Analog and Digital Communication

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Communication

- It is the process of conveying or transferring information from one point to another.

- People Communicate to convey their thought, ideas and feeling to others

- Example
  - Body Movement, facial expressions
  - Letters and newspaper/book
  - Conversation (face to face Communication)
  - Radio, TV
- Barriers – Distance and language

Simplex *A signal can **only** be sent (one way communication)*

e.g., a PA system, a megaphone, keyboard, mouse, etc.

Half Duplex *Signals can be sent and received* ***BUT NOT at the same time***

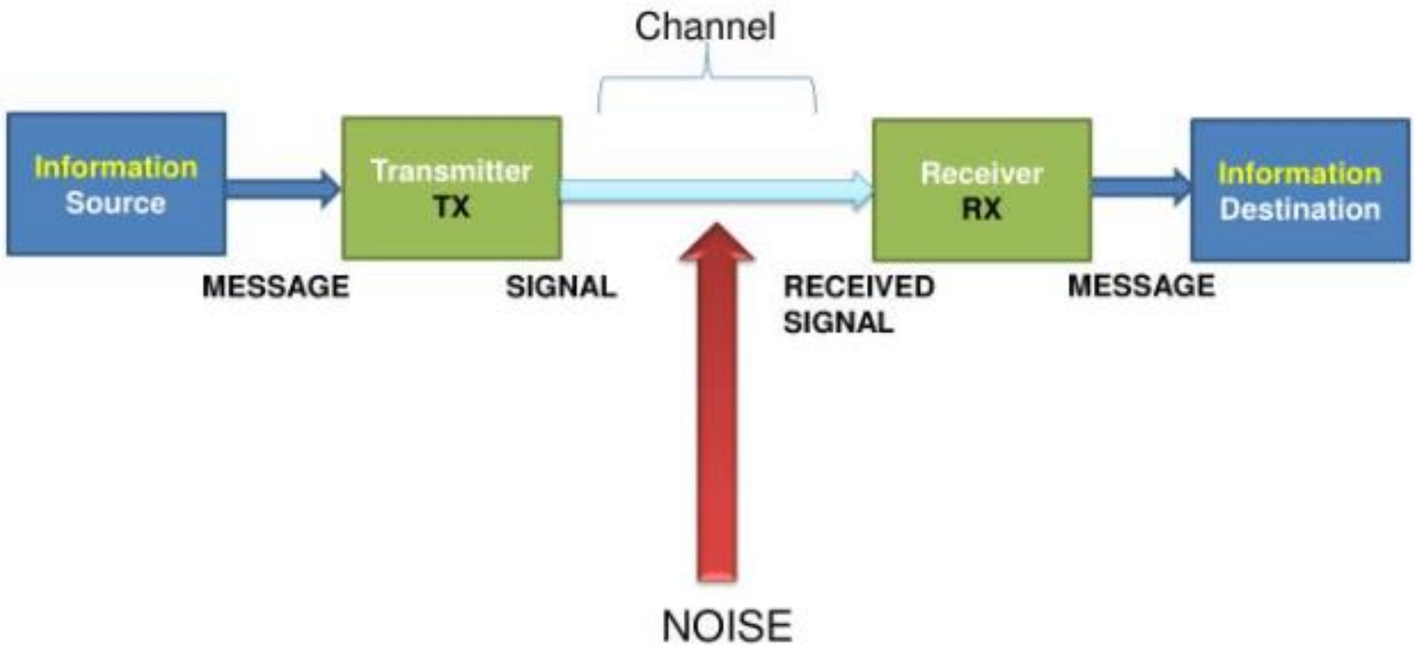
e.g., a walkie-talkie, an intercom, telegr

Full Duplex *Signals can be sent and received* ***AT the same time***

e.g., telephone, video-conference, etc.

Objective of communication system

- To transmit an information from source located at one point to destination located at another point with minimum distortion and noise. So that to produce the accurate output at receiver end.
    - **Elements of Communication System:**



Information source: The message or information to be communicated originates in information source. ***Message can be words, group of words, code, data, symbols, signals, audio, speech etc.***

Transmitter : The objective of the transmitter block is to collect the incoming message signal and modify it in a suitable fashion (if needed), such that, it can be transmitted via the chosen channel to the receiving point.

Channel : Channel is the physical medium which connects the transmitter with that of the receiver. ***The physical medium includes copper wire, coaxial cable, optical fiber cable and free space.***

Receiver: The receiver block receives the incoming modified version of the message signal from the channel and processes it to recreate the original (nonelectrical) form of the message signal.

Signal: It is a physical quantity which varies with respect to time or space or independent or dependent variable.

Ex: $m(t) = A \cos(\omega t+\phi)$

Where, A= Amplitude(Volts)

w = Frequency (rad/sec)

ϕ = Phase (rad)

With respect to communication, signals are classified into,

- Baseband signal • Bandpass signal

Baseband signal: If the signal contains zero frequency or near to zero frequency, it is called baseband signal.

Ex: Voice, Audio, Video, Bio-medical signals etc.

Bandpass signal: If the signal contains band of frequencies far away from base or zero, it is called bandpass signal. **Ex: AM, FM signals.**

Limitations:

Baseband signals are incompatible for direct transmission over medium. ***Ex: audio/voice signals can not travel long distance in air, signals get attenuated.***

Hence, for transmission of baseband signals Modulation techniques has to be used.

Modulation

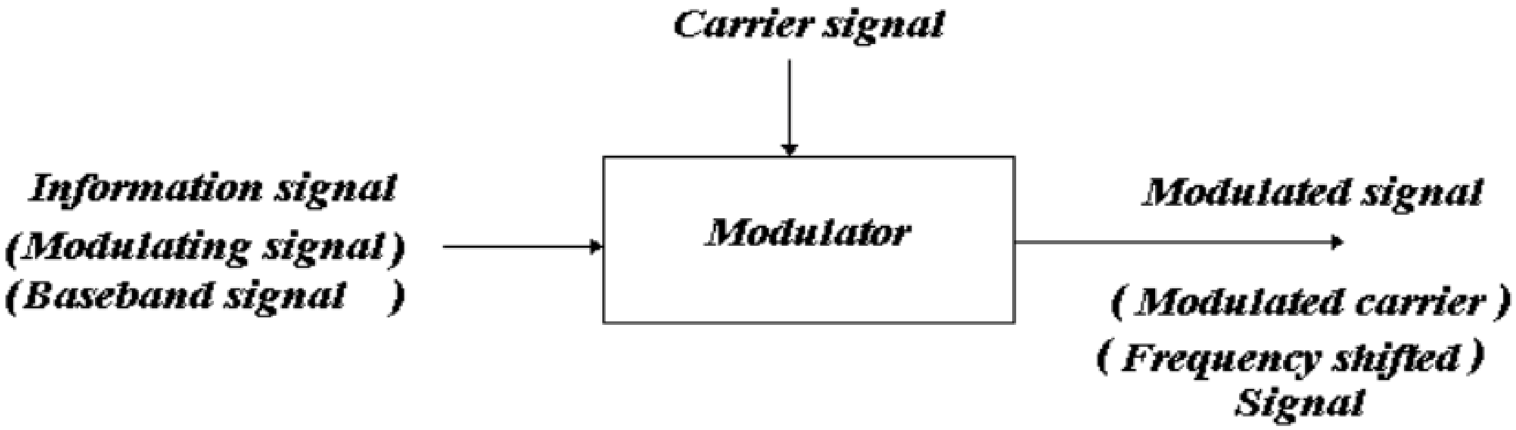
It is process of transmission of information signal using carrier signal.

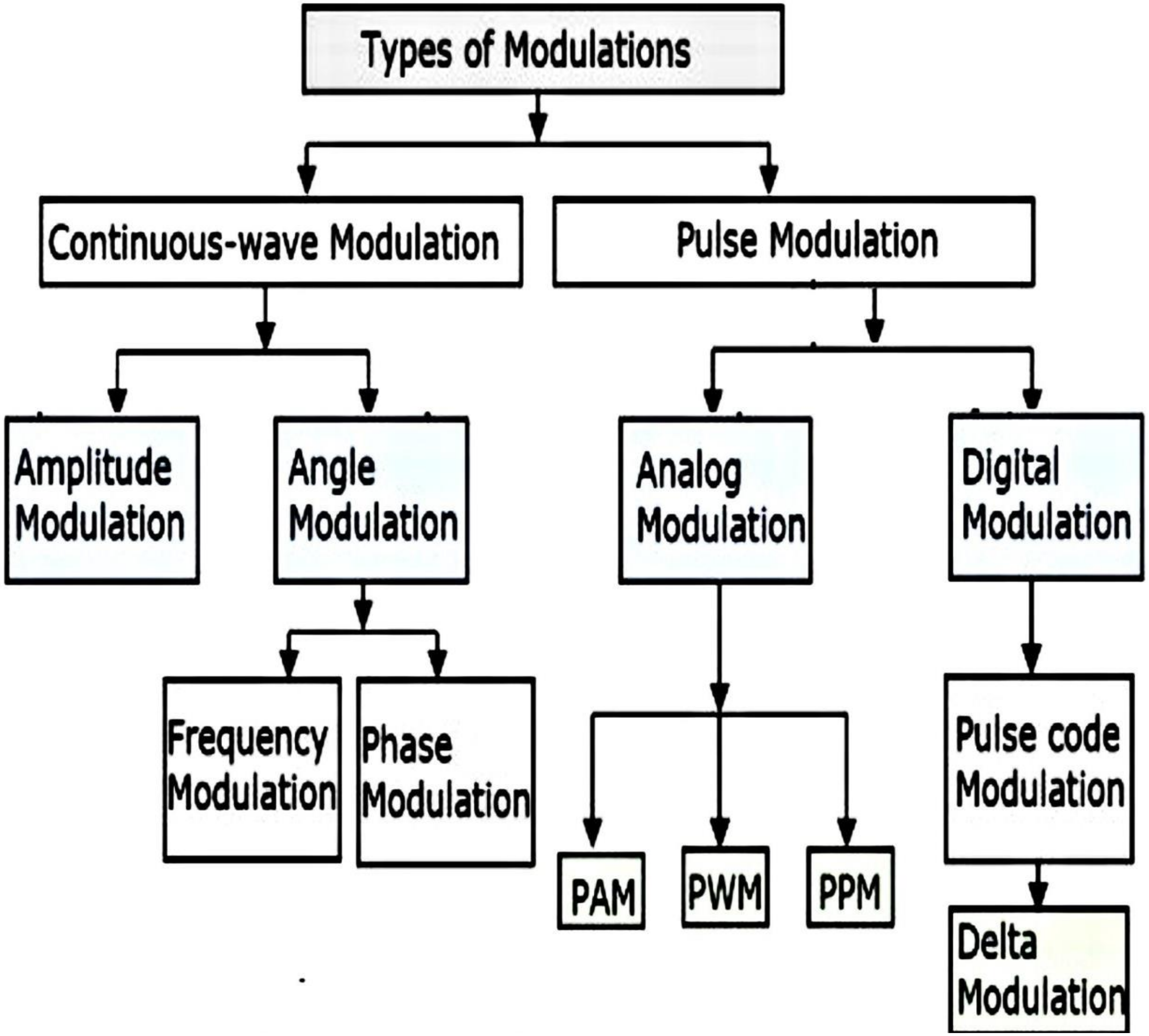
It is the process of varying the parameters of high frequency carrier in accordance with modulating or message or baseband signal.

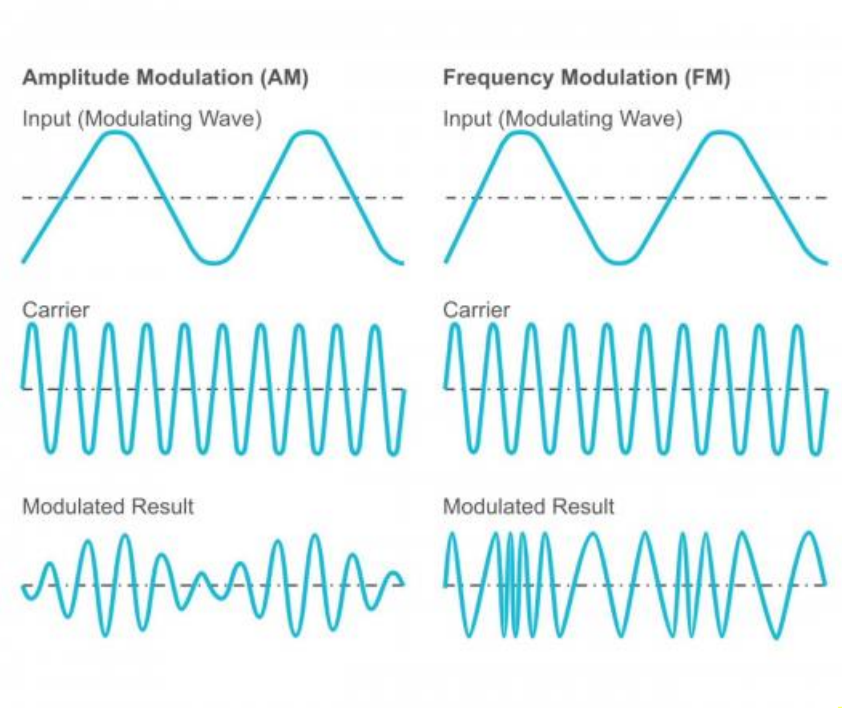
It is a frequency translation technique which converts baseband or low frequency signal to bandpass or high frequency signal.

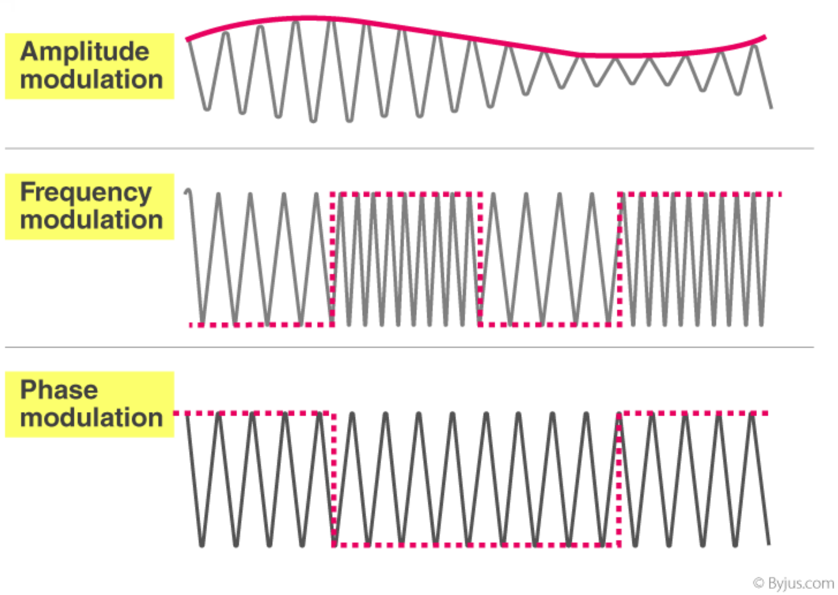
Benefits or Need of Modulation

- To reduce the height of antenna
- Avoids mixing of signals
- Increase the range of communication
- Improve quality of reception
- Allows multiplexing of signals




Types of Modulations
Continuous-wave Modulation
Pulse Modulation
Amplitude Modulation
Angle Modulation
Analog Modulation
Digital Modulation
Frequency Modulation
Phase Modulation
PAM
PWM
PPM
Pulse code Modulation
Delta Modulation


Amplitude Modulation (AM)
Input (Modulating Wave)
Carrier
Modulated Result
Frequency Modulation (FM)
Input (Modulating Wave)
Carrier
Modulated Result


Amplitude modulation
Frequency modulation
Phase modulation
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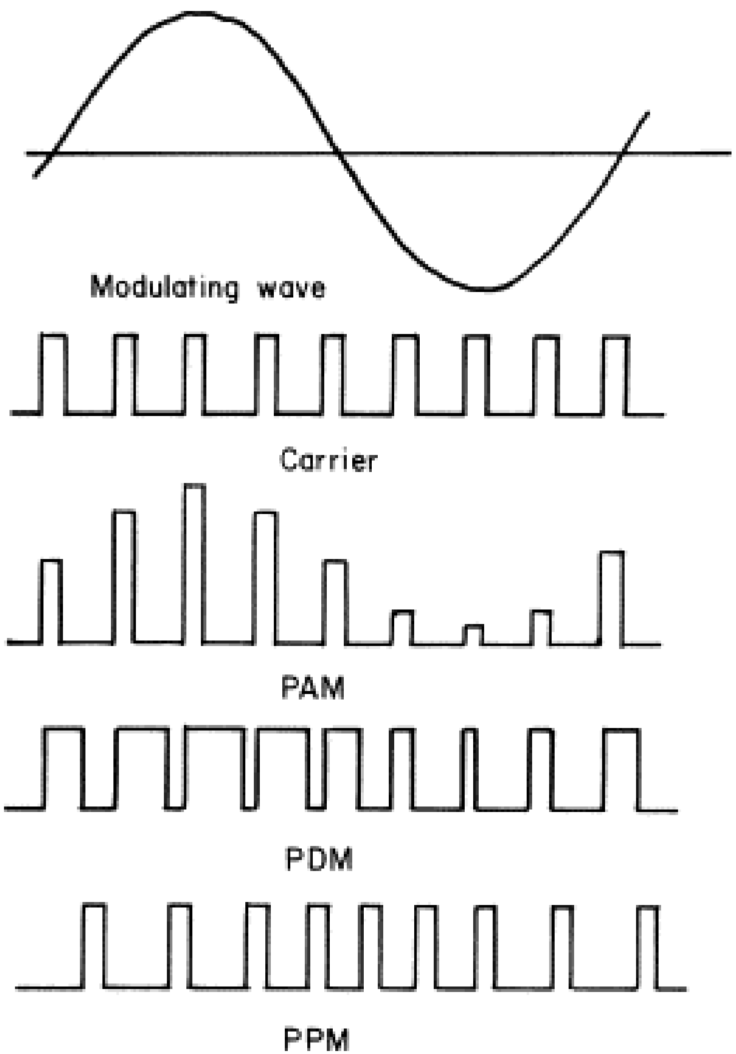

Modulating wave
Carrier
PAM
PDM
PPM

Amplitude Modulation

Amplitude Modulation is the process by which the amplitude of a carrier signal is varied according to modulating or message or baseband signal.

Modulating Signal (message or baseband signal)

$$m(t) = A_m \cos(2\pi f_m t)$$

Am – Amplitude of message signal, fm – frequency of message signal

Carrier Signal

$$C(t) = A_c \cos(2\pi f_c t)$$

Ac – Amplitude of carrier signal , *fc* – frequency of carrier signal

Modulated Signal

$$S(t) = A_c[1 + \mathrm{k_a}\ \mathrm{m(t)}]\cos(2\pi f_c t)$$

Ka is Amplitude Sensitivity of modulation

Modulation index is defined as the measure of amplitude variation about an un-modulated carrier.

$$S(t) = A_c[1 + \mathrm{k_a}\ \mathrm{m(t)}]\cos(2\pi f_c t)$$

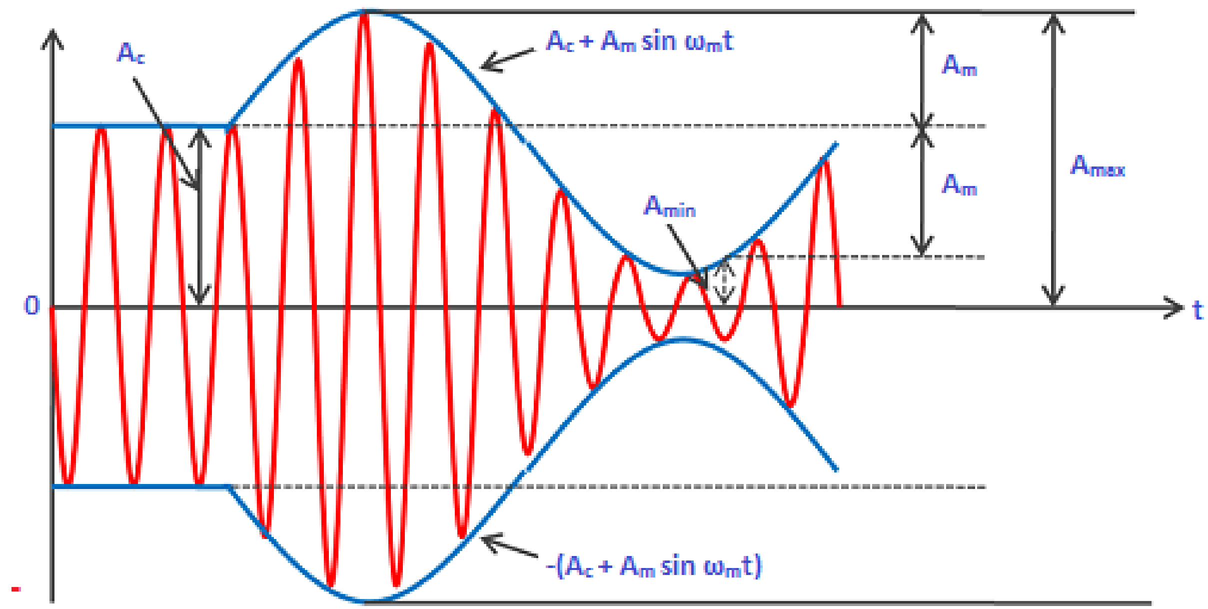
$$S(t) = A_c[1 + \mathrm{k_a}\ A_m \cos(2\pi f_m t)]\cos(2\pi f_c t)$$

$$S(t) = A_c[1 + \mu \cos(2\pi f_m t)]\cos(2\pi f_c t)$$

$$A_{max} = A_c[1 + \mu]$$

$$A_{min} = A_c[1 - \mu]$$

$$\mu = \frac{A_{max} + A_{min}}{A_{max} - A_{min}}$$



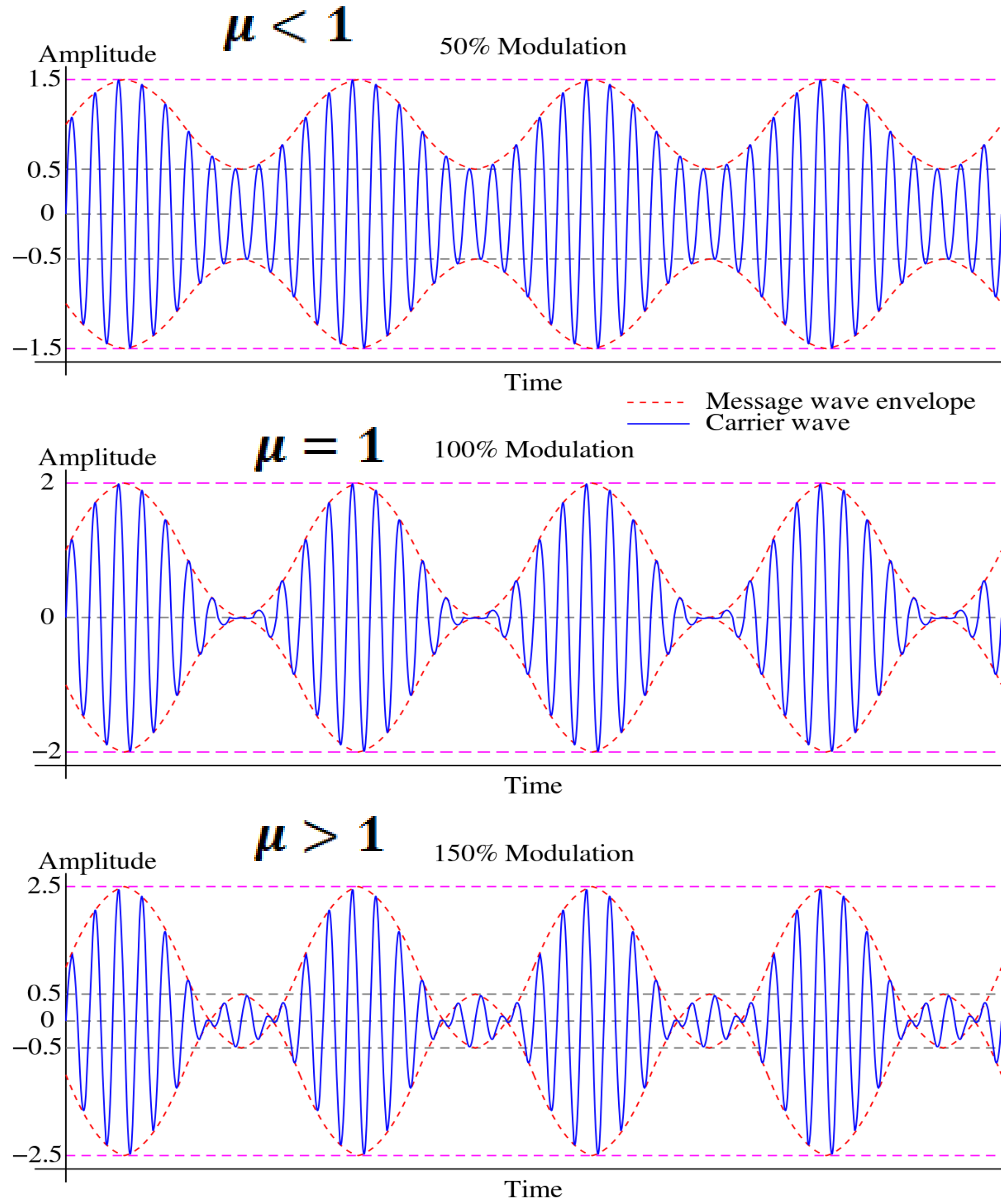
Over-modulation occurs when the maximum amplitude of the message signal or modulating signal is greater than the maximum amplitude of the carrier signal **Am>Ac**

$$\mu = \frac{A_m}{A_c}$$

$0 \leq \mu \leq 1$ is a required condition to do the demodulation

Two Conditions for AM

- **Modulation index must be less than one**
- **BW of Message signal must be small compared to BW of carrier signal**



Bandwidth of AM

$$S(t) = A_c[1 + \mu \cos(2\pi f_m t)]\cos(2\pi f_c t)$$

$$S(t) = A_c \cos(2\pi f_c t) + \mu A_c \cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$S(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2} 2\cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$S(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2}[\cos 2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t]$$

BW can be measured by subtracting lowest frequency From highest frequency

$$BW = f_{USB} - f_{LSB}$$

$$BW = (f_c + f_m) - (f_c - f_m) = 2 f_m$$

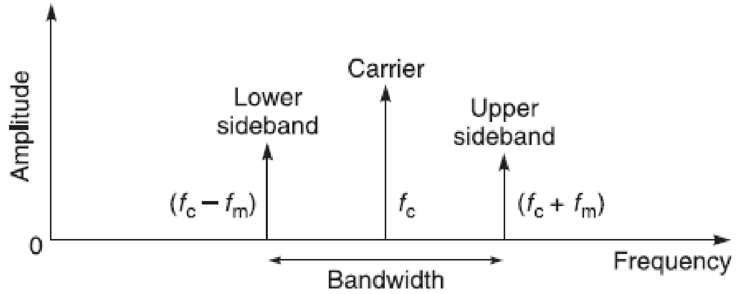
Bandwidth for AM wave is exactly twice of the bandwidth of message signal

Spectrum of AM

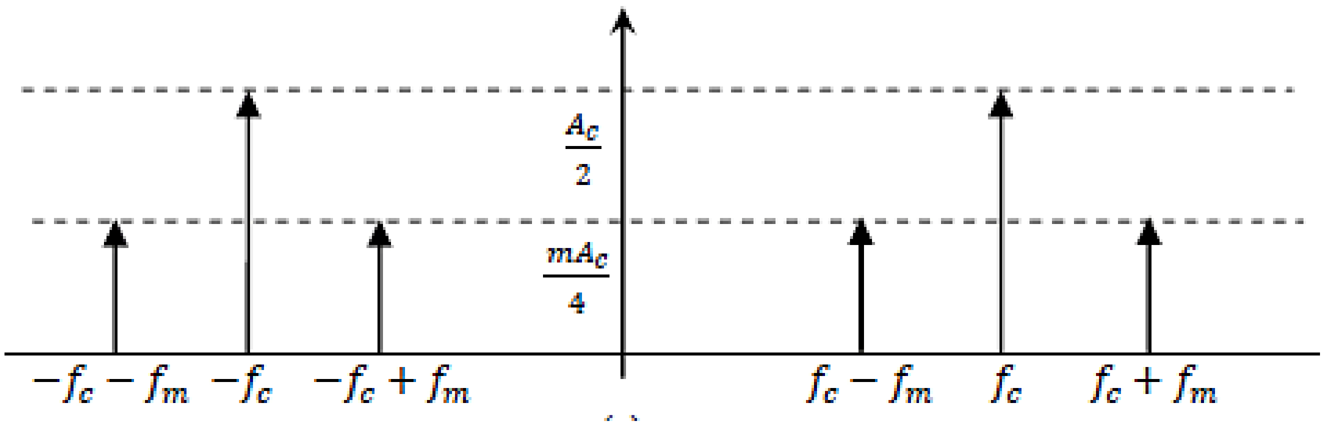
(consider single tone modulation)

$$S(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2}\left[\cos 2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t\right]$$

Apply FT of s(t)



$$S(f) = \frac{A_c}{2}[\delta(f + f_c) + \delta(f - f_c)] + \frac{\mu A_c}{4}[\delta(f + (f_c + f_m)) + \delta(f - (f_c + f_m))] + \frac{\mu A_c}{4}[\delta(f + (f_c - f_m)) + \delta(f - (f_c - f_m))]$$



Power of AM

$$S(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2}\left[\cos 2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t\right]$$

$$P_{total} = P_c + P_{USB} + P_{LSB}$$

$$P_c = \frac{\left(A_c/\sqrt{2}\right)^2}{R} = \frac{{A_c}^2}{2R}$$

$$P_{SB} = P_{USB} = P_{LSB} = \frac{{A_c}^2\mu^2}{8R}$$

$$P_{total} = \frac{{A_c}^2}{2R} + \frac{{A_c}^2\mu^2}{8R} + \frac{{A_c}^2\mu^2}{8R}$$

$$P_{total} = \frac{{A_c}^2}{2R}\left[1 + \frac{\mu^2}{4} + \frac{\mu^2}{4}\right]$$

$$P_{total} = \frac{{A_c}^2}{2R}\left[1 + \frac{\mu^2}{2}\right] \qquad P_{total} = P_c\left[1 + \frac{\mu^2}{2}\right]$$

For multi tone,

$$P_t = P_c\left[1 + \frac{{\mu_1}^2}{2} + \frac{{\mu_2}^2}{2} + \frac{{\mu_3}^2}{2} \dots\right]$$

$$\mu_{total} = \sqrt{{\mu_1}^2 + {\mu_2}^2 + {\mu_3}^2}$$

$$\frac{P_t}{P_c} = 1 + \frac{\mu^2}{2}$$

$$\frac{I_t}{I_c} = \sqrt{1 + \frac{\mu^2}{2}}$$

Problems

An Audio frequency signal 10sin 2π 500t is used to amplitude modulate a carrier of 50 sin $2\pi 10^5 t$. Assume modulation index =0.2 calculate 1) Sideband freq. 2) amplitude of each sideband freq. 3) Bandwidth 4)Total power delivered to the load of 600Ω.

$$P_{total} = \frac{{A_c}^2}{2R}\left[1 + \frac{\mu^2}{2}\right]$$

$$S(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2}\left[\cos 2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t\right]$$

Problems

The max and Min amplitudes of AM wave are 12v and 3v respectively. For a peak carrier signal voltage of Vc volts at 6MHz, Determine a)Modulation index b) carrier Power c) Total Average Power (assume load resistance of 100 ohms)

$$\mu = \frac{A_{max} + A_{min}}{A_{max} - A_{min}}$$

$$A_{max} = A_c[1 + \mu]$$

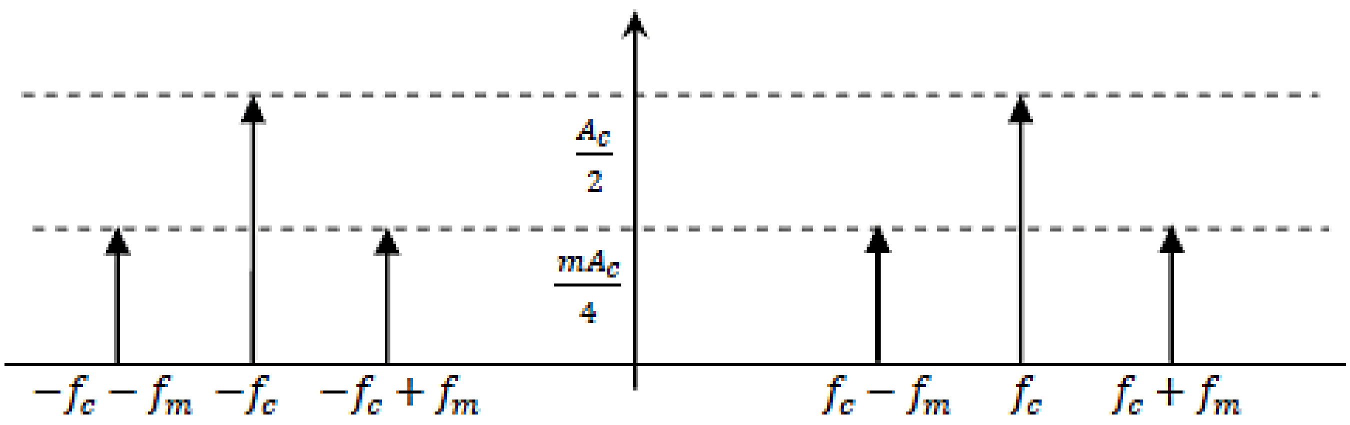
$$P_{total} = \frac{{A_c}^2}{2R}\left[1 + \frac{\mu^2}{2}\right]$$

Problems

A modulating signal is given by m(t)=2sin $2\pi 10^4$ t is used to amplitude modulate a carrier given by C(t)=10sin $2\pi 10^6$ t 1) write the expression for AM wave 2) Draw the two sided spectrum of modulated wave.

$$\mu = \frac{A_m}{A_c}$$

$$S(t) = A_c[1 + \mu\cos(2\pi f_m t)]\cos(2\pi f_c t)$$

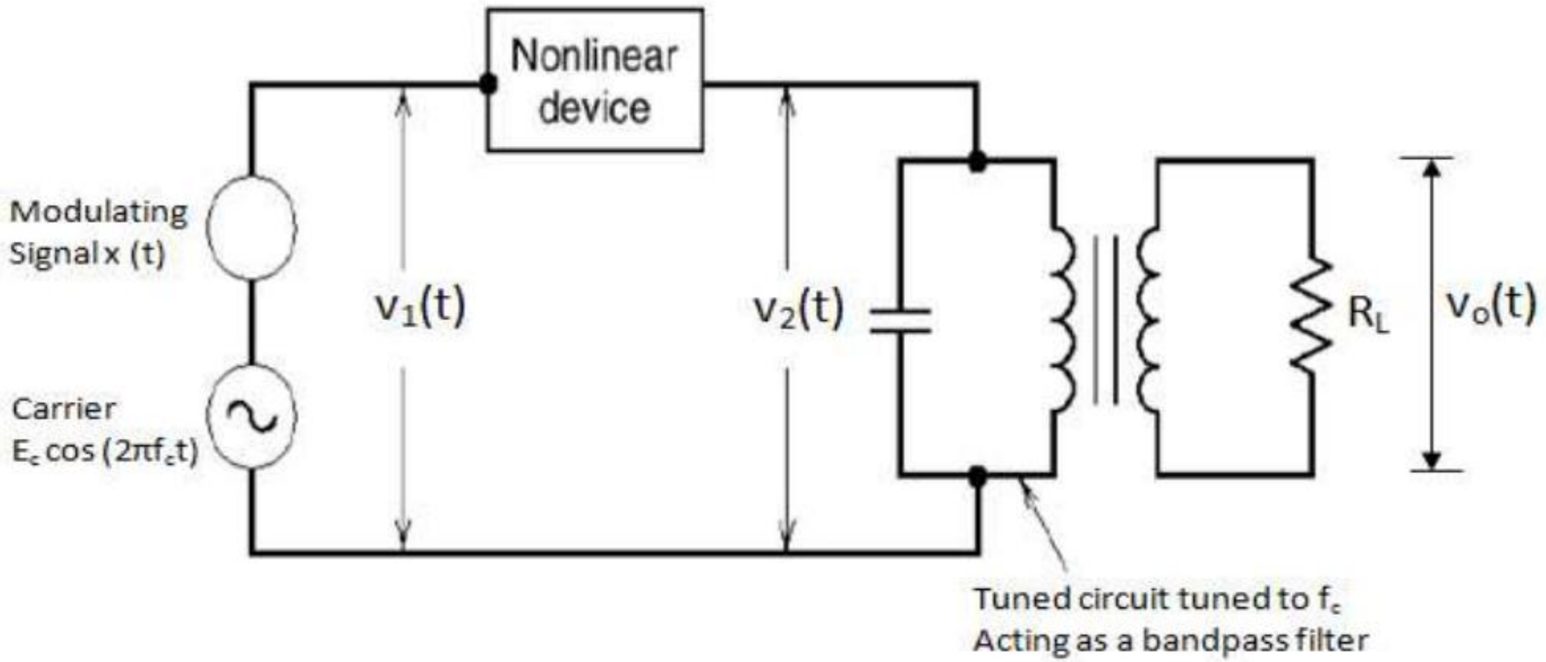


Generation of AM Wave

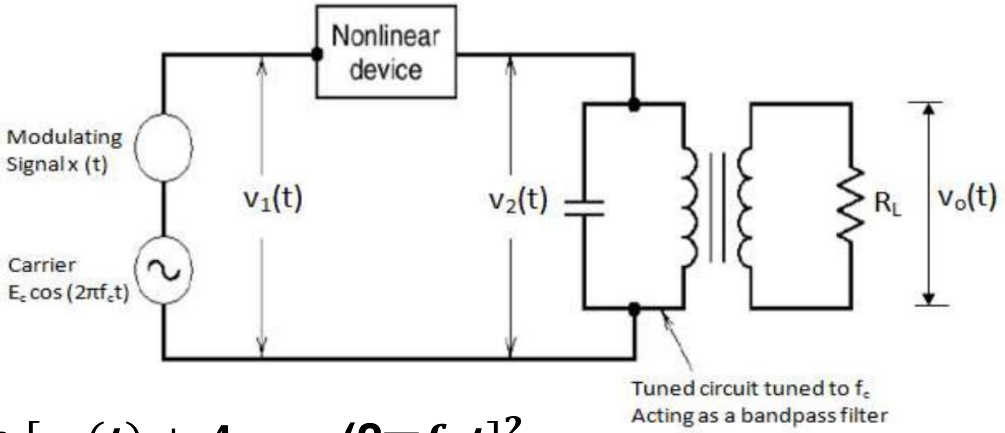
Square Law modulator

This circuit consists of, • A non-linear device • Band pass filter • Carrier source and modulating signal

The modulating signal and carrier are connected **in series** with each other and their sum V1(t) is applied at the input of non-linear device such as diode or transistor.



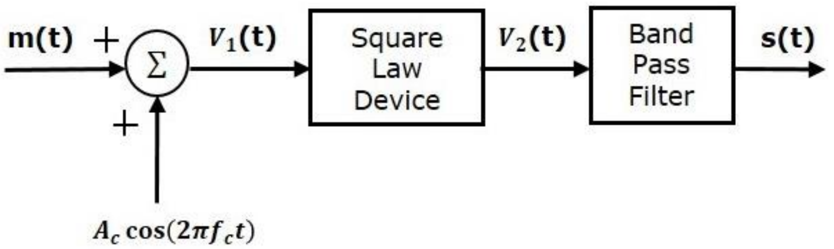
$$V_1(t) = m(t) + A_c\,cos(2\pi f_c t)$$



The input-output relation of non-linear device is

$$V_2(t) = a\,V_1(t) + b\,V_1^{\,2}(t)$$

$$V_2(t) = a\,[m(t) + A_c\,cos(2\pi f_c t] + b\,[m(t) + A_c\,cos(2\pi f_c t]^2$$



Unusual terms are eliminated by BPF

Output of BPF is given by,

V0(t) = a Ac Cos (2πfct)+ 2bm(t) Ac Cos (2πfct)

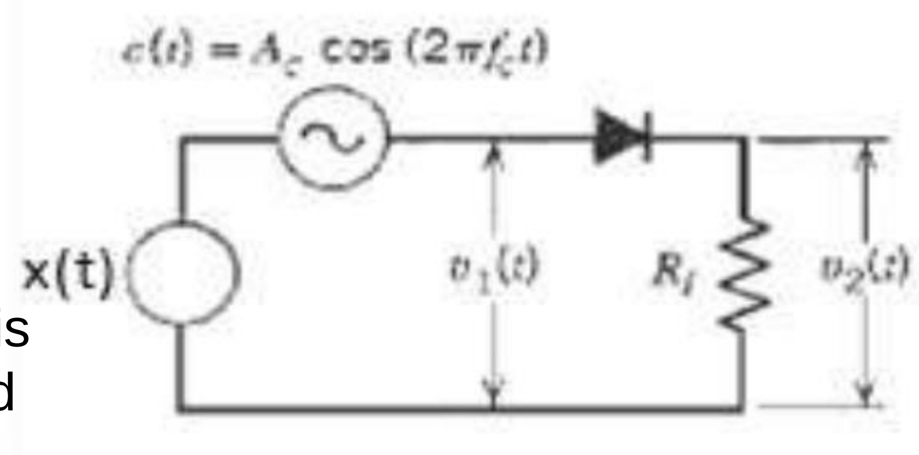
Switching Modulator

Similar to the square law modulator.

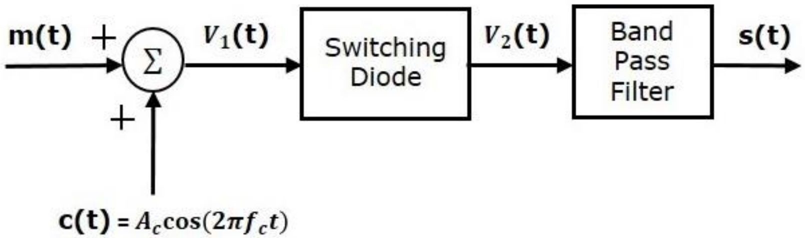
Square law modulator, the diode is operated in a non-linear mode,

Switching modulator, the diode has to operate as an ideal switch

The carrier signal c(t) is connected in series with modulating signal x(t)



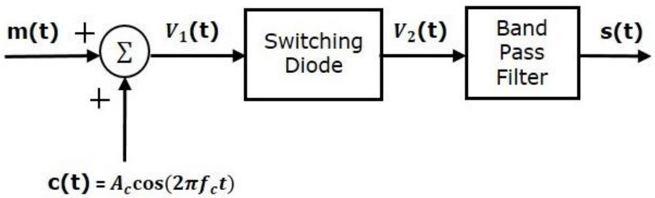
Sum of these two signals is passed through a diode. Output of the diode is passed through a band pass filter and the result is an AM wave

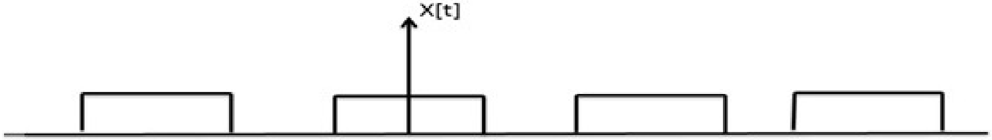


Amplitude of c(t) is much greater than x(t), so ON & OFF of diode is determined by c(t)

$$V_2(t) = \begin{cases} V_1(t) & if \quad c(t) > 0 \\ 0 & if \quad c(t) < 0 \end{cases}$$

$$V_1(t) = m(t) + c(t) = m(t) + A_c\cos(2\pi f_c t)$$





$$x(t) = \frac{1}{2} + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^n - 1}{2n-1}\cos(2\pi(2n-1)f_c t)$$

$$V_2(t) = V_1(t)\,x(t)$$

$$x(t) = \frac{1}{2} + \frac{2}{\pi}\cos(2\pi f_c t) - \frac{2}{3\pi}\cos(6\pi f_c t) + \ldots.$$

$$V_2(t) = \begin{cases} V_1(t) & if \quad c(t) > 0 \\ 0 & if \quad c(t) < 0 \end{cases}$$

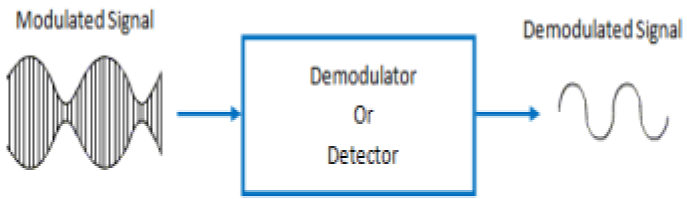
$$V_2(t) = \frac{m(t)}{2} + \frac{A_c}{2}\cos(2\pi f_c t) + \frac{2m(t)}{\pi}\cos(2\pi f_c t) + \frac{2A_c}{\pi}\cos^2(2\pi f_c t) -$$

$$\frac{2m(t)}{3\pi}\cos(6\pi f_c t) - \frac{2A_c}{3\pi}\cos(2\pi f_c t)\cos(6\pi f_c t) + \ldots..$$

$$s(t) = \frac{A_c}{2}\left(1 + \left(\frac{4}{\pi A_c}\right)m(t)\right)\cos(2\pi f_c t)$$

Detection of AM Wave

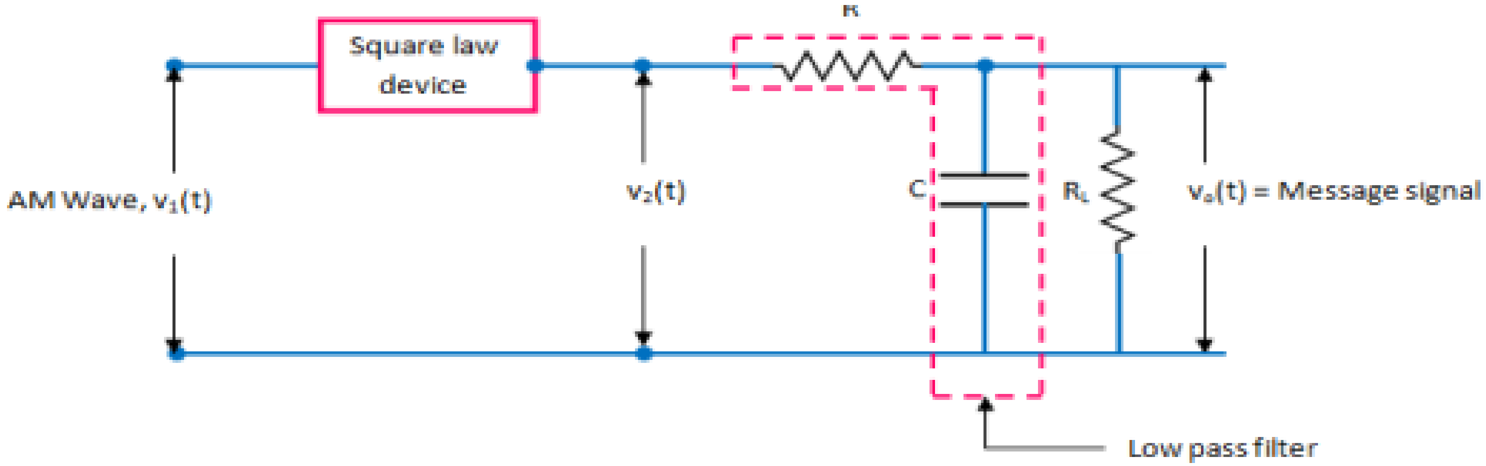
Demodulation or detection is the process of recovering the original message signal from the received modulated signal.



Types of AM Detectors

Square Law detector
Envelope detector

Square Law detector



The amplitude modulated wave is given as input to the square law device.

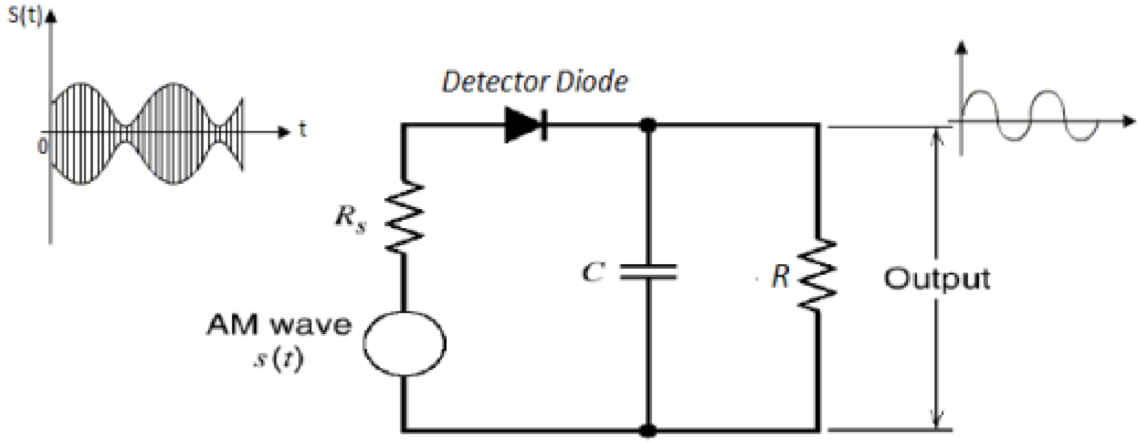
$$V_2(t) = a\,V_1(t) + b\,{V_1}^2(t)$$

When this is passed through square law device,

V2(t) = a Ac $cos(2\pi f_c t)$ + a Ac m x(t)$cos(2\pi f_c t)$ +
b Ac$^2 cos^2(2\pi f_c t)$ + 2 b Ac $cos(2\pi f_c t)$Ac m x(t)$cos(2\pi f_c t)$ +
b Ac$^2 m^2 x(t)^2 cos^2(2\pi f_c t)$

In order to extract the original message signal, V2(t) is passed through a low pass filter . The output of LPF is, V0(t) = m b Ac^2 x(t)

Envelope Detector



The standard AM wave is applied at the input of detector .

- In every positive half cycle of input, diode is forward biased which charges capacitor ‘C’.
- When capacitor charges to peak value of input voltage, diode stops conducting.
- The capacitor discharges through ‘R’ between positive peaks.
- This process continuous and capacitor charges and discharges repeatedly.

Advantages and Disadvantages of Amplitude Modulation

Amplitude Modulation is easier to implement.	**When it comes to power usage it is not efficient.**
Demodulation can be done using few components and a circuit.	**It requires a very high bandwidth that is equivalent to that of the highest audio frequency.**
The receiver used for AM is very cheap.	**Noise interference is highly noticeable.**

Double Sideband Suppressed Carrier (DSBSC)

Single-Side Band (SSB) Modulation

Vestigial Side Band Modulation (VSB)

Thank You