Tishk International University (TIU)

Mechatronics Engineering Department

Communication Systems ME 316

Lecture 4 : 4-11-2019

Systems and Signals , Modulation and Demodulation

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Outlines

- Systems and Signals
- Signals Classification
- Analog Transmission
- Modulation
- Types of Modulation
- Demodulation

Systems and Signals

Systems and Signals

- **Systems :** means the interconnection of operation that transfer an input signal into an output signal with different properties from those of the input signal , the system takes a signal as an input and transforms it into another signal that can be represented as the ration of the output signal over input signal when multiply the system by the input signal to get the out put signal, systems respond to signals and produce a new signals.

- **Signals :** means the function of one or more variables that transmit information on the nature of physical phenomenon. .
- **Examples :**
  - Speech Signal : face to face or telephone channel (one variable /one-dimensional).
  - Visual signal : signal taking the form of images of people / objects around us (two or more variables/multi-dimensional).

Signals Classification

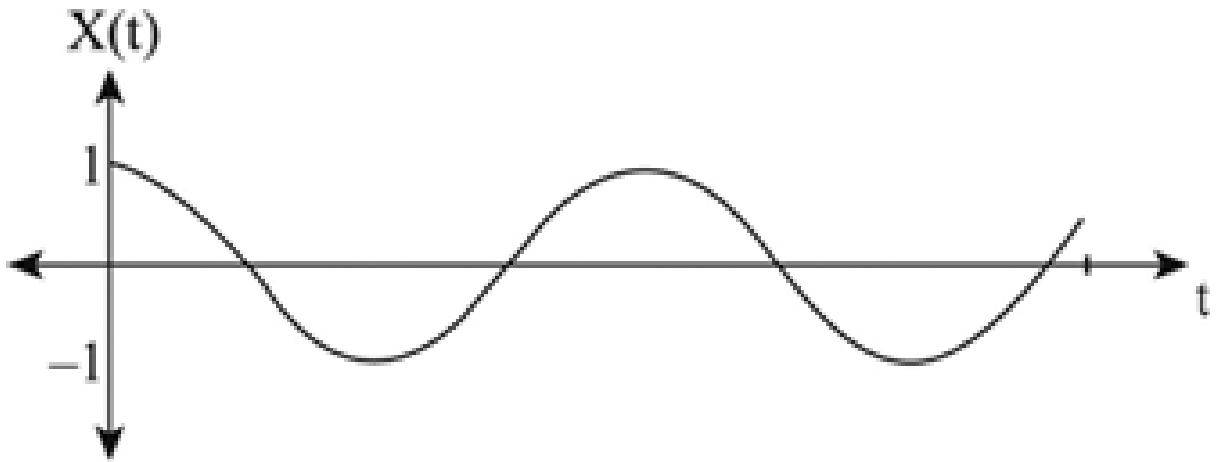
- **Signals in general may classified into :**

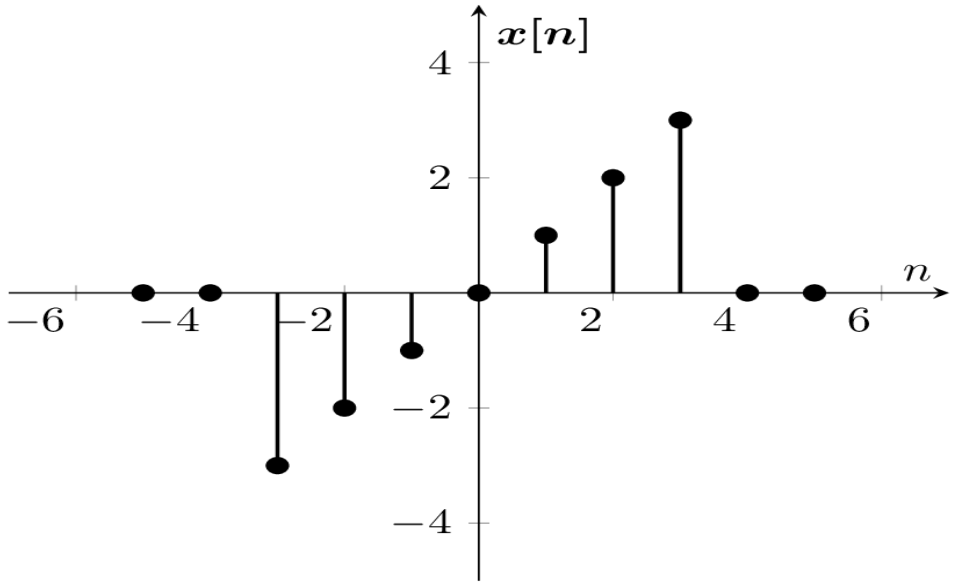
1. Continuous Time and Discrete Time Signals
2. Periodic and Aperiodic Signals
3. Deterministic and Random Signals
4. Energy and Power Signals
5. Even and Odd Signals
6. Complex and Real Signals

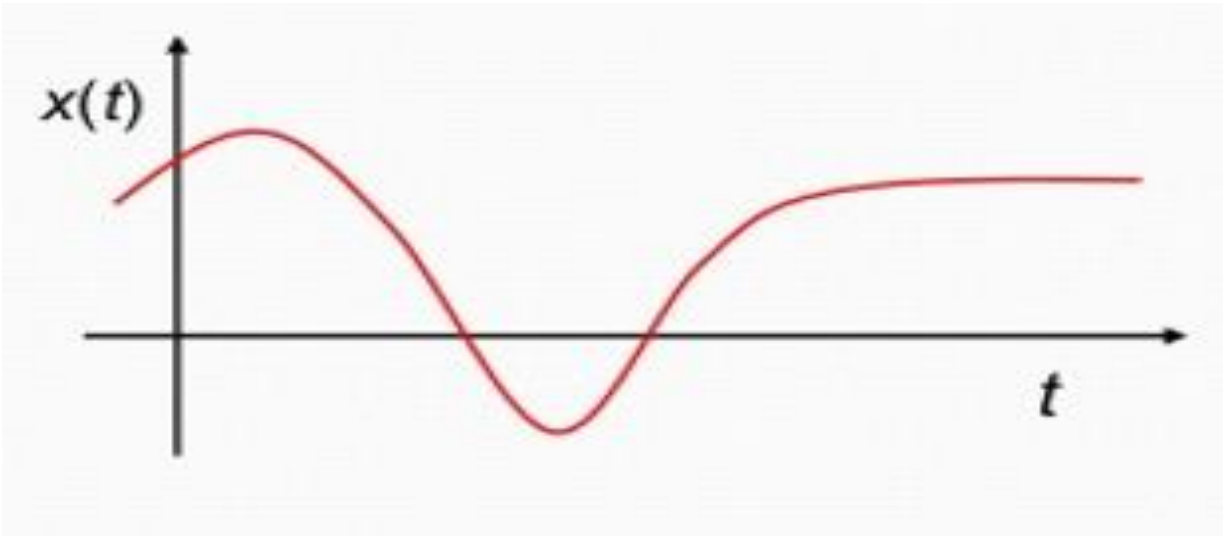
Signals Classification

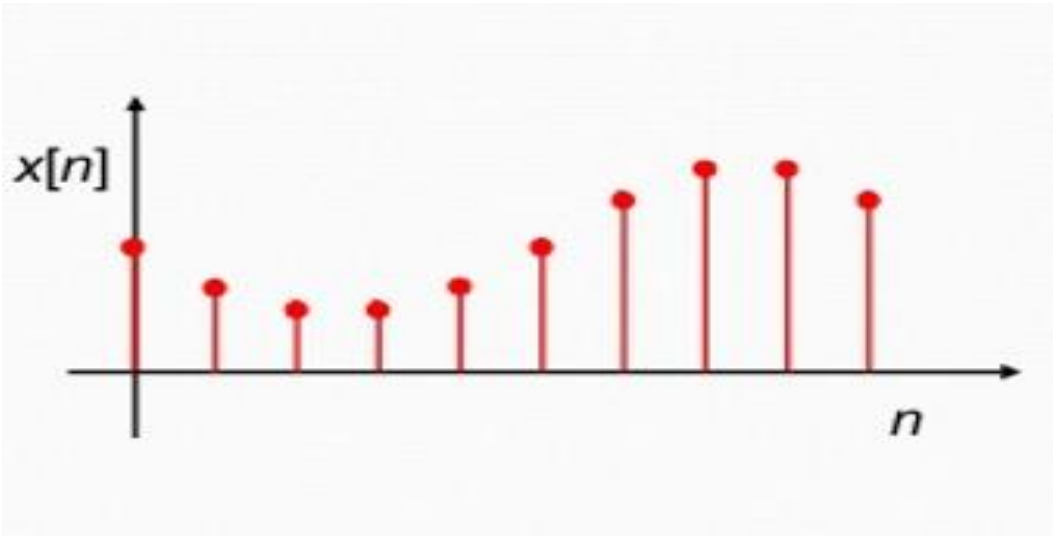
1. Continuous Time and Discrete Time Singles

- **Continuous Time Signals (CT) :** are defined the type of singles which include a continuous values with time (t), that means the signal have a values in every time and it is represented as a function of time **x(t)** , in the real world the most signals are continuous time.
  - The **CT signals** are an analog signals which used in **Analog Systems,** it is include the rang over real numbers.
- **Discrete Time Signals (DT) :** are defined the type of signals which only certain specific values of time ,that means this signal have a values only at some spacing of time or after specific duration of time ,it is represented as a function of **x[n]** , which is defined as (number of samples), some real world and many digital signals are discrete time ,as they are sampled.
  - The **DT signals** are used in **Digital Systems**, it is include the range over integers numbers.









Continuous Time Signals (CT)

Discrete Time Signals (DT)

Signals Classification

2. Periodic and Aperiodic Signals

- **Periodic Single : ** is the signal that repeat itself after equal amounts of time or the signal is repeat itself at a proper interval of time called (Periodic Signal), it is have the property that **x(t) = x (t + T)** ,each positive amount of time that signal repeat itself that means periodic signal, continues time signals are periodic.
  - **T :** is the minimum amount/value of time for one cycle to complete one period called (smallest amount of time).

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

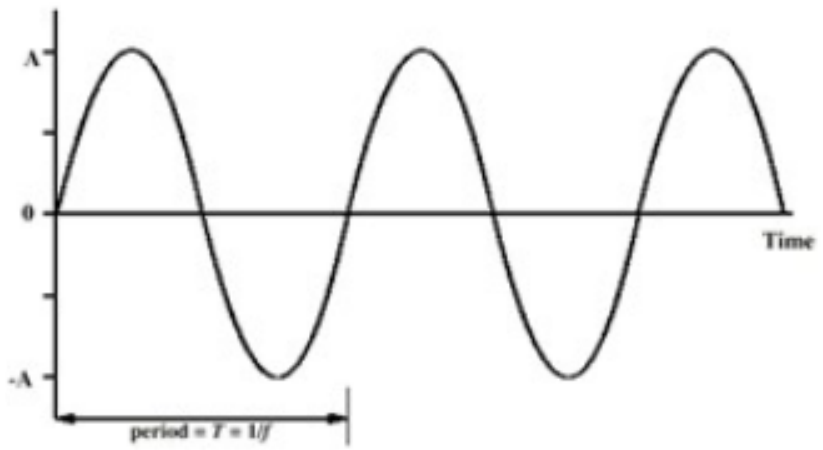
$$\omega = \frac{2\pi}{T} \qquad \omega = 2\pi f$$

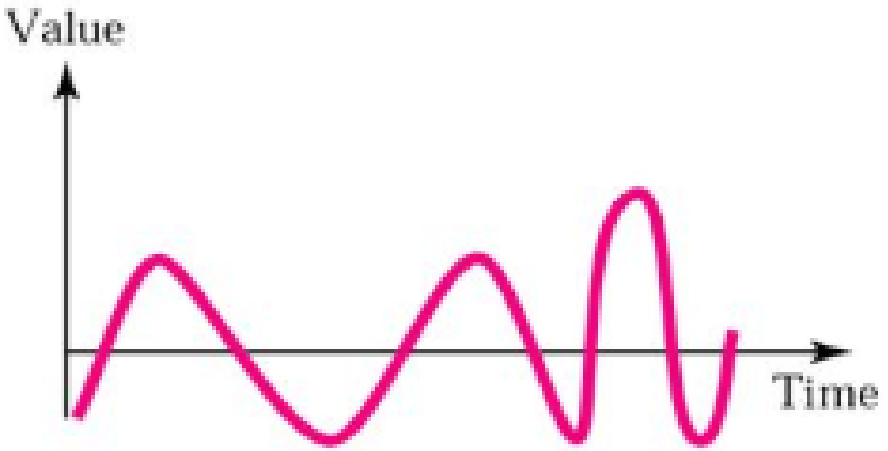
T= The fundamental periodic time of one complete cycle of x(t) , unit is sec.

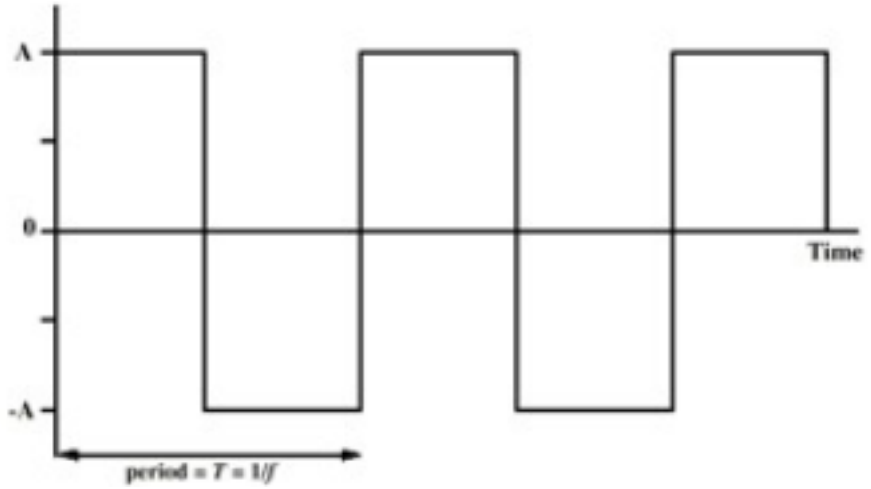
f= The fundamental frequency of x(t), the unit is Hz or cycle/Sec.

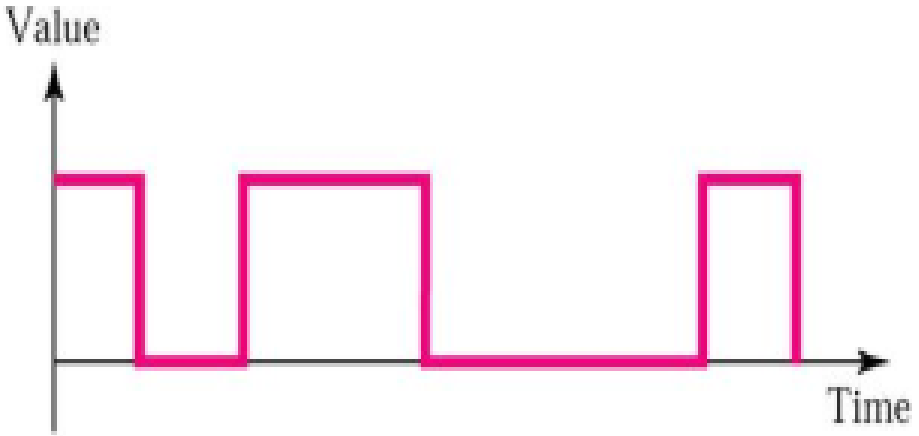
ω = Angular frequency , the unit rad/Sec.

- **Aperiodic Single (Non-periodic) Single : ** is the signal that will never repeat itself and get over in limited time called (Aperiodic Signal or Non - periodic Signal).







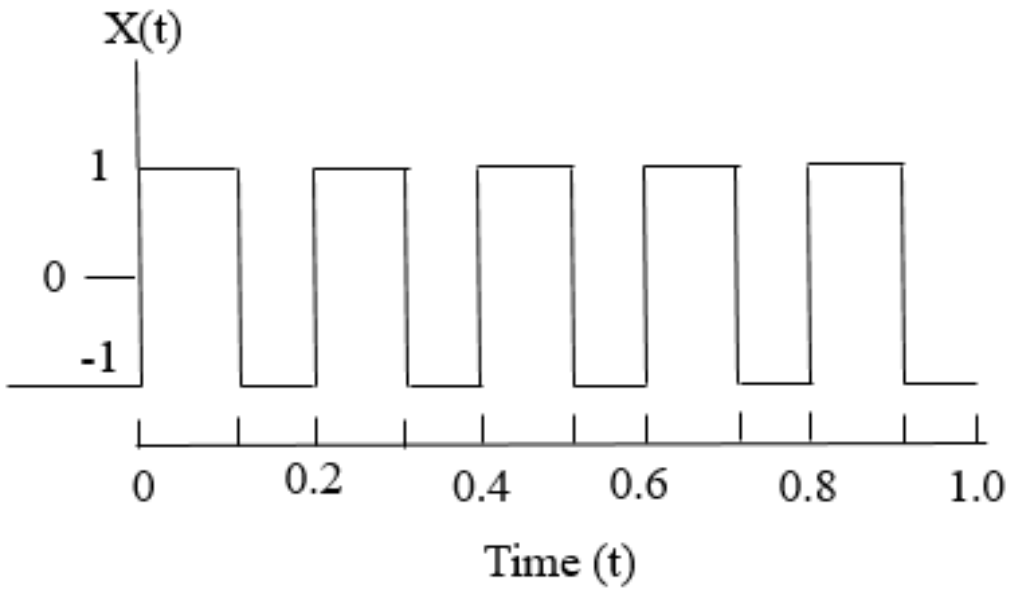


Periodic Single

Aperiodic Single (Non-periodic) Single

Signals Classification

- **Q1:** Determine the fundamental periodic , frequency and angular frequency for the following signals?

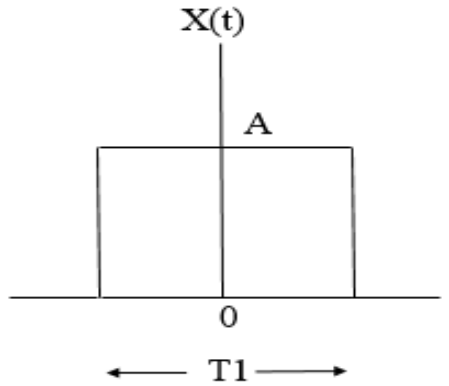


  - Answer:

$$T = 0.2 \text{ Sec.}$$

$$f = \frac{1}{T} = \frac{1}{0.2} = 5 \text{ Hz}$$

$$\omega = 2\pi f = \frac{2\pi}{T} = \frac{2\pi}{0.2} = 10\,\pi \quad \text{rad/Sec}$$

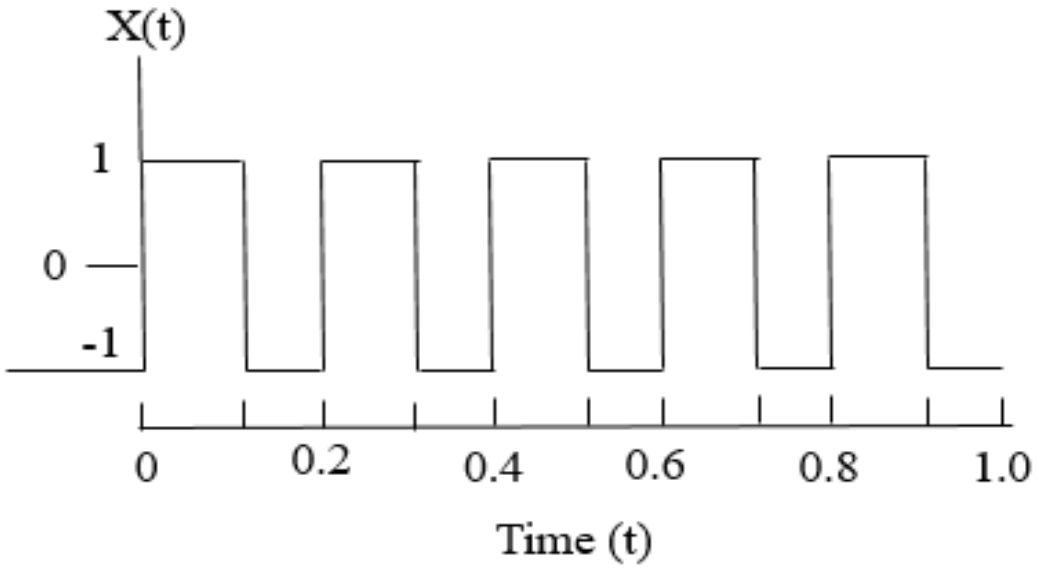


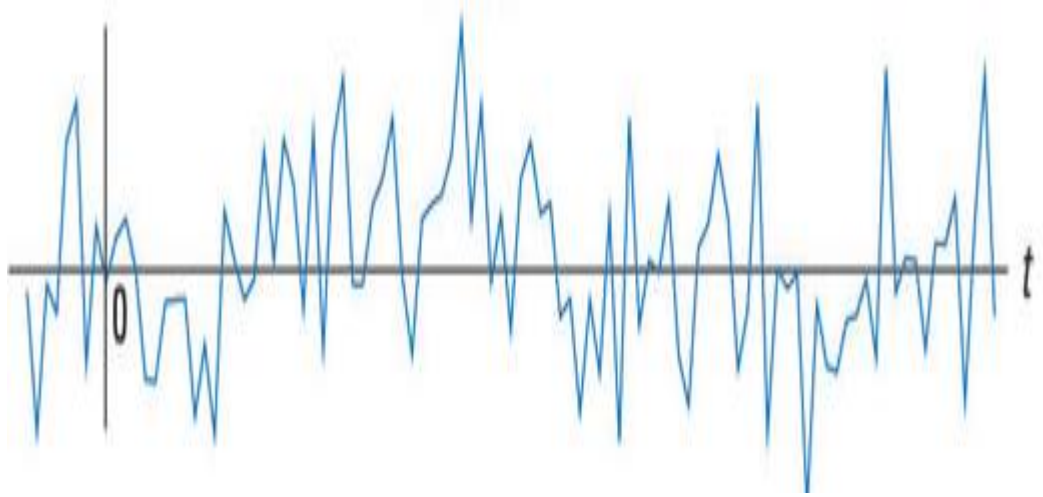
  - **H.W :** T = ? f = ? ω = ?

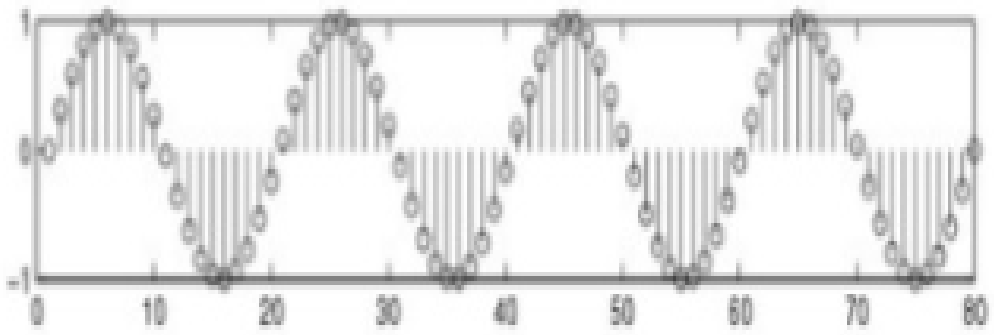
Signals Classification

3. Deterministic and Random Signals

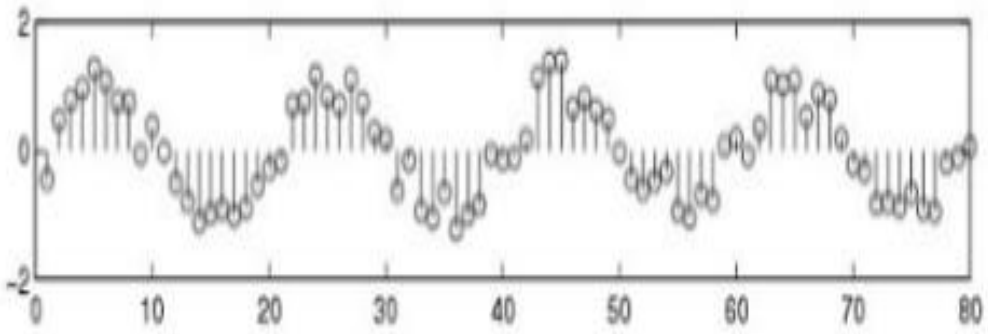
- **Deterministic Signal :** is the signal that has no uncertainty with respect to it is value at any time ,that means the signal which can predict the value of next time period .
  - The signals which can be written in any mathematical expression are called **"Deterministic Signal"** .
  - This signal can be modeled as a completely specific function of time .
  - Example : Sine , Cosine …etc.
- **Random Signal :** is a signal about which there is uncertainty before it happen , the signal that may a viewed as a group of different signals, that means the signal which can not predict what the value / shape for next time period.
  - The signal which amplitude between the positive and negative in a randomly fashion.
  - The signals which can not be written in mathematical expression are called **"Random Signal**" .
  - Example : Noise ,…etc.







Deterministic Signal



Random Signal

Signals Classification

4. Energy and Power signals

- **In general** , in this type of signals there are Three Cases :
  - Energy Signal (E) only.
  - Power Signal (P) only.
  - Neither Energy Signal nor Power Signal.
- **Energy Signal (E) :** a signal is refer to Energy signal if and only if the total energy satisfy the condition:

$$0 < E < \infty$$

.

- **Power Signal (P):** a signal is refer to Power Signal if and only if the average power satisfy the condition :

$$0 < P < \infty$$

- If the E = Finite it is called Energy Signal , the power of energy signal : $P = 0$
- If the P = Finite it is called Power Signal , the energy of power signal : $E = \infty$

Signals Classification

4. Energy and Power signals

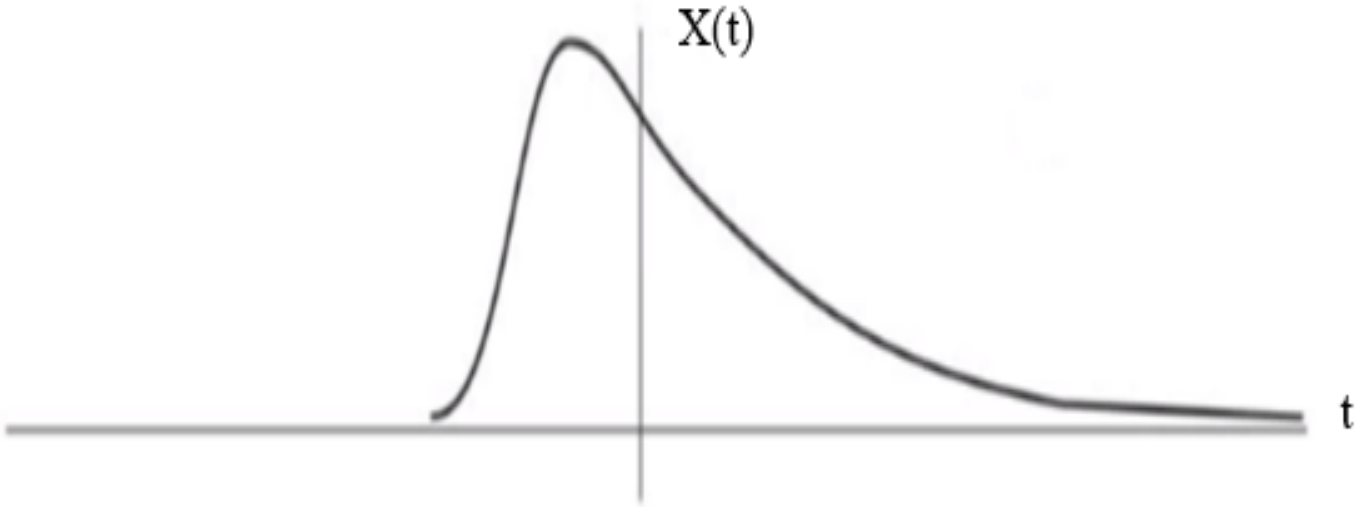
- The general formula of **Total Energy** :

$$E_x = \int_{-\infty}^{\infty} |x(t)|^2 \, dt$$ (Joules) (For Periodic and Aperiodic Signal)

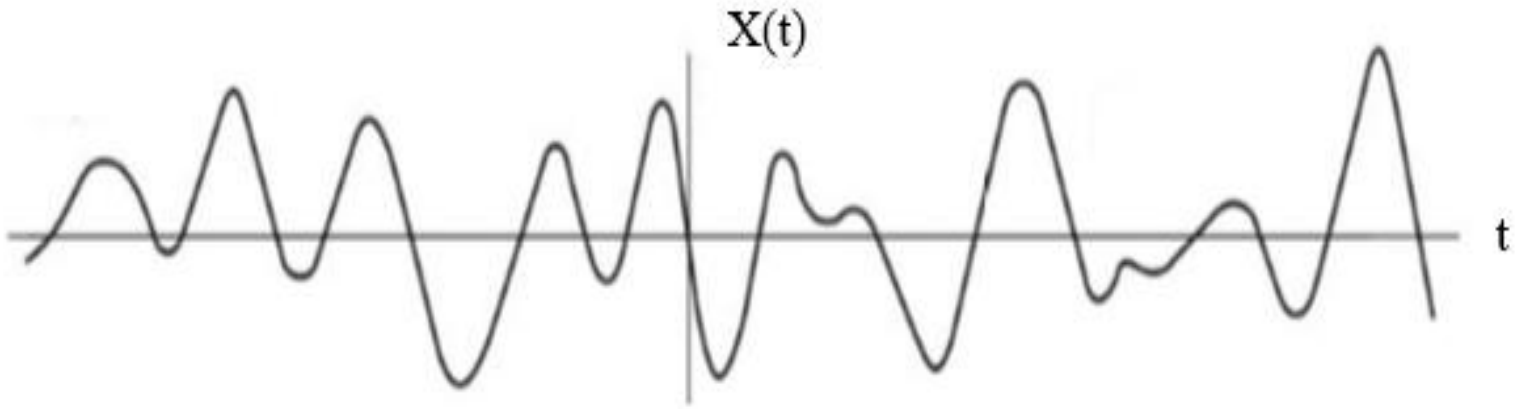
- The general formula of **Average Power** :

$$P_x = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} |x(t)|^2 \, dt$$ (Watts) (For Non- Periodic Signals)

$$P_x = \frac{1}{T} \int_{-T/2}^{T/2} |x(t)|^2 \, dt$$ (Watts) (For Periodic Signals)



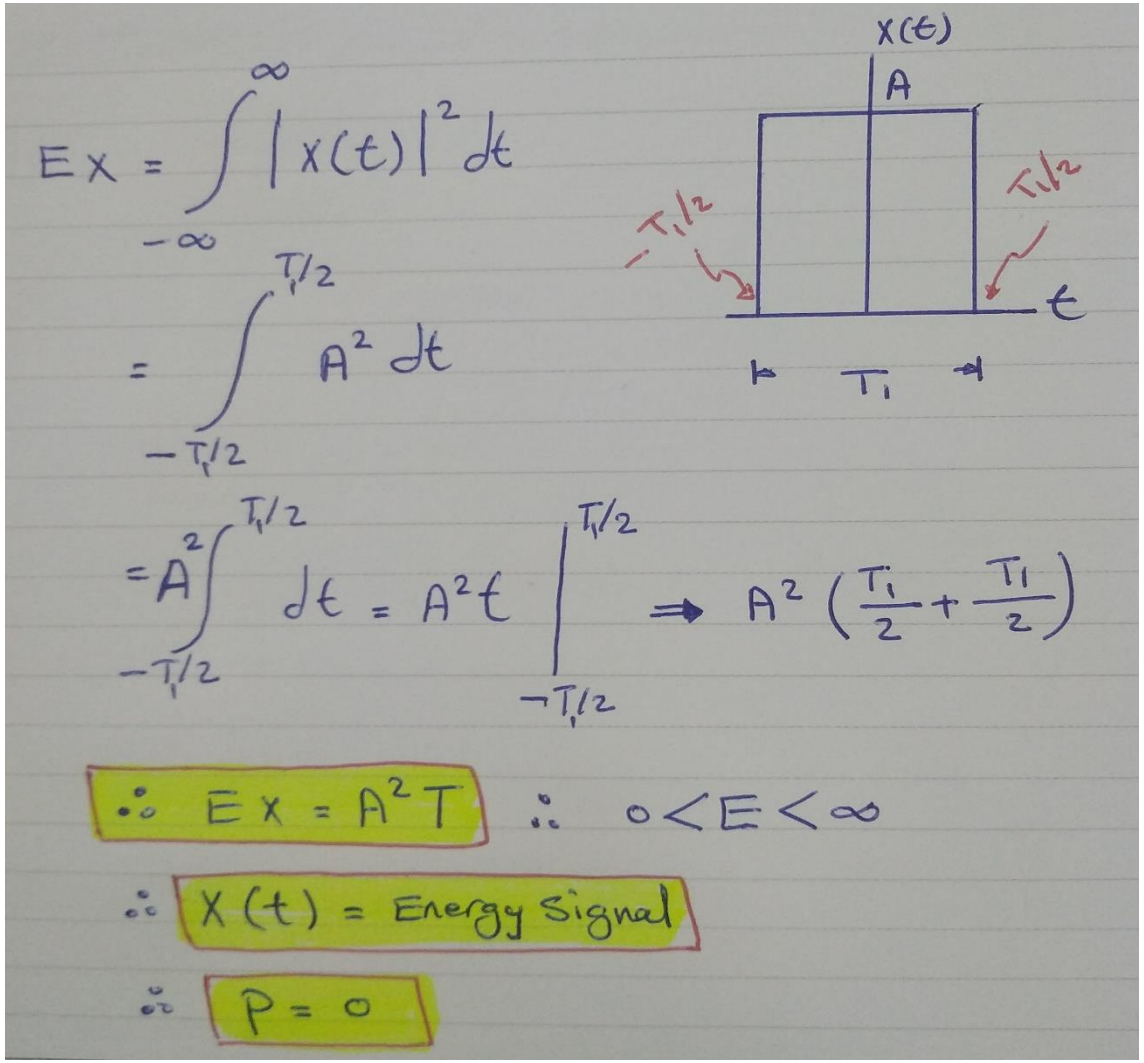
Energy Signal

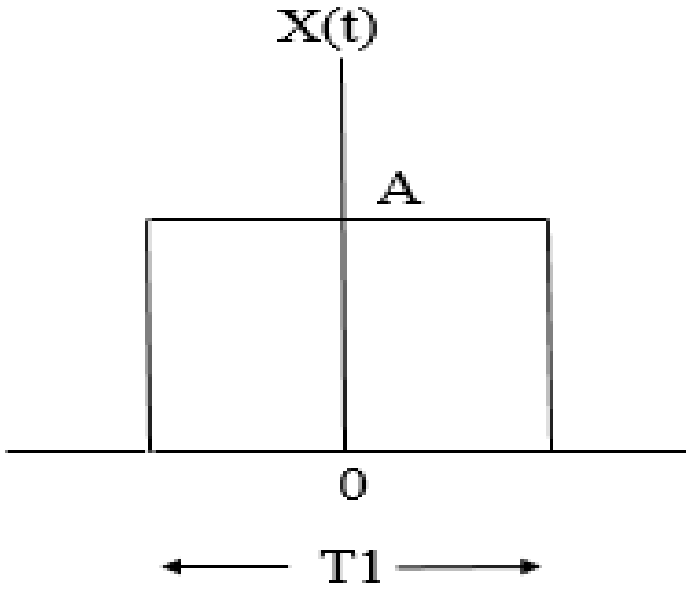


Power Signal

Signals Classification

- **Q2:** Determine the **Total Energy** of the pulse signal in the figure ?
  - Answer:

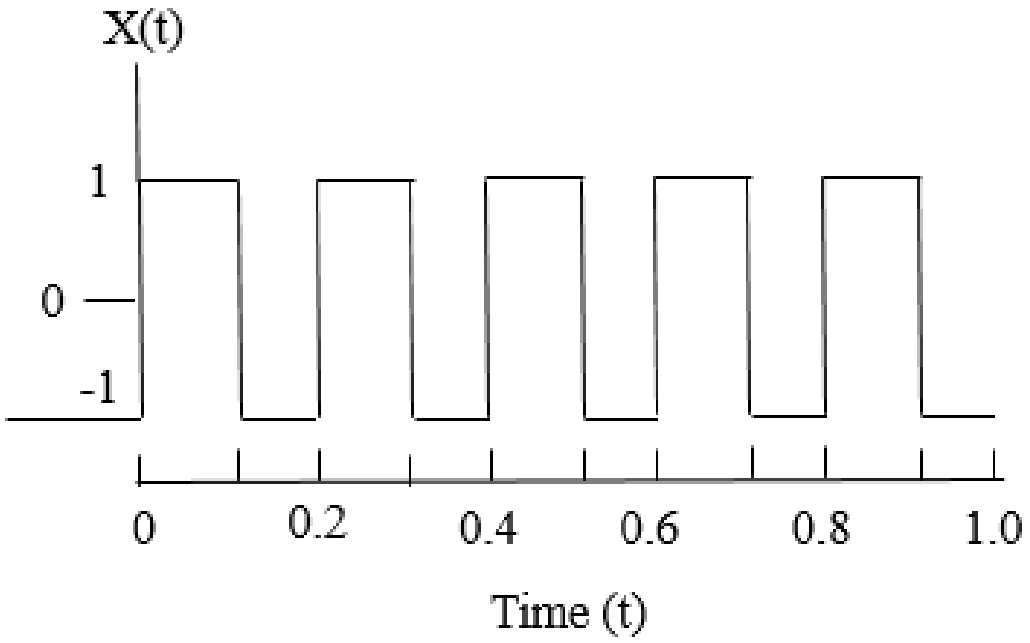




Signals Classification

H.W

- **Q3:** Determine the **Average Pow**er of signal in the figure ?



P = ?

E = ?

Signals Classification

5. Even and Odd Signals

- **Even Signal:** in CT signal x(t) is defined as **Even** signal $x_e(t)$ if :

$$x(-t) = x(t) \quad \text{or} \quad x(t) = x(-t) \quad \text{or} \quad x_e(t) = x_e(-t) \qquad \text{for all } t$$

- **Odd Signal:** in CT signal x(t) is defined as **Odd** signal $x_o(t)$ if :

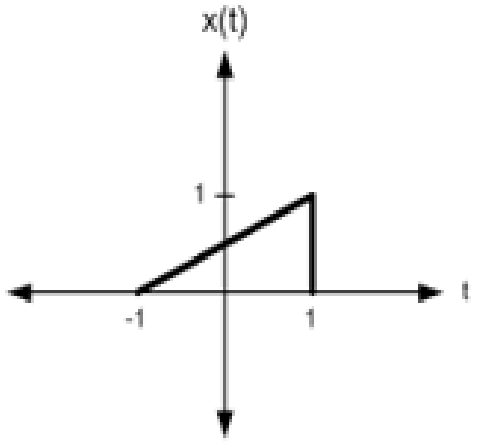
$$x(-t) = -x(t) \quad \text{or} \quad x(t) = -x(-t) \quad \text{or} \quad x_o(t) = -x_o(-t) \qquad \text{for all } t$$

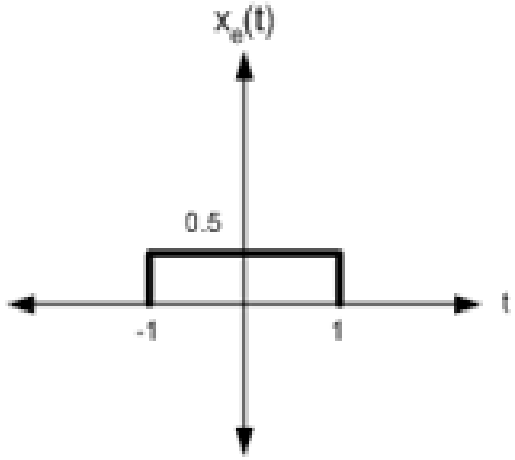
- **In general ,** any/each signal x(t) can be written as the sum of $x_e(t)$ and $x_o(t)$ parts/terms as :

$$x(t) = x_e(t) + x_o(t) \quad \text{and} \quad x(-t) = x_e(t) - x_o(t)$$

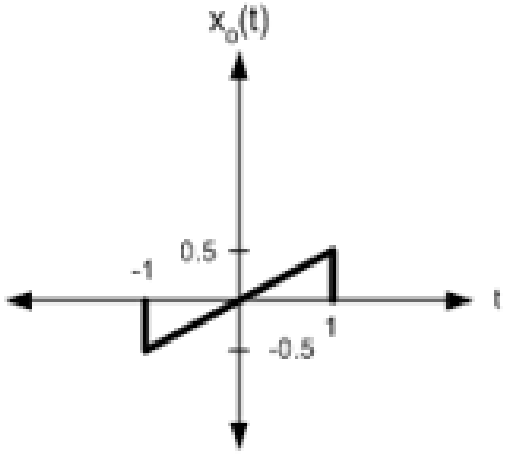
$$x_e(t) = \frac{1}{2}[x(t) + x(-t)] \qquad \text{and} \qquad x_o(t) = \frac{1}{2}[x(t) - x(-t)]$$

- **In summary ,** an **Even** Signals are **symmetric** about the vertical axis (time origin), while, an **Odd** Signals are **antisymmetric** about the origin.

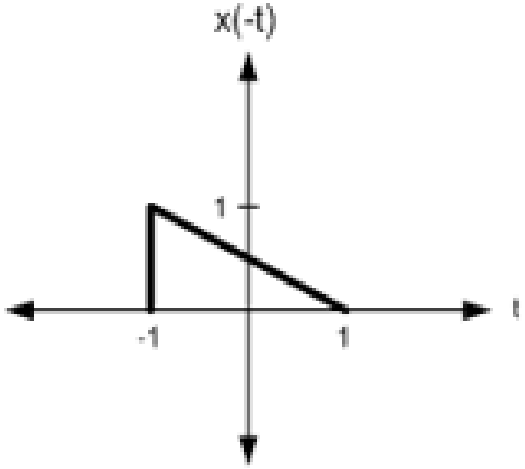


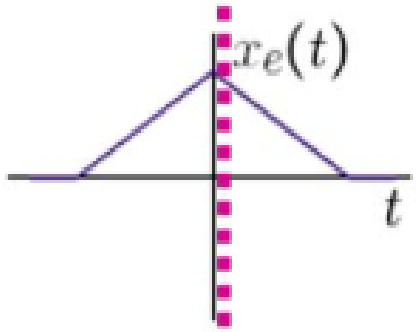


Even Signals

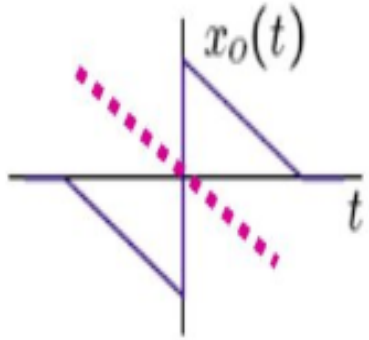


Odd Signals





Even Signals



Odd Signals

Signals Classification

6. Complex and Real Signals

- **Real Singles :** means the signal takes it is values in the set of real numbers $X(t) = \cos(t)$

- **Complex Signals :** means the signal takes it is values in the set of complex numbers (real and imaginary parts)
  - Define a complex signal and a complex exponential to be:

$$z(t) = x(t) + j\,y(t) \qquad e^{j\theta} = \cos(\theta) + j\,\sin(\theta)$$

  - A magnitude α (t) and phase θ (t) representation of a complex signal is also commonly used:

$$z(t) = \alpha(t)e^{j\theta(t)}$$

- **In communication**
  - Used to model signals.
  - Transfer/Transmit amplitude and phase information.
  - Represented by (Real and imaginary parts) , (magnitude and phase).

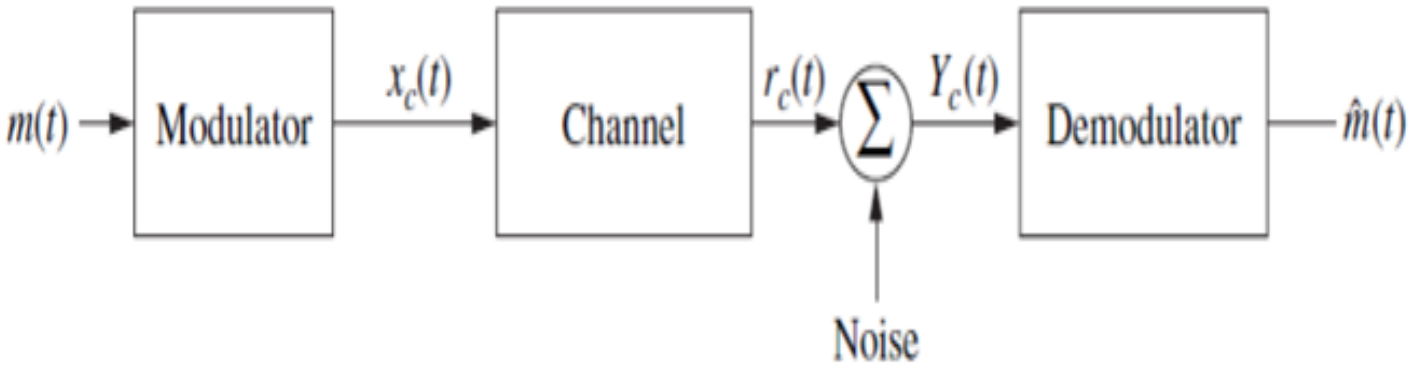
Modulation and Demodulation

Analog Transmission

- **The classical communication system include:**
  - **Modulator** producing a signal that is transmitted over a channel (a cable or radio propagation).
  - **Demodulator** which takes this signal and constructs an estimate of the transmitted message signal.
- **In general,** the job of **Communication System Engineers** is to design and optimize the modulators and demodulators in communication systems.
- The **block diagram** below shows the basic block diagram of analog communication system:

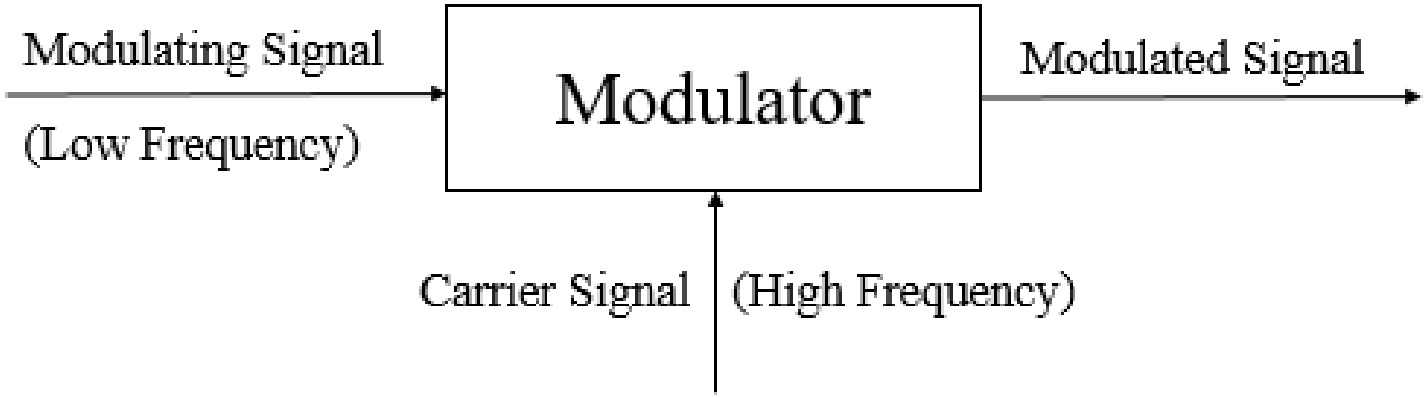
where $r_c(t)$ is the output of the channel, $Y_C(t)$ is the waveform observed with the receiver

$\hat{m}(t)$ is the estimate of the transmitted message signal.



Modulation

- **Modulation :**The process of provide strength to the information signal/message signal (low frequency) which is carrying or loading on the carrier signal (higher frequency) by the modulator to produce the modulated signal which able to travel for long distance through the transmission channel .
- **The principle of modulation** based on use a high frequency signal to carry information about a low – frequency signal such as (message signal , sound waves , voice , image …etc.).



Basic Block Diagram of Modulation

Modulation

- **Modulation:** is the process of changing one or more properties such as (amplitude, frequency or phase) of a carrier signal in accordance to the amplitude of modulating signal, m(t). A circuit which provide/performed the modulation in the transmitter called **modulator.**

- The process of **combine the information / modulating signal** with the carrier signal to generate the modulated signal then transfer the data /information between two different places , that means the modulation is the transmit/transfer the frequency, the information signal (low frequency) which combine with carrier signal (high frequency) to transmit the data/information for long distance by the channel / medium.

Modulation

- **Modulation Process:**

  - There are **Three Types** of Signals in the Modulation Process:

1. **Message /Information or Modulating Signal:** the signal which contains a message to be transmitted, is called as a message signal which has to undergo the process of modulation, to get transmitted, as well it is called as the modulating signal.
2. **Carrier Signal:** the high frequency signal, which has a certain amplitude, frequency and phase but contains **no information** is called as a carrier signal. It is an empty signal and is used to carry the signal to the receiver after modulation.
3. **Modulated Signal:** the resultant signal after the process of modulation is called as a modulated signal. This signal is a combination of modulating signal and carrier signal.

Modulation

- **In general**, the process of send the original signal in communication systems based on **two main types**:

- **Baseband Signal**: means the process of send the original signal without modulation (send the information signal directly) , the baseband communication system based on **Baseband signal.**
- Is a signal which transmits without using modulation. The term of **(Baseband)** is used to specific the band of frequencies of the signal delivered by the source or input transducer, such as (Voice, data and picture signals) are Baseband Signals.

- **Band pass Signal :** means the process of modulated the information signal / modulating signal then send by the carrier signal ,the band pass communication system based on **Band Pass Signal**.
- The signals which are modulated called band pass signal. Its spectrum take the frequency spectrum from certain lowest frequency to the highest frequency .

Modulation

- **Why we need the modulation ?**

  - **Modulation** is required to send the information over long distances as low frequency signals are not able to cover large area.
  - **The main principle** of modulation to transfer the radio communication which based on the wavelength and the height of antenna .

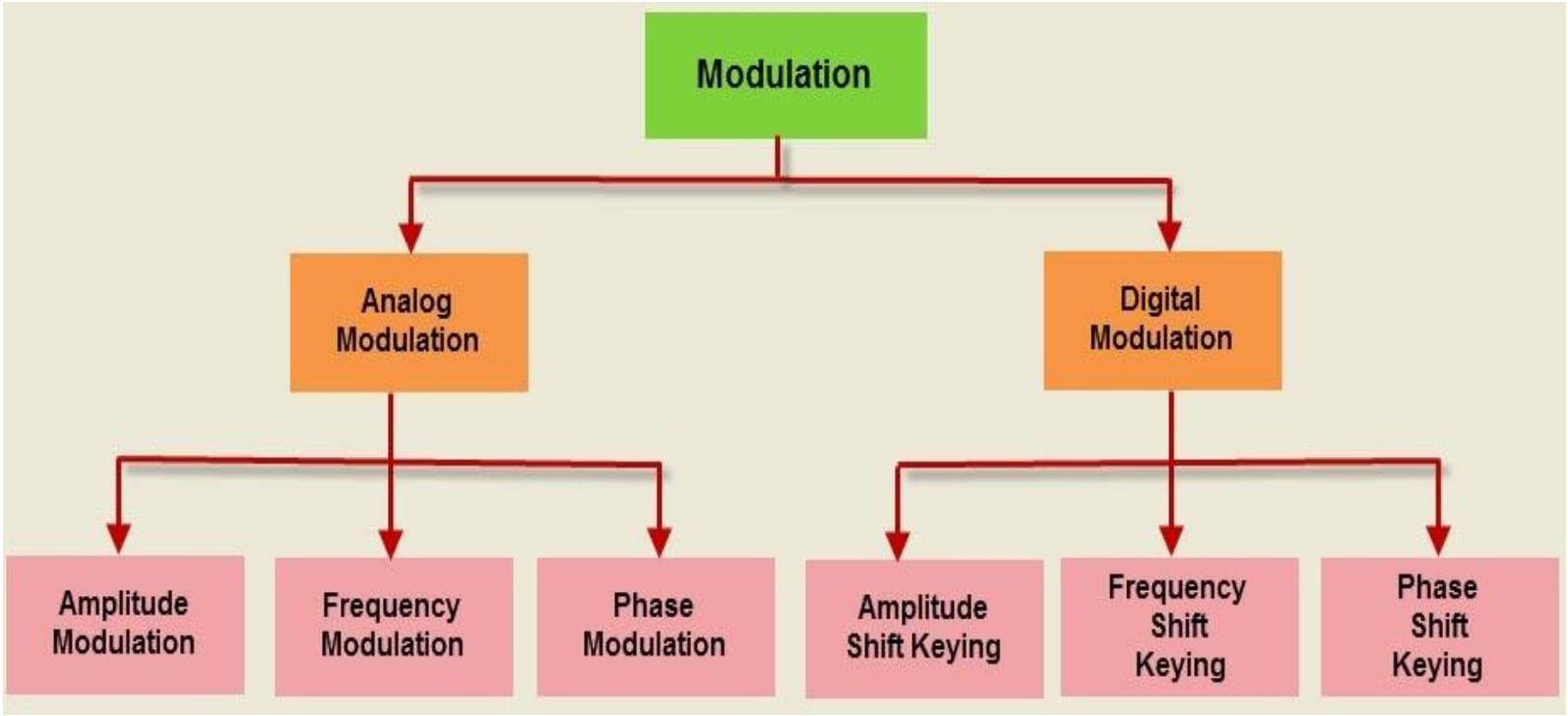
- **Why we require modulation?**

  - To improve the quality of reception.
  - To Improves the strength of the signal
  - To increase the range of communication.
  - To reduce the antenna height.
  - To decrease and avoid the noise, distortion and interference effects.

Types of Modulation

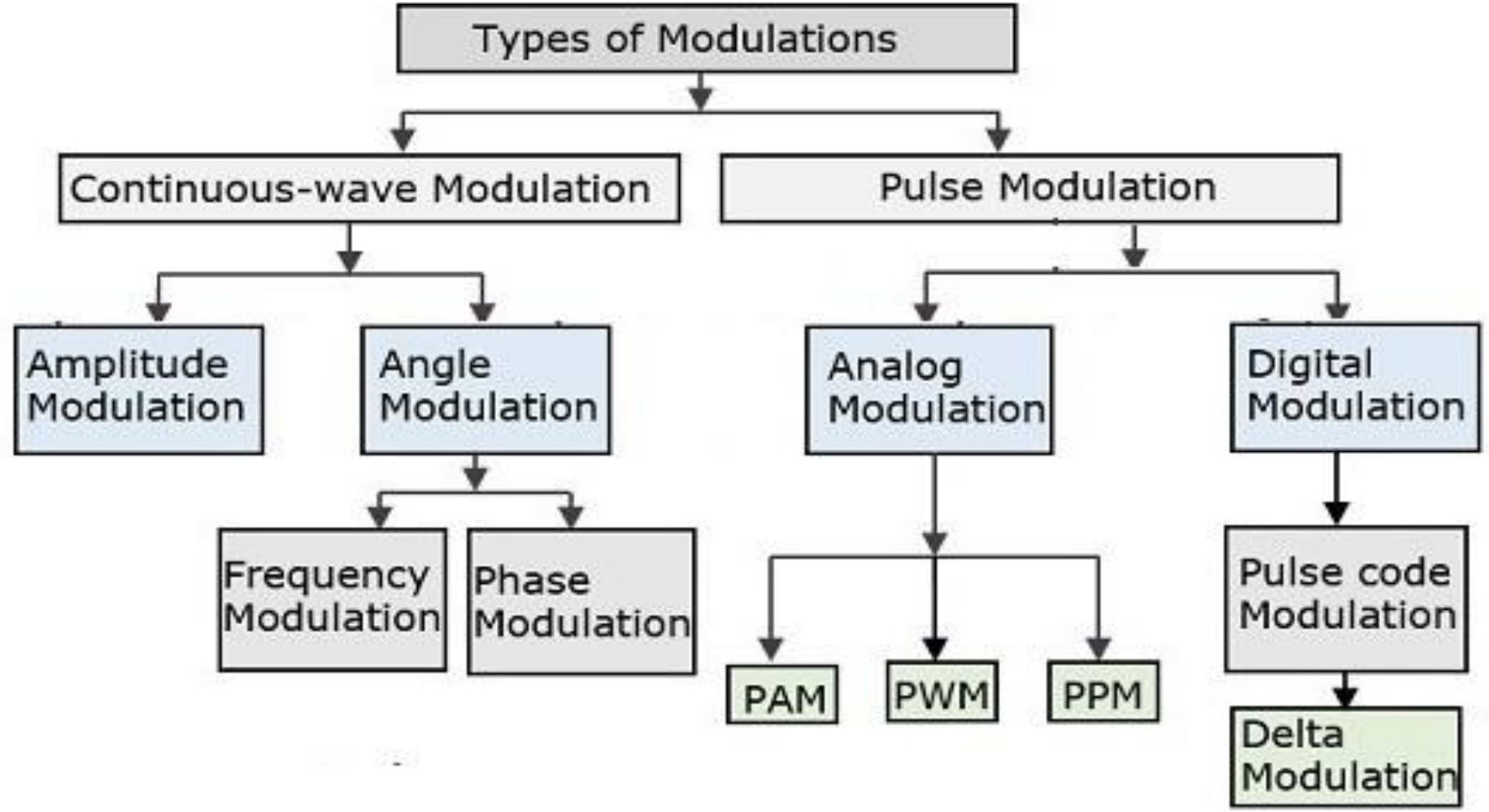
- In general ,the **Modulation Techniques** divided into **two main types :**

1. **Analog Modulation:** is the process of converting an analog input signal into a signal that is suitable for RF transmission , anlage modulation include (AM, FM, PM).
2. **Digital Modulation:** is the process of converting a digital bit stream into an analog signal which is suitable for RF transmission , digital modulation include (ASK, FSK ,PSK).



Types of Modulation

- For more specific, the **Modulation Techniques** based on **Continuous wave** and **Pulse Modulation** :



Types of Modulation

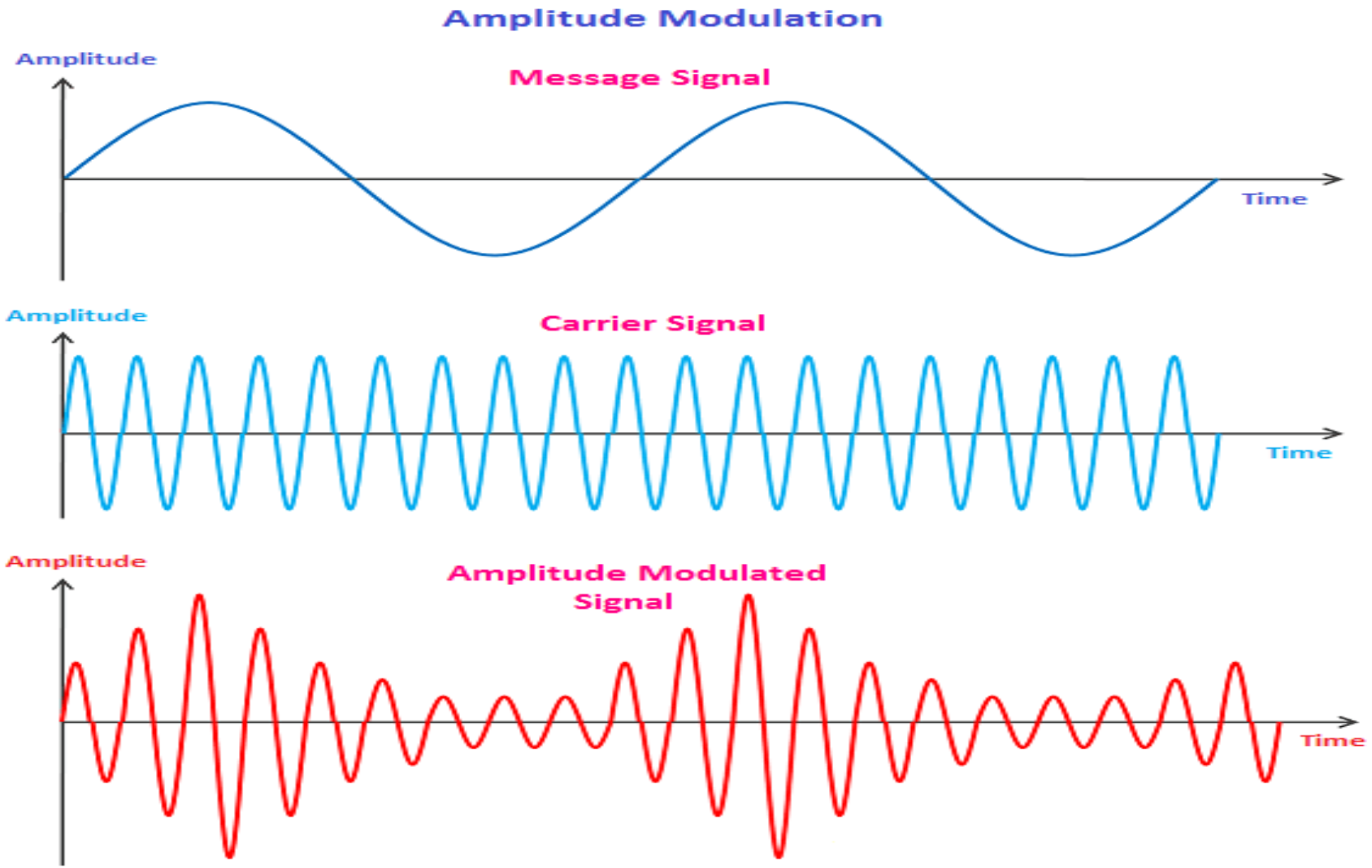
- There are **Three types** of Analog modulation which based on **Continuous Wave Modulation** :

1. **Amplitude modulation (AM):** is a kind of modulation where the amplitude of the carrier signal is changed in proportion to the message signal while the phase and frequency are kept constant.

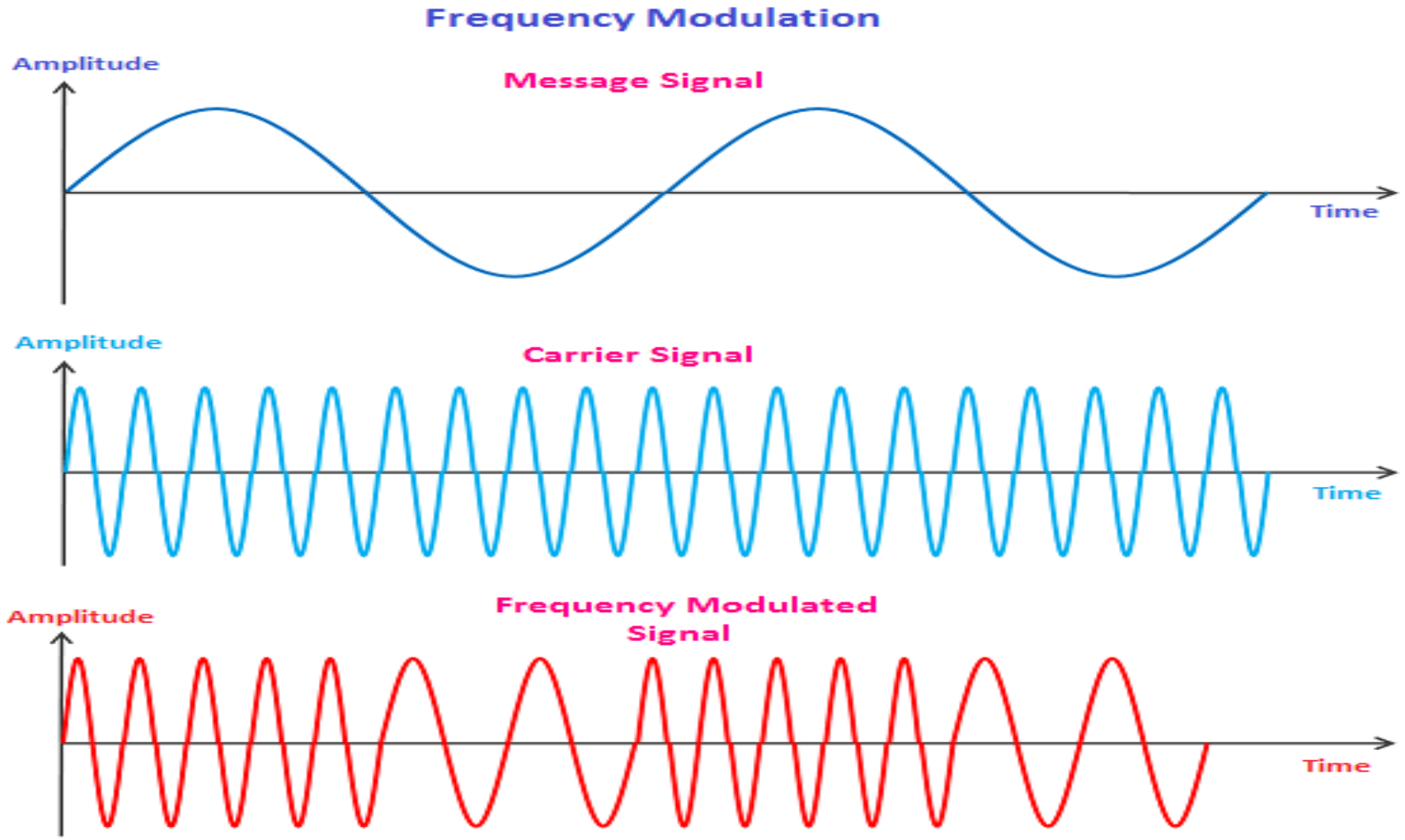
2. **Frequency modulation (FM)** : In this modulation the frequency of the carrier signal is changed in proportion to the message signal while the phase and amplitude are kept constant is called frequency modulation.

3. **Phase modulation (PM)** : This is the modulation where the phase of the carrier signal is changed according to the low frequency of the message signal is called phase modulation.

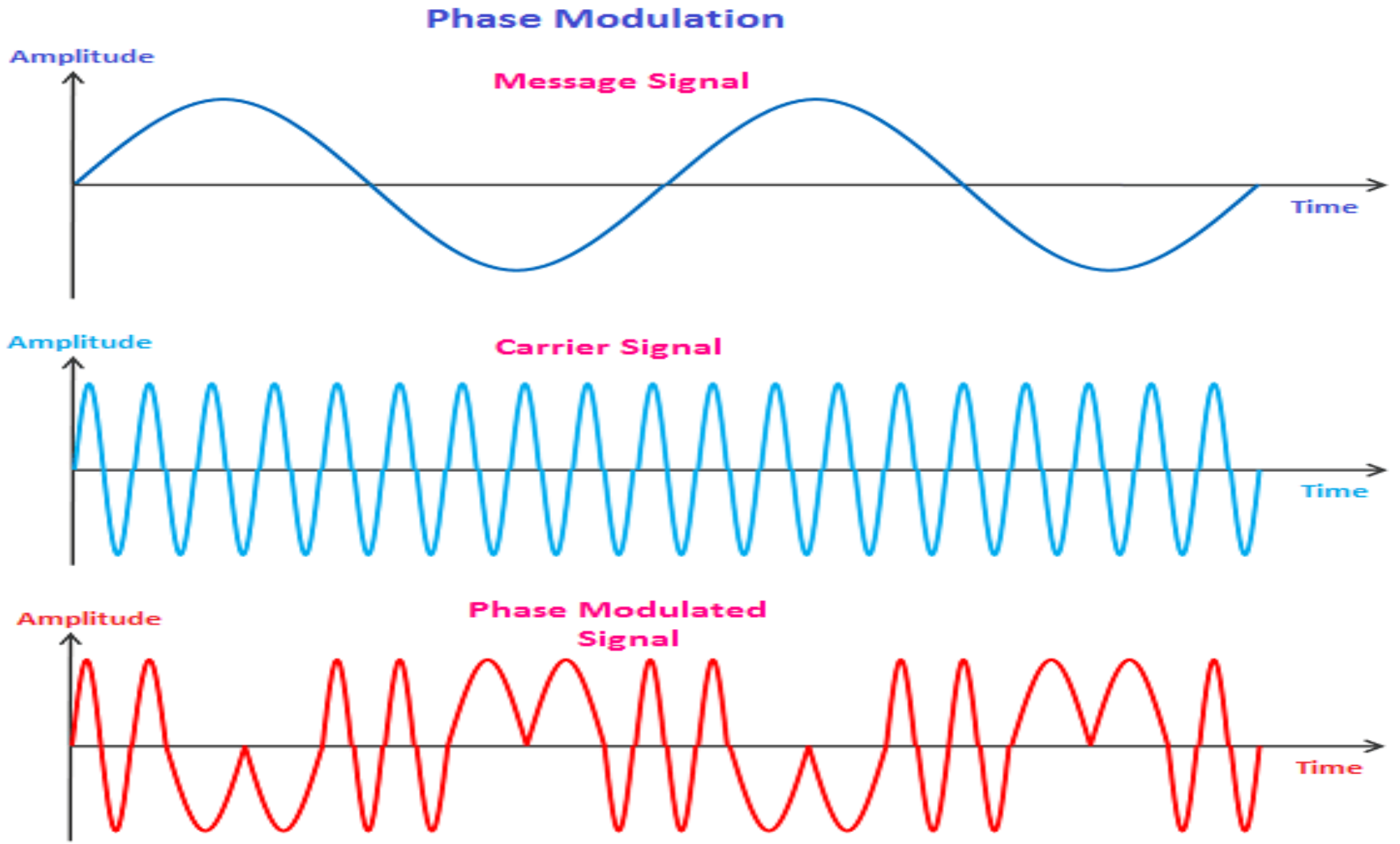
Types of Modulation



Types of Modulation



Types of Modulation



Types of Modulation

- **Pulse Modulation:** in pulse modulation, a periodic sequence of rectangular pulses, is used as a carrier wave. This is further divided into analog and digital modulation.

  - **In analog modulation technique**: if the amplitude / duration / position of a pulse is varied in accordance with the immediate/direct values of the baseband modulating signal, then this technique is called as:

a. Pulse Amplitude Modulation (PAM)

b. Pulse Width Modulation (PWM)

c. Pulse Position Modulation (PPM)

  - **In digital modulation:** the modulation technique used is Pulse Code Modulation (PCM) where the analog signal is converted into digital form of 1s and 0s. As the resultant is a coded pulse train, this is called as PCM. This is further developed as Delta Modulation (DM).

Demodulation

- **Demodulation:** is the reverse process of modulation and converts the modulated carrier back to the original information ,A circuit which provide/performed the demodulation in receiver is called **demodulator.**
- The process of **recovering the original signal** from the modulated wave is called demodulation or detection, at the broadcasting station, modulation is done to transmit the audio signal over larger distances to a receiver. When the modulated wave is picked up by the radio receiver, it is necessary to recover the audio signal from it. This process in the radio receiver is called **demodulation.**
- The **principle of demodulation** based on the process of separate the information signal from the carrier signal to receive the original information by the distention .
- The reverse process of **separating** the (low frequency) message signal from (high frequency) carrier signal in the receiver is called demodulation .

Demodulation

- **Why we need the demodulation ?**

  - The **wireless signal** consists of radio frequency (high frequency) carrier wave modulated by audio frequency (low frequency). The diaphragm of a telephone receiver or a loud speaker cannot vibrate with high frequency. Moreover, this frequency is beyond the range of human ear. So, it is necessary to separate the audio frequencies from radio- frequency carrier waves.

- **What the difference between Modulation and Demodulation?**

  - **Modulation** is the process of imposing data information on the carrier.
  - **Demodulation** is the recovery of original information at the distant end from the carrier.
  - **Modem is** the device that performs both modulation and demodulation.
  - **Both processes** try to transfer information with the minimum noise, distortion and loss, even there are different methods for **modulation and demodulation** processes, each has it is own advantages and disadvantages.
  - **Example**: AM is used in shortwave and radio wave broadcasting, FM is mostly used in high-frequency radio broadcasting and pulse modulation is known for digital signal modulation.

Modulation Vs Demodulation

Modulation	Demodulation
The **principle of Modulation**: based on use a high - frequency signal to **carry** information about a low – frequency signal such as (message signal , sound waves , voice , image …etc.).	The **principle of Demodulation:** based on the process of **separate** the information signal from the carrier signal to receive the original information by the distention.
The **Modulation** process occur inside the **“ Transmitter ”.**	The **Demodulation** process occur inside the **“ Receiver ”.**
The circuit which is required to provide and performed the **Modulation** is called **“ Modulator ”.**	The circuit which is required to provide and performed the **Demodulation** is called **“ Demodulator ”.**
In modulation, the modulating signal combine with carrier signal to generate the modulated signal, that means convert the **“ Low frequency to High frequency” .**	**In demodulation ,** the original signal recovering / separate from the modulated signal, that means convert **“ the High frequency to Low frequency ”.**