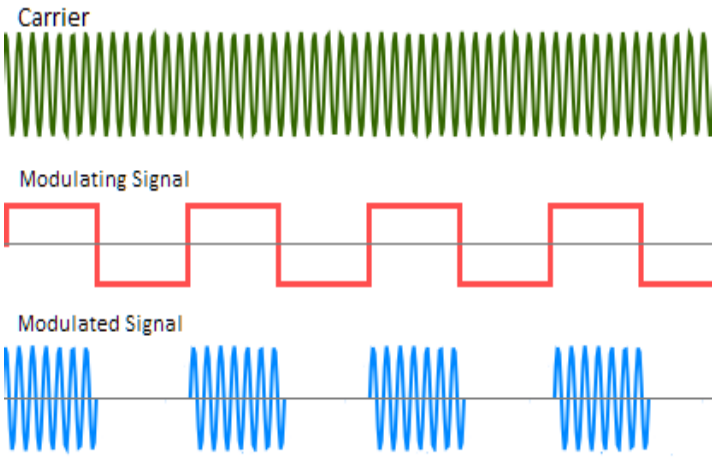
Digital Modulation

- Analog modulation refers to the process of transferring digital low frequency baseband signal, like digital bit stream from computers over a higher frequency carrier signal such as a radio frequency band.
- Digital modulation is the process of encoding a digital information signal into the amplitude, phase, or frequency of the transmitted signal.
- Digital modulation in somewhat similar to the analog modulation except base band signal is of discrete amplitude level.
- For binary signal it has only two level, either high or logic 1 or low or logic 0. The modulation scheme is mainly three types.

1. ASK or Amplitude shift Key
2. FSK or Frequency shift key
3. PSK or Phase shift key

1. Amplitude Shift Keying (ASK)

- In this conversion technique, the amplitude of an analog carrier signal is modified to reflect binary data.
- When binary data represents digit 1, the amplitude is held at 1(High), otherwise it is set to 0(**Low)**. Both frequency and phase remain same as in the Original carrier signal



Amplitude Shift Key

Advantages

- It can be used to transmit digital data over optical fiber.
- The receiver and transmitter have a simple design which also makes it comparatively inexpensive.
- It uses lesser bandwidth as compared to FSK thus it offers high bandwidth efficiency.

Disadvantages

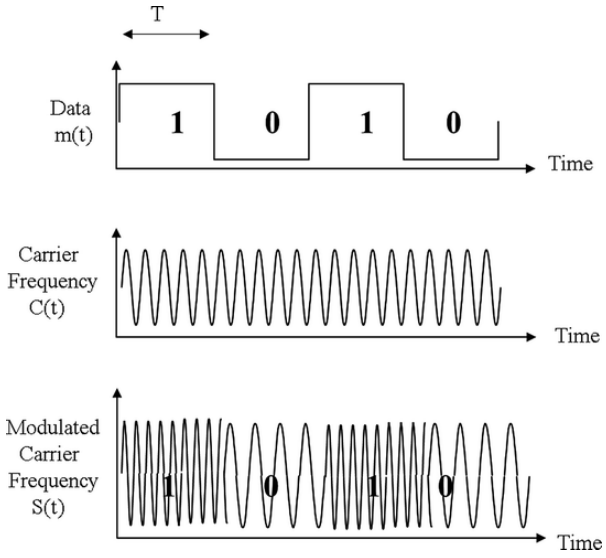
- It is susceptible to noise interference and entire transmissions could be lost due to this.
- It has lower power efficiency.

Amplitude shift keying applications are

- Low-frequency RF applications
- Home automation devices
- Industrial networks devices
- Wireless base stations
- Tire pressuring monitoring systems

2. Frequency Shift Keying (FSK)

- In this conversion technique, the frequency of the analog carrier signal is modified to reflect binary data.
- FSK is also known as Binary Frequency Shift Keying (BFSK)
- Frequency shift keying shows how the frequency characteristics of a binary signal changed according to the carrier signal.
- In FSK, the binary information can be transmitted through a carrier signal along with frequency changes
- The output of a frequency shift keying modulated wave is high in frequency for a binary high input and is low in frequency for a binary low input. The amplitude and phase of the carrier signal remain constant.
- in FSK by increasing the number of waves in place relevant to 1 bits and decreasing the amount of waves in pace relevant to 0

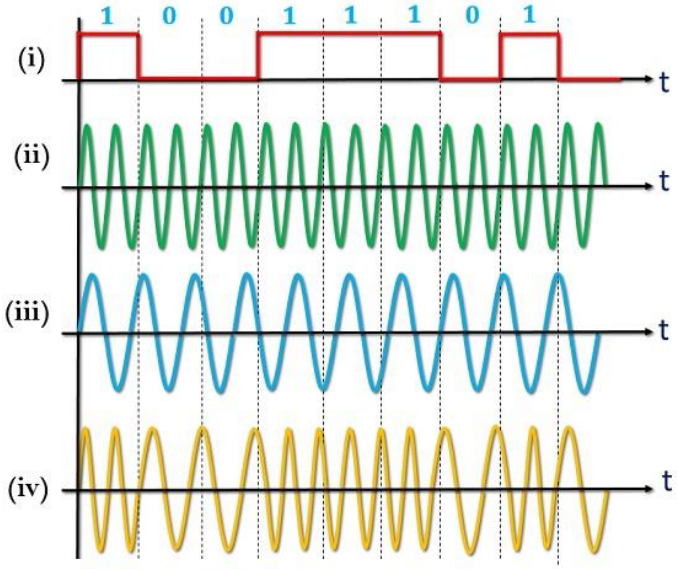


Advantages

- Frequency shift keying modulated signal can help avoid the noise problems beset by ASK.
- It has lower chances of an error.
- It provides high signal to noise ratio.
- The transmitter and receiver implementations are simple for low data rate application.

Disadvantages

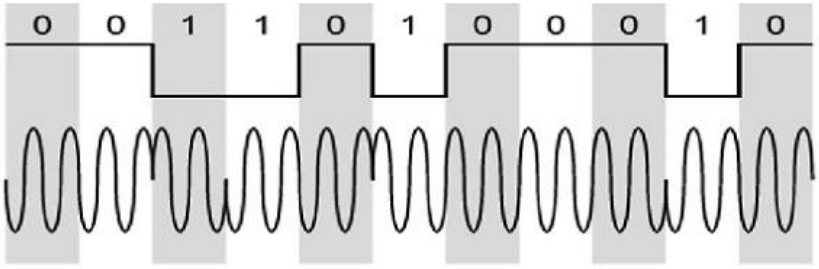
- It uses larger bandwidth as compared to ASK thus it offers less bandwidth efficiency.
- It has lower power efficiency.

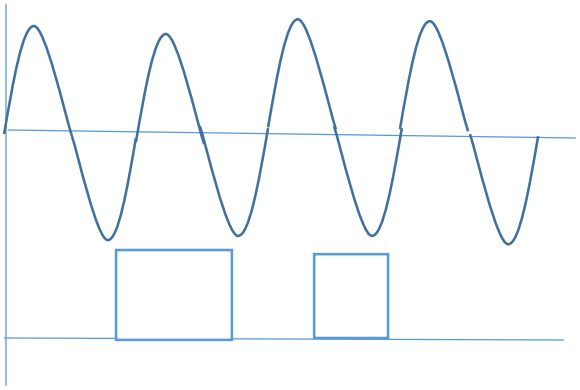


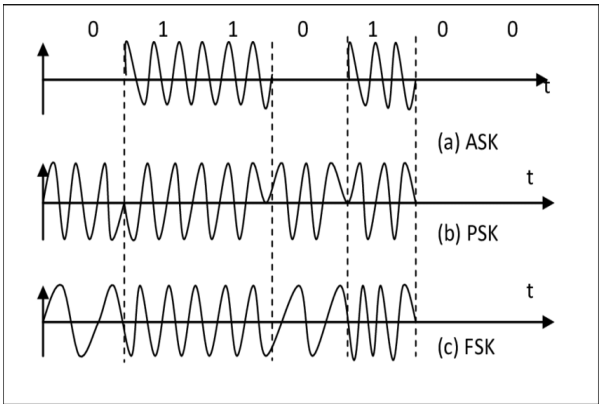
(i) Digital bitstream
(ii) High frequency carrier wave
(iii) Low frequency carrier wave
(iv) FSK modulated wave

3. Phase Shift Keying (PSK)

- In this conversion scheme, the phase of the original carrier signal is altered to reflect the binary data.
- **It** is a type of digital modulation technique where we transmit the data by modulating the phase of the carrier signal.
- The modulation is carried out by changing the inputs at regular intervals of time.
- Use finite phases and each of these phases can be represented by a unique pattern of bits.
- The number of bits used is the same in each case.
- A demodulator is used to determine the phase of the signal and recover the original data from it.
- Conversion of the carrier wave into an angle of 180^0 in the place relevant to 1 bit, 0^0 for 0bit when transmission of data





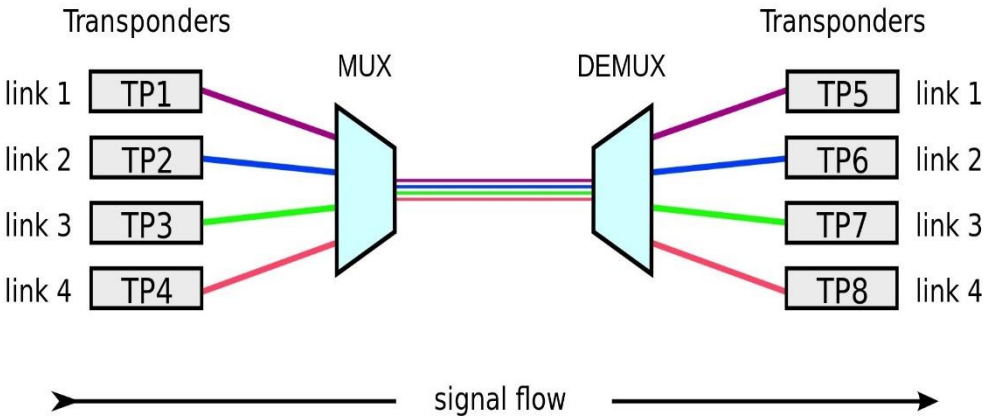


○ Synchronization: synchronization is used to ensure that the data streams are received And transmitted correctly between two devices. Usually a clock signal is transmitted in Sequence with a data stream to maintain proper signal timing.

Multiplexing

- Multiplexing is the process of combining multiple signals into one signal, over a shared medium.
    - For example, in telecommunications, several telephone calls may be carried using one wire.

- Multiplexing originated in telegraphy in the 1870s, and is now widely applied in communications. In telephony, George Owen Squier is credited with the development of telephone carrier multiplexing in 1910.
- If analog signals are multiplexed, it is Analog Multiplexing and if digital signals are multiplexed, that process is Digital Multiplexing.
- The multiplexing divides the capacity of the communication channel into several logical channels, one for each message signal or data stream to be transferred.
- A device that performs the multiplexing is called a **multiplexer** (MUX), and a device that performs the reverse process is called a **demultiplexe**r (DEMUX or DMX).

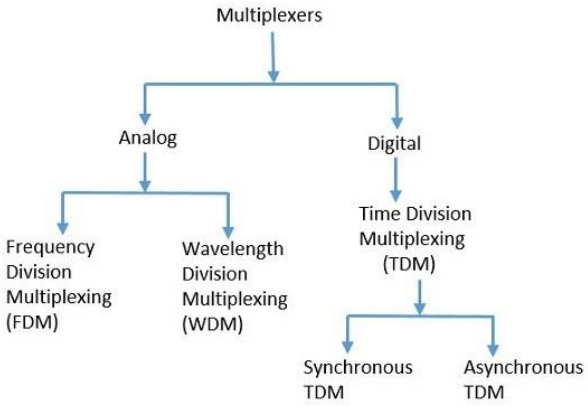


Advantages of Multiplexing:

- More than one signal can be sent over a single medium.
- The bandwidth of a medium can be utilized effectively.
- The transmission medium is used to send the signal from sender to receiver. The medium can only have one signal at a time.
- If there are multiple signals to share one medium, then the medium must be divided in such a way that each signal is given some portion of the available bandwidth. For example: If there are 10 signals and bandwidth of medium is100 units, then the 10 unit is shared by each signal.
- When multiple signals share the common medium, there is a possibility of collision. Multiplexing concept is used to avoid such collision.
- Transmission services are very expensive

Types of Multiplexers

- There are mainly two types of multiplexers, namely
    1. Analog
    2. Digital.
- They are further divided into
    1. Frequency Division Multiplexing (FDM),
    2. Wavelength Division Multiplexing (WDM),
    3. Time Division Multiplexing (TDM).



Analog Multiplexing

The signals used in analog multiplexing techniques are analog .The analog signals are multiplexed according to their frequency (FDM) or wavelength (WDM).

Frequency Division Multiplexing

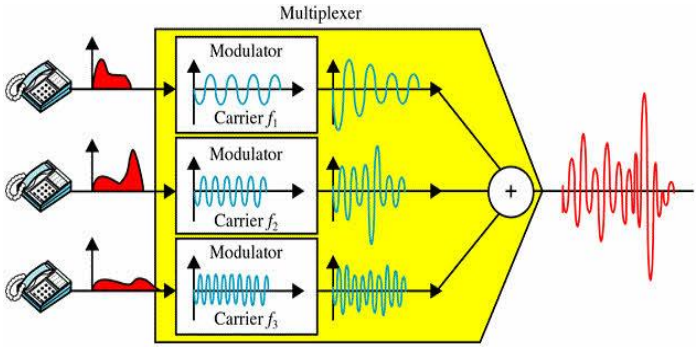
- In analog multiplexing, the most used technique is Frequency Division Multiplexing (FDM).
- This technique uses various frequencies to combine streams of data, for sending them on a communication medium, as a single signal.
- **Frequency Division Multiplexing** is a technique in which the available bandwidth of a single transmission medium is subdivided into several channels.
- The input signals are translated into frequency bands by using modulation techniques, and they are combined by a multiplexer to form a composite signal.
- The main aim of the FDM is to subdivide the available bandwidth into different frequency channels and allocate them to different devices.
- Using the modulation technique, the input signals are transmitted into frequency bands and then combined to form a composite signal.

Advantages Of FDM:

- FDM is used for analog signals.
- FDM process is very simple and easy modulation.
- A Large number of signals can be sent through an FDM simultaneously.
- It does not require any synchronization between sender and receiver.

Disadvantages Of FDM:

- FDM technique is used only when low-speed channels are required.
- It suffers the problem of crosstalk.
- A Large number of modulators are required.
- It requires a high bandwidth channel.

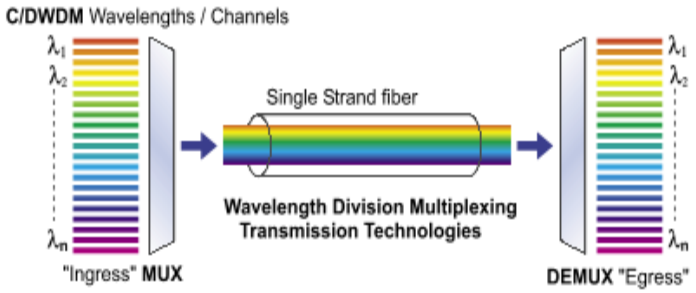


Example −

- A traditional television transmitter, which sends a number of channels through a single cable uses FDM
- It is used in FM and AM broadcasting. Each FM radio station has different frequencies, and they are multiplexed to form a composite signal. The multiplexed signal is transmitted in the air.

Wavelength Division Multiplexing (WDM)

- Wavelength Division Multiplexing is an analog technique, in which many data streams of different wavelengths are transmitted in the light spectrum.
- If the wavelength increases, the frequency of the signal decreases.
- Wavelength Division Multiplexing is same as FDM except that the optical signals are transmitted through the fiber optic cable.
- WDM is used on fiber optics to increase the capacity of a single fiber.



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

Advantages of WDM

- In WDM full-duplex transmission is possible.
- It is easier to reconfigure.
- Optical components are more reliable and provide higher bandwidth.
- Provide high security and faster access to new channel.
- Low cost and easy system expansion.
- Simultaneous transmission of various signals.

Disadvantages of WDM

- Optical line termination has to have transmitter array with one transmitter for each optical network unit, adding a new ONU could be a problem unless transmitters were provisioned in advance.
- Each ONU must have a wavelength-specific laser.
- The cost of the system increases with addition of optical components.

Digital Multiplexing

The term digital represents the discrete bits of information. The available data is in the form of frames or packets,

Time Division Multiplexing (TDM)

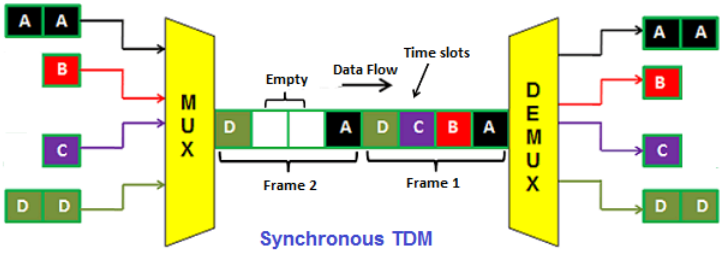
- In TDM, the time frame is divided into slots. This technique is used to transmit a signal over a single communication channel, with allotting one slot for each message.
- It is a digital technique.
- In Frequency Division Multiplexing Technique, all signals operate at the same time with different frequency, but in case of Time Division Multiplexing technique, all signals operate at the same frequency with different time.
- In Time Division Multiplexing technique, the total time available in the channel is distributed among different users. Therefore, each user is allocated with different time interval known as a Time slot at which data is to be transmitted by the sender.
- A user takes control of the channel for a fixed amount of time.
- In Time Division Multiplexing technique, data is not transmitted simultaneously rather the data is transmitted one-by-one.
- In TDM, the signal is transmitted in the form of frames. Frames contain a cycle of time slots in which each frame contains one or more slots dedicated to each user.
- It can be used to multiplex both digital and analog signals but mainly used to multiplex digital signals.

There are two types of TDM:

1. Synchronous TDM
2. Asynchronous TDM

Synchronous TDM

- A Synchronous TDM is a technique in which time slot is pre assigned to every device.
- In Synchronous TDM, each device is given some time slot irrespective of the fact that the device contains the data or not.
- If the device does not have any data, then the slot will remain empty.
- In Synchronous TDM, signals are sent in the form of frames. Time slots are organized in the form of frames. If a device does not have data for a particular time slot, then the empty slot will be transmitted.



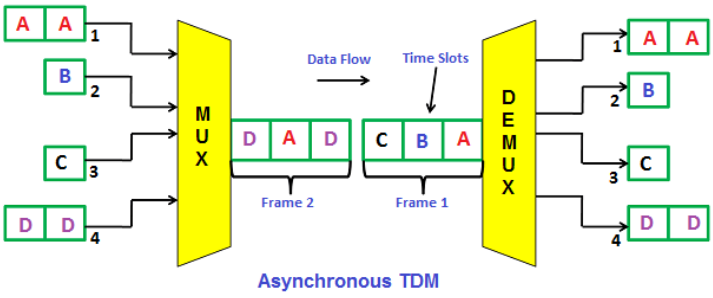
- The most popular Synchronous TDM are T-1 multiplexing, ISDN multiplexing, and SONET multiplexing.
- If there are n devices, then there are n slots

Disadvantages Of Synchronous TDM:

- The capacity of the channel is not fully utilized as the empty slots are also transmitted which is having no data
- The speed of the transmission medium should be greater than the total speed of the input lines.

Asynchronous TDM

- An asynchronous TDM is also known as Statistical TDM.
- An asynchronous TDM is a technique in which time slots are not fixed as in the case of Synchronous TDM. Time slots are allocated to only those devices which have the data to send. Therefore, we can say that Asynchronous Time Division multiplexor transmits only the data from active workstations.
- An asynchronous TDM technique dynamically allocates the time slots to the devices.
- In Asynchronous TDM, total speed of the input lines can be greater than the capacity of the channel.
- Asynchronous Time Division multiplexor accepts the incoming data streams and creates a frame that contains only data with no empty slots.
- Controlling the timing of operations by the use of pulses sent when the previous operation is completed rather than at regular intervals.



Advantages

- It is optimized to transport voice, data and video i.e. single network for everything.
- It is used for mixed traffic, real-time and non-real time traffic types.
- It is easy to integrate with LAN, MAN and WAN network types i.e. seamless integration.

  It uses simplified network infrastructure.

Disadvantages

- Complex mechanisms are used
- Congestion may cause cell losses
- switch is very expensive compare to LAN hardware