- Introduction

As we are living in an era of communication wherein we can easily transfer any form of information (video, audio, and other data) in the form of electrical signals to any other device or destined area. Although it is common in our perceptual experience that sending or receiving signals or data is simple, but it involves quite complex procedures, possibilities, and involved scenarios within the communication systems. So, in the scope of communication systems, modulation plays hold crucial responsibility in the communication system to encode information digitally in the analog world. It is very important to modulate the signals before sending them to the receiver section for larger distance transfer, accurate data transfer, and low-noise data reception. To be clear, let us dive into the detailed concept of knowing what is modulation, different types in it, and what are the types of modulation techniques used in communication systems.

- What is Modulation?

Modulation is a process of changing the characteristics of the wave to be transmitted by superimposing the message signal on the high-frequency signal. In this process video, voice and other data signals modify high-frequency signals – also known as the carrier wave. This carrier wave can be DC or AC or pulse chain depending on the application used. Usually, a high-frequency sine wave is used as a carrier wave signal.

These modulation techniques are classified into two major types: analog and digital or pulse modulation. Prior to discussing further the different types of modulation techniques, let us understand the importance of modulation.

- Why Modulation is Used in Communication?

In the modulation technique, the message signal frequency is raised to a range so that it is more useful for transmission. The following points describe modulation’s importance in the communication system.

In signal transmission, the signals from various sources are transmitted through a common channel simultaneously by using multiplexers. If these signals are transmitted simultaneously with a certain bandwidth, they cause interference. To overcome this, speech signals are modulated to various carrier frequencies in order for the receiver to tune them to the desired bandwidth of his own choice within the range of transmission.

Another technical reason is antenna size; the antenna size is inversely proportional to the frequency of the radiated signal. The order of the antenna aperture size is at least one by a tenth of the wavelength of the signal. Its size is not practicable if the signal is 5 kHz; therefore, raising frequency by modulating process will certainly reduce the height of the antenna.

Modulation is important to transfer the signals over large distances since it is not possible to send low-frequency signals for longer distances.

Similarly, modulation is also important to allocate more channels for users and to increase noise immunity.

- How modulation works

Information can be added to the carrier by varying its amplitude, frequency, phase, polarization -- for optical signals -- and even quantum-level phenomena like spin.

Modulation is usually applied to electromagnetic signals: radio waves, lasers/optics and computer networks. Modulation can even be applied to a direct current -- which can be treated as a degenerate carrier wave with a fixed amplitude and frequency of 0 Hz -- mainly by turning it on and off, as in Morse code telegraphy or a digital current loop interface. The special case of no carrier -- a response message indicating an attached device is no longer connected to a remote system -- is called baseband modulation.

Modulation can also be applied to a low-frequency alternating current -- 50-60 Hz -- as with powerline networking.

- Definations

- Modulating Signal

This signal is also termed as a message signal. It holds the data that has to be transmitted and so this termed as message signal. It is considered as the baseband signal where it undergoes a modulation process to get broadcasted or communicated. Because of this, it is the modulating signal.

- Carrier Signal

This is the high range of frequency signal which is with specific amplitude, frequency, and phase levels, but it does not hold any data. So, it is termed as carrier signal as it is an empty one. This is simply utilized to transmit the message to the receiver section after the process of modulation.

- Modulated Signal

The consequential signal that is obtained after the procedure of modulation is called a modulated signal. This is the product of both the carrier and modulating signals.

- Different Types of Modulation

The two types of modulation: analog and digital modulation techniques have already been discussed. In both the techniques, the baseband information is converted to Radio Frequency signals, but in analog modulation, these RF communication signals are a continuous range of values, whereas in digital modulation these are prearranged discrete states.

- Analog Modulation

In this modulation, a continuously varying sine wave is used as a carrier wave that modulates the message signal or data signal. The Sinusoidal wave’s general function is shown in the figure below, in which, three parameters can be altered to get modulation – they are mainly amplitude, frequency, and phase, so the types of analog modulation are:

Amplitude modulation (AM)

Frequency modulation (FM)

Phase modulation (PM)

- Amplitude Modulation

Amplitude modulation or AM is a modulation technique that is used in electronic communication. It is most commonly used for transmitting messages with a radio carrier wave. It varies the instantaneous amplitude of the carrier signal or waves according to the message signal's instantaneous amplitude.

If we denote the message signal as m(t) and c(t)= Acoswct, then amplitude modulation signal F(t) will be written as:

F(t)= Acoswct+m(t) coswct

F(t)=[A+m(t)] coswct

History of Amplitude modulation

Amplitude modulation was the earliest modulation technique used for transmitting audio in radio broadcasting. It was developed during the first quarter of the 20th century and was based on the Roberto Landell De Moura and Reginald Fessenden's radiotelephone experiments proposed in 1900.

Advantages of Amplitude Modulation

Amplitude Modulation is easy to implement. It is the simplest type of modulation.

Amplitude Modulation, we can easily do Demodulation by using few components and a circuit.

The hardware design of both the transmitter and receiver is very simple, that's why it is cost-effective.

The receiver used for Amplitude Modulation is very cheap.

Disadvantages of Amplitude Modulation

Amplitude Modulation is not a very power efficient technique.

Amplitude Modulation requires a very high bandwidth that is equivalent to that of the highest audio frequency.

Amplitude Modulation is very susceptible to noise. You can easily notice the noise.

Usage of Amplitude Modulation

Amplitude Modulation is used in AM radio communication. AM radio broadcast is an example of Amplitude Modulation.

- Frequency Modulation

Frequency Modulation or FM is the process of encoding the information in a carrier wave by varying the instantaneous frequency of the wave. It varies the instantaneous frequency of the carrier signal according to the instantaneous

amplitude of the message signal.

If we denote the message signal as m(t) and c(t)= Acoswct, then Frequency modulation signal F(t) will be written as:

F(t)= Acos(wc t+kf ∫m(α)dα)

Advantages of Frequency Modulation

Frequency Modulation is widely used for FM radio broadcasting.

It is also used in telemetry, sound synthesis, seismic prospecting, radar, and monitoring newborns for seizures via EEG, two-way radio systems, magnetic tape-recording systems and some video-transmission systems.

The main advantage of using frequency modulation in radio transmission is that it has a larger signal-to-noise ratio. That's why it rejects radio frequency interference better than an equal power amplitude modulation (AM) signal. This is the main reason why most music radio channels prefer to broadcast over FM radio.

In FM, Modulation and Demodulation do not receive any channel noise.

Disadvantages of Frequency Modulation

FM consists of a complicated circuit than AM for modulation and Demodulation.

Usage of Frequency Modulation

The main example of Frequency Modulation is FM radio broadcasting.

- Phase modulation (PM)

Phase modulation or PM is the technique of varying the carrier signal's instantaneous phase according to the instantaneous amplitude of the message signal. It encodes the message signal as changes occurred in the instantaneous phase of a carrier signal.

If we denote the message signal as m(t) and c(t)= Acoswct, then Phase modulation signal F(t) will be written as:

F(t)= Acos(wct+kpm(t))

Advantages of Phase modulation

Phase Modulation is mainly used for transmitting radio waves. It is also used in many digital transmission coding schemes and technologies such as Wi-Fi, GSM and satellite television.

In PM, Modulation and Demodulation do not receive any channel noise.

Disadvantages of Phase modulation

The PM modulation and Demodulation consists of a complicated circuit than AM and FM.

Usage of Phase modulation

Phase Modulation is mainly used in Wi-Fi, GSM and satellite television.

- Digitial Modulation

Digital Modulation is a technique in which digital signals/data can be converted into analog signals. For example, Base band signals.

Digital Modulation can further be classified into four types:

Amplitude Shift Key(ASK) Modulation

Frequency Shift Key (FSK) Modulation

Phase Shift Key (PSK) Modulation

- Amplitude Shift Key (ASK) Modulation

As the name suggests, in Amplitude Shift Key or ASKS Modulation, the amplitude is represented by "1," and if the amplitude does not exist, it is represented by "0".

Using Amplitude Shift Key Modulation is very simple, and it requires a very low bandwidth.

Amplitude Shift Key Modulation is vulnerable to inference or deduction.

- Frequency Shift Key (FSK) Modulation

In Frequency Shift Key or FSK Modulation, different notations f1 and f2 are used for different frequencies.

Here, f1 is used to represent bit "1," and f2 represents bit "0".

It is also a simple modulation technique but uses different frequencies for different bits; bandwidth requirement becomes high.

- Phase Shift Key (PSK) Modulation

In Phase Shift Key or PSK Modulation, the phase difference is used to differentiate between the "1" and "0" bits.

If the bit is "1", a simple wave is drawn, and if the bit becomes "0", the phase of the wave is shifted by "180 or π".

PSK Modulation is more complicated than ASK and FSK Modulation, but it is robust too.

- Advantages of modulation:

It reduces the size of the antenna.

It reduces the cost of wires.

It prohibits the mixing of signals.

It increases the range of communication.

It improves the reception quality.

It easily multiplexes the signals.

It also allows the adjustment of the bandwidth.

- Disadvantages of modulation:

The cost of the equipment is higher.

The receiver and the transmitter are very complicated.

For better communication, the antennas for the FM system must be kept closed.

It is not efficient for large bandwidth.

Power wastage takes place.