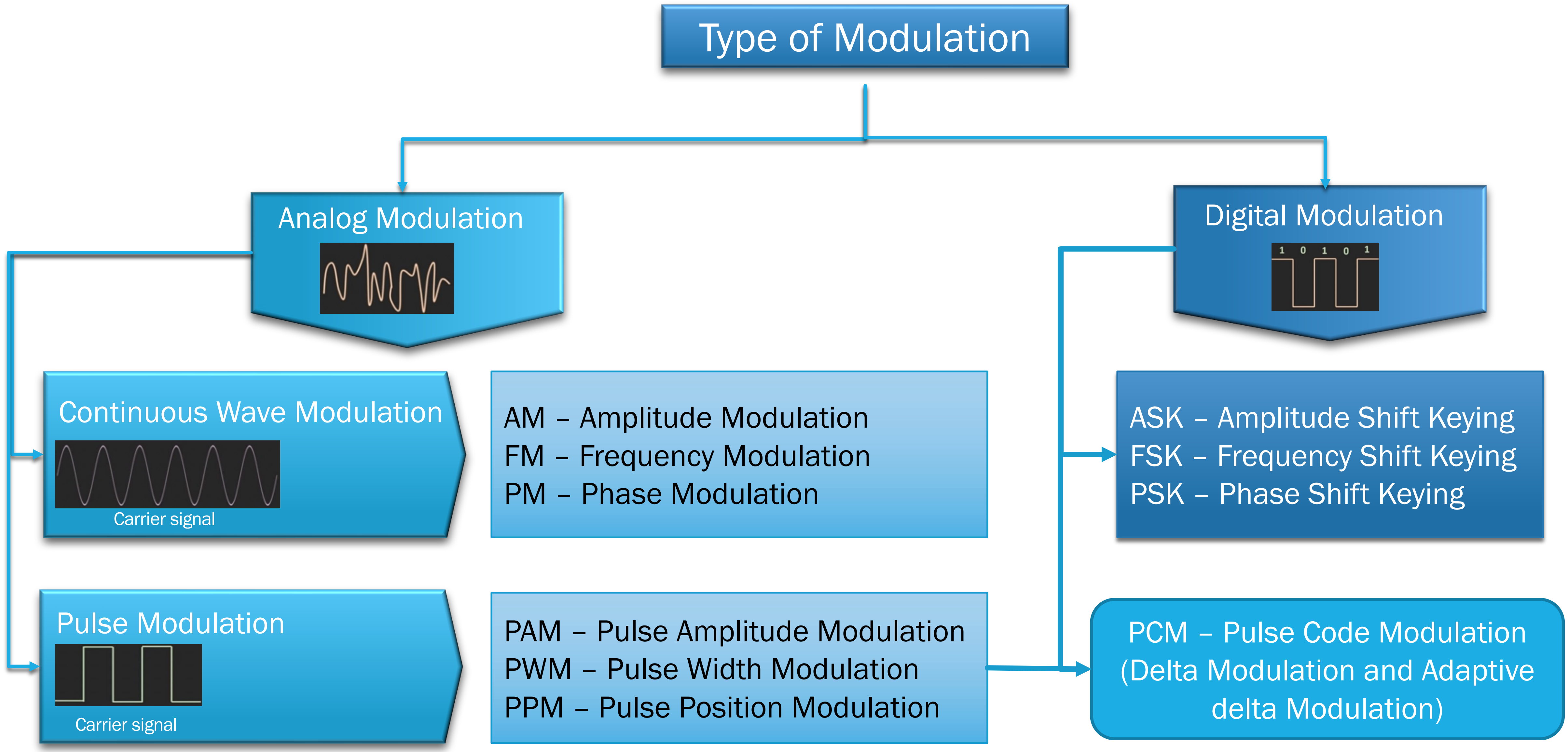
UNIT 7
FM, PM, PAM, PWM and PPM

PROF. THUSHARA WEERAWARDANE

Outcomes

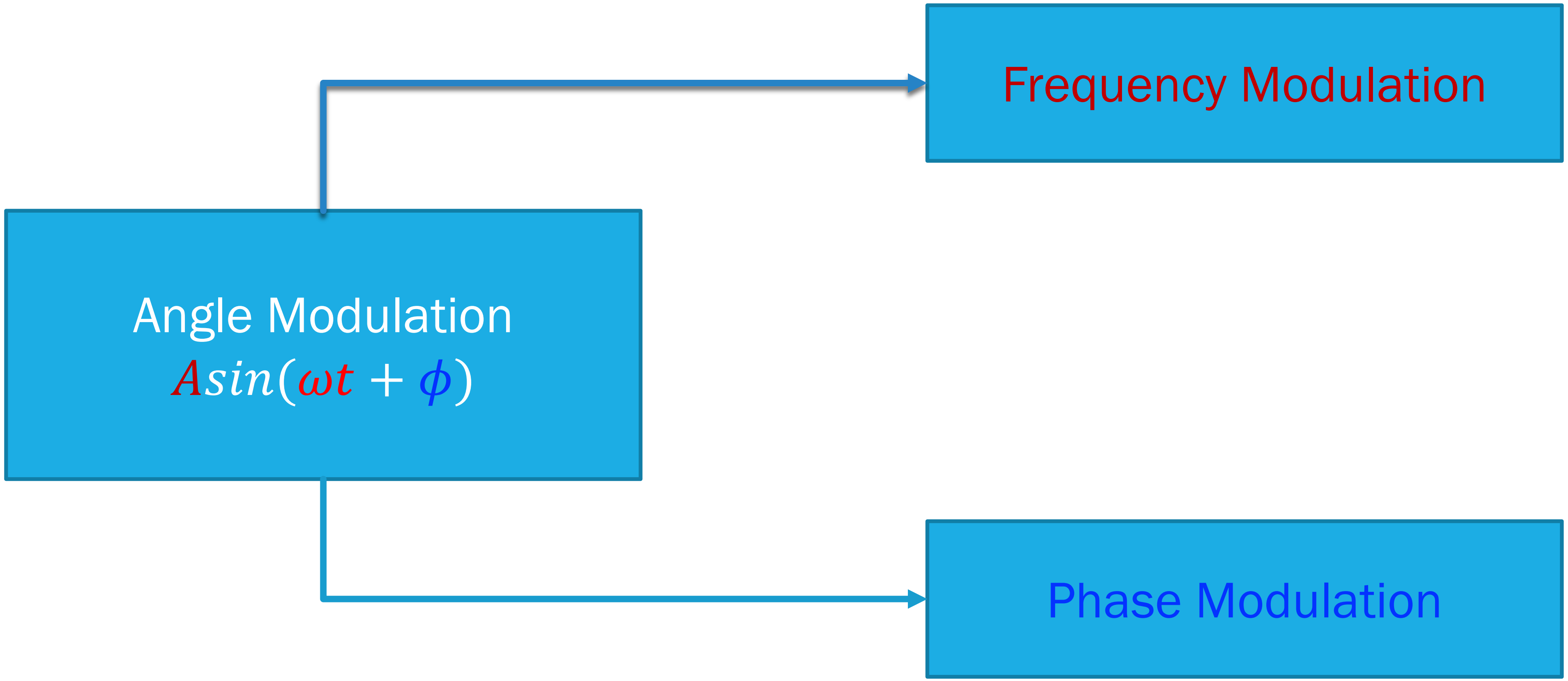
- Define Analog Modulation Categorization
- Describe FM, PM, and Pulse Modulation Techniques
- Compare Pulse Modulation Schemes
- Analyze the Impact Pulse Modulation for Wireless communication



Type of Modulation
Analog Modulation
Digital Modulation
1 0 1 0 1
Continuous Wave Modulation
Carrier signal
AM – Amplitude Modulation
FM – Frequency Modulation
PM – Phase Modulation
ASK – Amplitude Shift Keying
FSK – Frequency Shift Keying
PSK – Phase Shift Keying
Pulse Modulation
Carrier signal
PAM – Pulse Amplitude Modulation
PWM – Pulse Width Modulation
PPM – Pulse Position Modulation
PCM – Pulse Code Modulation
(Delta Modulation and Adaptive
delta Modulation)

FREQUENCY MODULATION

Angle Modulation



Frequency Modulation

- Frequency modulation is a technique or a process of encoding information on a particular signal (analogue or digital) by varying the carrier wave frequency in accordance with the amplitude of the modulating signal.
- In simple: the frequency of the carrier signal changes with respective to the modulating signal

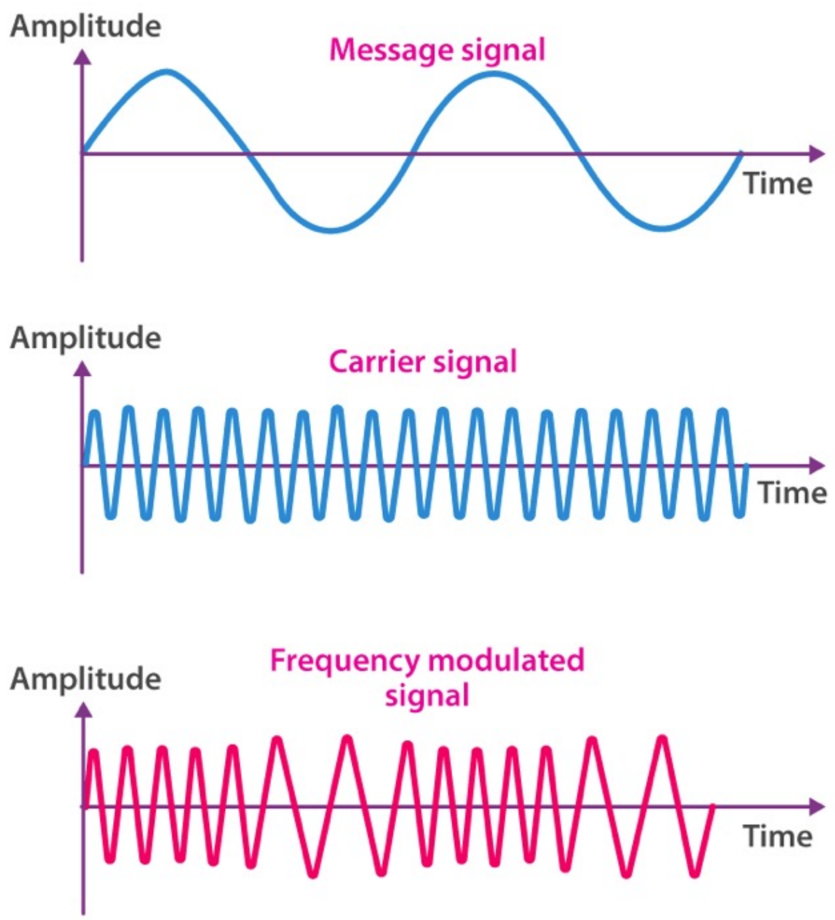
General Concept $y(t) = A sin(\omega t + \phi)$

$\omega(t) = F(m(t))$

FM Modulated Signal $s(t) = A_c sin(\omega_c t + \frac{\Delta f}{f m} \sin(\omega_m t))$

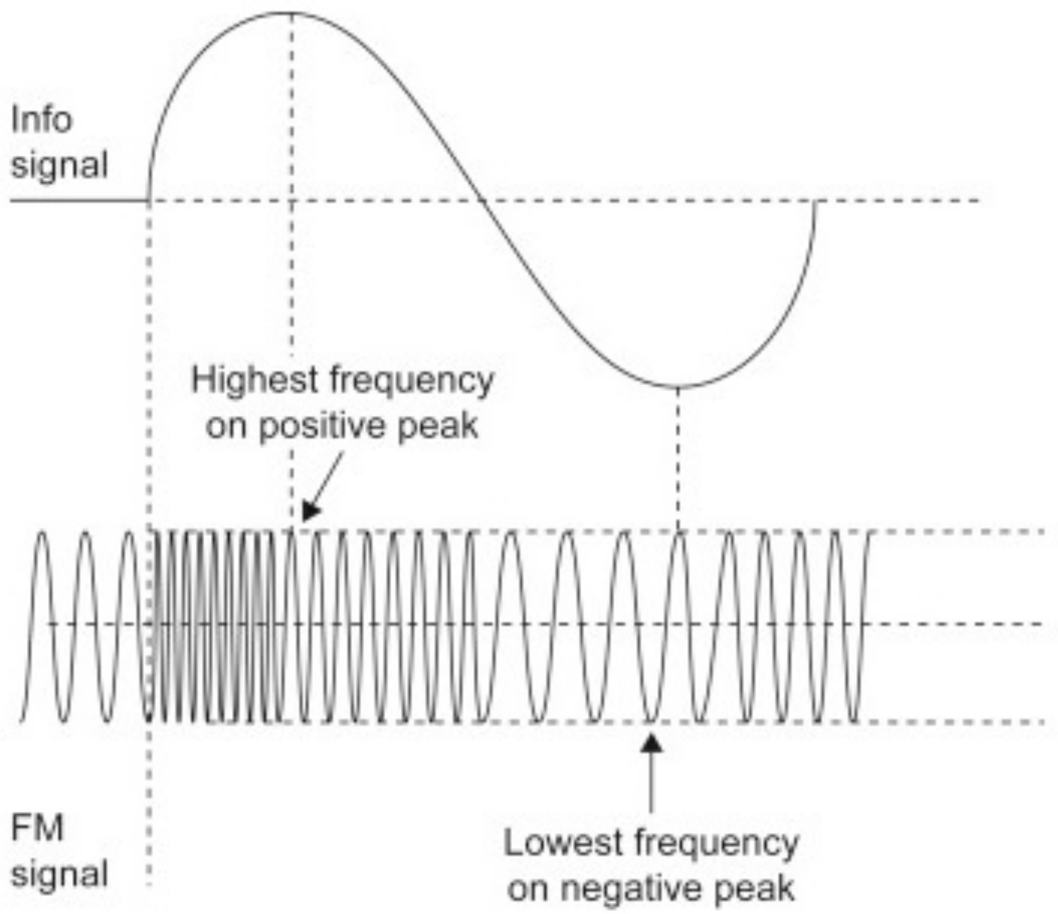
$\omega_c - carrier\ freq,\ \beta = \frac{\Delta f}{f m} - modulating\ index,\ \omega_m - signal\ frequency$

$\Delta f = peak\ freq. deviation, \quad f_m = BW\ of\ baseband\ signal$



BW$= 2(\Delta f + f_m)$

FM and Its Applications



<u>Applications</u>

- Radio broadcasting
- TV sound transmission
- Cellular radio
- Some use cases in Radar, telemetry, seismic prospecting and in EEG

Advantages and Disadvantages of FM

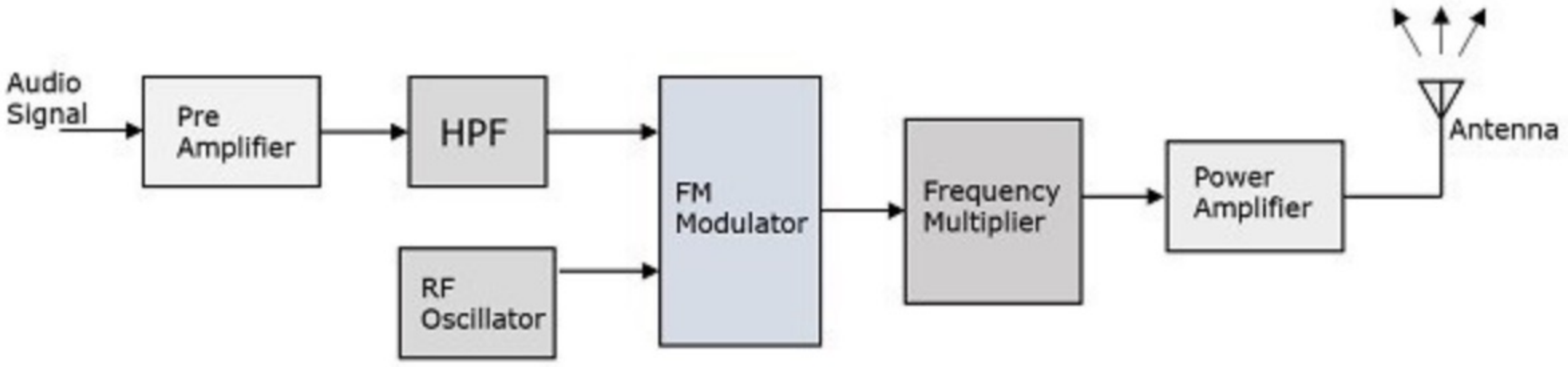
Advantages

- Noise Reduction (Large SNR), results in low radio frequency interference.
- Lesser interference among adjacent stations (Guard band is use for channel separation)
- Efficient use of power (low power consumption) and also the radiated power is less

Disadvantage

- Require large BW
- More complicated receiver and transmitter. Therefore, equipment cost is higher

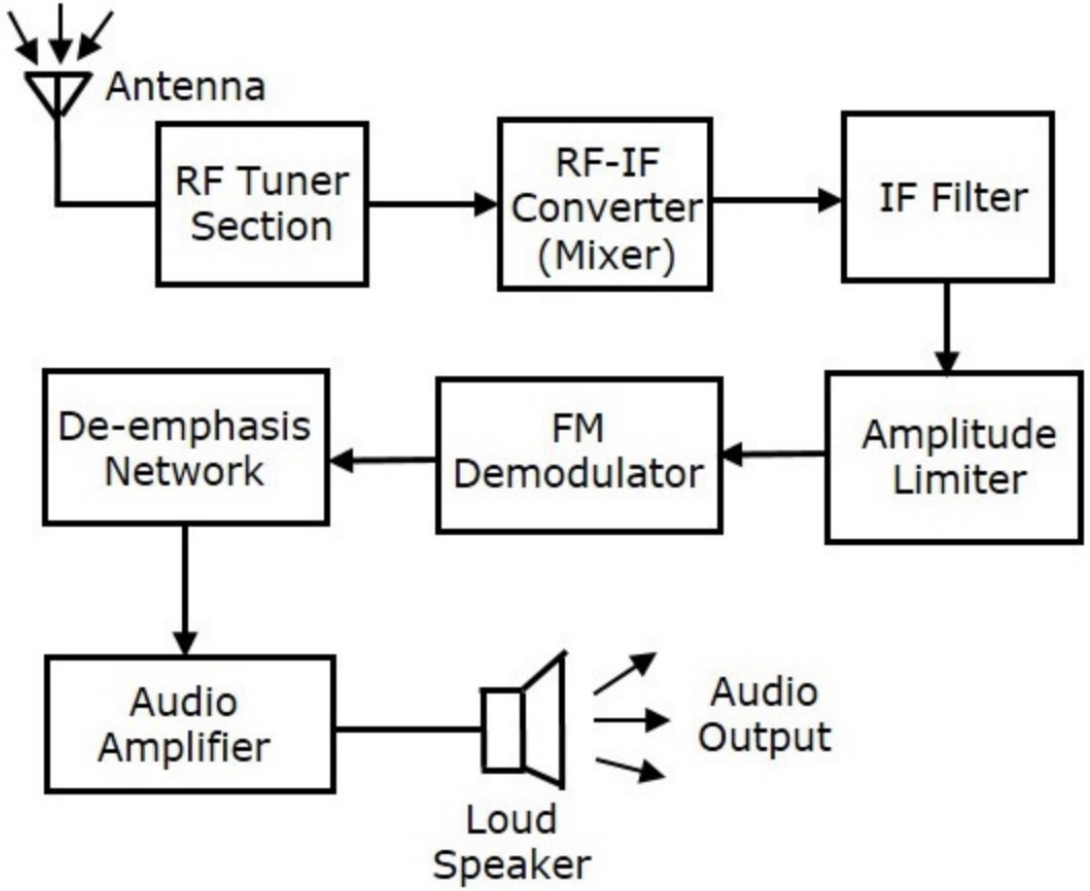
FM Transmitter



- Pre amplifier boost the level of the audio signal (mic)/modulating signal
- High pass filter (HPF) acts as a pre-emphasis network to filter out noise and improve the SNR of the signal
- The oscillator circuit generates a high frequency carrier, which is sent to the modulator along with the modulating signal.
- Several stages of frequency multiplier are used to increase the operating frequency.
- Even then, the power of the signal is not enough to transmit. Hence, a RF power amplifier is used at the end to increase the power of the modulated signal.
- This FM modulated output is finally passed to the antenna to be transmitted.

FM Receiver

- RF Tuner (LC circuit): Select the frequency and also tune the oscillator
- RF-IF Mixer: it has local oscillator which provide constant frequency and mixed with input signal, IF (intermediate frequency) translated to a fix carrier frequency
- IF Filter: is a bandpass filter which process desired frequency and eliminate unwanted frequencies.
- Amplitude Limiter: maintain constant amplitude of FM wave by avoiding impact of channel noise which can distort the amplitude
- De-emphasis network does the opposite of emphasis network, and uses LPF to remove unwanted frequencies
- Audio Amplifier is the power amplifier, which uses to amplify the detected signal



Amplitude Modulation Vs Frequency Modulation

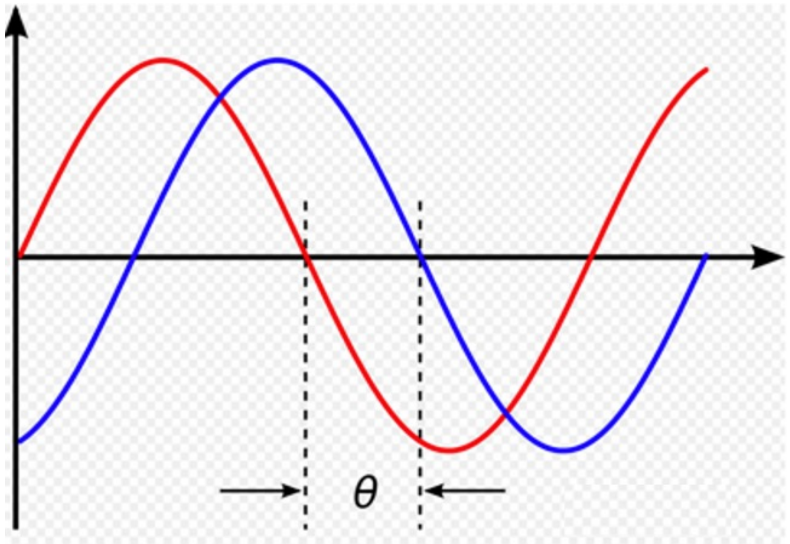
Amplitude Modulation	Frequency Modulation
Frequency and phase remain the same	Amplitude and phase remain the same
Can be transmitted over a long distance but has poor sound quality.	Better sound quality with higher bandwidth.
The frequency range varies between 535 to 1705 kHz	For FM it is from 88 to 108 MHz mainly in the higher spectrum
Signal distortion can occur in AM	Less instances of signal distortion
Consists of two sidebands	An infinite number of sidebands
Circuit design is simple and less expensive	Circuit design is intricate and more expensive
Easily susceptible to noise	Less susceptible to noise

PHASE MODULATION

Angle Modulation

Angle Modulation
$Asin(\omega t + \phi)$

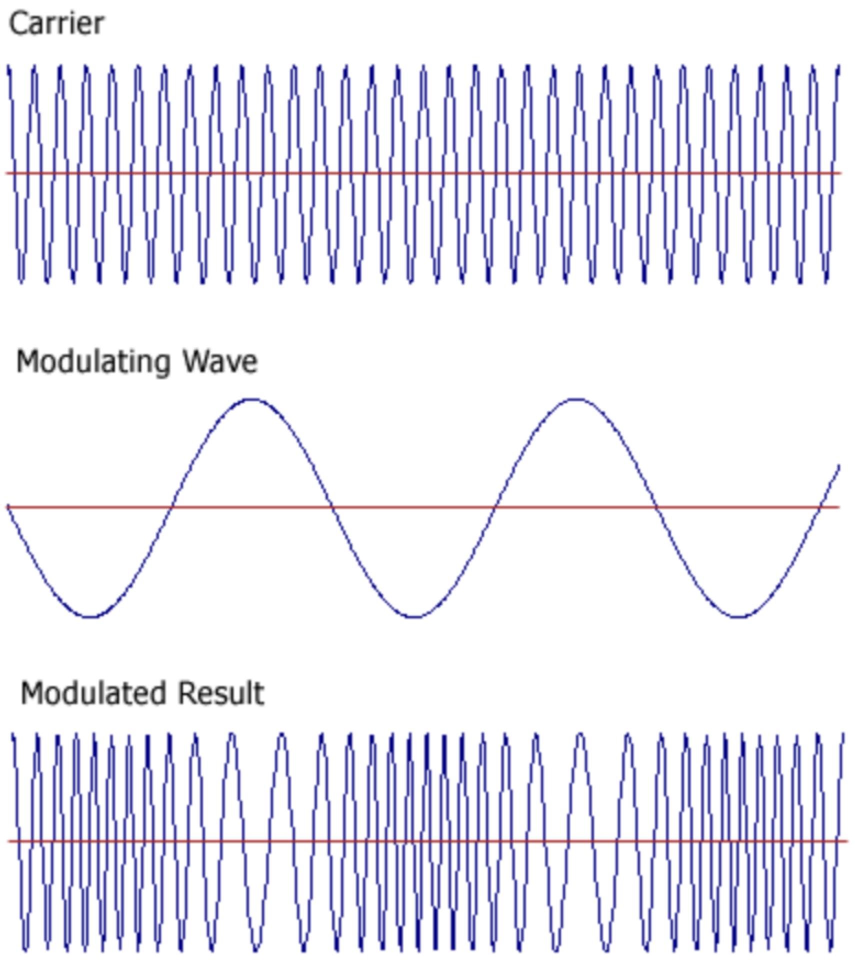
Frequency Modulation



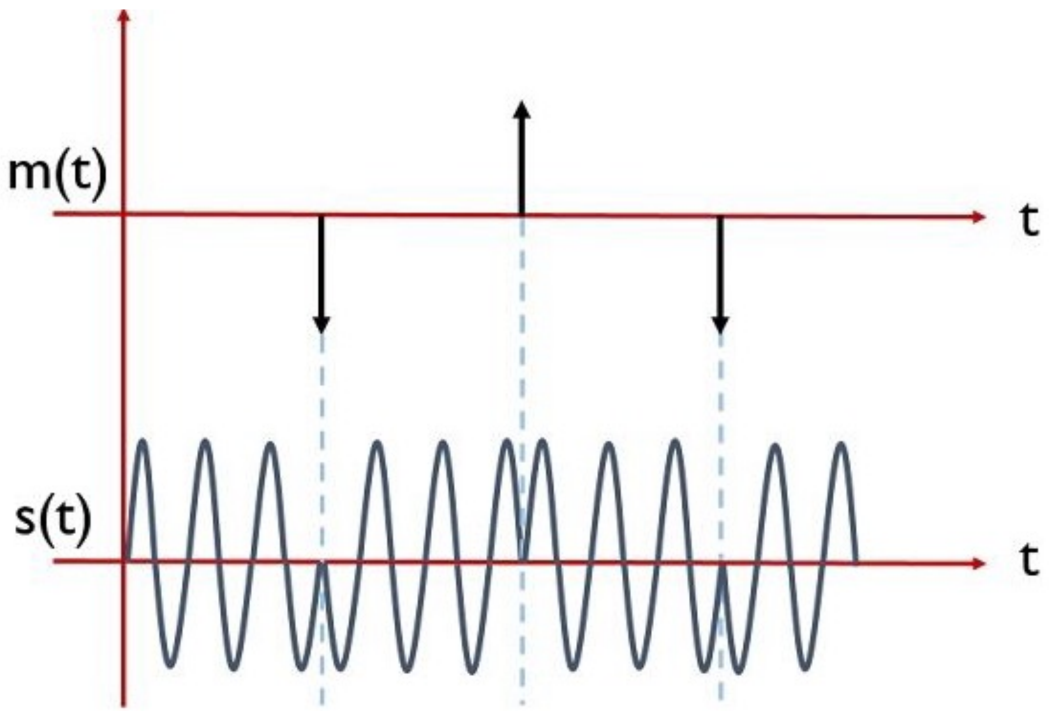
Phase Modulation

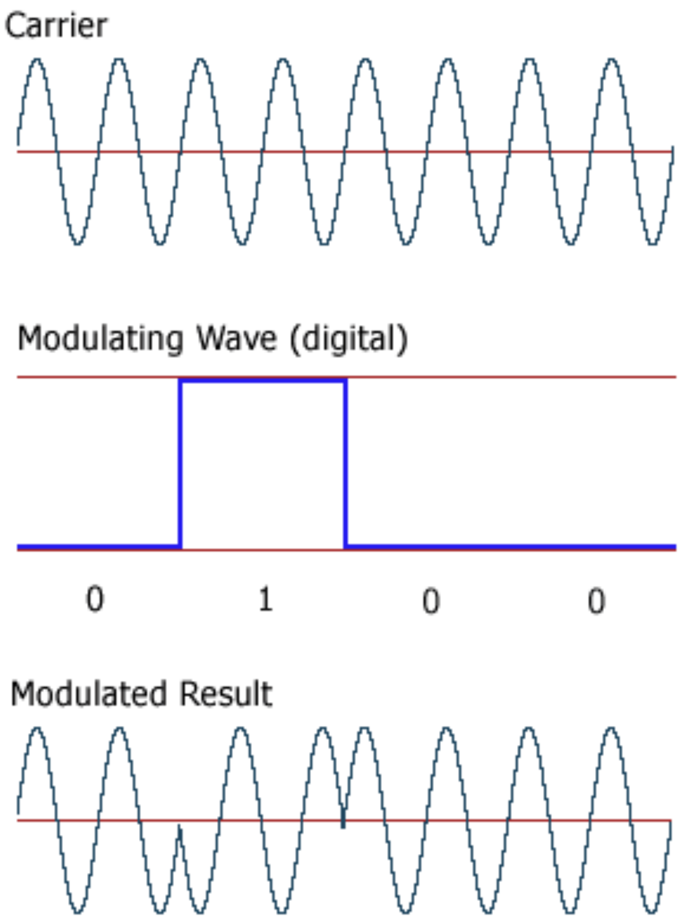
Phase Modulation

- Phase modulation is a type of modulation where the phase of the carrier signal varies as per amplitude variations of the message signal
- When there is a positive amplitude, the phase varies in one direction, while there is a negative amplitude, the phase varies in other directions.
- The sine wave movement can also be represented as points in a circle. So, when the phase increases, then the time also progresses and there occurs a phase difference between the points.



Example of Phase Modulation





Key Aspects of PM

- The noise immunity of the phase modulation is better than amplitude modulation. However, the noise immunity of the phase modulation is not as good as frequency modulation.
- The signal-to-noise (SNR) ratio of the phase modulation is better than amplitude modulation. However, the signal-to-noise (SNR) of the phase modulation is not as good as frequency modulation.
- The phase modulation and frequency modulation are closely related to each other. In both phase and frequency modulation, the total phase angle of the modulated signal varies.
- In frequency modulation, the total phase angle of a carrier wave changes for a short period due to the change in frequency of the carrier wave. In phase modulation, the frequency of a carrier wave changes for a short period due to the change in phase of a carrier wave.

PM equations

$Instanteneous\ Phase,\ \phi_i$

$carrier\ frequency$

$$A_c cos(\omega_c t + \phi_i)$$

$$\phi_i = k_p m(t),$$

where k_p is the phase sensitivity

m(t) is the modulating signal

$Modulated\ signal,$ $s(t) = A_c cos(\omega_c t + k_p m(t))$

$lets\ take\ m(t) = A_m cos(\omega_m t)$

$$s(t) = A_c cos(\omega_c t + \beta cos(\omega_m t))$$

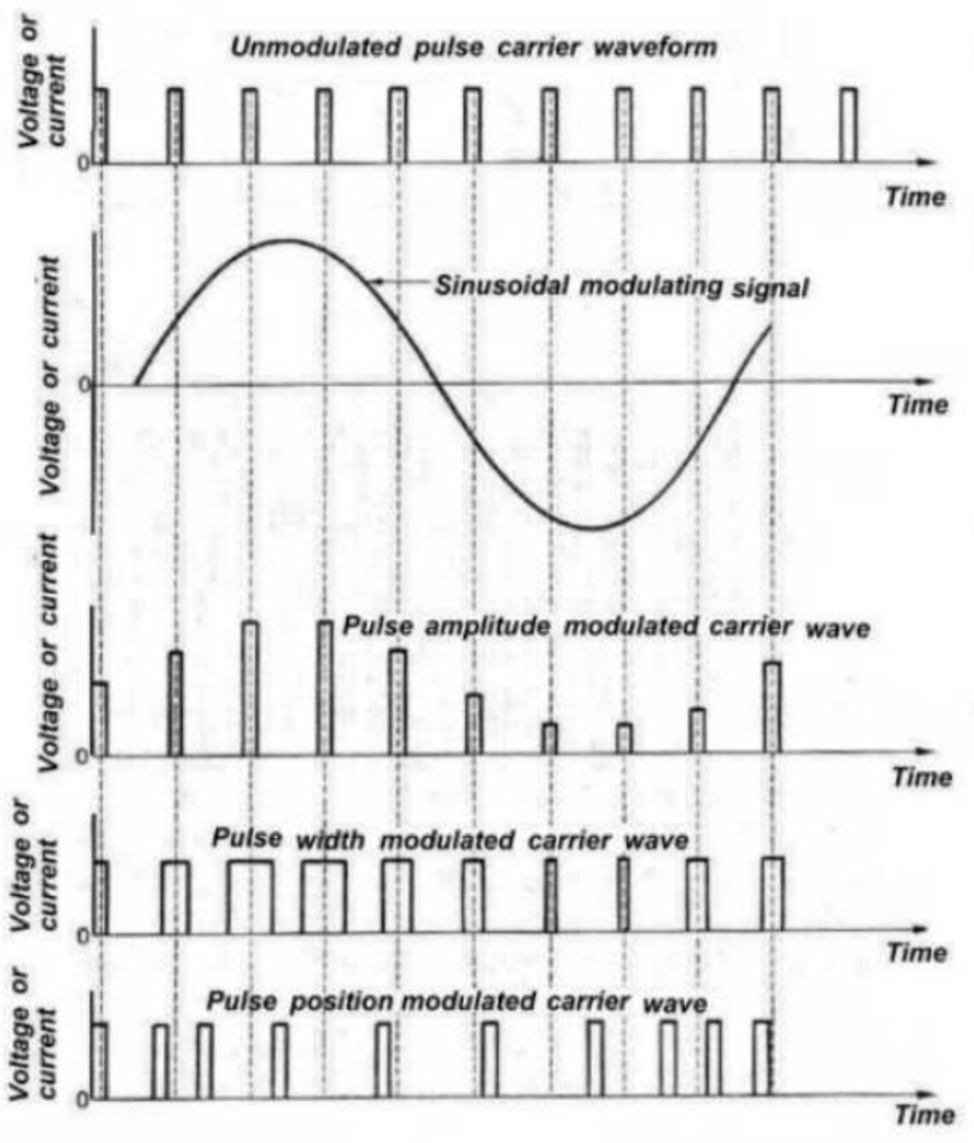
$where\ \beta\ is\ the\ modulation\ index$

$\beta = \Delta\emptyset = k_p\ A_m$ $\Delta\emptyset$ = Phase deviation

PULSE MODULATION

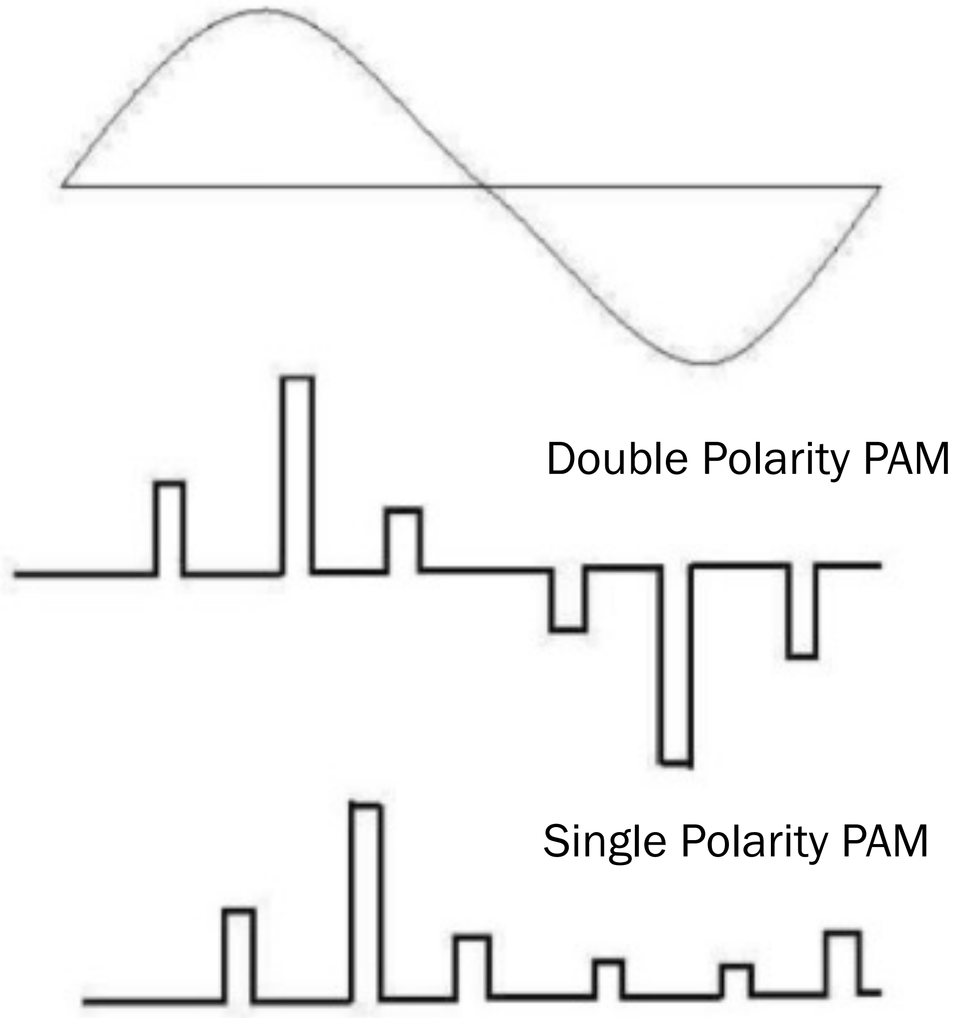
Three Schemes of Pulse Modulation

- **Pulse Amplitude Modulation (PAM)**
- **Pulse Width Modulation (PWM)** is called Pulse Duration Modulation (PDM) or Pulse Time Modulation (PTM)
- **Pulse Position Modulation**



Pulse Amplitude Modulation (PAM)

- The amplitude of the pulse carrier varies proportional to the instantaneous amplitude of the message signal.
- The Pulse Width and Position is Constant
- Two main types
  1. Double Polarity and
  2. Single Polarity



Two Pulse Amplitude Modulation Schemes

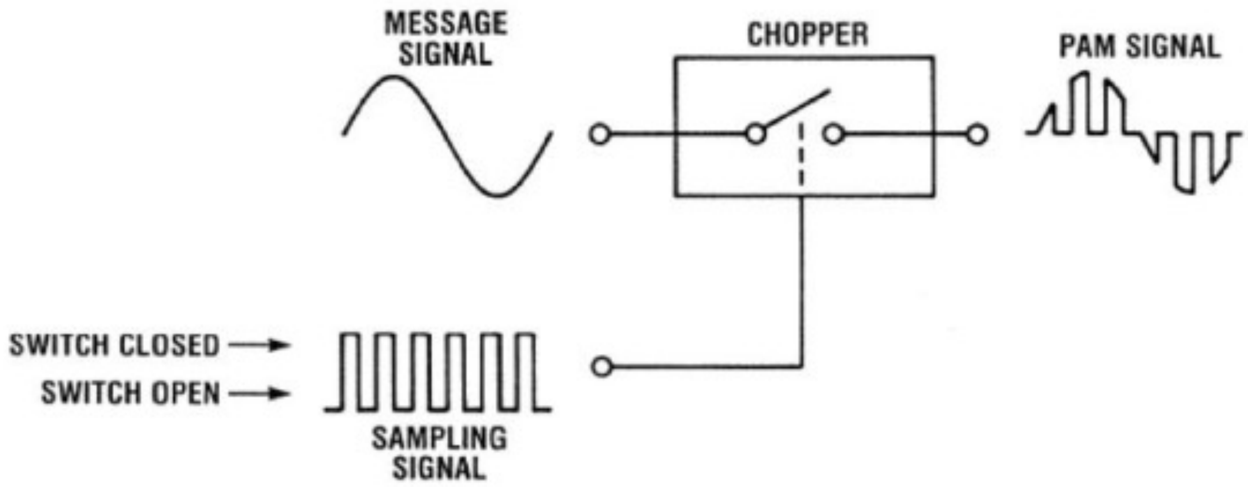
Natural Pulse Amplitude Modulation

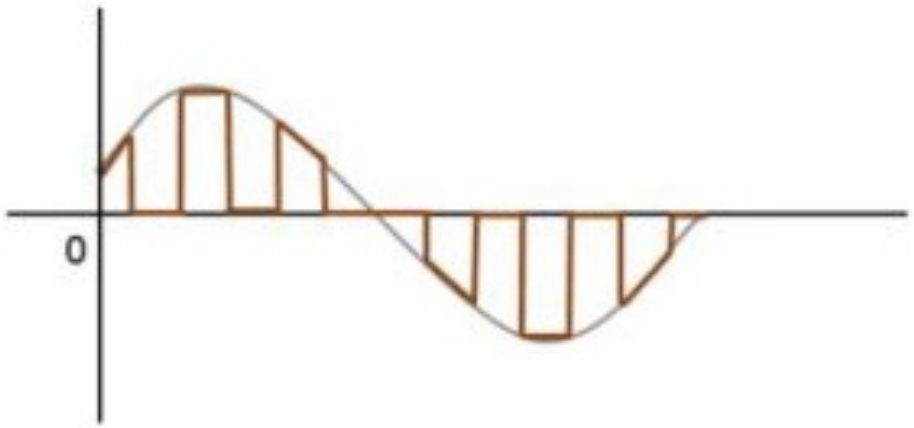
Flap-top Pulse Amplitude Modulation

Natural PAM

- The amplitude of each pulse is directly proportional to modulating signal amplitude at the time of pulse occurrence. Then follows the amplitude of the pulse for the rest of the half-cycle.

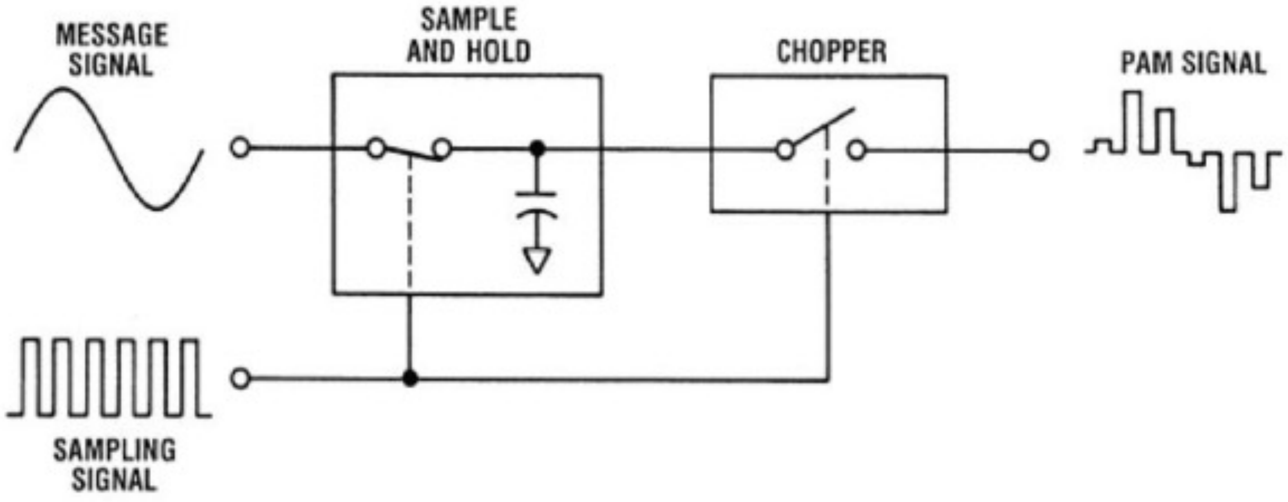
- A PAM is generated by using pulse train, called sampling signal to operate an electronic switch or “chopper”.

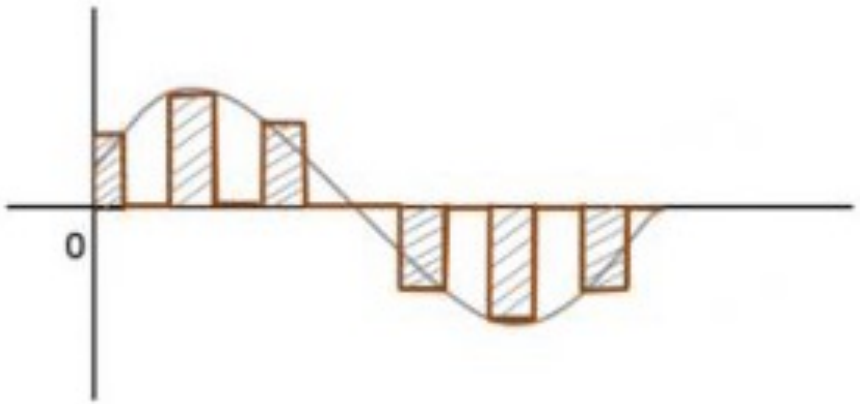




Flat-Top PAM

- The amplitude of the signal cannot be changed with respect to the analog signal to be sampled. The tops of the amplitude remain flat.
- A sample-and-hold circuit is used in conjunction with the chopper to hold the amplitude of each pulse at a constant level during the sampling





PAM Aspects

- It is to be noted in case of PAM, that **flat-top sampling is widely used** and is more popular than natural sampling. This is so because, at the time of signal transmission the channel noise introduces some form of distortion in it, that can be easily eliminated in case of flat-tops.
- As against when natural sampling is done in case of PAM signals, then the top of the pulses varies according to the modulating signal. So, in this case, the elimination of noise component from the sampled signal becomes somewhat difficult at the time of detection.
- At the same time, **natural sampling is a bit complex process** as compared to flat top sampling. Hence, flat top sampling is preferred in pulse amplitude modulation.

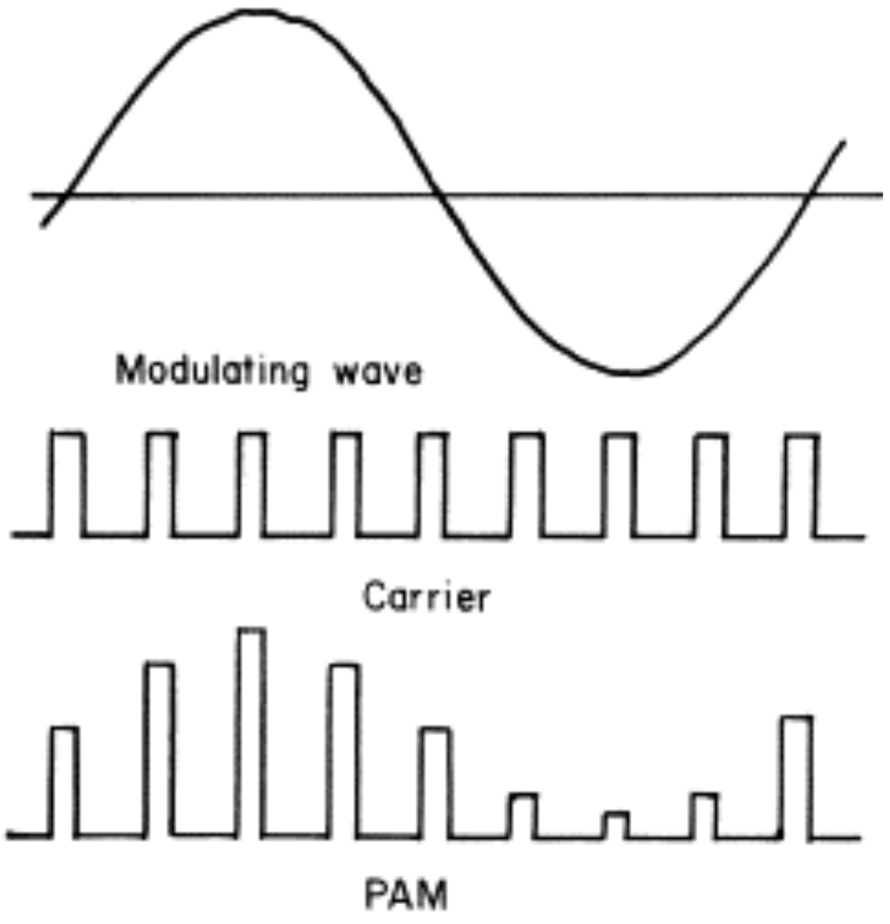
PAM Cont.

- Pulse duration (τ) is supposed to be very small to the period, T_s between two samples
- Let's take maximum frequency of signal, f_m

$$f_s \geq 2\, f_m$$

$$T_s \leq \frac{1}{2\, f_m}$$

- Transmission BW, $B_T \geq \frac{1}{2\tau}$



PAM Advantages, Disadvantages and Applications

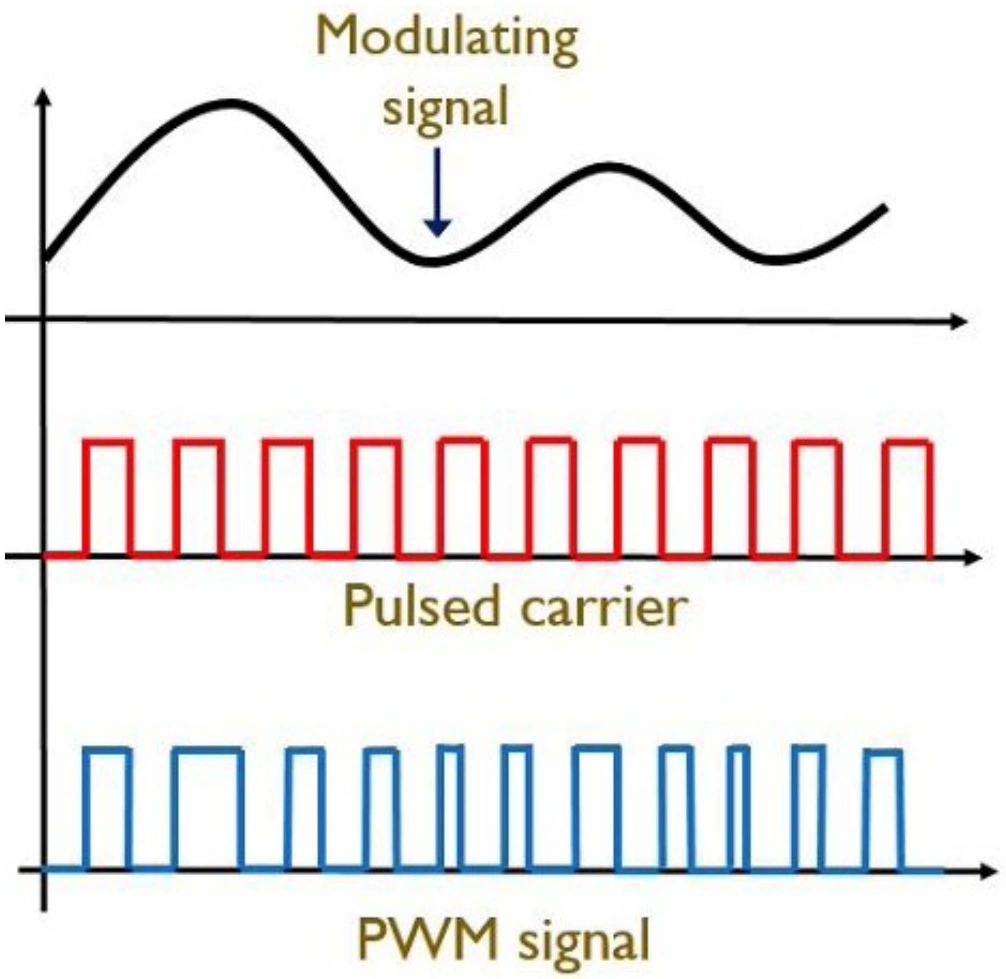
- Advantages
  - It allows multiplexing, that is the sharing of the same transmission media by different sources or users.
  - Both Modulation and demodulation are simple.
  - Easy construction of transmitter and receiver circuits.
- Disadvantages
  - Requires larger transmission BW
  - Interference of noise is maximum
  - the amplitude is varying. Therefore, the power required will be more

- Applications
  - Mainly used in Ethernet communication.
  - Many microcontrollers use this technique in order to generate control signals.
  - It is used in Photo-biology.
  - It acts as an electronic driver for LED circuits.

PULSE WIDTH MODULATION (PWM)

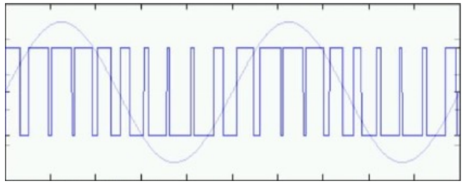
Pulse Width Modulation (PWM or PDM or PTM)

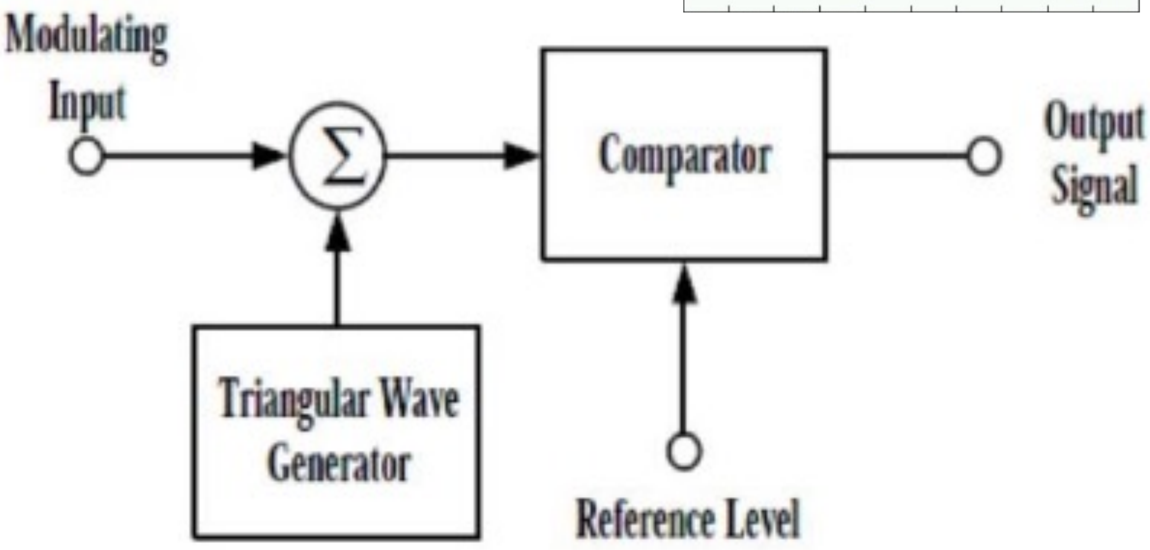
- Pulse Width Modulation (PWM) is called Pulse Duration Modulation (PDM) or Pulse Time Modulation (PTM)
- The duration/width/time of the pulse carrier varies proportional to the instantaneous amplitude of the message signal.
- The amplitude and position of the signal remains constant.
- Limited noise due to constant Amplitude (immune to the noise)

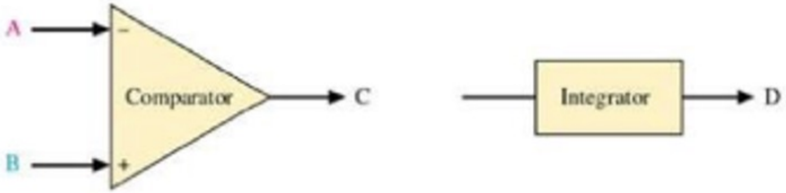


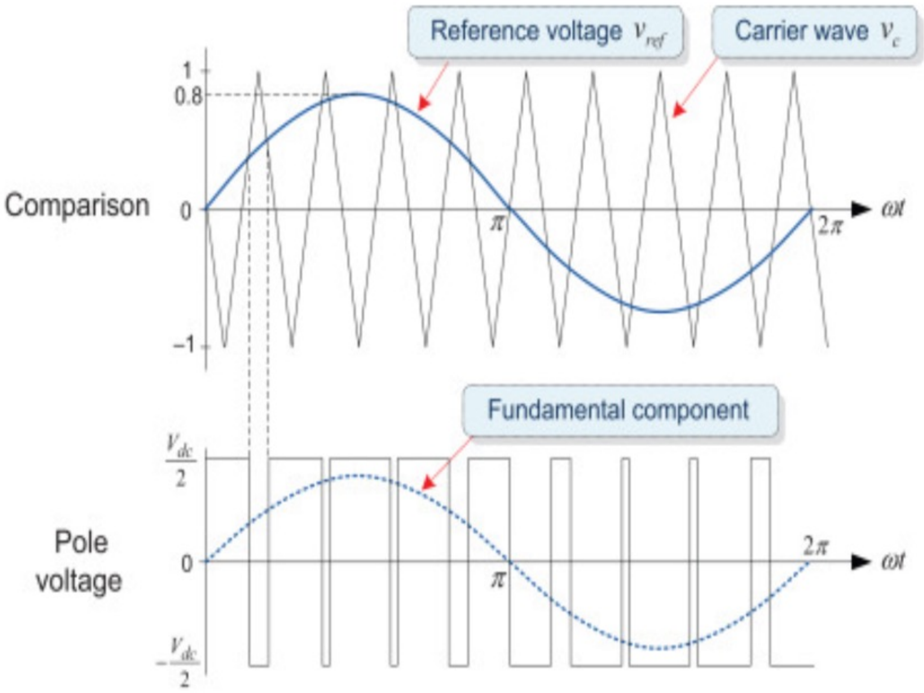
PWM signal generation

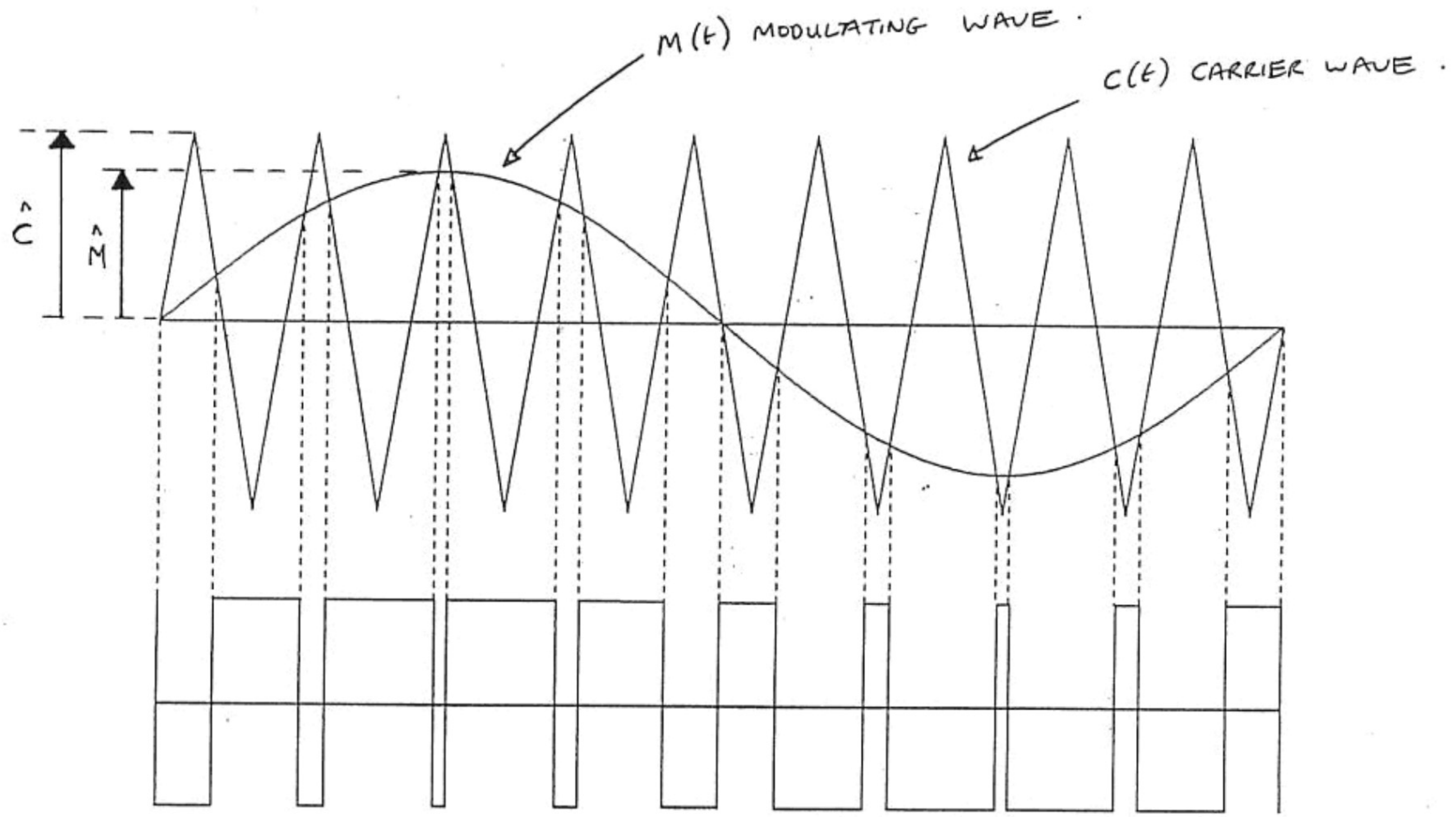
PWM signal output is generated by comparing summation results with reference level











Generation of Pulse Width Modulation using natural sampling
Frequency ratio = 9, Modulation depth = 0.8 $(\hat{M}/\hat{C})$

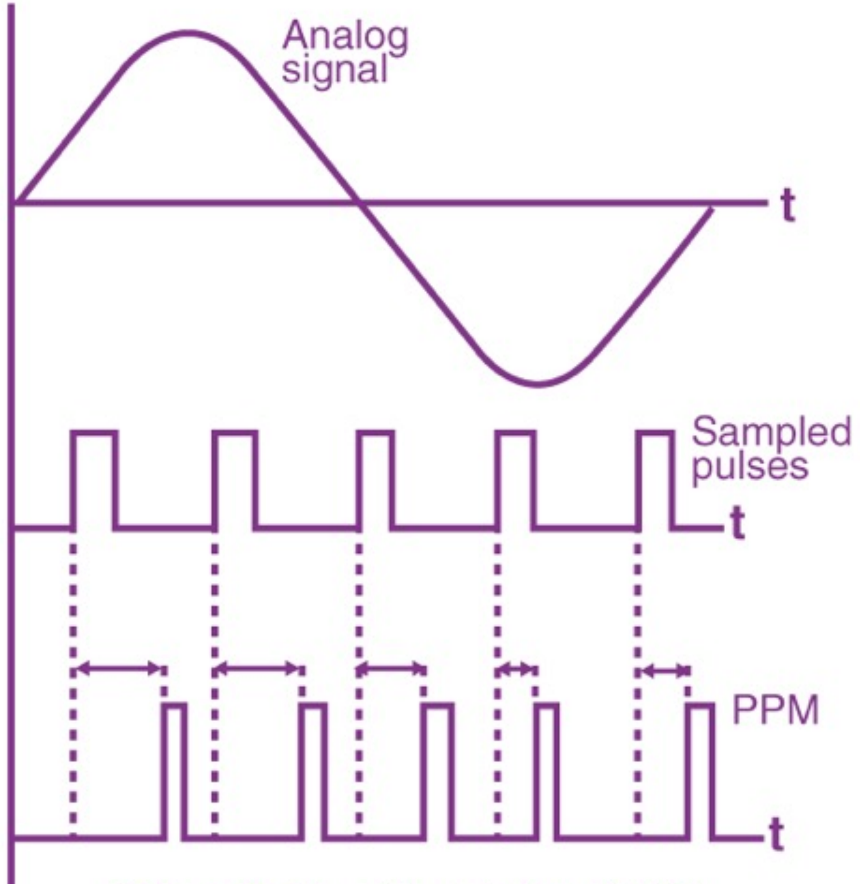
PWM: Advantages, Disadvantages and Applications

- Advantages
  - Low power consumption.
  - It has an efficiency of about 90 per cent.
  - Noise interference is less.
  - High power handling capacity.
- Disadvantages
  - The circuit is more complex.
  - Voltage spikes can be seen.
  - The system is expensive as it uses semiconductor devices.
  - Switching losses will be more due to high PWM frequency.
- Applications
  - Used in encoding purposes in the telecommunication system.
  - Used to control brightness in a smart lighting system (light dimmers).
  - Helps to prevent overheating in LED’s while maintaining it’s brightness.
  - Used in audio and video amplifiers.
  - DC motors and Anti-lock Breaking System

PULSE POSITION MODULATION (PPM)

Pulse Position Modulation (PPM)

- In PPM, the position of each pulse varies according to the instantaneous value of the message signal.
- The amplitude and width of the pulses are kept constant
- The transmitter has to send synchronizing pulses (or simply sync pulses) to keep the transmitter and receiver in synchronism.
- Pulse position modulation is done in accordance with the pulse width modulated signal.
- Each trailing of the pulse width modulated signal becomes the starting point for pulses in PPM signal.



Pulse Position Modulation (PPM)

PPM: Advantages, Disadvantages and Applications

- Advantages
  - As it has constant amplitude noise interference is less.
  - Signal and noise separation is very easy
  - Among all three types, it has the most power efficiency.
  - Due to constant pulse width and amplitude, transmission power for each pulse same
  - Require less power compared to PAM and PWM because short duration of pulse

- Disadvantages
  - The system requires more bandwidth.
  - Synchronization between transmitter and receiver is a must

- Applications
  - It is used in the air traffic control system and telecommunication systems.
  - Remote controlled cars, planes, trains use pulse code modulations.
  - It is used to compress data and hence it is used for storage.

Comparison between PAM, PWM and PPM

	PAM	PWM	PPM
Relation with modulating signal	Pulse Amplitude is varied	Pulse Width is varied	Pulse Position is varied
BW of the transmission	depends on the width of the pulse	depends on the rise time of the pulse	depends on the rising time of the pulse
Instantaneous transmitter power	varies with the amplitude of the pulses	varies width of the pulses	remains constant
System complexity	high	simple	simple
Noise interference	high	low	low

ANY QUESTION??

THANK YOU!!