Ministry of Higher Education and Scientific Research
Southern Technical University
Basra Technical Institute
Department of Electronic Technologies

Communications Systems Education Bag

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Course syllabus

Communications Systems

Week	Details
1	Time and Frequency Domain, periodic and non periodic Function.
2	Fourier Series, Odd and Even Function
3,4,5,6	Filters, Types of Filters, Low pass filter (LPF), High pass Filter, Band pass Filter and Band stop (reject) filter in passive and Active.
7	Modulation. Define and Explain types of Modulation
8	Amplitude Modulation (AM)
9	Modulation Index and Modulation Depth
10	Bandwidth in Amplitude Modulation, Power Relation in Amplitude Modulation
11	Types of Amplitude Modulation
12	Double Sideband with carrier, Generation of Amplitude Modulation
13	Double Sideband Suppressed Carrier (DSBSC), Single Sideband (SSB), Vestigial Sideband (VSB) and Compatible Single Sideband (CSSB)
14	Demodulation (Detection) of Amplitude Modulation (AM)
15	AM transmitter and AM Receiver (Super heterodyne Receiver)
16	Pulse Modulation, Analog Pulse Modulation
17	Types of Pulse Modulation
18	Pulse Amplitude Modulation (PAM), Generation and Detection
19	Pulse Time Modulation
20	Pulse duration Modulation (PDM) or Pulse Width Modulation (PWM), Pulse Position Modulation, Generation and Detection
21	Properties and Application of Analog Pulse Modulation
22	Time Division Multiplexing (TDM)
23	Digital Pulse Modulation, Pulse Code Modulation (PCM), Delta Pulse Code Modulation (DPCM), Different Pulse Code Modulation (DPCM) and Delta Modulation (DM)
24	Angle Modulation and Instantaneous Frequency, phase and Frequency Modulation (PM and FM)
25	Phase Modulation (PM) and Modulation Index
26	Frequency Modulation (FM) and modulation Index
27	Types of Frequency Modulation (FM), Narrow Band Frequency

	Modulation (NBFM), Narrow Band Phase Modulation (NBPM) and Wide Band Frequency Modulation (WBFM)
28	Generation of Wide Band Frequency Modulation (WBFM)
29	Average Power in Phase Modulation (PM) and Frequency Modulation (FM), Frequency Detection
30	Digital Modulation, Types of Digital Modulation, Amplitude Shift King (ASK), Frequency Shift King (FSK) and Phase Shift King (PSK)

What will we Study in This Course?

In this course, we will study the basic methods that are used for communication in today's world and the different systems that implement these communication methods. Upon the successful completion of this course, you should be able to identify the different communication techniques, know the advantages and disadvantages of each technique, and show the basic construction of the systems that implement these communication techniques.

Communication

Is the process of link between two point for information change

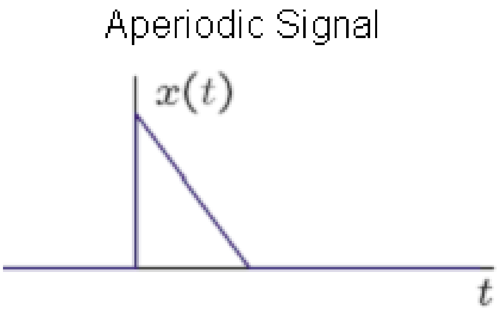
CH -1-

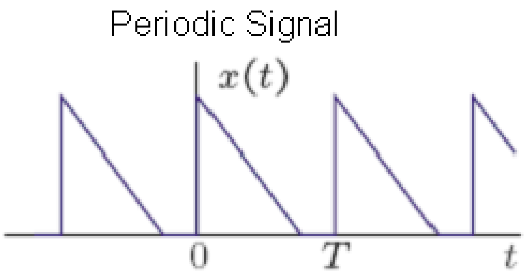
(1) Time and frequency domain:

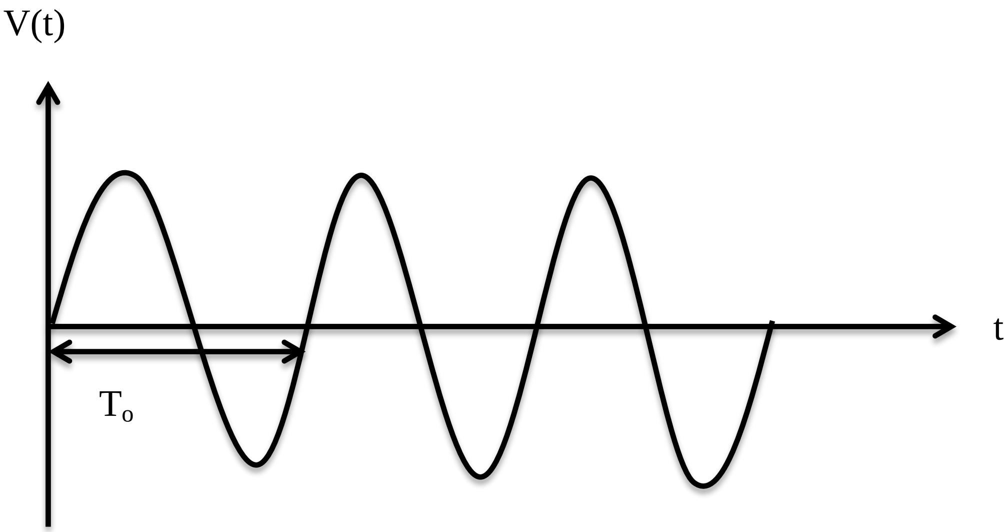
(1-1) Time Domain :

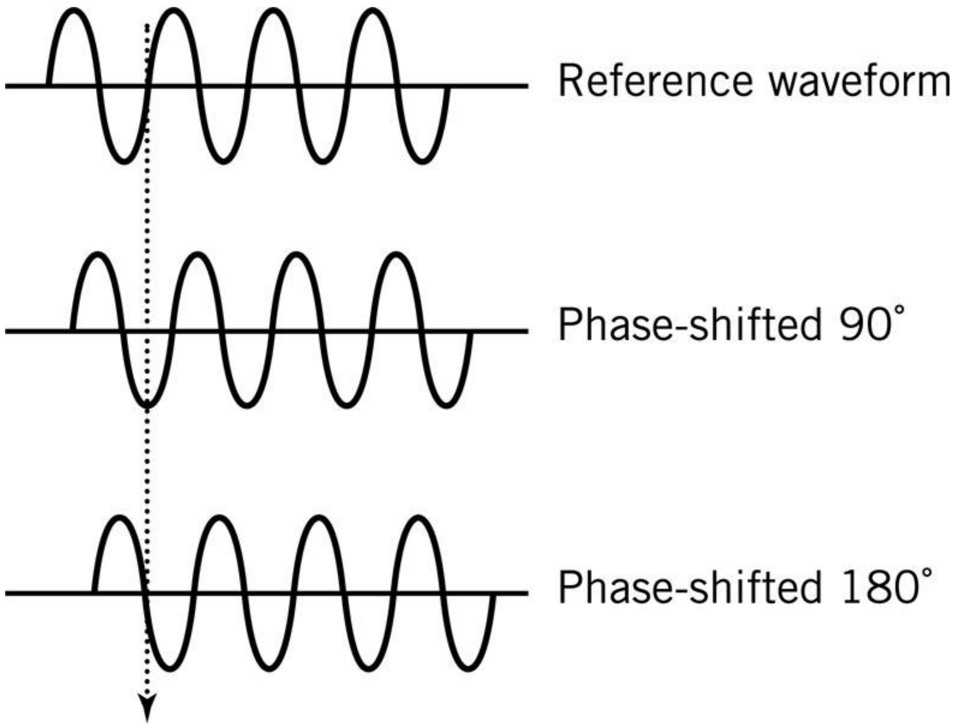
The time –domain is changes in signal amplitude with respect to time .

(1-2) Periodic Function :



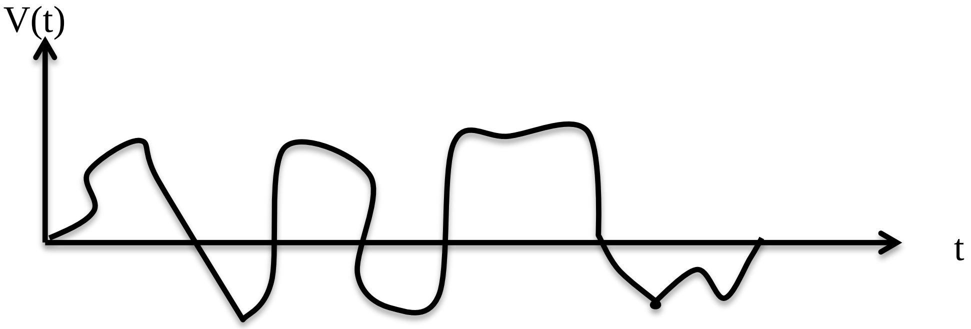






(1-3) Non Periodic Function or (Aperiodic)

Random signal are those signals that take random values at any given time . like all message signal and noise .



(1-4) Frequency Domain:

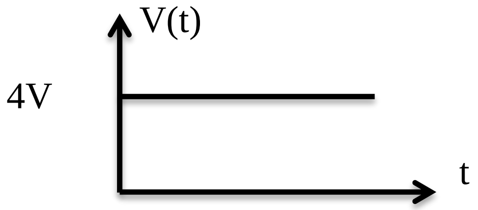
A peak amplitude of the signal with respect to frequency .

W=2πf [rad]

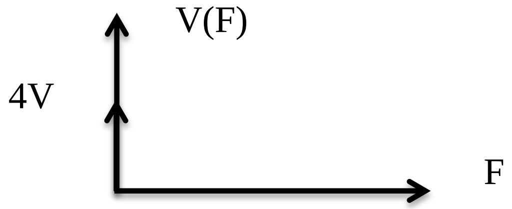
F=1/T [H_Z]

Example : Sketch the function Y= 4 volt in time and frequency domain?

Solution:



Time domain



Frequency domain

Example : Sketch the time and frequency domain of the signal?

1) $V(t) = 10$ Volt

2) $V(t) = 10 \cos 50\pi t$ Volt

3) $V(t) = 5 + 10 \cos 5\pi t$ Volt

4) $V(t) = (20\cos 50t)^2$ Volt

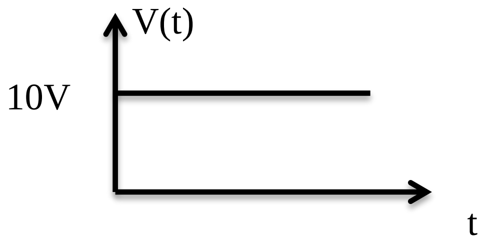
5) $V(t) = (5 + 20\cos 50t)^2$ Volt

6) $V(t) = (3\cos 2t + 20\cos 50t)^2$ (Home work)

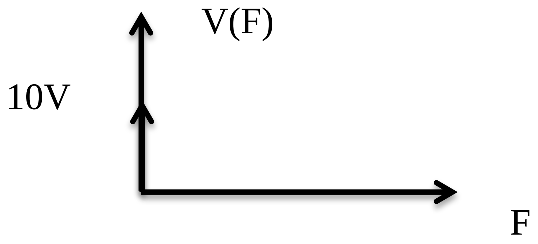
…………………………………………………………………

Solution :

1)



Time domain



Frequency domain

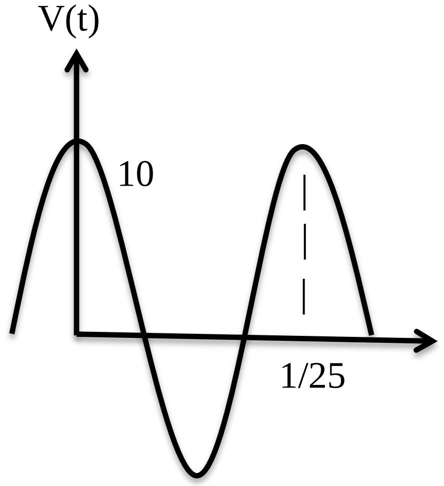
2) $V(t) = 10 \cos 50\pi t$ Volt

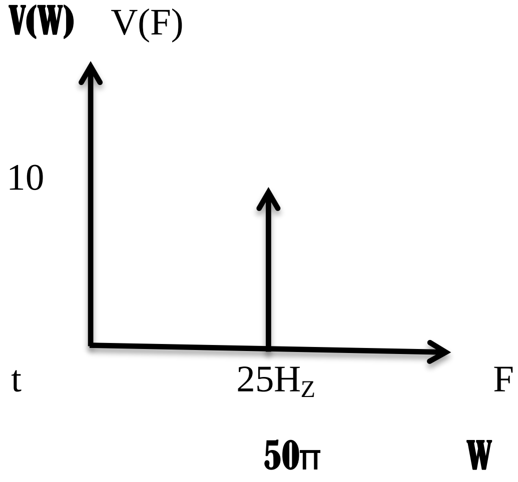
$W = 2\pi f = 50\pi$ [rad]

$F = w/2\pi$

$= (50\pi/2\pi) = 25$ [H_Z]

$T = 1/25$ [sec]





3) $V(t) = 5 + 10 \cos 5\pi t$ volt

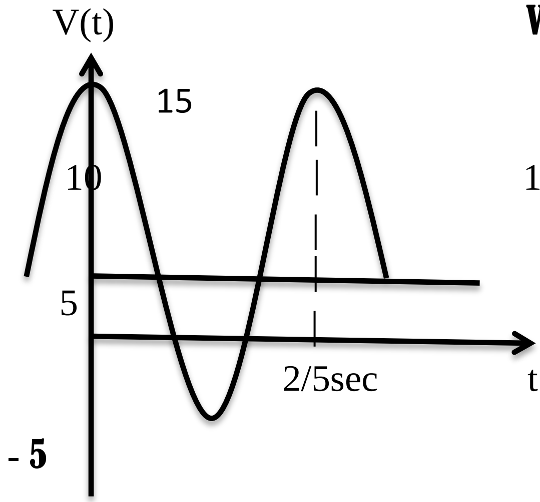
$W = 5\pi$

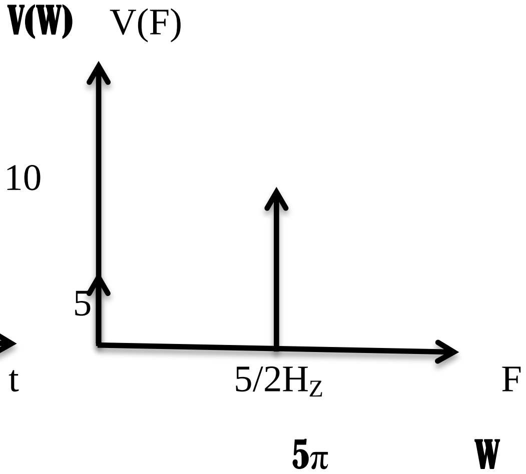
$2\pi f = 5\pi$

$F = 5\pi / 2\pi$

$F = 5/2$ [H_Z]

$T = 2/5$ [sec]





4) $V(t) = (20\cos 50t)^2$

$V(t) = 400\cos^2 50t$

Where : $\cos^2 A = 0.5\,[1+\cos 2A]$

$V(t) = (400/2)[\,1 + \cos 100t] = 200 + 200\cos 100t$

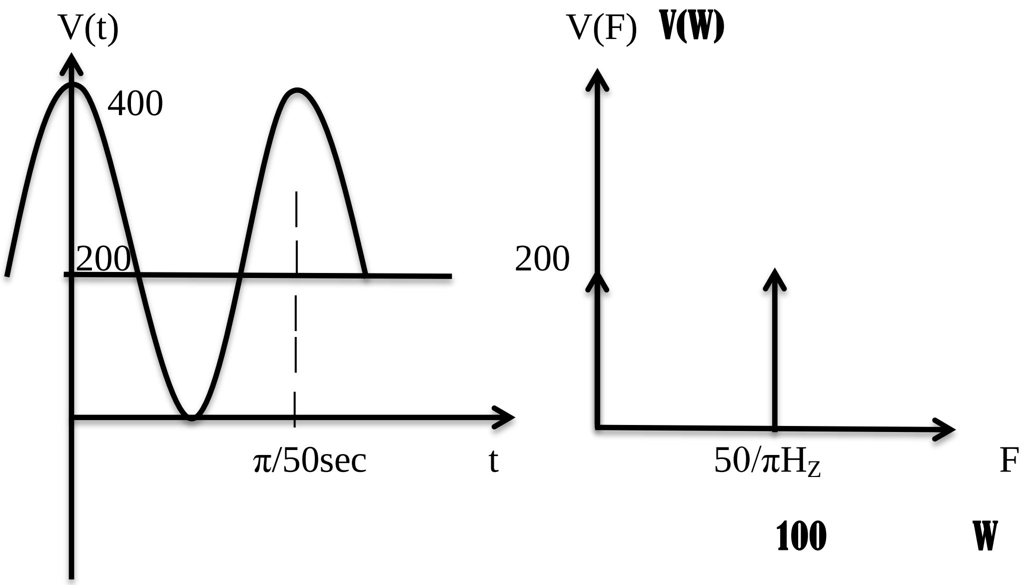
$W = 100$ [rad]

$2\pi f = 100$

$F = 100/\,2\pi$

$F = 50/\pi$ $[H_Z]$

$T = \pi/50$ [sec]



5) $v(t) = (5 + 20\cos 50t)^2$

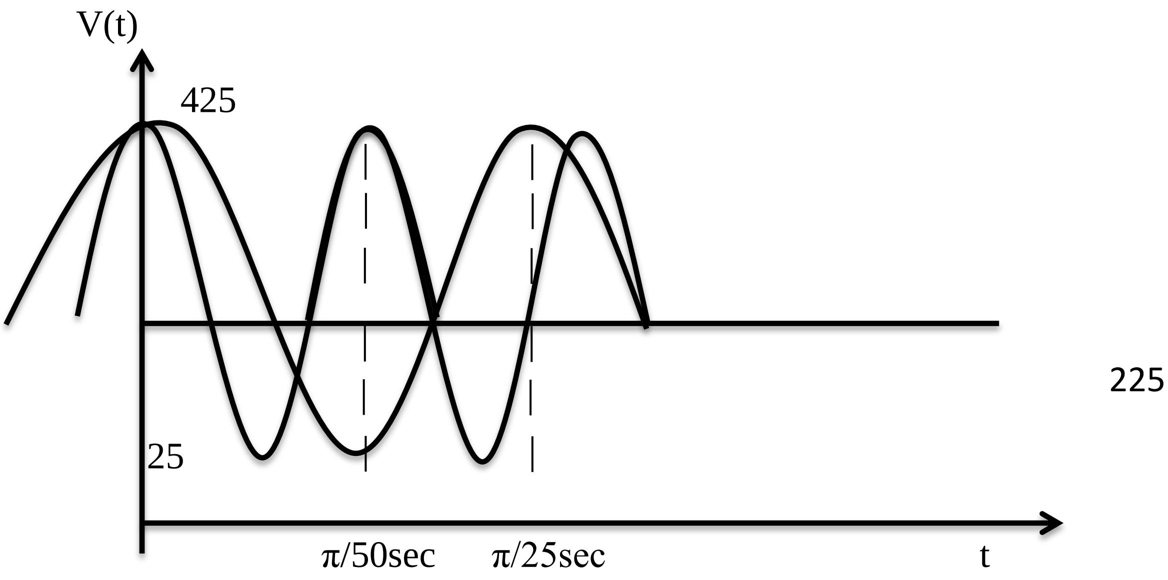
$V(t) = 25 + 200\cos 50t + 400\cos^2 50t$

$V(t) = 25 + 200\cos 50t + (400/2)[1 + \cos 100t]$

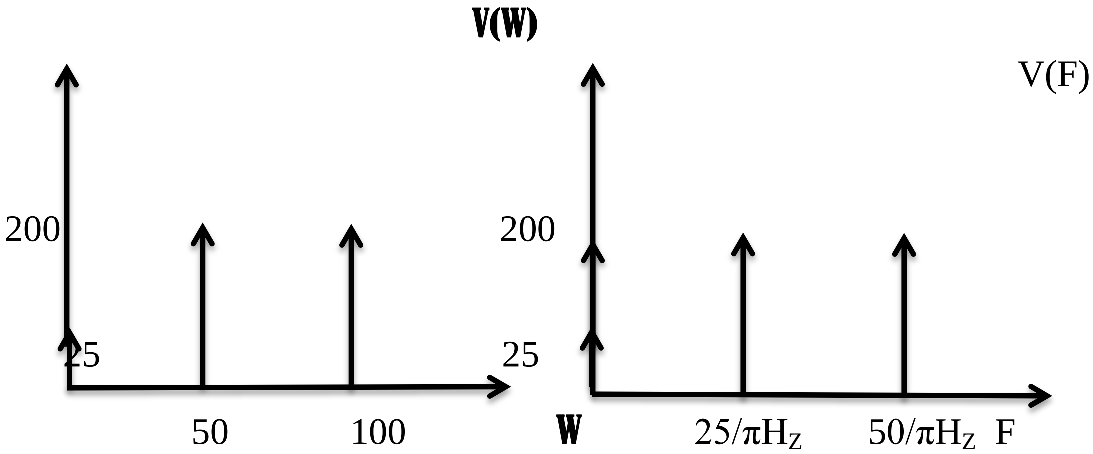
Where : $\cos^2 A = 0.5\,[1+\cos 2A]$

$V(t) = 25 + 200\cos 50t + 200 + 200\cos 100t$

$V(t) = 225 + 200\cos 50t + 200\cos 100t$



Time domain



Frequency domain

Notes:

$$\sin(\alpha \mp \beta) = \sin\alpha \cos\beta \mp \cos\alpha \sin\beta$$

$$\cos(\alpha \mp \beta) = \cos\alpha \cos\beta \pm \sin\alpha \sin\beta$$

$$\sin\alpha \cos\beta = \frac{1}{2}\{\sin(\alpha + \beta) + \sin(\alpha - \beta)\}$$

$$\cos\alpha \sin\beta = \frac{1}{2}\{\sin(\alpha+\beta) - \sin(\alpha-\beta)\}$$

$$\sin\alpha \sin\beta = -\frac{1}{2}\{\cos(\alpha+\beta) - \cos(\alpha-\beta)\}$$

$$\cos\alpha \cos\beta = \frac{1}{2}\{\cos(\alpha+\beta) + \cos(\alpha-\beta)\}$$

$$\cos^2\alpha = \frac{1}{2}(1 + \cos2\alpha)$$

$$\text{Cos}2\alpha = 1 - 2\sin^2\alpha$$

$$\text{Cos}2 = 2\cos^2\alpha - 1$$

(1-5) Fourier series:

Any periodic signal un sinusoidal wave can representation infinity from different sinusoidal wave in amplitude, frequency, and phase although to dc component.

$$V(t) = V_0 + \sum_{n=1}^{\infty}(V_n \cos(\mathrm{n}w_o\ t + \varnothing_n))$$

V_o = DC component

V_n = spectral amplitude

nw_o : Radians frequency

$w_o = 2\pi f_o$ ………….. $f_o = w_o / 2\pi$

$f_o = 1/T_o$ (fundamental frequency)

Reciprocal of the periodic T_o is called fundamental frequency

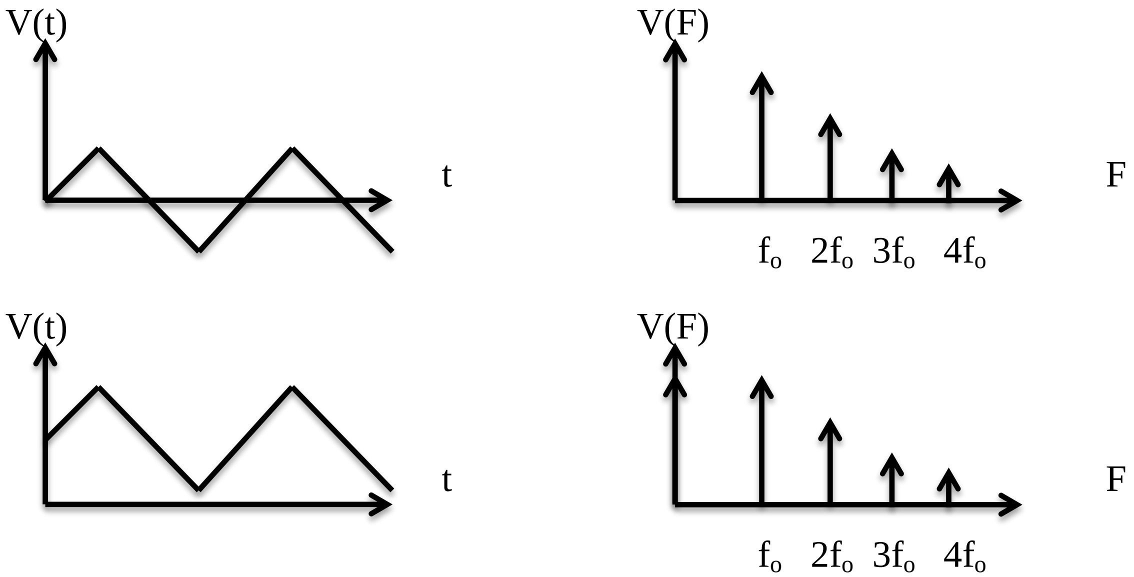
$$V(t) = V_0 + \sum_{n=1}^{\infty}(V_n \cos(\mathrm{n}w_o\ t + \varnothing_n))$$

$= V_o + V_1 \cos(w_o t + \varnothing_1) + V_2\cos(w_o t + \varnothing_2) + V_3 \cos(w_o t + \varnothing_3)$

constant fundamental 2nd harmonic 3rd harmonic

$+$ ………+ ………..

The Fourier series is the key to the frequency domain analysis of the signal .



(a) Fourier cosine series: The Fourier series of an even periodic function f (x) having period 2π contains cosine terms only (i.e. contains no sine terms) and may contain a constant term.

$$\text{Hence } f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos nx$$

(b) Fourier sine series: The Fourier series of an odd periodic function f (x) having period 2π contains sine terms only (i.e. contains no constant term and no cosine terms).

$$\text{Hence } f(x) = \sum_{n=1}^{\infty} b_n \sin nx$$

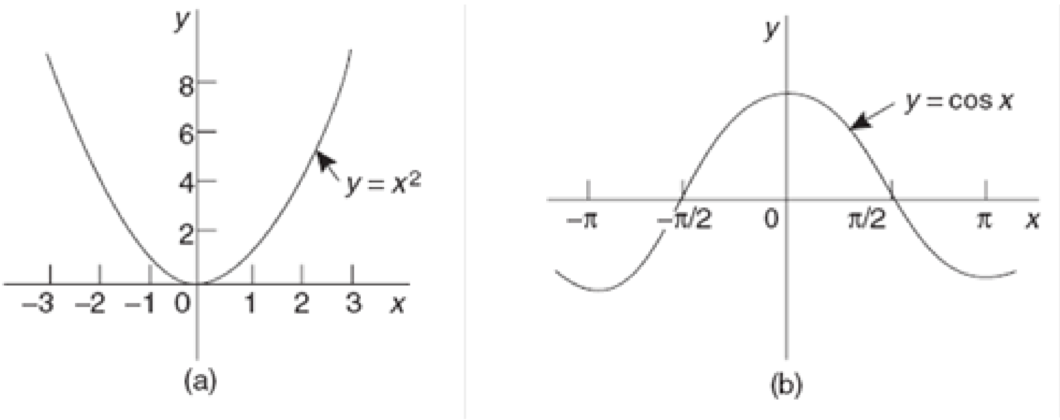
(1-6)Even and odd functions:

Even functions: A function y = f (x) is said to be even if f (−x)= f (x) for all values of x.

Graphs of even functions are always symmetrical about the y-axis.

(i.e. is a mirror image).

Two examples of even functions are $y = x^2$ *and* $y = \cos x$ as shown in figure below.

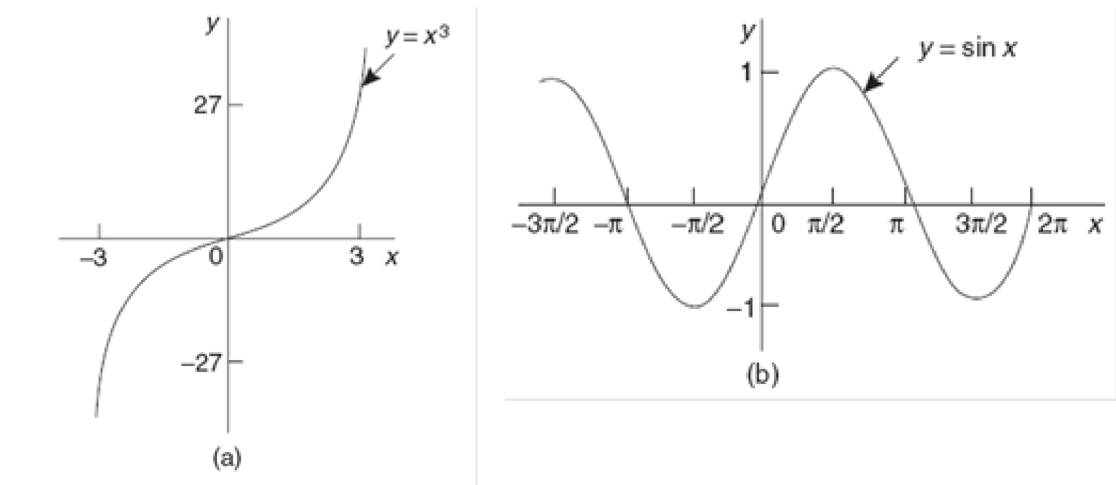


Even Function

Odd functions: A function y = f (x) is said to be odd if f (−x)= − f (x) for all values of x.

Graphs of odd functions are always symmetrical about the origin.

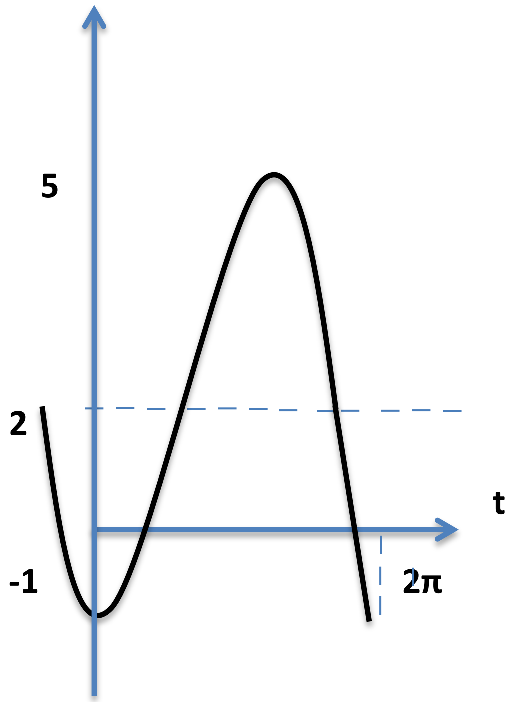
Two examples of odd functions are $y = x^3$ and $y = \sin x$ as shown in figure below.

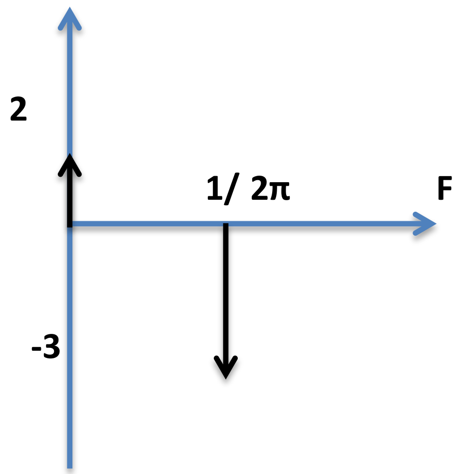


Odd Function

A- Sketch time and frequency domain of the signal y(t) = 2-3cost?

(24/05/2016) (الدور الاول)





H.W: Draw the frequency spectrum (F.D) of the following function?

1) $V(t) = 2\cos^2 t.\cos 10t$

2) $V(t) = (2\cos 5t+10\cos 20t)^2$

3) V(t) = 10c0s10t.3cost

4) V(t) = sin2t

5) V(t) =1+ sint

6) y(x) = sinx-2

7) y(x) = 2-3sinx

8) $V(t) = (3\cos 10t + 2\sin 60t)^2$

9) y(x) = 2-3cosx

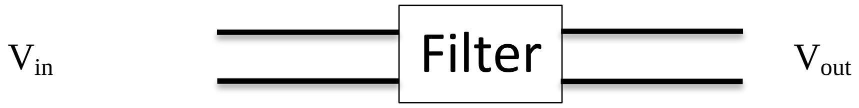
10) **Draw the frequency domain (spectrum) of the signal:-**

V(t) =5 + 10 cos 5πt volt

CH -2-

(2) Filters :

It is a four terminals network which passes certain frequency and rejects either frequency.



(2-1) Type of filters :

There are four basic type of filters are there frequencies which are used in communication system.

They are :

1) Low Pass Filter (LPF)

2) High Pass Filter (HPF)

3) Band Pass Filter (BPF)

4) Band Stop (Reject) Filter (BSF) or (BRF)

And the type of filters as there component:-

1- RC filter

2- LC filter

3- Crystal filter

4- Digital filter

Cut- off frequency :

As the frequency in to the amplitude in volt is reduced to 0.707 of the original value.

(2-2)Decible :

The ratio of any two values of the same quantity (power, voltage or current) can be expressed in decibels (dB).

(2-3) Loss :

Loss or attenuation is the dissipation of signal strength as signal travels along any transmission medium. it is usually expressed in decibels (dB).

$L_{dB} = 10 \text{ Log } (P_i / P_o)$

Example: Suppose a 10mW , $1KH_Z$ signal is launched into a wire pair . At the distance end of wire pair the signal is measured at 0.2 mW . what is the loss in decibels on the line for this signal?

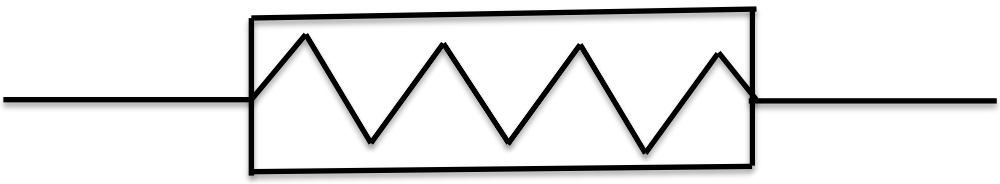
Solution:

$L_{dB} = 10 \text{ Log} (10/0.2) = 10 \text{ Log } (50) = 17dB$

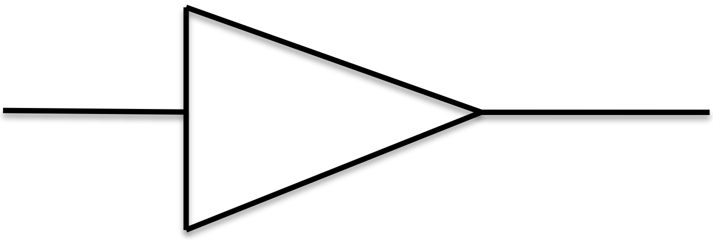
Attenuator: is a device placed in a circuit to purposely cause less.

Amplifier: Does just the reverse ; that is , it gives a signal gain.

The symbol of it:



Symbol of attenuator



Symbol of amplifier

In communication system gain is measured in (dB). The (dB) is used to measured the ratio of two levels of power or power gain G_{dB}.

$$G_{dB}=10 \text{ Log } (P_o / P_i)$$

Example: Find the gain in (dB) to the circuit shown below. The input power equal to :-

1) $P_o = P_i$

2) $P_o = 2P_i$

3) $P_o = 0.5P_i$

Solution:

$$G_{dB}=10 \text{ Log } (P_o / P_i)$$

1) $G_{dB}=10 \text{ Log } (P_o / P_i) = 0$

2) $G_{dB}=10 \text{ Log } (P_o / P_i) = 3dB$

3) $G_{dB}=10 \text{ Log } (P_o / P_i) = - 3dB$

Notes: $G_{dB} = - \alpha_{dB}$

$\alpha_{dB} = - 10 \text{ Log } (P_o / P_i)$

in the circuit shown below :-

$P = I^2 R = V^2 / R$

$$G_{dB}=10 \text{ Log } (P_o / P_i) = 10 \text{ Log } (I^2_o R_o / I^2_i R_i)$$

$=10 \text{ Log } (I^2_o / I^2_i) +10 \text{ Log } (R_o / R_i)$

If $(R_o = R_i)$ at Max power

$G_{dB} =10 \text{ Log } (I^2_o / I^2_i) + 0 = \quad =10 \text{ Log } (I_o / I_i)^2 =20 \text{ Log } (I_o / I_i)$

$$G_{dB}=10 \text{ Log } (P_o / P_i) = 10 \text{ Log } (V^2_o/ R_o) /(V^2_i/ R_i)$$

$= 10 \text{ Log } (V^2_o/ V^2_i) \times (R_i / R_o) = 10 \text{ Log } (V_o/ V_i)^2 \times (R_i / R_o)$

If $(R_o = R_i)$ at Max power

$G_{dB} = 20 \text{ Log } (V_o/ V_i)$

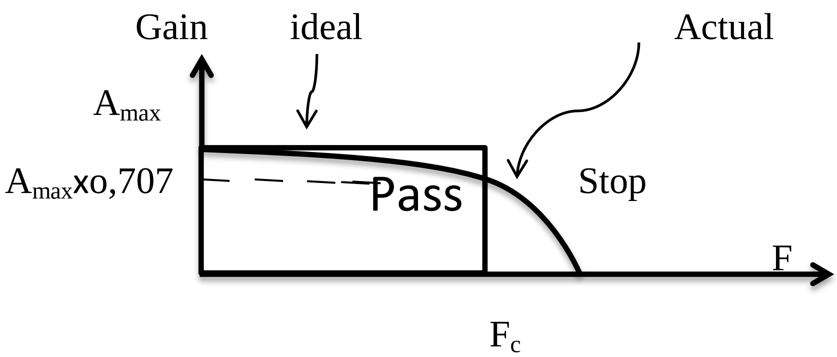
(2-4) Passive filters :

(2-5) RC filters :

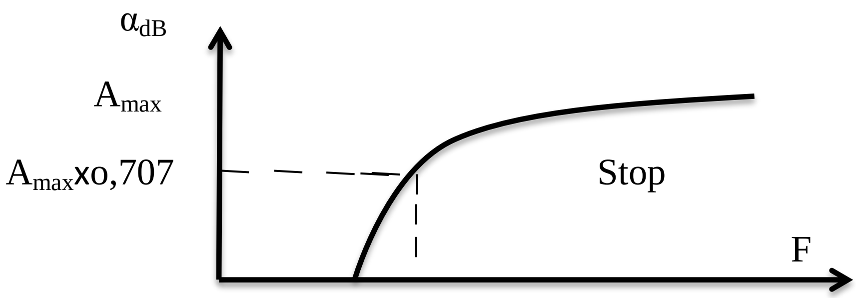
It is a filter which may be consist resistor and capacitor.

(2-5-1) RC (LPF) :

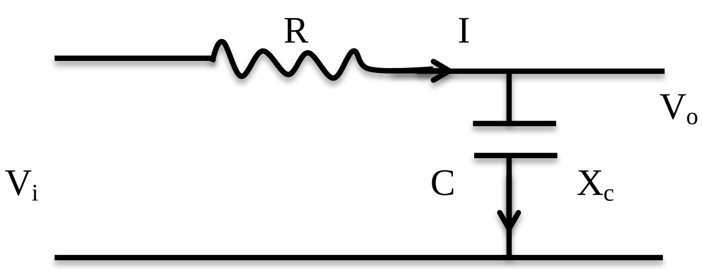
Ideal LPF : is a filter which passes are below than cut-off frequency (f_c).



Frequency response of practical and ideal LPF



Frequency response of practical LPF

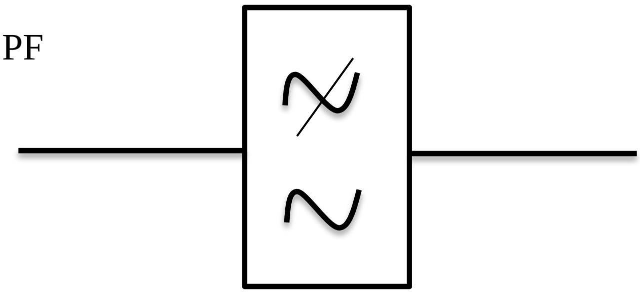


Circuit diagram of passive RC LPF

At Low frequency At high frequency

$V_o \approx V_i$ $X_c \approx 0$

The symbol of LPF



To find the cut-off frequency of RC LPF.

From the circuit diagram of RC LPF:-

$V_o = V_i$

$V_o = [X_c / (R + X_c)]V_i$

$$V_{out} = \frac{1/j\omega C}{R + 1/j\omega C} V_{in}$$

$$V_o = \frac{1}{(jwcR+1)} \quad V_i$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1 + j\omega RC}$$

$$G = (V_i / V_o) = \frac{1}{(jwcR+1)}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\sqrt{1+\omega^2R^2C^2}\angle\tan^{-1}(\omega RC)} = \frac{1}{\sqrt{1+\omega^2R^2C^2}}\angle -\tan^{-1}(\omega RC)$$

and thus the magnitude is

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\sqrt{1+\omega^2R^2C^2}}$$

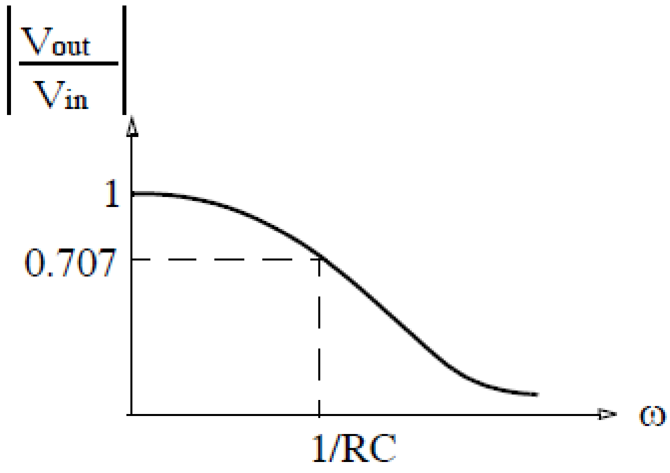
as $\omega \to 0$, $|V_{out}/V_{in}| \cong 1$

and as $\omega \to \infty$, $|V_{out}/V_{in}| \cong 0$

for $\omega = 1/RC$, $|V_{out}/V_{in}| = 1/(\sqrt{2}) = 0.707$

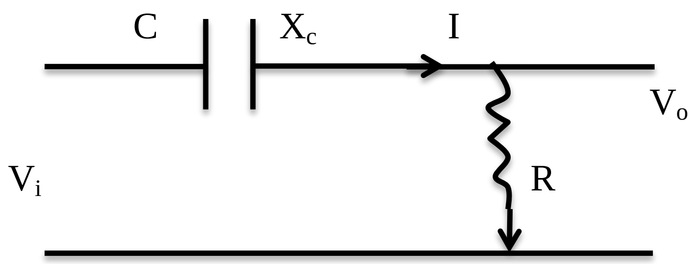
$F_c = \frac{1}{2\pi RC}$

$W_c = \frac{1}{RC}$



(2-5-2) RC (HPF) :

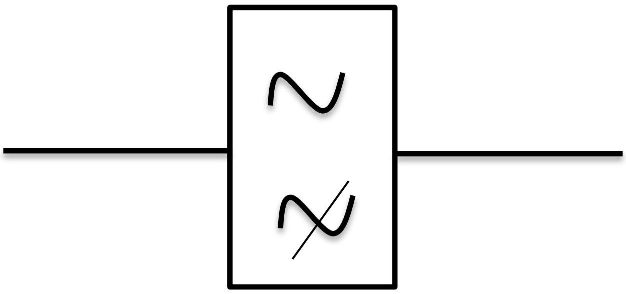
LPF



Circuit diagram of passive RC HPF

At Low frequency	At high frequency
$V_o \approx 0$	$V_o \approx Vi$
$X_c \approx \infty$	$X_c \approx 0$

The symbol of HPF



To find the cut- off frequency

$$V_{out} = \frac{R}{R + 1/j\omega C} V_{in}$$

$$G(j\omega) = \frac{V_{out}}{V_{in}} = \frac{j\omega RC}{1 + j\omega RC} = \frac{j\omega RC + \omega^2 R^2 C^2}{1 + \omega^2 R^2 C^2} = \frac{\omega RC(j + \omega RC)}{1 + \omega^2 R^2 C^2}$$

$$= \frac{1}{\sqrt{1 + 1/(\omega^2 R^2 C^2)}} \angle \operatorname{atan}(1/(\omega RC))$$

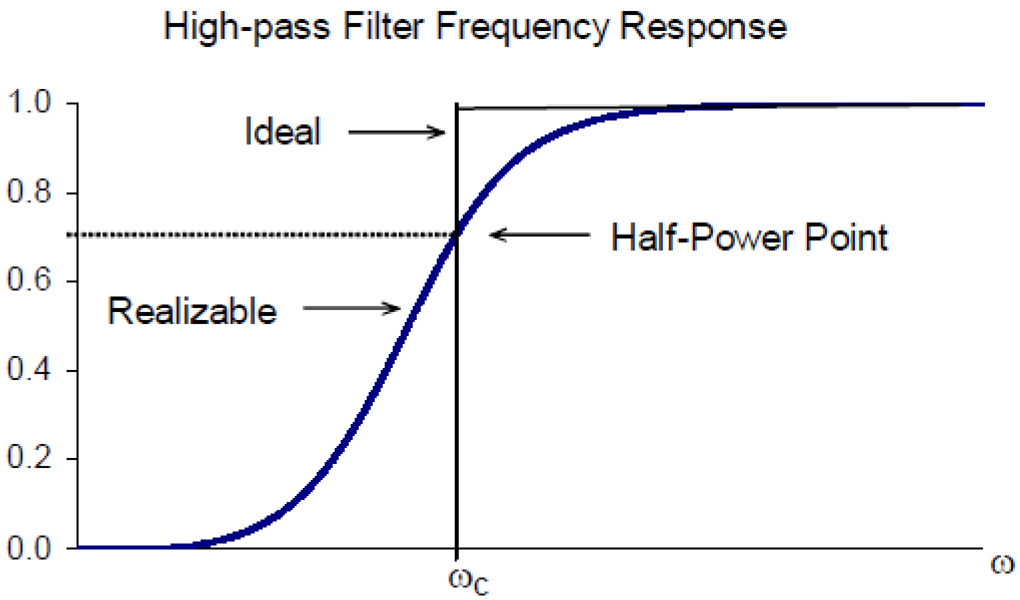
$$|G(j\omega)| = \frac{1}{\sqrt{1 + 1/(\omega^2 R^2 C^2)}}$$

at $\omega = 0$

$$|G(j\omega)| \cong 0$$

For $\omega = 1/RC$

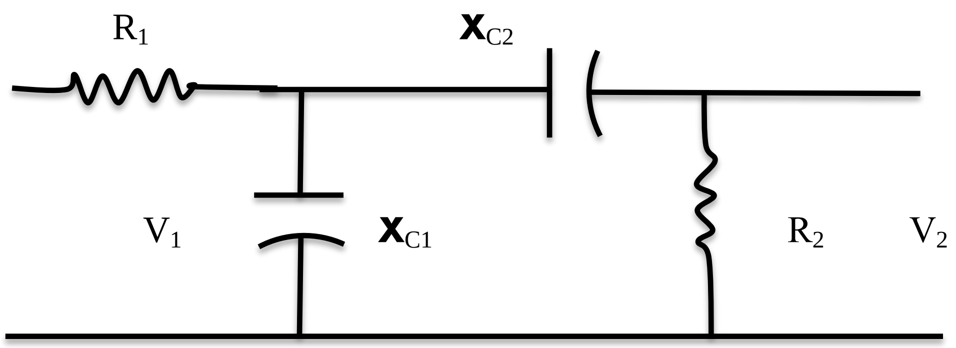
$$|G(j\omega)| = 1/\sqrt{2} = 0.707$$



(2-5-3) RC (BPF) :

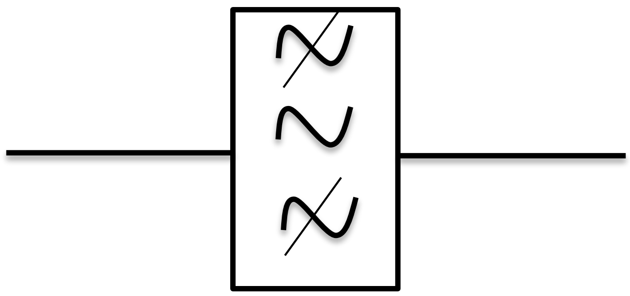
It is a filter which passes a certain band of frequencies and rejects all the other frequencies.

It can be construction by connected LPF and HPF in cascade.



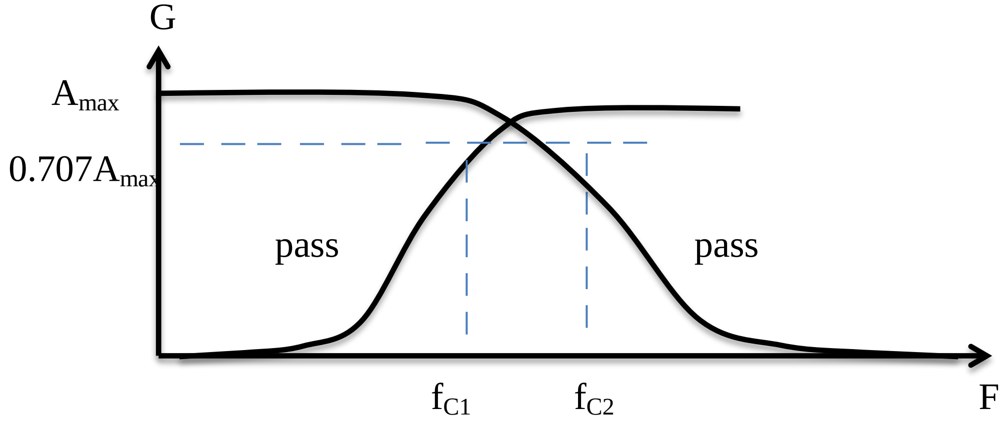
Circuit diagram of passive RC BPF

Note: to make the filter work : $R_2 >> R_1$



The symbol of BPF

$F_{C1}= 1/2\pi R_2C_2$, $F_{C2}= 1/2\pi R_1C_1$



Frequency response of BPF

Example: Design RC-BPF which have cut-off frequency $f_{C1}= 20kH_z$ and $f_{C2}=80kH_z$, suppose (R_s =75Ω , R_1 =100Ω) then find the band width?

Solution:

$F_{C1}= 1/2\pi R_2C_2$

$F_{C2}= 1/2\pi R_1C_1$

To make filter work : : $R_2>>R_1$

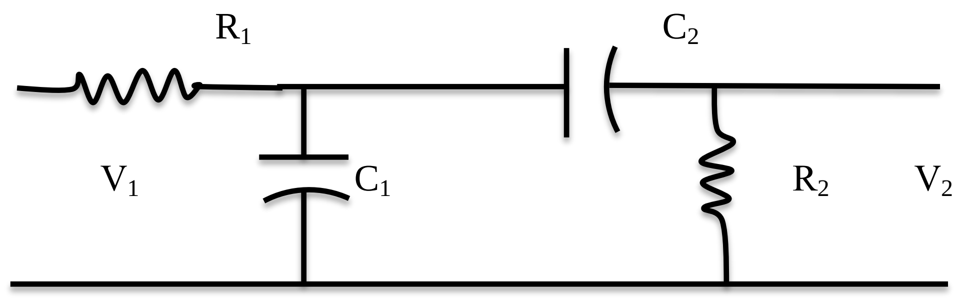
$R_1 = 75+100=175\Omega$

$R_2 = 10R_1 = 10(175) = 1750\Omega$

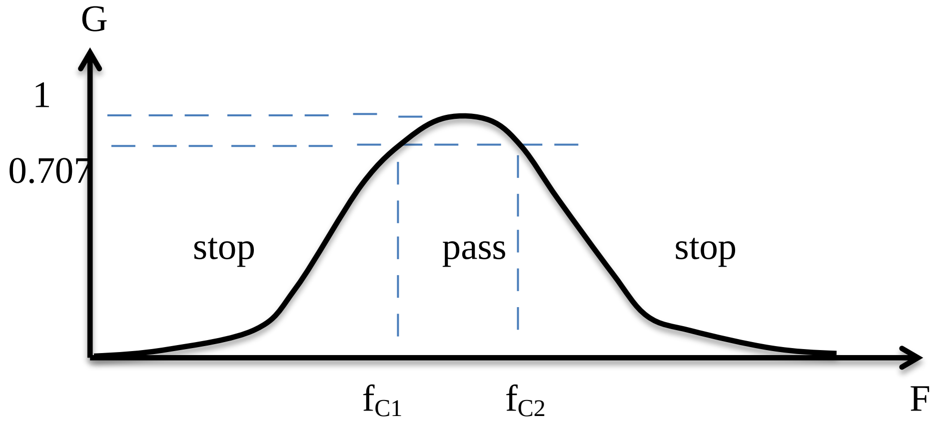
$C_2= 1/2\pi R_2 F_{C1} = 1/[(2\pi(1750)(20000)]= 4.55\mu F$

$C_1= 1/2\pi R_2 F_{C2} = 1/[(2\pi(175)(80000)] =$ μ F

B.W= F_{C2} - F_{C1} = 80000 - 20000 = $60KH_Z$



Circuit diagram of passive RC BPF

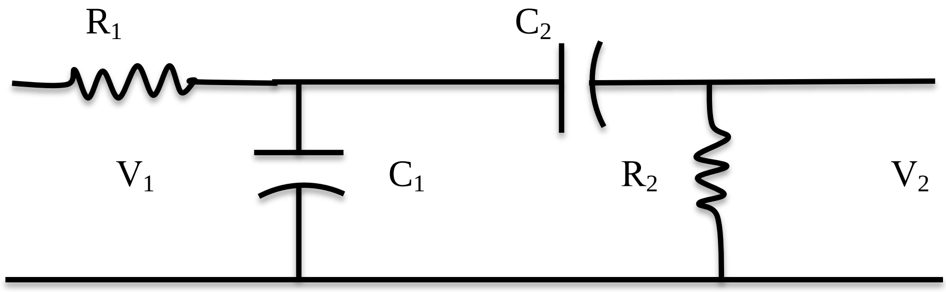


Frequency response of BPF

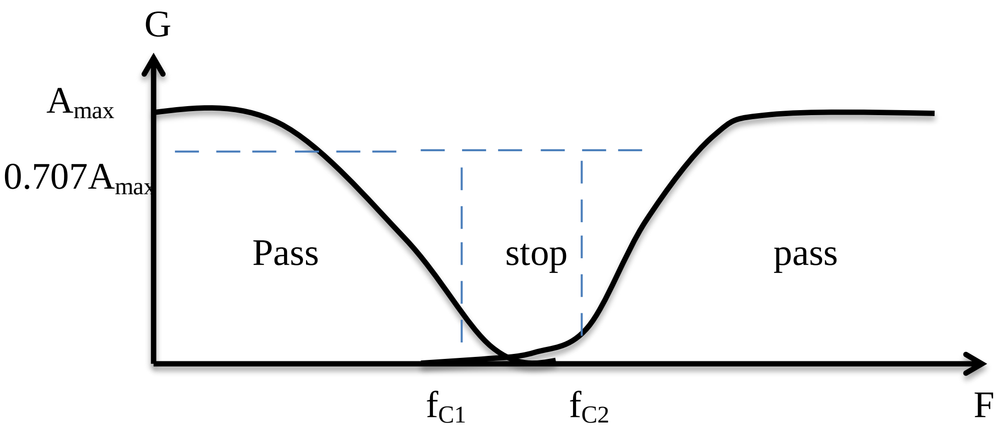
(2-5-4) RC BRF or (BSF) :

It is a filter which passes all the other frequencies except a certain band of frequencies .

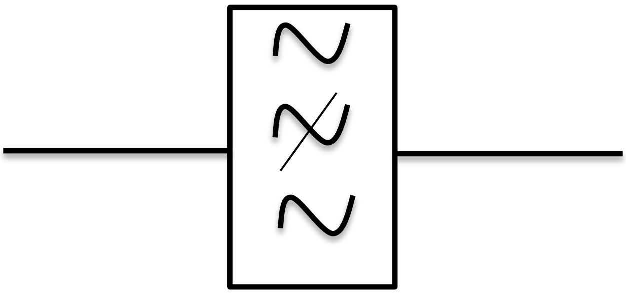
It can be construction by connected LPF and HPF .



Circuit diagram of BRF



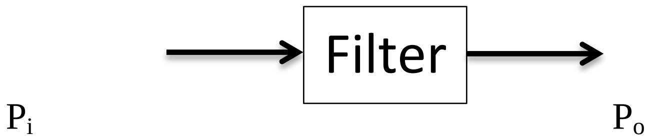
Frequency response of BRF



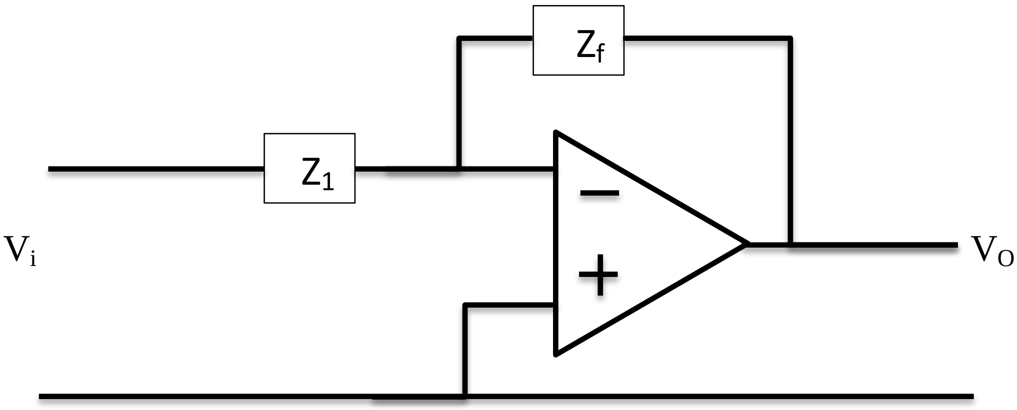
The symbol of BRF

(2-6) RC Active filters :

An *active filter* is an electronic circuit consisting of an amplifier and other devices such as resistors and capacitors.
Operational amplifiers are used extensively as active filters.



$P_i < P_o$

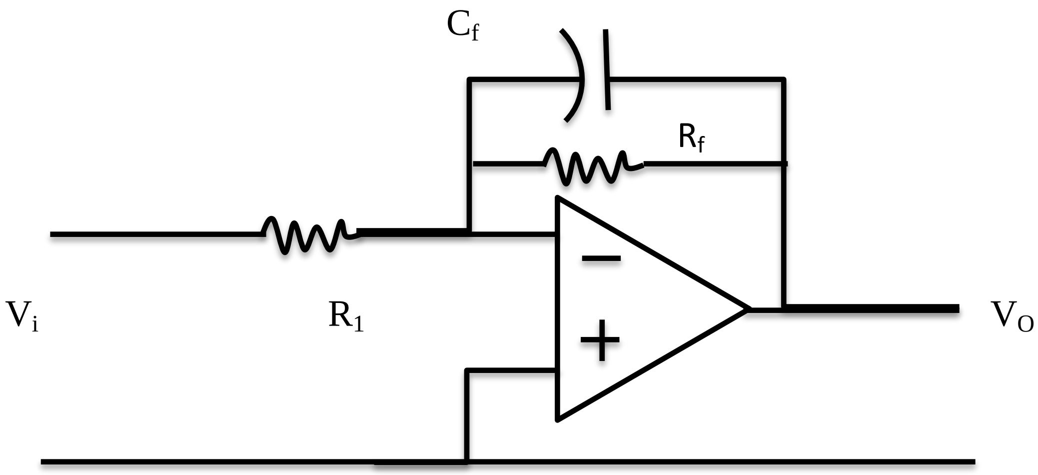


Block diagram of active first order Filter

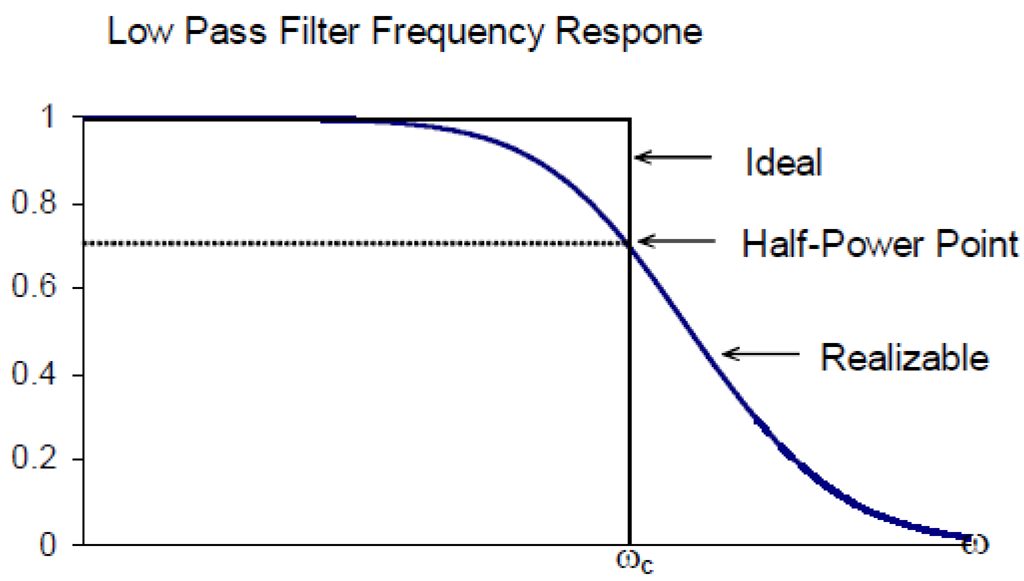
(2-6-1) Active (LPF) :

$G = (V_O / V_i) = - (Z_f / Z_1)$

A *low-pass filter* transmits (passes) all frequencies below a *critical* (*cutoff*) frequency



Circuit diagram of active (LPF)

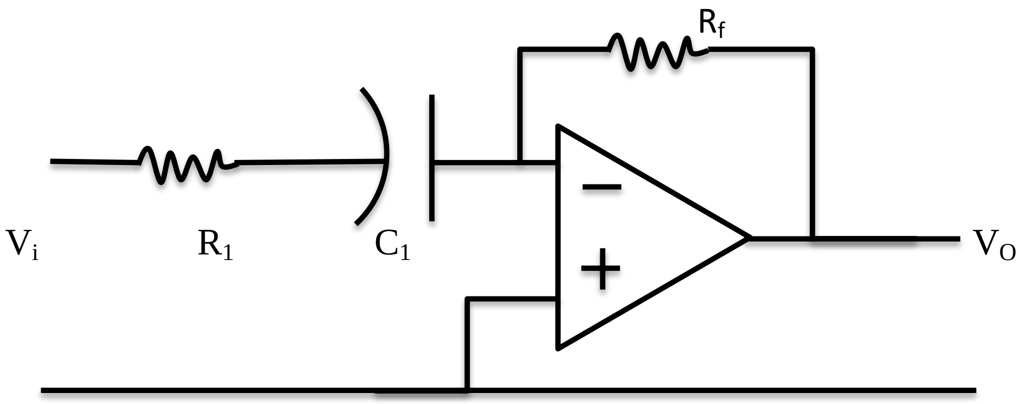


amplitude frequency response

$$W_c = 1 / (R_f C_f)$$

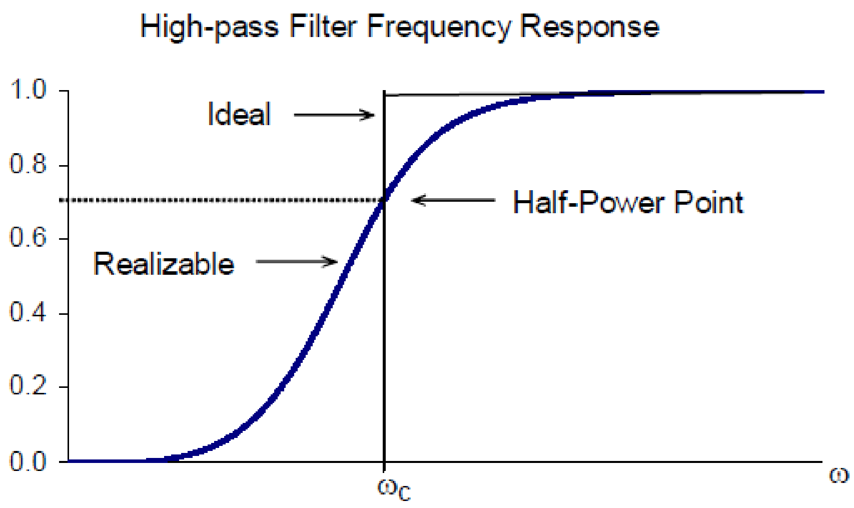
(2-6-2) RC Active (HPF) :

A high-pass filter transmits (passes) all frequencies above a critical (cutoff) frequency , and attenuates (blocks) all frequencies below the cutoff frequency. An op amp high-pass filter is shown in Figure.



Circuit diagram of active (HPF)

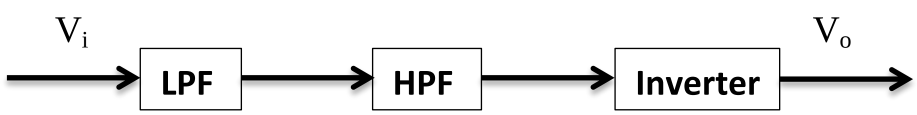
$$W_c = 1 / (R_1 C_1)$$



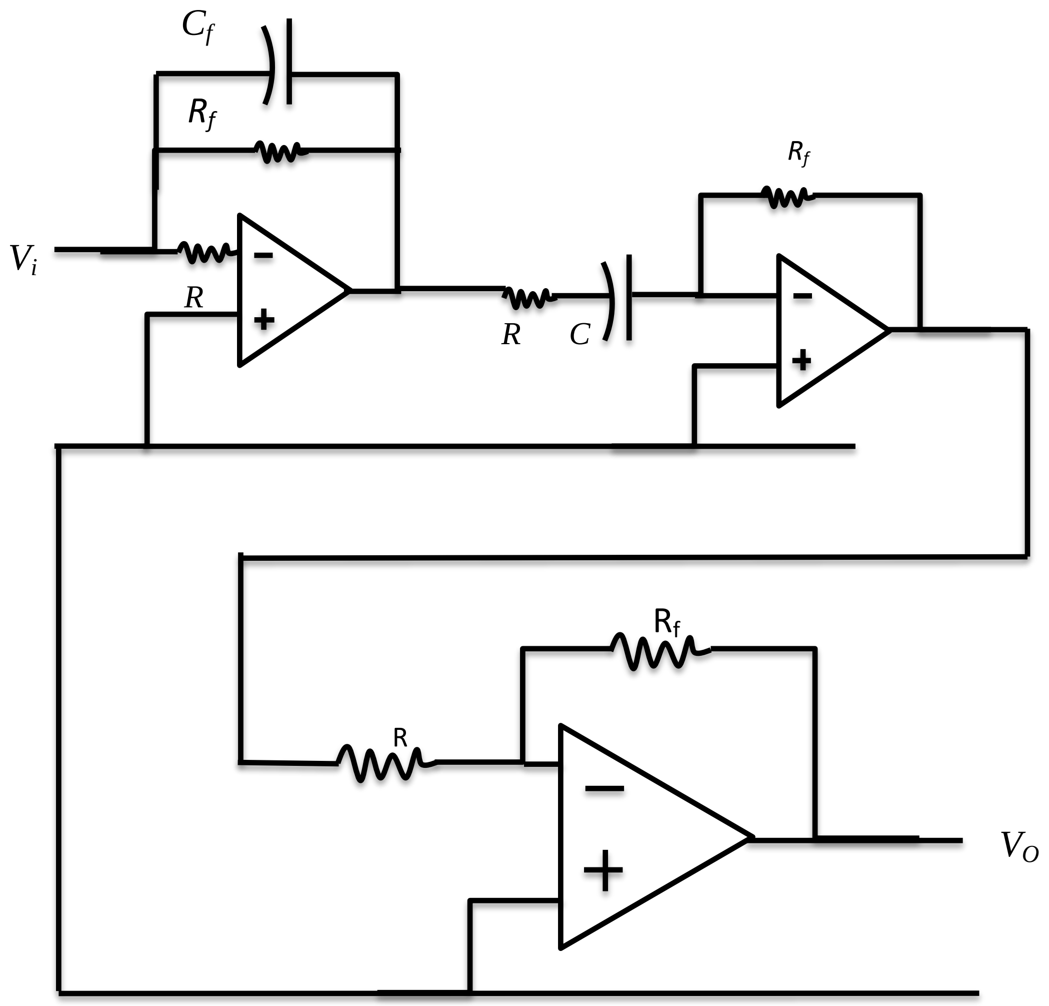
amplitude frequency response

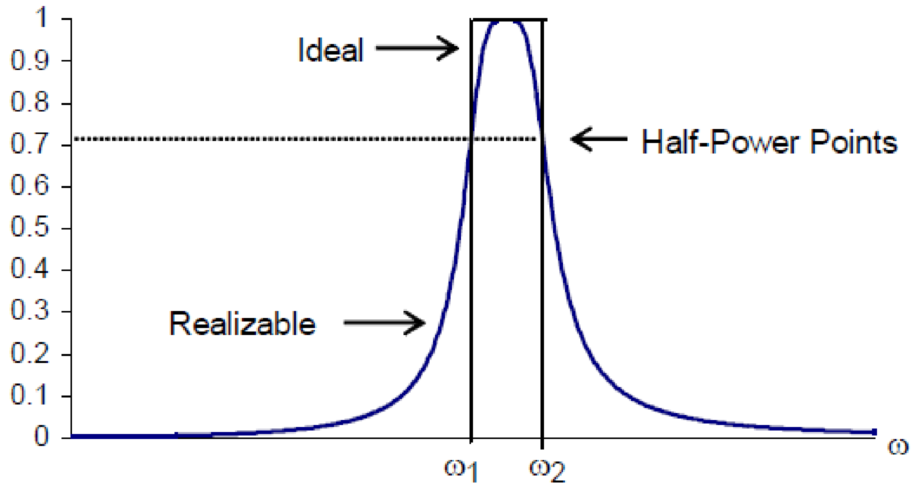
(2-6-3) Active (BPF) :

A band-pass filter transmits (passes) the band (range) of frequencies between the critical (cutoff) frequencies denoted as ω_1 and ω_2, where the maximum value of Gain (G) which is unity , falls to $0.707A_{max}$, while it attenuates (blocks) all frequencies outside this band.



Block diagram of active BPF





active Band-pass filter frequency response

$W_o = \sqrt{w_1 w_2}$

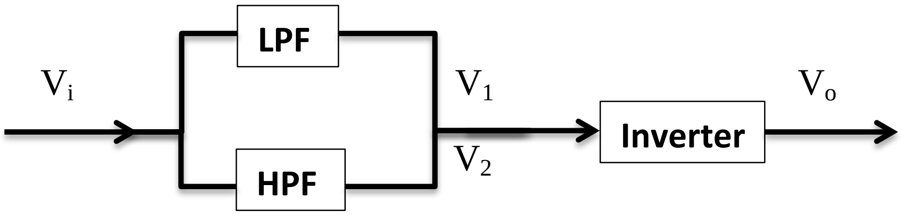
$B.W = w_2 - w_1$

$W_2 = 1/(RC_1)$

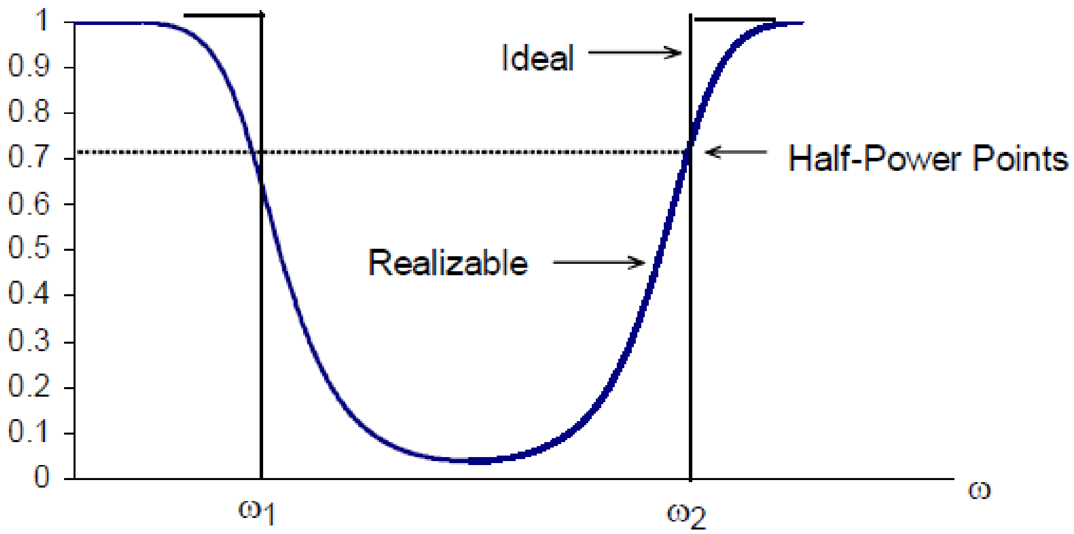
$W_1 = 1/(RC_2)$

(2-6-4) RC (BRF) or (BSF) :

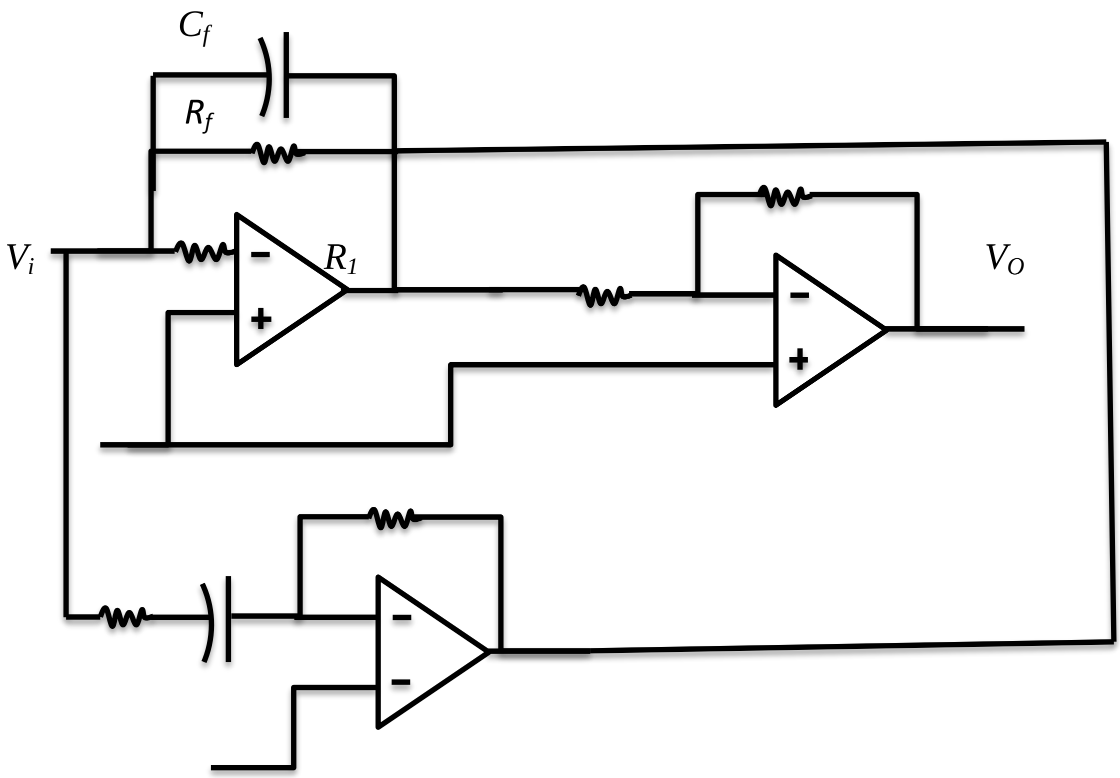
Band-elimination(الإزالة) or band-stop or band-rejection filter attenuates (rejects) the band (range) of frequencies between the critical (cutoff) frequencies denoted ω_1 and ω_2, where the maximum value of which is unity, falls to $0.707A_{max}$, while it transmits (passes) all frequencies outside this band. An op amp band-stop filter is shown in Figure.



Block diagram of active BRF



Band-Elimination (BSF)Filter Frequency Response



Circuit diagram of active BRF

$W_o = \sqrt{w_1 w_2}$

$B.W = w_2 - w_1$

$W_2 = 1/(RC_1)$

$W_1 = 1/(RC_2)$

$V_o = V_1 + V_2$

Example: Design RC active LPF with dc gain of 4 and cut- off frequency of $500H_Z$ if $C_f=0.2\ \mu F$?

Solution:

$W_C = 1/(R_f C_f)$

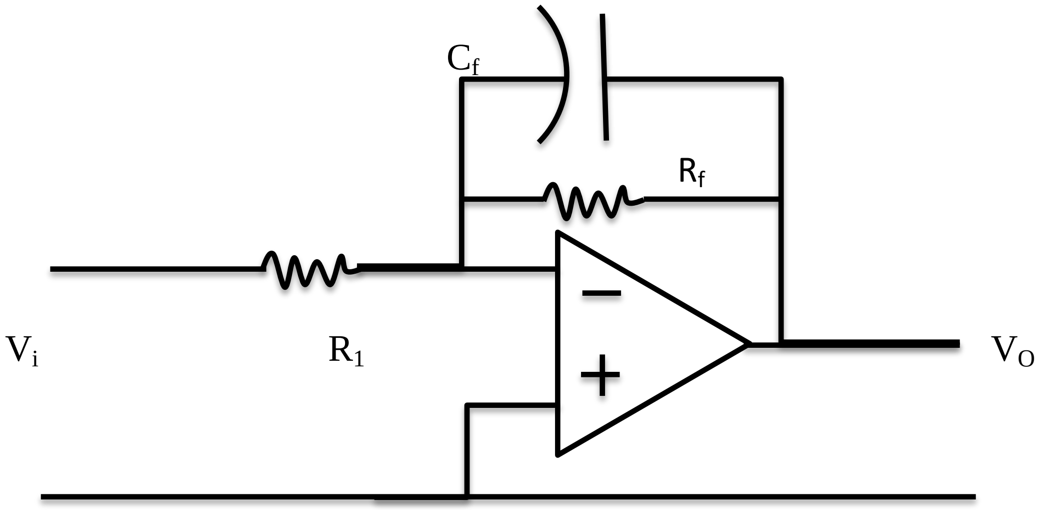
$G = (V_o / V_i) = -(Z_f / Z_1)$

$R_f = 1 / [2(3.14)(500)(0.2x10^{-6})] = 1.59K\Omega$

$R_1 = (R_f /4) = (1.59K\Omega /4) = 397.5\Omega$

$\therefore R_1 \approx 400\ \Omega$

$\therefore R_f \approx 1.6K\ \Omega$



6) $V(t) = (3 \cos 2t + 20 \cos 50t)^2$

Solution :

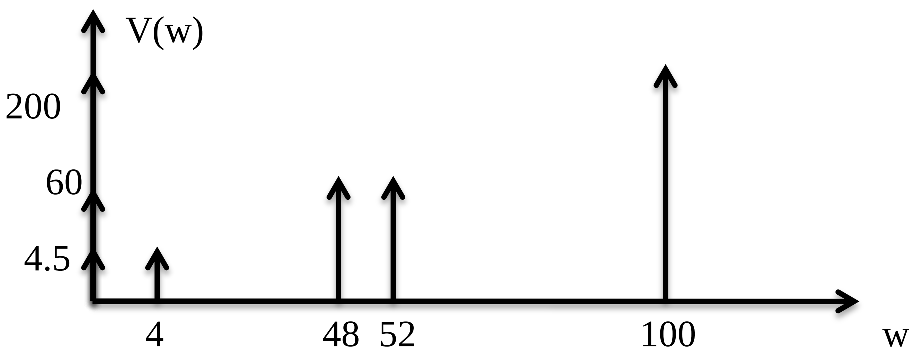
$V(t) = (3 \cos 2t)^2 + 2(3 \cos 2t)(20 \cos 50t) + (20 \cos 50t)^2$

$= 9 (\cos^2 2t) + 120 (\cos 50t . \cos 2t) + 400\cos^2 50t$

$= 9 [(1/2)(1+\cos 4t)] + 120 [(1/2)\{\cos(50+2)t + \cos(50-2)t \}]$

$+ 400[(1/2)(1+\cos 100t)].$

$= 4.5 + 4.5\cos 4t + 60\cos 52t + 60\cos 48t + 200 + 200\cos 100t.$



CH-3-

Modulation

(3-1) Define modulation

Modulation is the process of translating the frequency spectrum of the signal from low frequency region in to higher frequency band.

Or (Modulation is the process of variation of some characteristic of a high frequency wave (carrier wave) in accordance with the instantaneous value of a modulating signal).

The process is being achieved by passing the signal and carrier wave through anon liner device together with BPF.

:Reasons for modulation

1- To transmit more than one signal Simultaneous on the same medium.

2- Exchange of power and bandwidth.

3- Stability and noise rejection.

4- to reduce the size of the antenna required.

The frequency and wave length ƛ of an electromagnetic are related through the phase velocity C.

$C = \lambda f$

$\lambda = C / f$

the audio frequency between $20H_Z$ to $20KH_Z$

$\lambda = (C / f) = (3X10^8 / 10X10^3) = 30Km$

It is obviously impractical to built antenna of this size.

Wave length is conventionally measured in meters and is represented by the symbol λ

Example: the international calling and distress frequency is 500 kHz what is the equivalent wavelength in meter?

500000 $\lambda = 3X10^8$ m/sec

λ = 600m , length of antenna L = 0.47 λ في احسن الحالات

Modulation can take deferent forms depend on the :-

1- Types of (Carrier) Modulation.

2- The method by which the characteristic of the carrier wave is change by the modulation.

(3-2) Type of modulation:

1- Analog data, analog signal:

Analog data in electrical form can be transmitted easily and cheaply.

a- Amplitude modulation (AM) .

b- Angle modulation:-

I- Frequency modulation (FM).

II- Phase modulation (PM).

2- Digital data, analog signal:

Some transmission media will only propagate analog signals.

This system is based on digital signals or pulses.The basis of such a system is the use of a digital carrier signal, which is modulated by an analogue signal.

Pulse Modulation: Pulse-Amplitude Modulation (PAM) , Pulse- width Modulation PWM or PDM (Pulse-duration modulation), (Pulse-position modulation) PPM.

3- Analog data, digital signal:

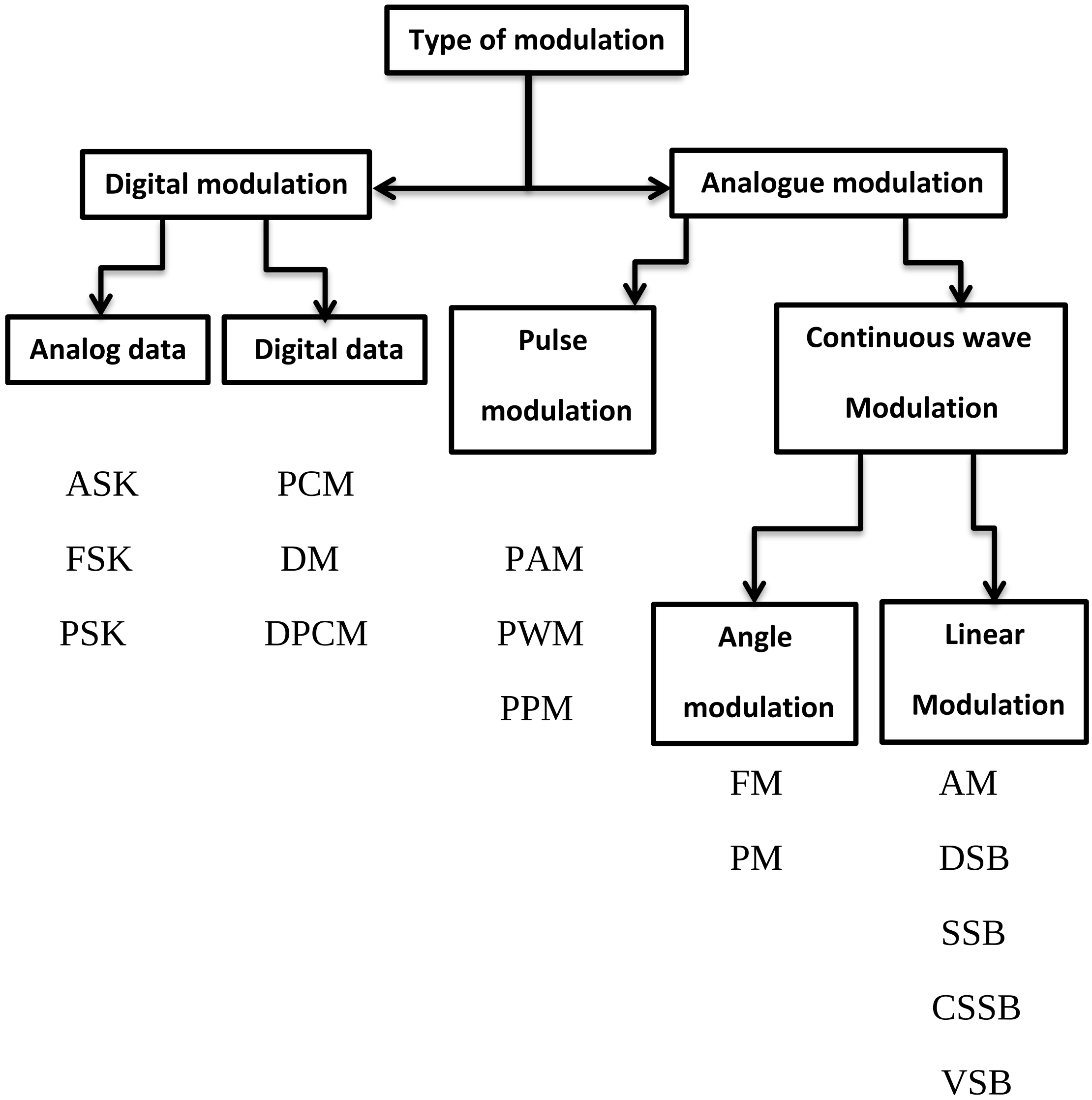
Permits use of modern digital transmission and switching equipment.

Amplitude Shift Keying (ASK) , Frequency Shift Keying (FSK) , Phase Shift Keying (PSK) , DPSK (Differential phase-shift keying).

4- Digital data, digital signal:

Equipment less complex and expensive than digital-to-analog modulation equipment.

PCM (Pulse-Code Modulation) , DM (Delta Modulation) , Delta-Sigma Modulation (Sigma-delta modulation) , Differential pulse-code modulation.



CH- 4 -

Amplitude Modulation

(4-1) Amplitude Modulation: The information signal varies the instantaneous amplitude of the carrier.

Or (amplitude of carrier varied according to message signal).

Case(1): Information signal sinusoidal wave:-

Carrier wave :

$$V_c(t) = \underbrace{E_c}_{\text{Peak voltage}} \cos(\underbrace{\omega_c t+\phi_c}_{\text{angle}}) = E_c \cos(\underbrace{2\pi f_c}_{\text{frequency}} t+\underbrace{\phi_c}_{\text{phase}})$$

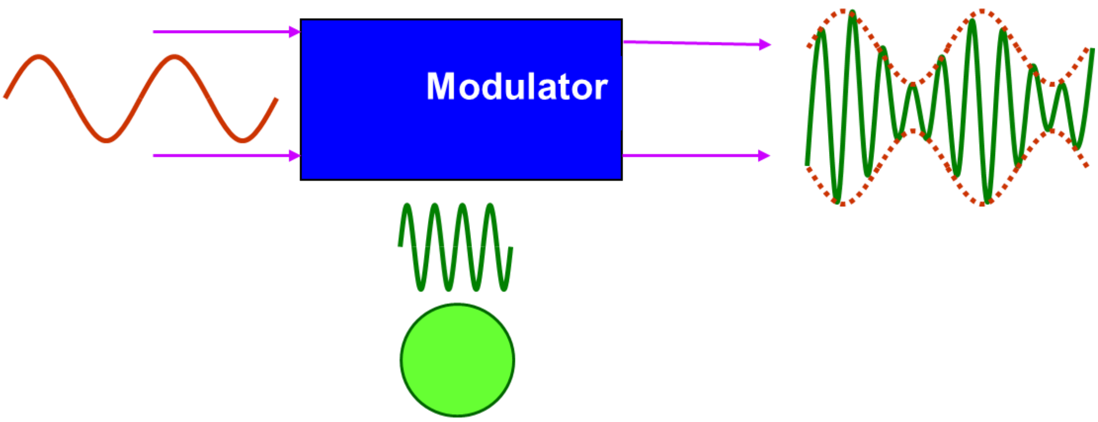
Information signal:

$$V_m(t) = \underbrace{E_m}_{\text{Peak voltage}} \cos\omega_m t = E_m \cos\underbrace{2\pi f_m}_{\text{frequency}} t$$

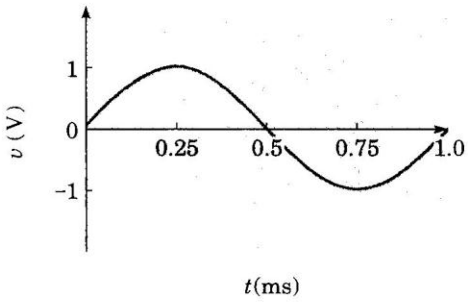
Where: $\omega_c >> \omega_m$

Let $\phi c = 0$

$Vs(t) = E_m \cos\omega_m t$

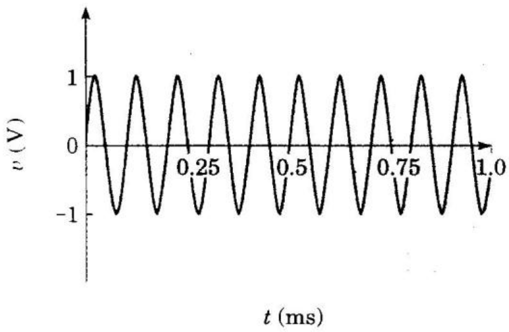


$Vc(t) = E_c \cos\omega_c t$



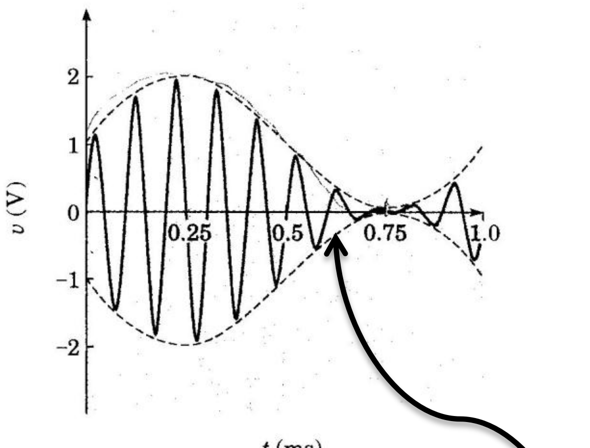
(a) e_m

(a) Modulating Signal



(b) e_c

b) Carrier Signal)



(c) 100% Amplitude modulation

c) Modulated Signal

Envelope Equation $(E_c + E_m \cos\omega_m t)$

$V(t) = [\ E_c + E_m \cos\omega_m t\ ]\ \cos\omega_c t$ **Modulated Signal**

$V(t) = E_c\ [1 + (E_m / Ec) \cos\omega_m t]\ \cos\omega ct$

$$\mathbf{V(t) = E_c\,[1 + (m)\cos\omega_m t]\cos\omega_c t}$$

$$v(t) = (1 + m \cdot \cos\omega_m t) \cdot E_C \cos\omega_C t$$

Where : m is the Modulation index

$$\mathbf{V(t) = E_c\,[1 + (m)\cos\omega_m t]\cos\omega_c t}$$

$$\mathbf{V(t) = E_c\cos\omega_c t + (m)\,E_c\cos\omega_m t\cos\omega_c t}$$

$$\mathbf{V(t) = E_c\cos\omega_c t + [(m\,E_c)/2]\cos(\omega_c + \omega_m)t + [(m\,E_c)/2]\cos(\omega_c - \omega_m)t}$$

Carrier upper side band upper side band

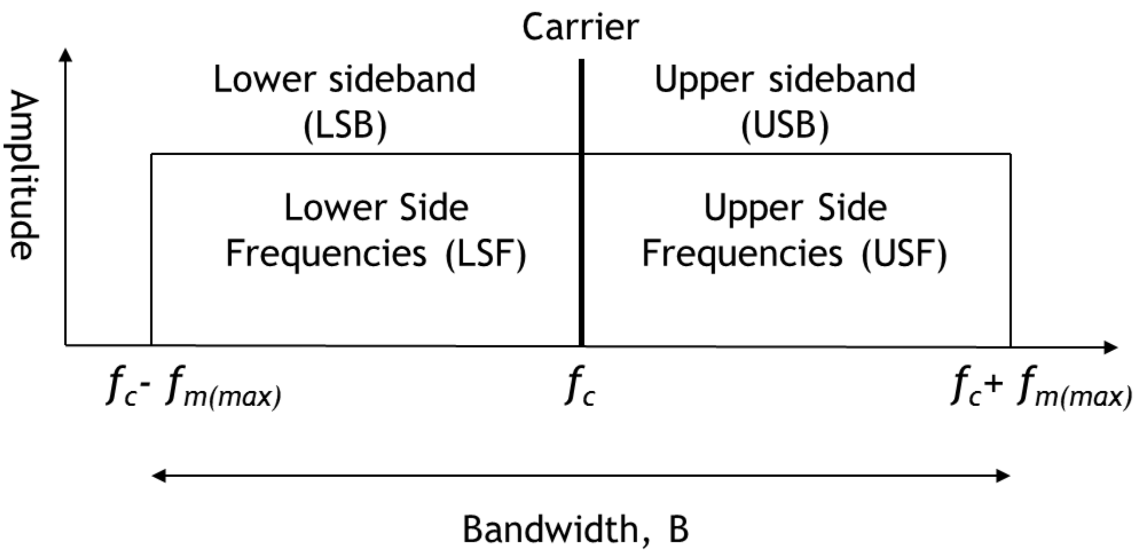
Then the band width of AM = 2W$_m$

<u>Case (2):</u> Information signal $V_m(t)$:-

$$\mathbf{V(t) = E_c\,[1 + (m)\,V_m(t)]\cos\omega_c t}$$

$$\mathbf{V(t) = E_c\cos\omega_c t + (m)\,E_c\,V_m(t)\cos\omega_c t}$$

Carrier USB+LSB



(4-2) Modulation Index and Modulation bepth :

(Modulation Index : The ratio between the amplitudes of the modulating signal and carrier, expressed by the equation.)

$$m = \frac{E_m}{E_c}$$

m = modulation coefficient (unit less)

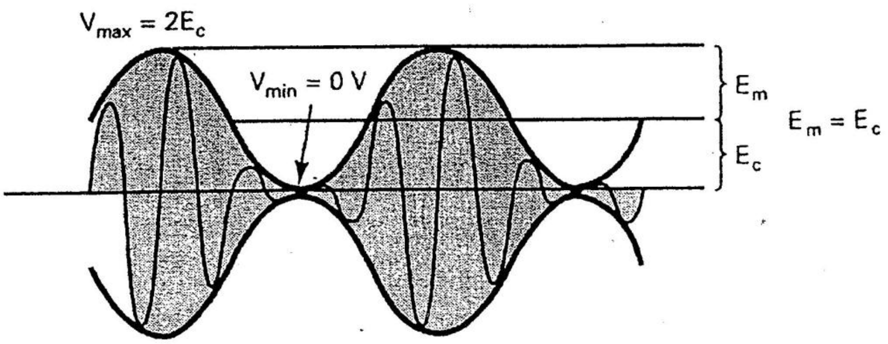
E_m = peak change in the amplitude of output waveform voltage (volts).

E_c = peak amplitude of the carrier voltage (volts).

Percent Modulation, M is m stated as a percentage i.e :-

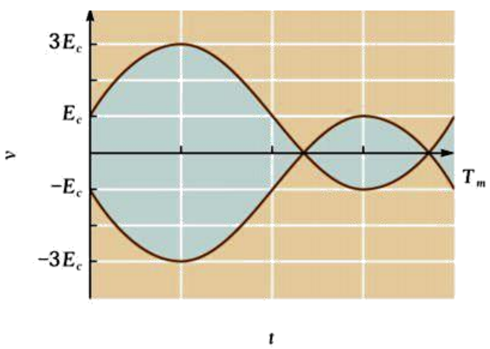
M = m X 100

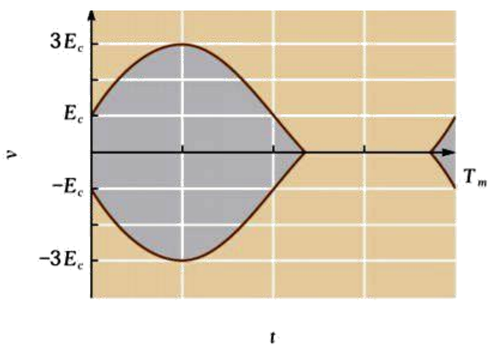
When E_m = Ec, i.e m = 1, there is no distortion at the output signal.



(m = 1.0) 100% modulated wave

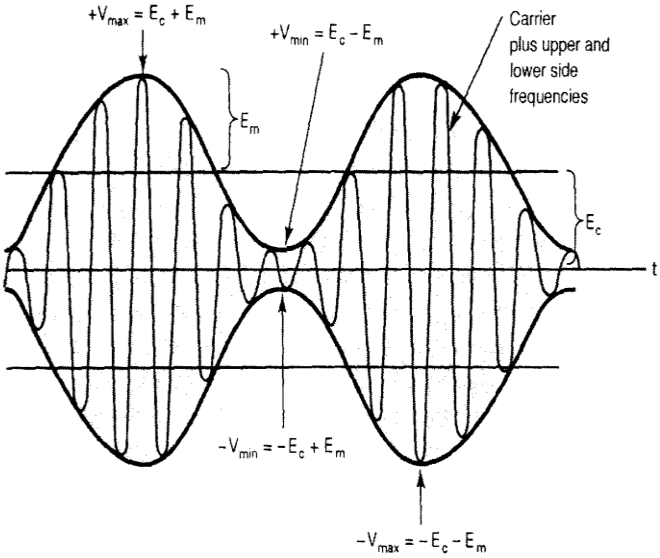
When m > 1, over modulation





Generally, amplitude of message signal should be less than amplitude of carrier signal to avoid over modulation.

$$\mathbf{E_m < E_c}$$



- Percentage of Modulation can be derived as follows:

$$E_m = \frac{1}{2}(V_{\max} - V_{\min}) \qquad E_c = \frac{1}{2}(V_{\max} + V_{\min})$$

then, $$m = \frac{E_m}{E_c} = \frac{\frac{1}{2}(V_{\max} - V_{\min})}{\frac{1}{2}(V_{\max} + V_{\min})} = \frac{(V_{\max} - V_{\min})}{(V_{\max} + V_{\min})}$$

and $$M = \frac{(V_{\max} - V_{\min})}{(V_{\max} + V_{\min})} \times 100$$ where $V_{max} = E_c + E_m$, $V_{min} = E_c - E_m$

Modulation Index for Multiple Modulating Frequencies

Two or more sine waves of different, uncorrelated frequencies modulating a single carrier is calculated by the equation

$$m = \sqrt{m_1^2 + m_2^2 + \bullet\bullet\bullet}$$

Example: If the modulated signal of AM:-

$V(t) = 20(4+4\sin 2\pi 10^4 t)\cos 2\pi 10^6 t$ determine E_c , m , f_c , f_m ?

Solution :

$V(t) = E_c\,[1+ (m)\, V_m(t)]\, \cos\omega_c t$ General equation of AM

$V(t) = 20(4+4\sin 2\pi 10^4 t)\cos 2\pi 10^6 t$

$V(t) = 80(1+\sin 2\pi 10^4 t)\cos 2\pi 10^6 t$

$E_c = 80$ v , m=1 , $f_c = 10^6$ H_Z , $f_m = 10^4$ H_Z

(4-3) Band width in Amplitude Modulation :

Bandwidth: is the difference between the upper and lower sideband frequencies.

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

- **Example:**

  A standard AM broadcast station is allowed to transmit modulating frequencies up to 5 kHz. If the AM station is transmitting on a frequency of 980 kHz, what are sideband frequencies and total bandwidth?

Solution:

$f_{USB} = 980 + 5 = 985$ kHz

$f_{LSB} = 980 - 5 = 975$ kHz

$BW = f_{USB} - f_{LSB} = 985 - 975 = 10$ kHz

$BW = 2\,(5\text{ kHz}) = 10$ kHz

$\therefore$ **$BW = 2f_m$**

(4-4) Power relation in Amplitude Modulation :

Power in a transmitter is important, but the most important power measurement is that of the portion that transmits the information

AM carriers remain unchanged with modulation and therefore are wasteful

$P = I \cdot V = V^2 / R = I^2 \cdot R$ DC power

$P = I_{rms} . V_{rms} \cos\theta$ AC power

$V_{rms} = V_m / \sqrt{2}$, $I_{rms} = I_m / \sqrt{2}$

$P = (I_{rms})^2 . R = (V_{rms})^2 / R$

$P_t = P_c + P_{LSB} + P_{USB}$, Pt = total transmitted power.

$$\mathbf{V(t) = E_c \cos\omega_c t + [(m E_c)/2] \cos(\omega_c + \omega_m)t + [(m E_c)/2] \cos(\omega_c - \omega_m)t}$$

Carrier upper side band upper side band

$P_c = [(V_{rms})^2 / R] = [(E_C / \sqrt{2})^2 / R] = \mathbf{[(E_C)^2 /2 R]}$

Pc = transmitted power in carrier

$P_{LSB} = P_{USB} = [(V_{rms})^2 / R] = \mathbf{[(m E_c)/2 /\sqrt{2})^2 / R] = [(m E_c)^2/8 / R]}$

$P_{LSB} = P_{USB} = \mathbf{[(m E_c)^2/8 R]}$

$P_t = \mathbf{[(E_C)^2 /2 R] + [(m E_c)^2/8 R] + [(m E_c)^2/8 R]}$

$P_t = \mathbf{[(E_C)^2 /2 R] + [(m E_c)^2/4 R] = [(E_C)^2 /2 R][1 + [(m)^2/2]}$

$\because \quad P_c = \mathbf{[(E_C)^2 /2 R]}$

$\therefore$

$$P_t = P_c\left(1 + \frac{m^2}{2}\right)$$

Note: The amplitude of the side band depend on the modulation index.

$\because \quad P_t = \mathbf{[(E_C)^2 /2 R][1 + [(m)^2/2] = [(E_C)^2 /2 R + ((E_C)^2 /2 R) .((m)^2/2)]}$

$\therefore \quad P_t = \mathbf{P_C + P_C[(m)^2/2] = P_C + P_{DSB}}$

$$P_{lsb} = P_{usb} = \frac{m^2 P_c}{4}$$

$\mathbf{P_{DSB} = P_C[(m)^2/2]}$

Example:

1) **The total power content of an AM wave is 1500W .For a 100 percent modulation ,determine : P_c , P_{USB} ,P_{LSB}**

Solution:

$$P_T = \left[1 + \frac{m^2}{2}\right] P_C$$

$$P_{Usf} = P_{Lsf} = \frac{1}{4} m^2 P_C$$

P_c = 1000w , P_{USB} =P_{LSB} = 250w

2) An AM transmitter has P_t = 24Kw for 100% modulation . find the power transmitted for m=0.6, and power of DSB?
Solution:-

$$P_t = P_c\left(1 + \frac{m^2}{2}\right)$$

24Kw = p_c [1 + (1/ 2)]= p_c (3/2)
p_c = (2/3) 24kw = 16kw
p_t = 16kw [1 + (m^2/ 2)] = 16kw [1 + (0.6^2/ 2)]=
p_t = 16kw [1 + (0.36/ 2)] = 16kw (2.36/ 2) = 18.88kw

3) An audio signal given by 15sin2π(2000t) amplitude modulation a sinusoidal carrier wave 60sin2π(100x10^3t) Determine :-

a-modulation index

b- percent modulation

c- frequencies of signal and carrier

d- frequency spectrum of the modulated wave

Ans: a- 0.25 , b- 25% , c- 2KHz … 100KHz , d- 100KHz ..102KHz..98KHz

Q4) If signal is $x(t) = 3\cos(2\pi\, 10^3 t)$ volt , and the carrier signal is $10\cos(2\pi\, 10^6 t)$ volt of the AM transmitter find :- M ,USB and LSB frequency ,USB and LSB amplitude ,percentage power in the DSB (transmission efficiency) and draw the frequency spectrum ?

Solution:

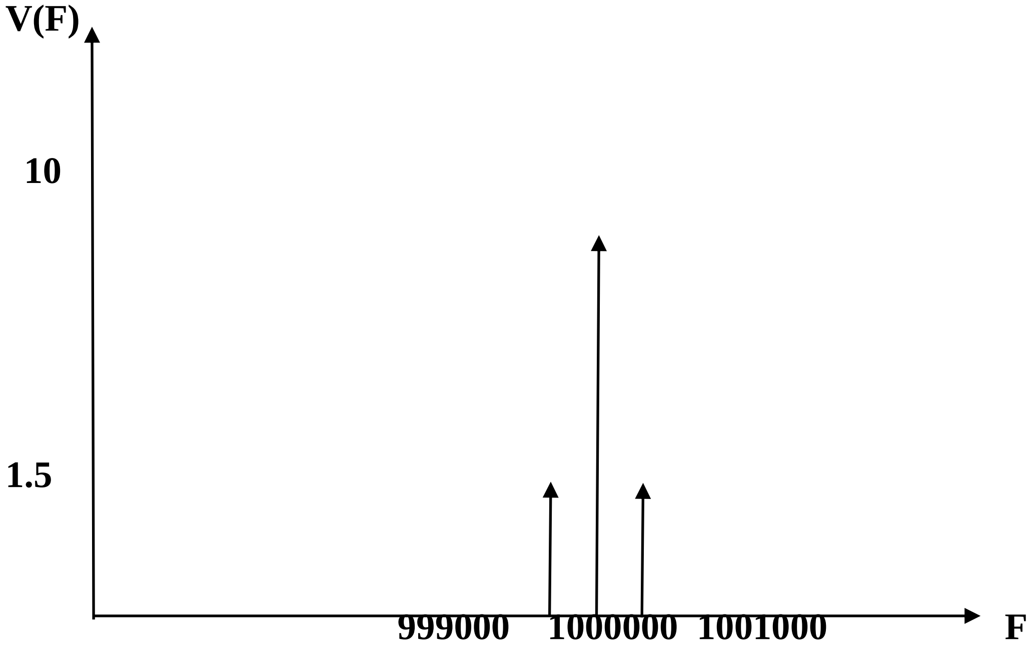
$M==(E_m/E_c) \times 100\% = (3 / 10)100\% = 30\%$

$f_{USB} = 10^6 + 10^3 = 1001000\ H_Z$

$f_{LSB} = 10^6 - 10^3 = 999000\ H_Z$

$V_{USB} = V_{LSB} = (mV_c/2) = (0.3(10)/2) = 1.5\ V$

$Efficiency(100\%) = (m^2/2+m^2) \times 100\% = (0.3^2/2+0.3^2) \times 100\% = 4.3\%$



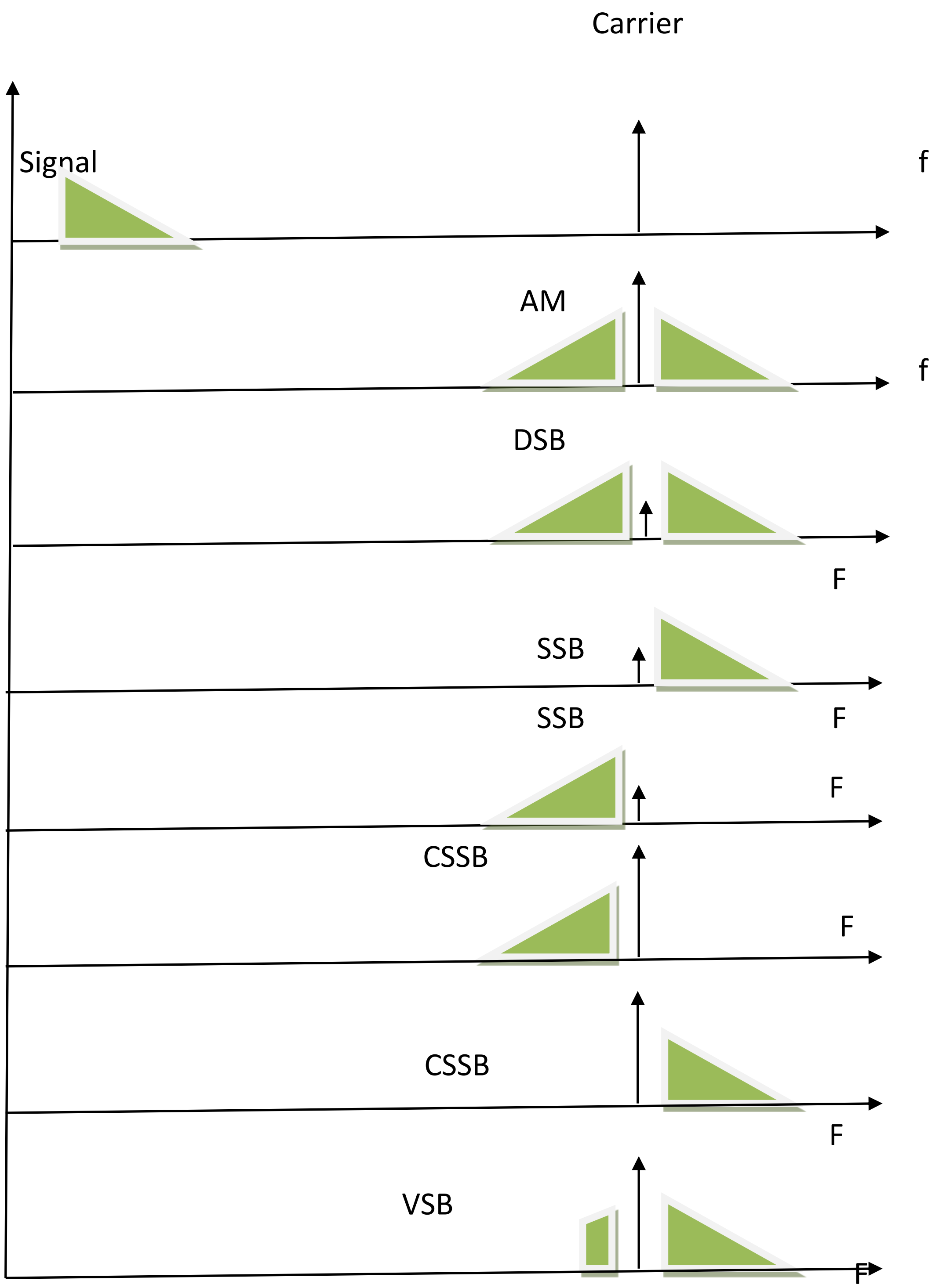
Home Work :

Q1) prove this equation $\frac{PDSB}{Pt} = \frac{m2}{2+m2}$

Q2) **If the Modulated signal is:-**
$V(t) = 10(2 + 2\cos 2000\pi t)\cos 2\pi 10^6 t$, Determine :- Vc , m , W_c ,fs ,Vs , and draw the frequency spectrum of Modulated signal?

(4-5) type of Amplitude Modulation :

Form the frequency spectrum of AM signal it can observing the type of AM.



frequency spectrum of AM

<u>(4-5-1)Double Sideband with carrier (we will call it AM)</u>: This is the most widely used type of AM modulation. In fact, all radio channels in the AM band use this type of modulation.

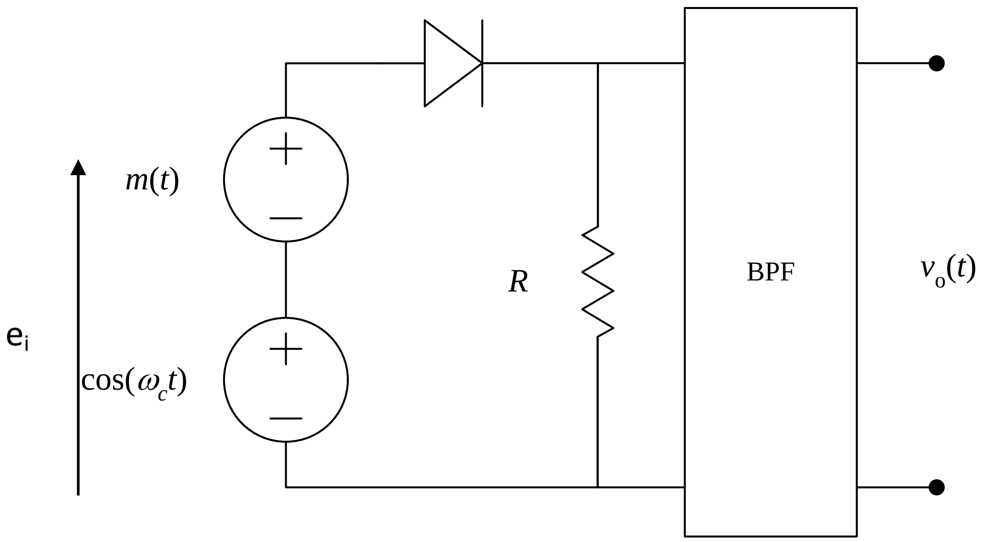
<u>Generation of AM :</u>

There are two type of AM modulation:-

1-Low level modulation:-

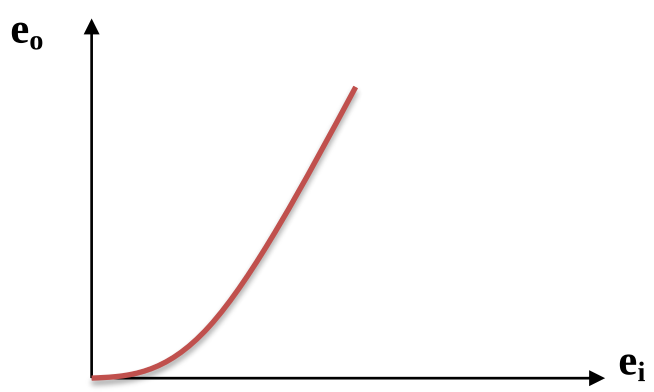
a- Square Low level modulation.

This type of modulation use the nonlinear characteristic of certain electronic device such as diode or transistor .



Block diagram of square low modulation

Non linear due to curvature characteristic **.**



The above curve can be represented by the following equation :-

$e_o = a_1e_i + a_2e_i^2 + a_3 e_i^3 + \ldots\ldots$

Where :-

e_i : input voltage

e_o : output voltage

a_1 , a_2 , a_3 …… are constant

$e_i=V_m(t) + E_c\cos w_ct$

$e_o = a_1(V_m(t) +E_c\cos w_ct) + a_2 (V_m(t) + E_c\cos w_ct)^2 + a_3(V_m(t) + E_c\cos w_ct)^3 +\ldots\ldots\ldots+\ldots\ldots$

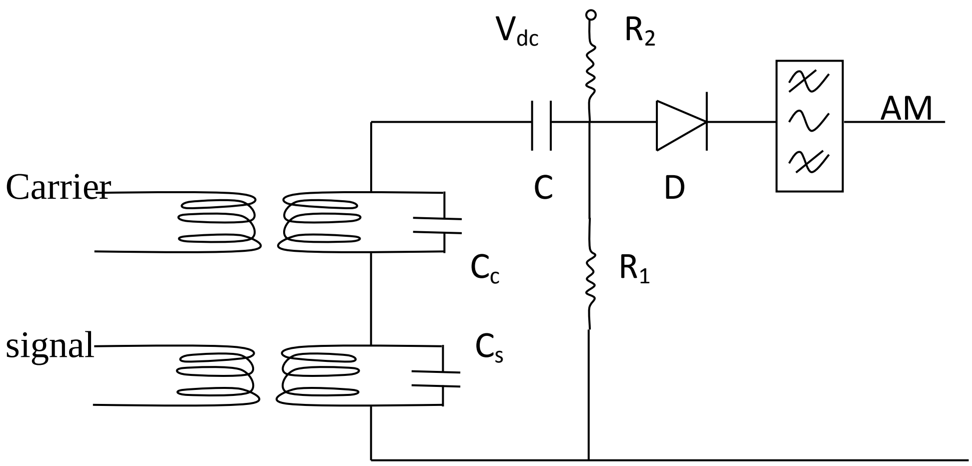
the result of equation……

$e_o = a_1V_m(t) + a_2 V^2_m (t) +(a_2E^2_c/ 2)+ (a_2E^2_c/ 2) \cos 2w_ct$

$+ a_1E_c\cos w_ct +2 a_2 V_m(t) E_c\cos w_ct+ \ldots\ldots\ldots +\ldots\ldots\ldots\ldots$

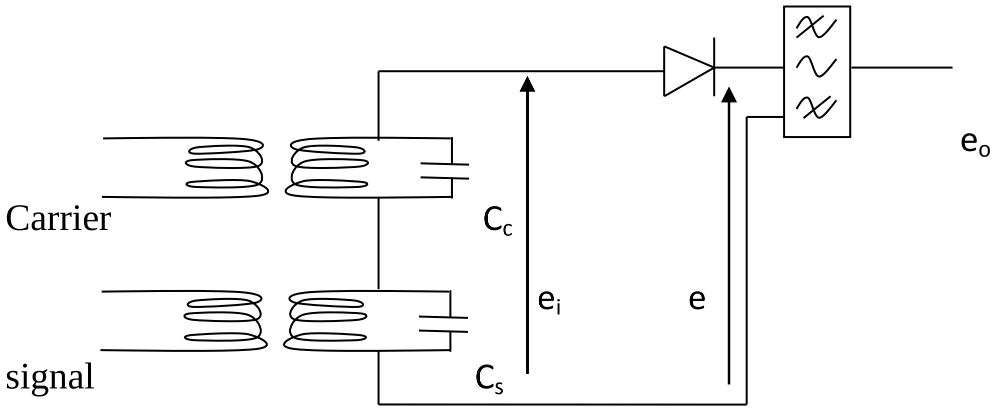
Wanted terms USB , LSB

The unwanted terms can be filters out by using BPF.



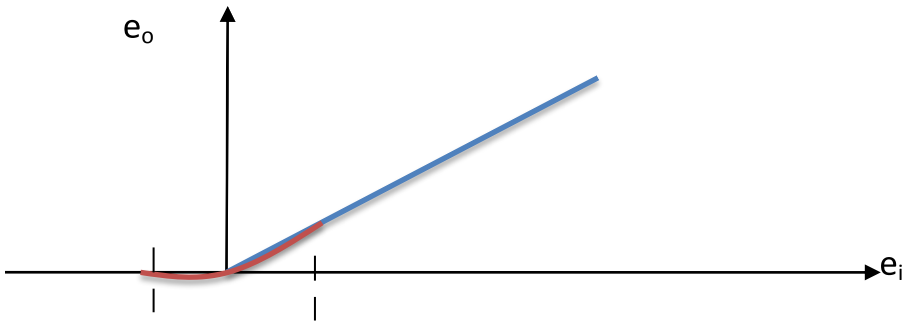
Circuit diagram of square law modulation

b-Piece wise linear modulation .



circuit diagram of Piece wise linear modulation

In this circuit $V_c(t)$ more larger than $V_m(t)$ to operate the diode from reveres bias condition to one forward condition . the over all characteristic is made up of two linear region as shown in fig.

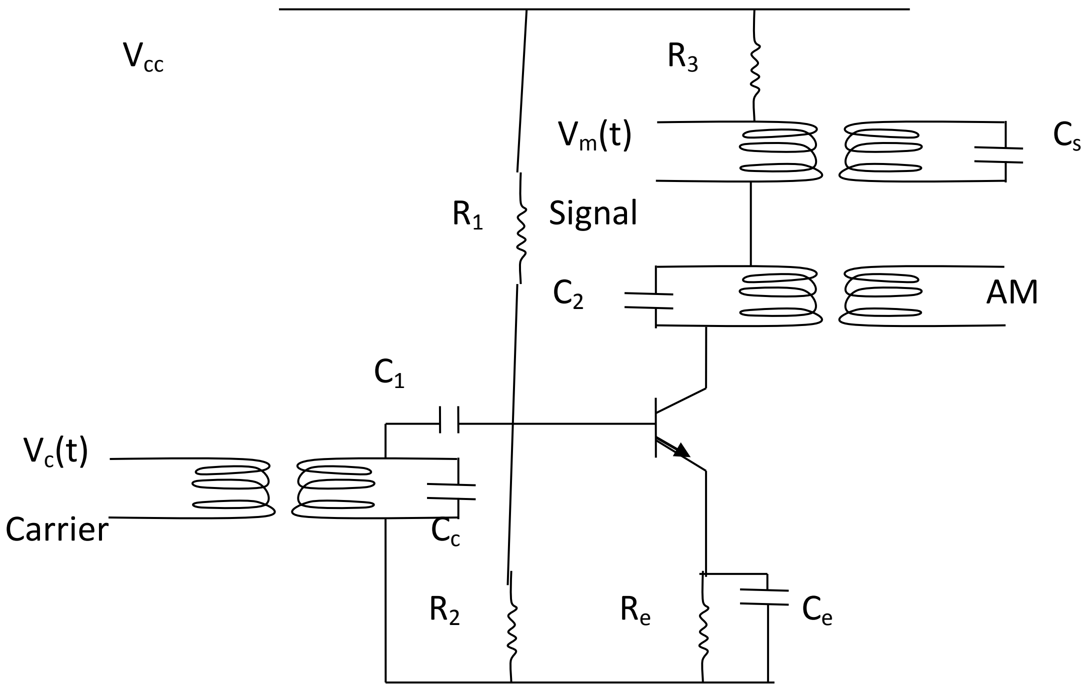


region of carrier

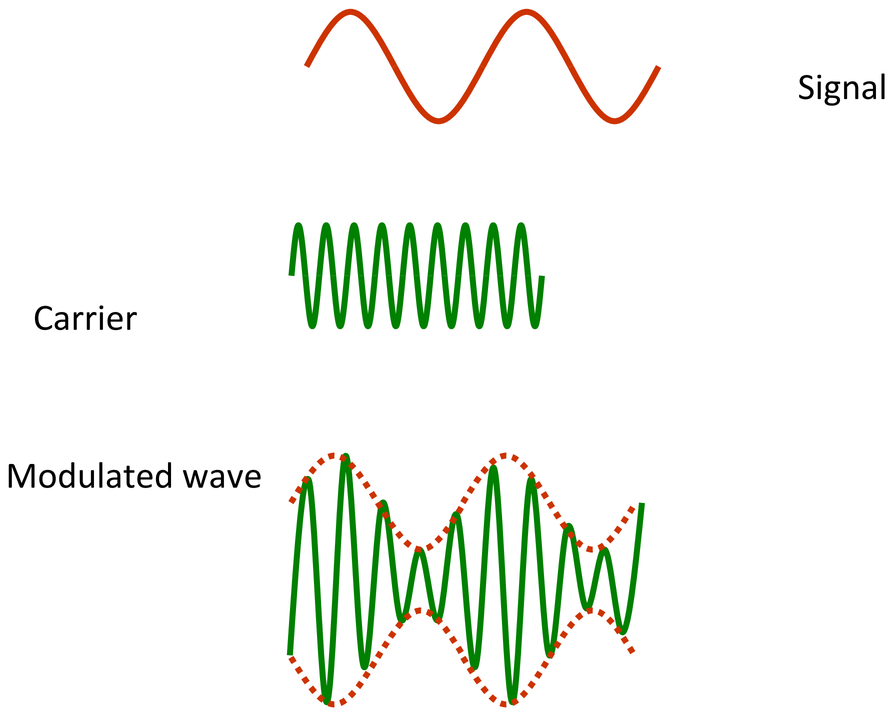
2-High level modulation

It can be generate AM signal by operating an amplifier in a non linear mode (class C amplifier) by using transistor .

The output stage of the transmitter is used as modulator . the carrier is applied to the input circuit of class C to switch the transistor on and off according to the cycle . The output of the modulator are tuned circuit to pass only the desired frequency band (carrier , USB , LSB) and reject all other unwanted frequencies



Circuit diagram of high level modulation



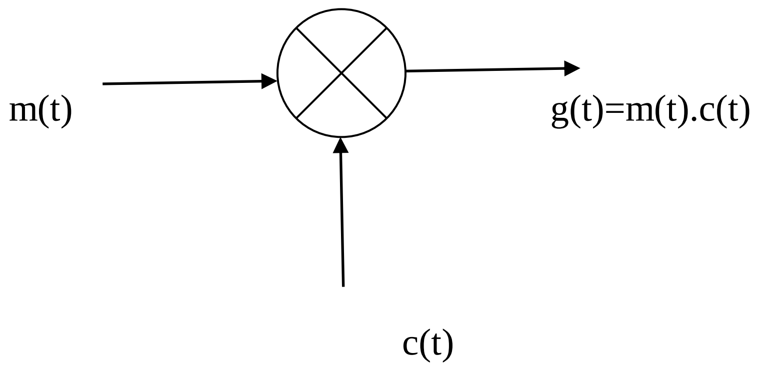
Wave form of AM

(4-5-2)Double Sideband Suppressed Carrier (DSBSC):

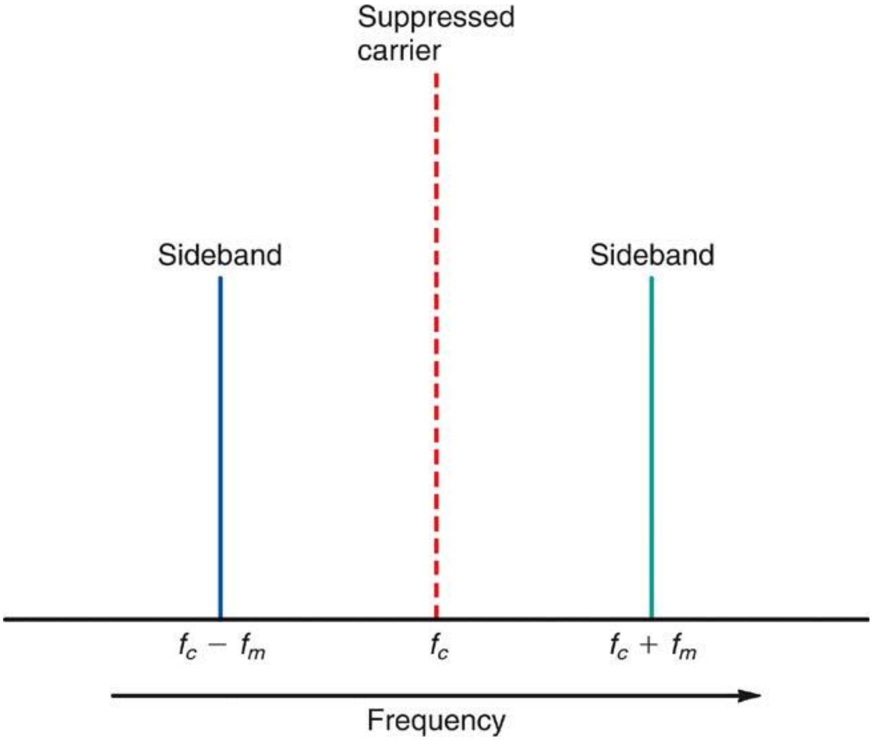
This is the same as the AM modulation above but without the carrier.

The small carrier signal is called (pilot carrier) the advantage of it to destination of detection .

DSB=USB ⊕LSB ⊕ pilot carrier



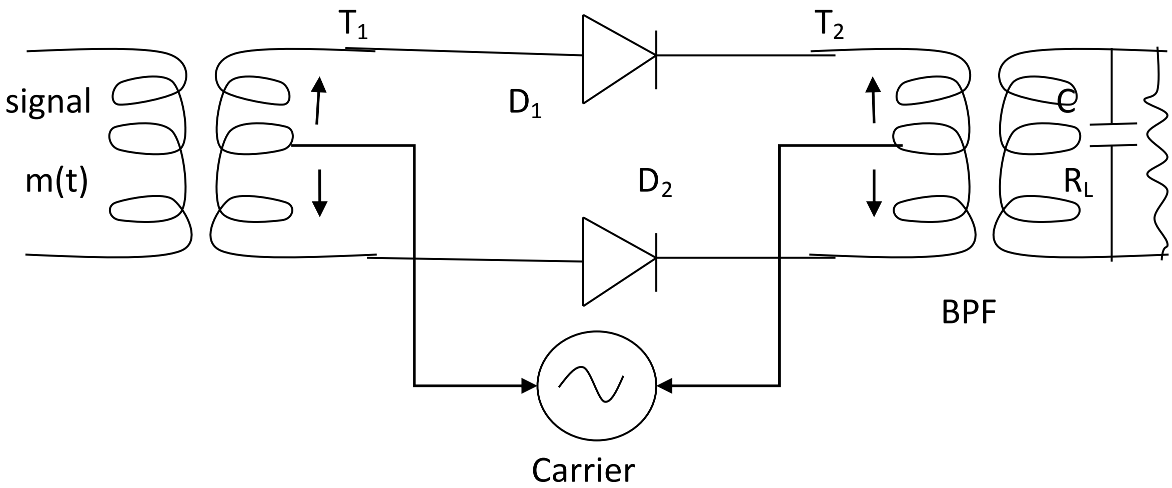
Block diagram of DSBsc



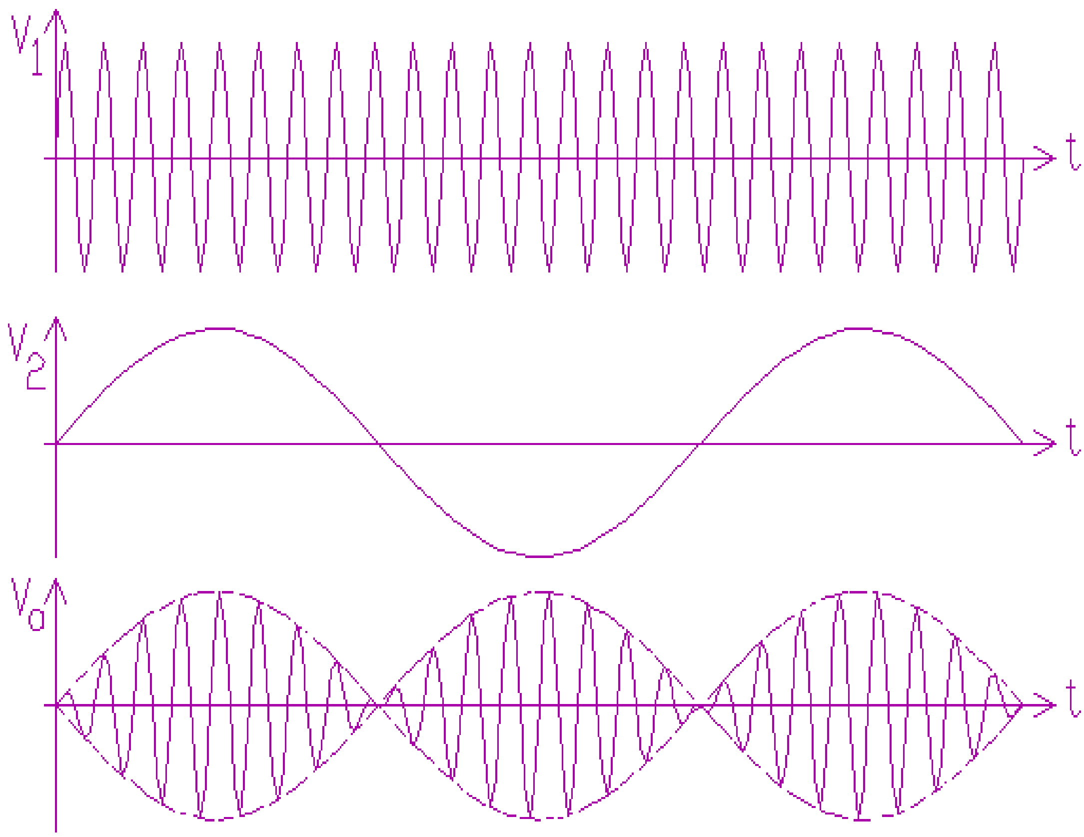
Frequency spectrum of DSB

Generation of Double side band (DSBSC) :

1)Balance modulation :

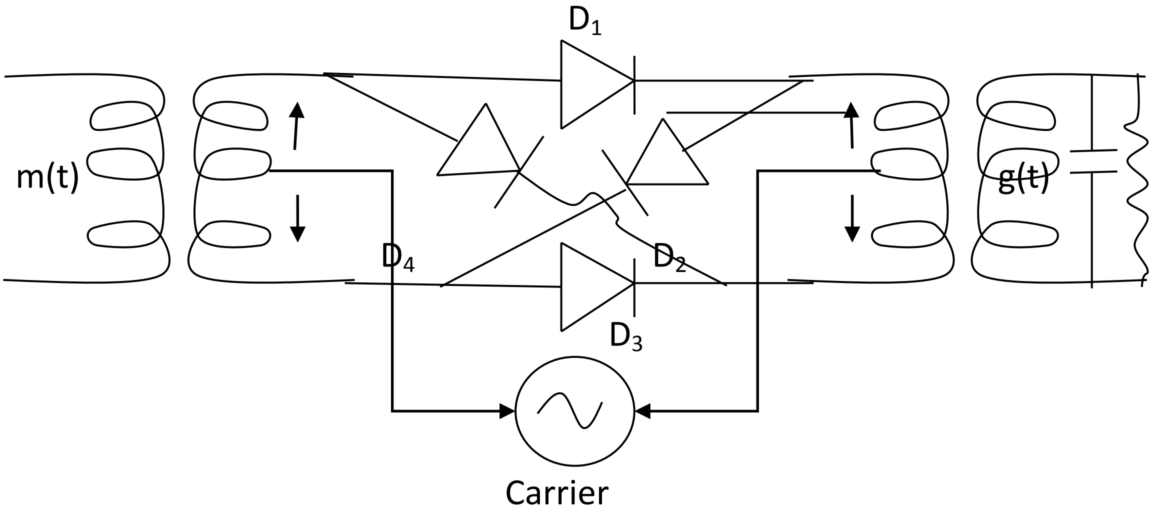


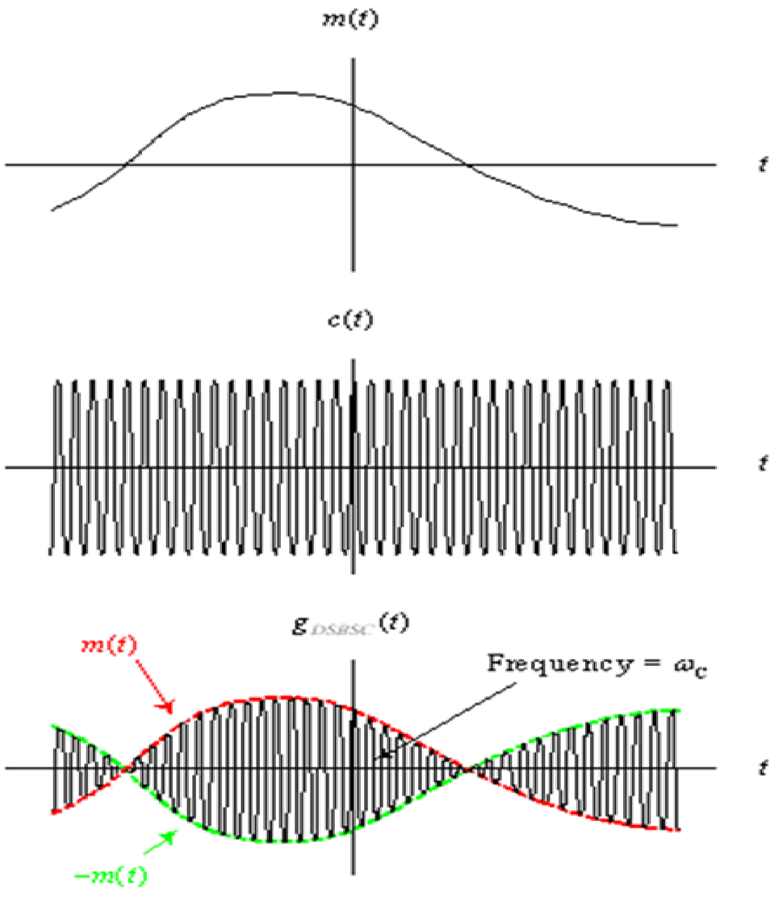
Circuit diagram of balance modulation



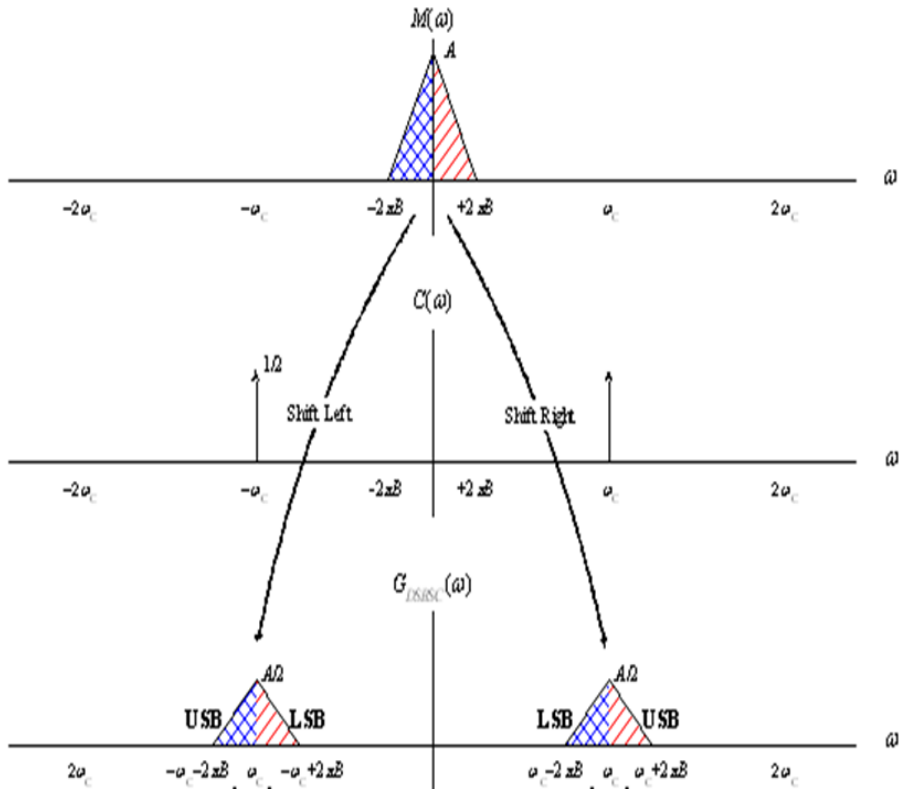
Wave form of balance modulation

2) <u>Double Balance modulation</u> :



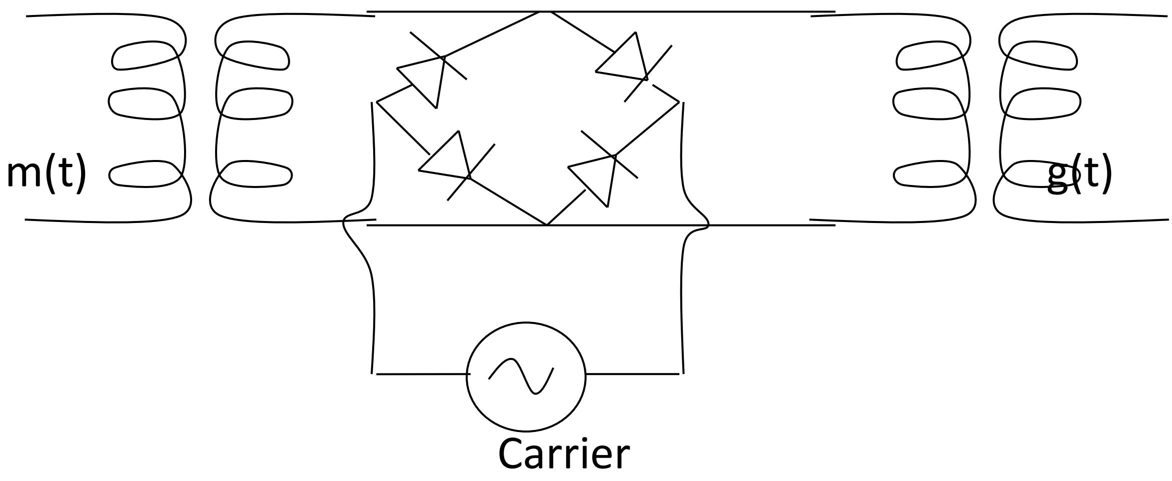


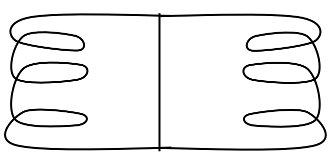
Time Representation of DSBSC Modulation

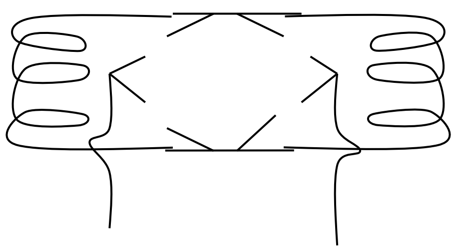


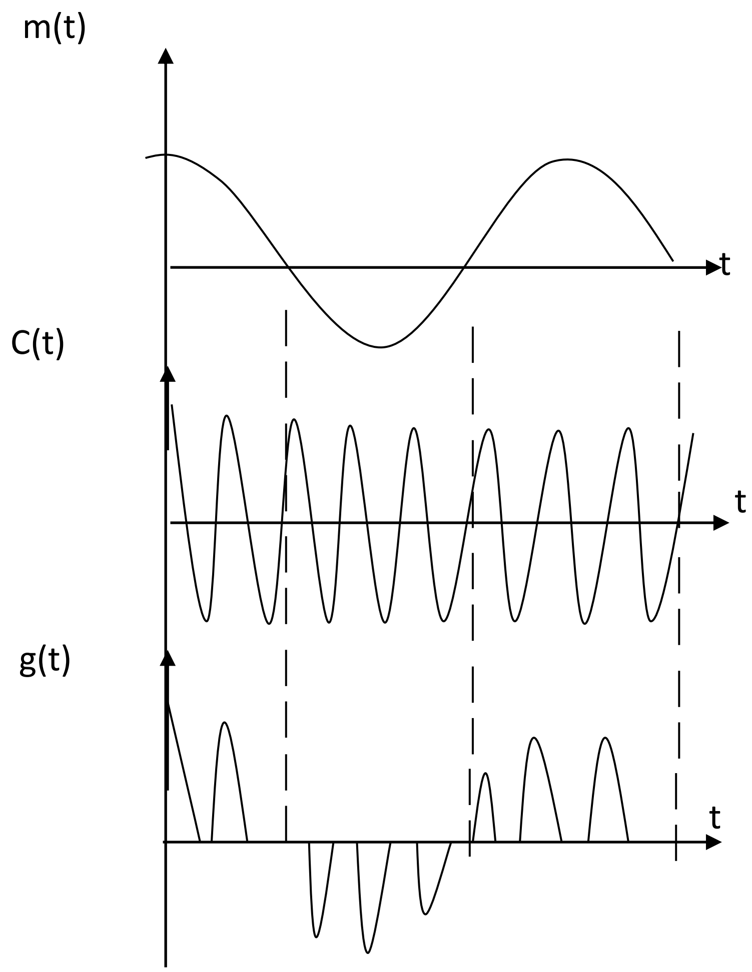
Frequency Representation of DSBSC Modulation

3)<u>Diode Bridge Modulation(Ring)</u> :









(4-5-3)Single Sideband (SSB):

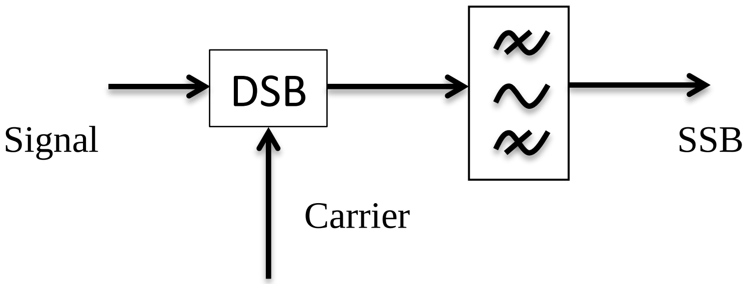
In this modulation, only half of the signal of the DSBSC is used.

Generation of single side band (SSBSC) :

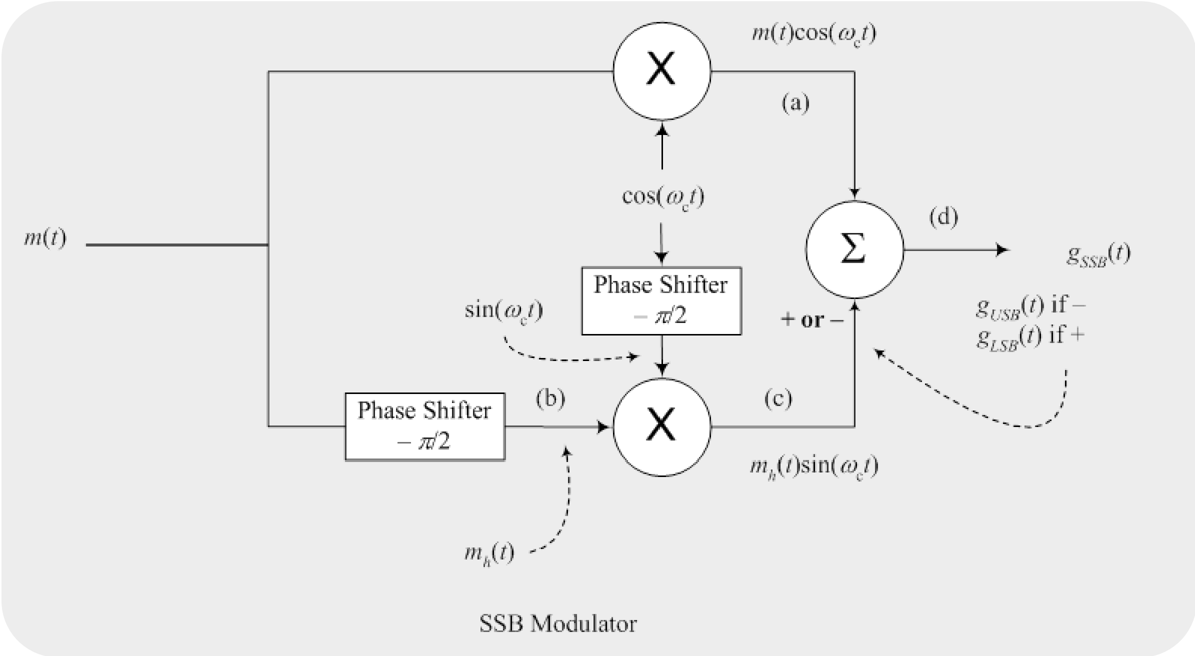
SSB = LSB ⊕ pilot carrier

SSB =USB ⊕ pilot carrier

1-Direct method :(Filter Method)



2- InDirect method : (Phasing method)

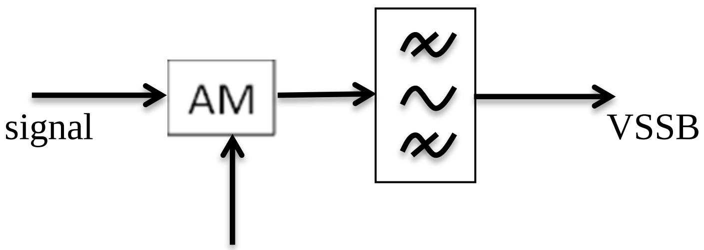


Block diagram of Single Sideband (SSB) Indirect method

(4-5-4)Vestigial Sideband (VSB):

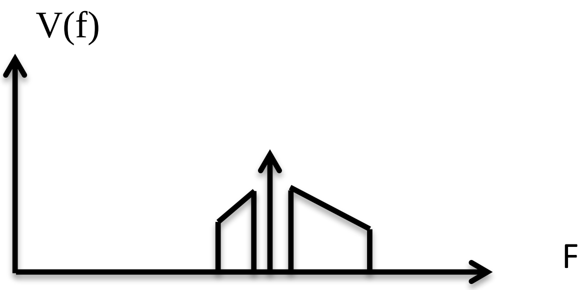
This is a modification(التعديل) of the SSB to ease the generation and reception of the signal.

Generation of Vestigial side band (VSSB) :



Carrier

Block diagram of Vestigial Sideband (VSB)



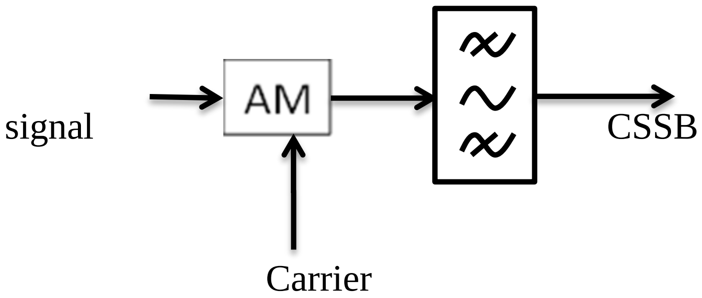
(4-5-5)compatible single side band :

In this modulation Only half of the signal with large carrier

Generation of Compatible single side band (CSSB) :

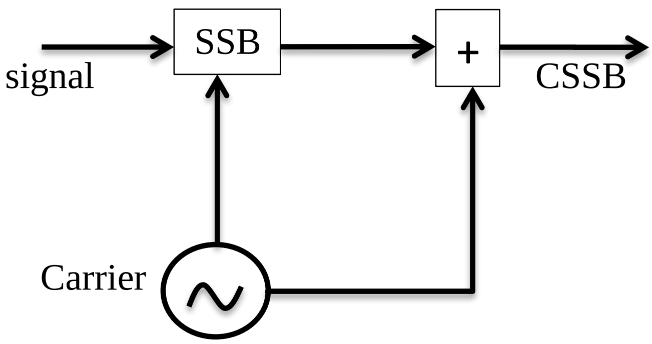
To generate CSSB by to method :-

a)



Block diagram of CSSB from AM

b)



Block diagram of CSSB from SSB

(4-6)Advantages of SSB

Superior detected signal-to-noise ratio compared to that of AM
SSB has one-half the bandwidth of AM or DSB-SC signals

Disadvantages of DSB and SSB

Single and double-sideband are not widely used because the signals are .difficult to recover (i.e. demodulate) at the receiver

A low power, pilot carrier is sometimes transmitted along with sidebands in order to more easily recover the signal at the receiver.

Applications of (VSB)

A vestigial sideband signal (VSB) is produced by partially suppressing the lower sideband. This kind of signal is used in TV transmission

(4-7)Advantages of AM :-

1- AM is an easier method of transmitting and receiving speech signals.
2- It requires simple and inexpensive receivers.

3- It is a fairly efficient system of modulation.

(4-8)Disadvantages of AM :

1. AM is more likely to suffer from noise.
2. Appreciable energy is contained by three components of AM wave. Sufficient energy can be saved by suppressing carrier wave and one of the side bands. This process makes the equipment complex.

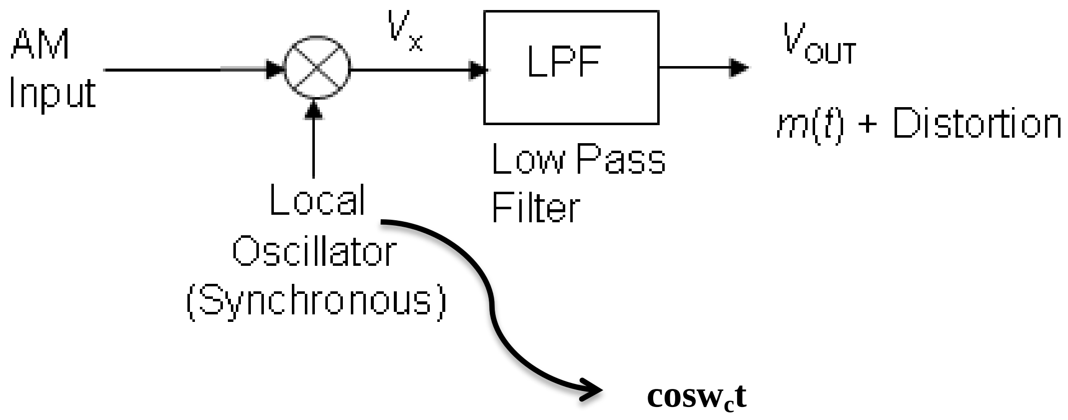
(4-9)Demodulation (Detection)of AM :

Demodulation is the invers of modulation, in this process we get the information signal from the modulated signal .there are two methods to detection AM .

1- Coherent (synchronous) detector:-

This is relatively more complex and more expensive. The Local Oscillator (LO) must be synchronized or coherent, i.e. at the same frequency and in phase with the carrier in the AM input signal

.g(t)



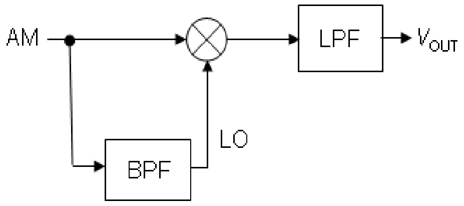
$$g(t)=E_c\,[\,1+mV_m(t)]\cos w_c t$$
$$V_X(t)= g(t)\,.\,\cos w_c t$$

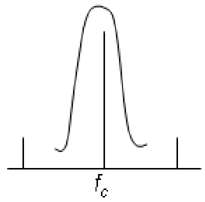
$$V_X(t)=(\,E_c\,[\,1+mV_m(t)]\cos w_c t\,)\,.\,\cos w_c t$$

$$V_X(t)=(E_c/2)+(mE_c/2)V_m(t)+(E_c/2)\cos 2w_c t+(mE_c/2)V_m(t)\cos 2w_c t$$

DC — signal — 2nd harmonic of the carrier — USB ,LSB around the 2nd harmonic

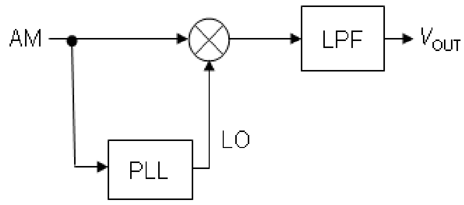
If the AM input contains carrier frequency, the LO or synchronous carrier may be derived from the AM input.





BPF – tuned to f_c

OR

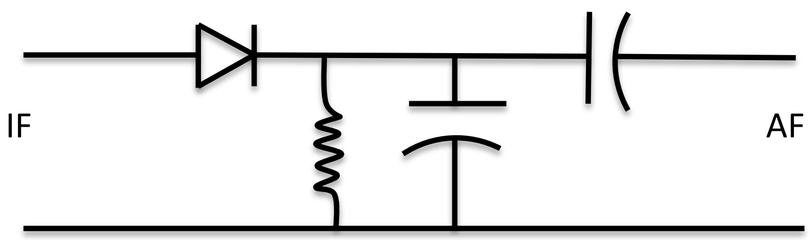


Phase Locked Loop locked at f_c – regenerating a LO

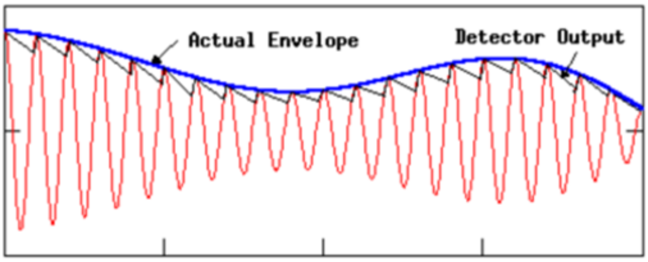
2-Non-coherent detector:-

a) Envelope detector.

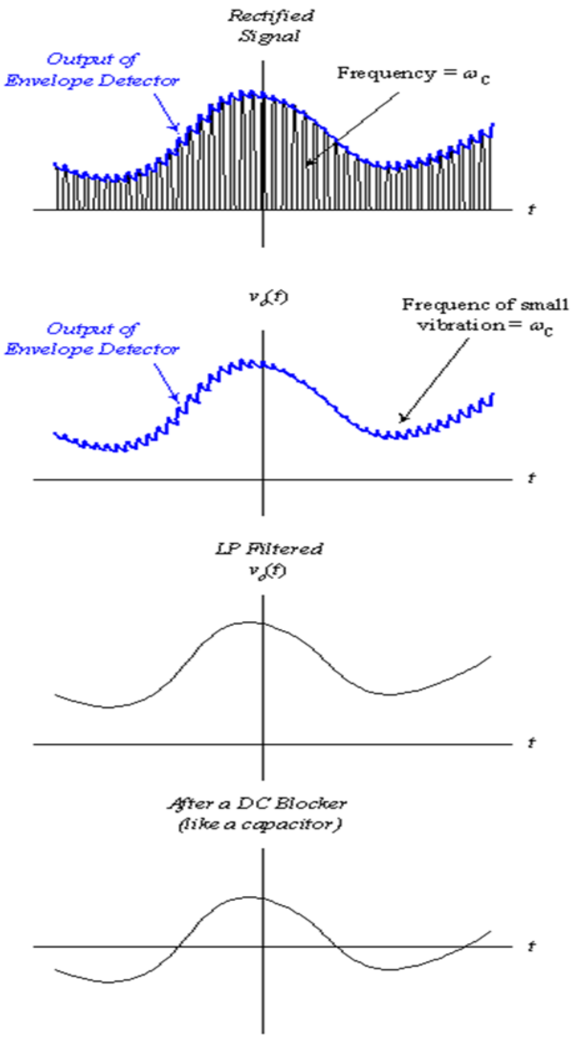
- The operations of the circuit requires careful selection of $\tau = RC$
- If *RC* is too large, discharging will be slow and the circuit cannot follow a decreasing envelope.
- When *RC* is too small the ripples will be high.
- $f_m < 1/(2\pi RC) < f_c$
- The ripples are finally removed by LPF.
- The DC value is blocked by a capacitor.



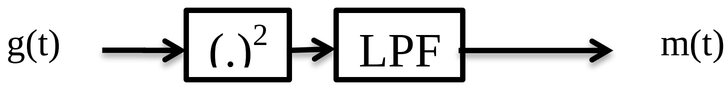
Circuit diagram of envelope detector



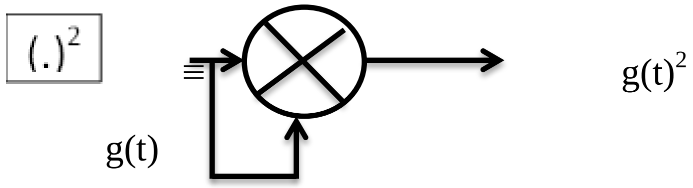
Where A is constant



b)Square circuit :-



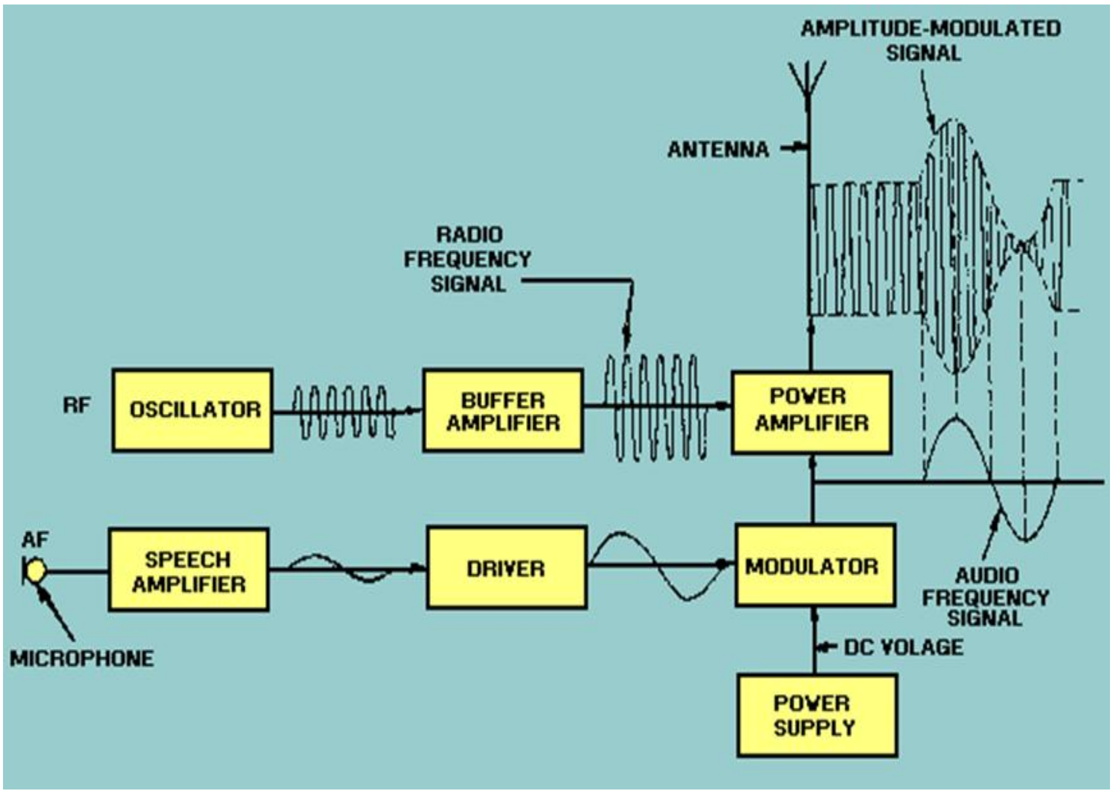
where :



The result of AM detection in this table

Type of detection	AM	DSB	SSB	CSSB	VSB
Coherent	✓	✓	✓	✓	✓
envelope	✓			✓	✓
Square circuit	✓				

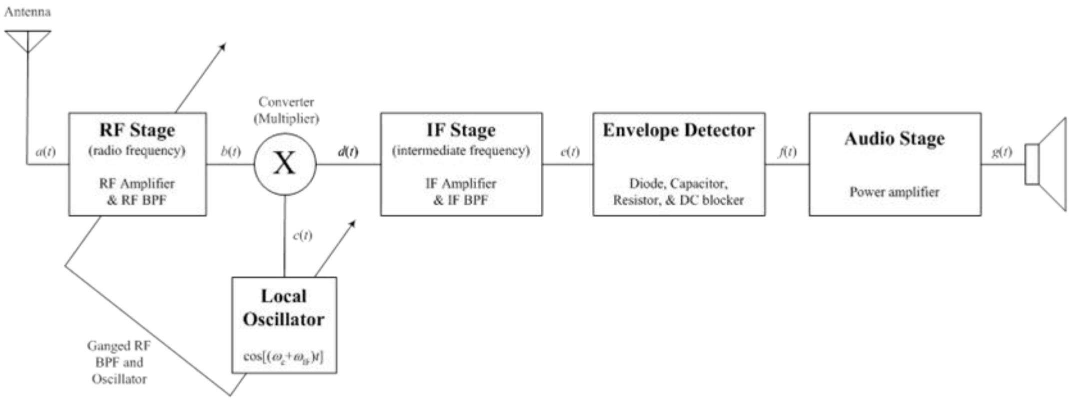
(4-10) AM Transmitter :



BLOCK DIAGRAM OF AM Transmitter

(4-11) AM Receiver(Super heterodyne Receiver):

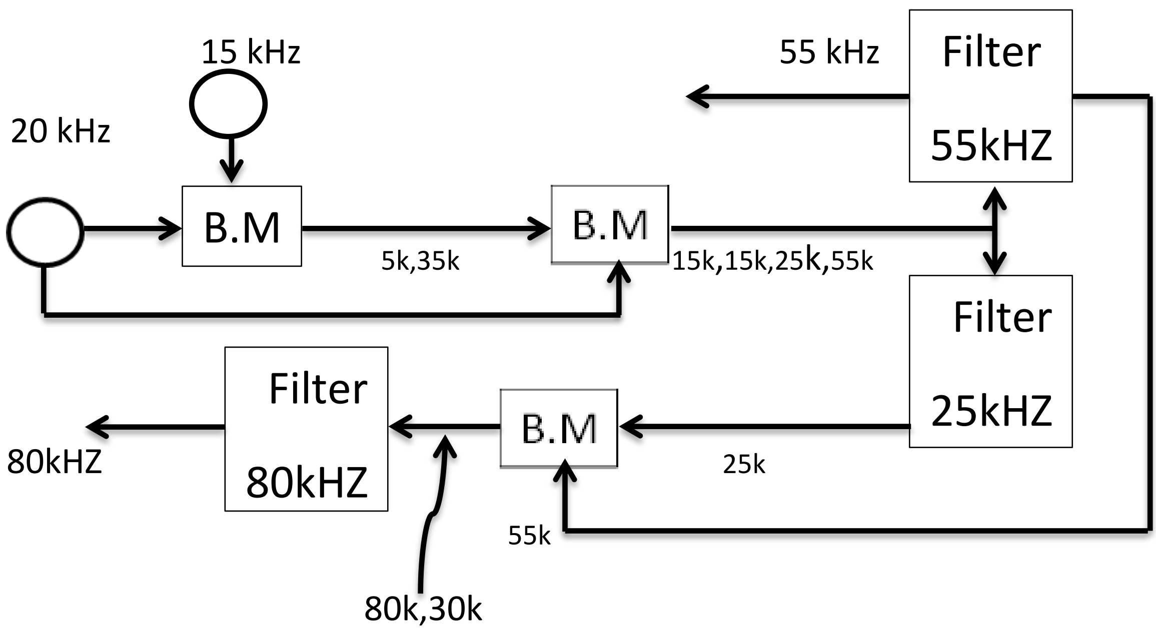
Heterodyne – to mix two frequencies together in a nonlinear device or to .transmit one frequency to another using nonlinear mixing



Block diagram of super heterodyne receiver

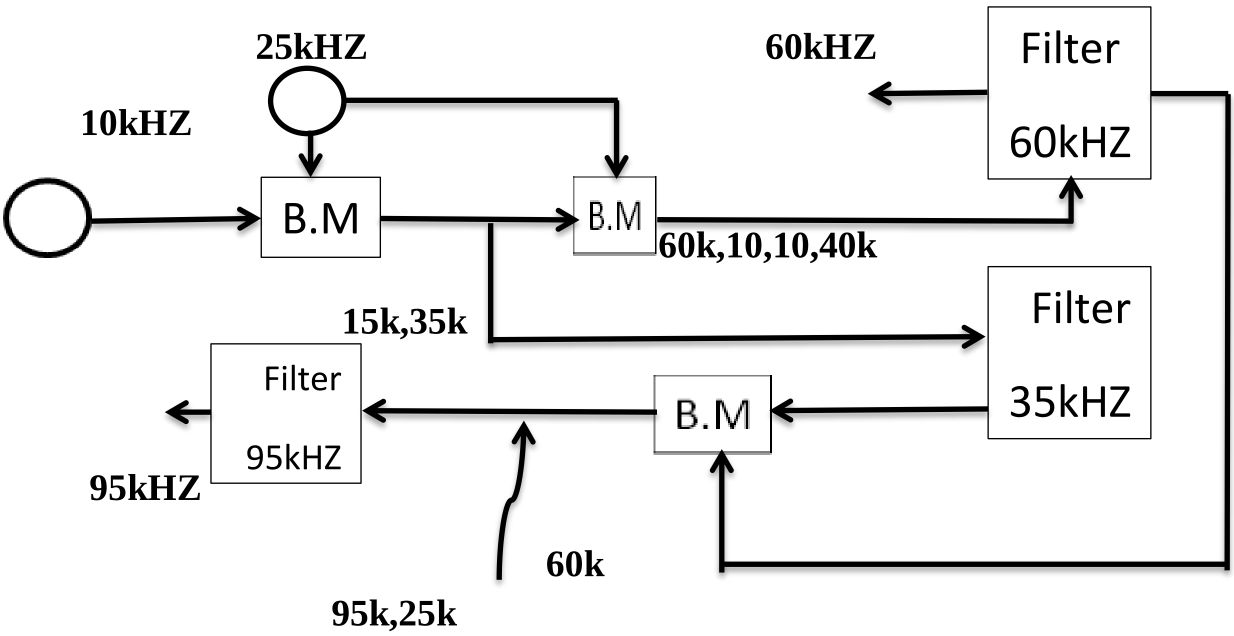
Example: Given two sinusoidal source of 15 kHz and 20 kHz frequencies, suggest a block diagram for obtaining 55 kHz and 80 kHz sinusoidal signal from the given sources by using not more than 3 balance modulation and four different filters. For each block on the diagram, specify the characteristics and input frequencies.

Solution:



Example :Given two sinusoidal source of 10kHZ and 25kHZ frequencies , suggest a block diagram for obtaining 60kHZ and 95kHZ sinusoidal signal from the given sources by using not more than 3 balance modulator and 3 different filters . for each block on the diagram , specify the characteristics and input frequencies ?

Solution:

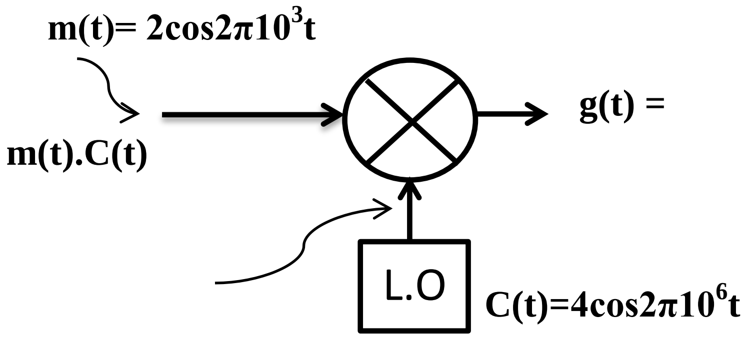


Q 1) An AM transmitter has P_t =80KW and m=0.6 Calculate:-

(1) Pc ,(2) Lower side band power, (3) Double side band power ?

Q 2)) If signal is $x(t) = 3\cos(2\pi\ 10^3 t)$ volt , and the carrier signal is $10\cos(2\pi\ 10^6 t)$ volt find :-M ,USB and LSB frequency ,USB and LSB amplitude ,percentage power in the DSB (transmission efficiency).

Q3)) From the figure Find g(t) , and draw the frequency spectrum of g(t)?

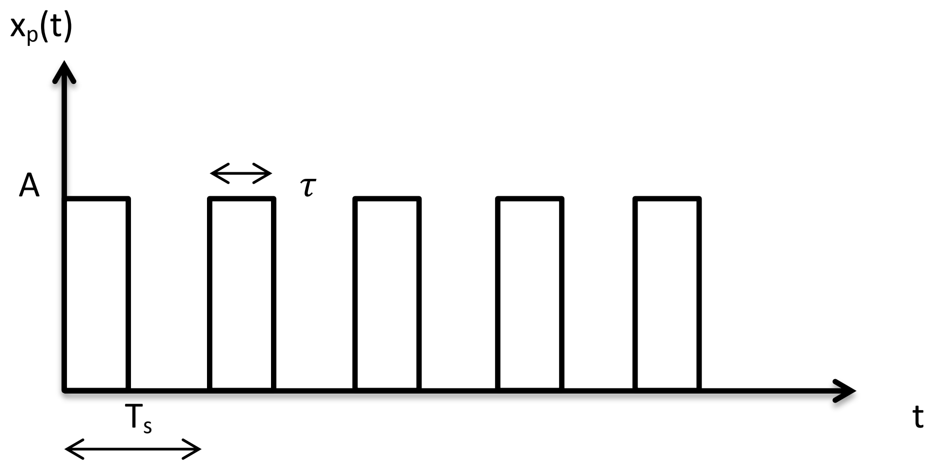


CH- 5 -

(5) Pulse Modulation

(5-1) Analoge Pulse Modulation

In this type of modulation the carrier wave is (pulse signal) the specification of pulse signal is :-



Where: -

τ : Pulse Duration (Width)

A : Pulse amplitude

T_s : Sampling period

(5-2) Sampling theorem

The sampling rate(sampling frequency) must be at least greater than or equal to two times of the highest frequency contained in the continous signal.

i-e $f_s \geq 2f_m$

where :-

f_s : sampling frequency

f_m : frequency of imformation signal

$f_s = 1/T_s$

(5-3) Type of Pulse Modulation

1- Pulse – Amplitude Modulation (PAM)

2- Pulse – Frequency Modulation (PFM)

3- Pulse – Time Modulation:-

a- Pulse – Width Modulation (Pulse – Duration Modulation)

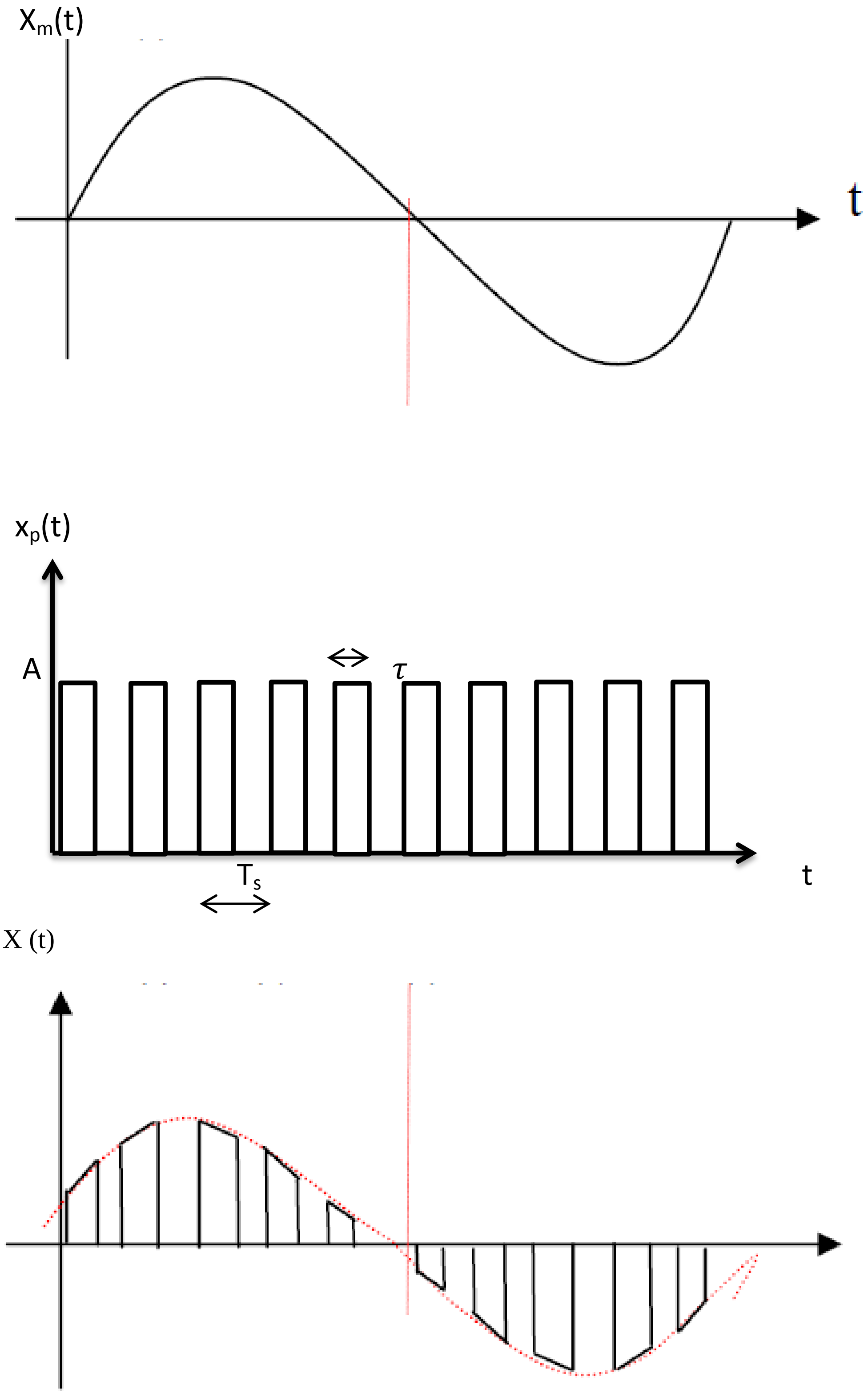
b- Pulse-Position Modulation (PPM)

(5-3-1) Pulse - Amplitude Modulation(PAM)

The pulse amplitude varies in direct proportion to the sample values of x(t).
The duration and the frequency of the pulse kept constant .

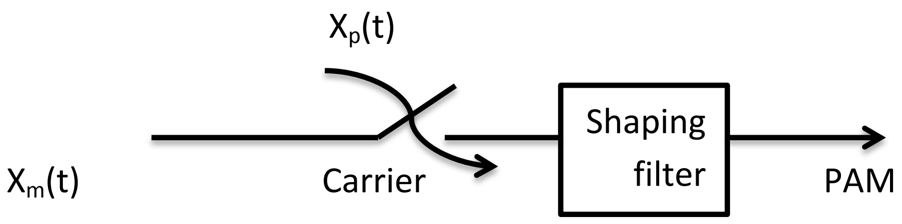
OR

- Modulation in which the amplitude of pulses is varied in accordance with the modulating signal.



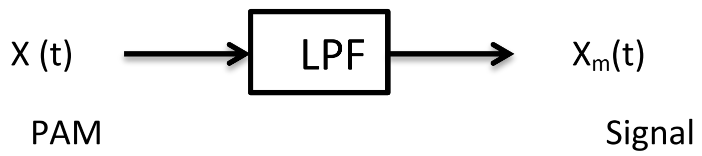
Wave form of Pulse – Amplitude Modulation(PAM)

(5-3-1-1) Generation of (PAM)

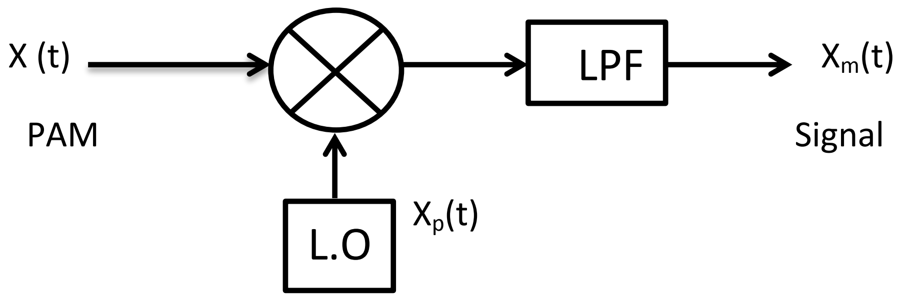


(5-3-1-2) Detection of (PAM)

(1)LPF



(2) Coherent detector



Note:

In PAM (Just in non ideal sampling e $f_s \geq 2f_m$) , we may notice some distortion in the spectrum of the resulting (detected) signal becuase of the non flatness resulting spectrum of PAM

(5-3-2) Pulse – Time Modulation

The sample values of a message can also modulate the time parameters of a pulse train, namely the pulse width or its position.

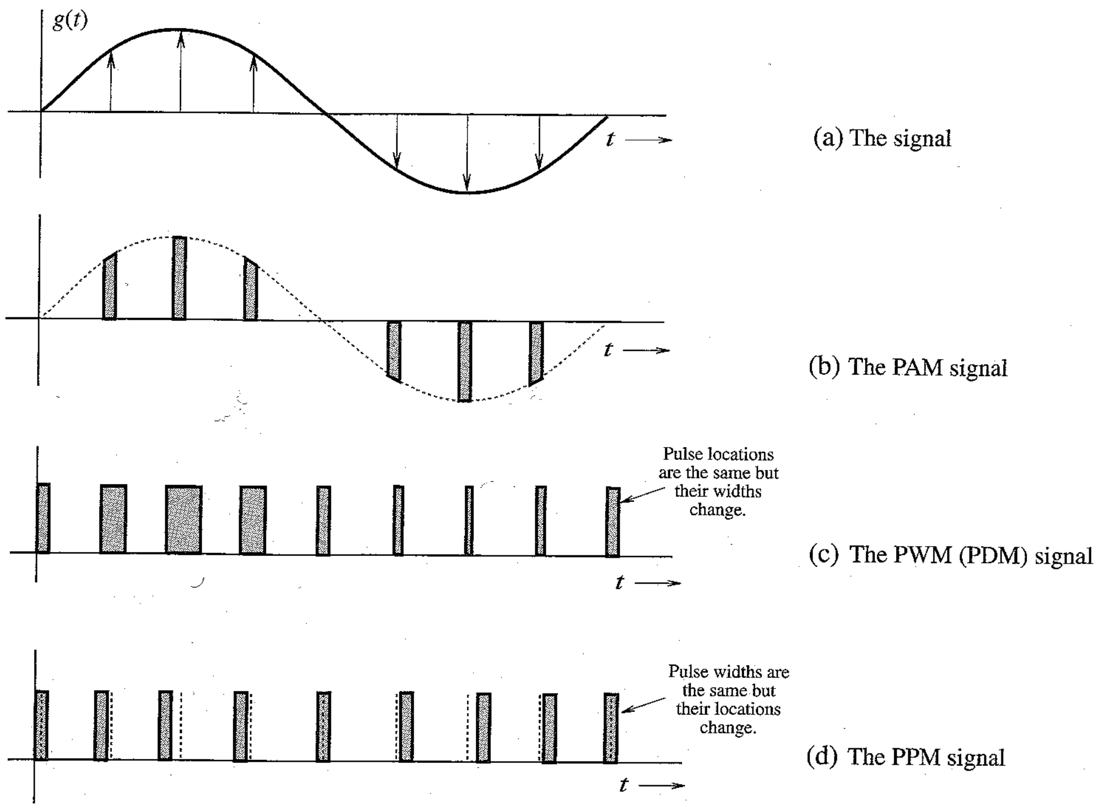
The corresponding processes are designated as **pulse-duration (PDM)** and **pulse-position modulation (PPM)** .
PDM is also called **pulse-width modulation** (PWM).

Note:

The pulse width or pulse position varies in direct proportion to the sample values of **x(t).**

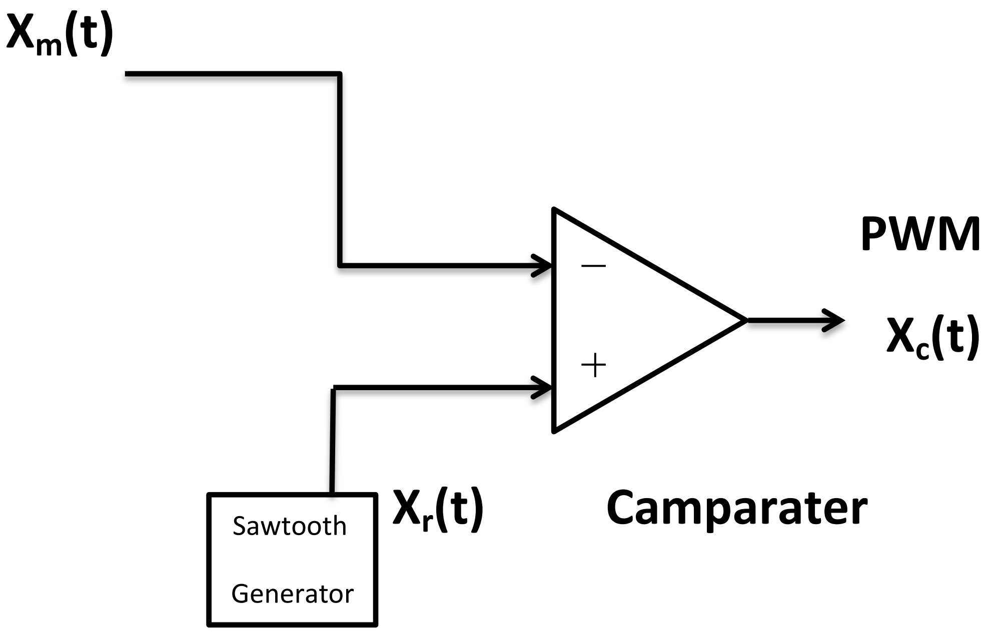
Note:

We lump PDM and PPM together under one heading for two reasons:-
First:- in both cases a *time* parameter of the pulse is being modulated, and the pulses have *constant* **amplitude.**
Second:- a close relationship exists between the modulation methods for PDM and PPM.

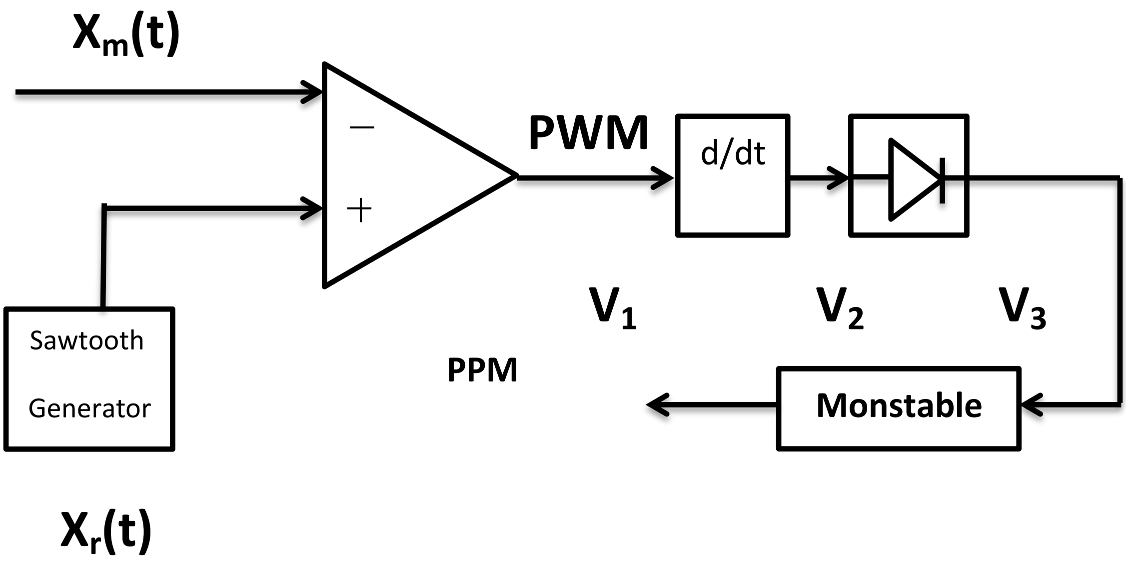


Wave form of Pulse – (PAM),(PWM),(PPM)

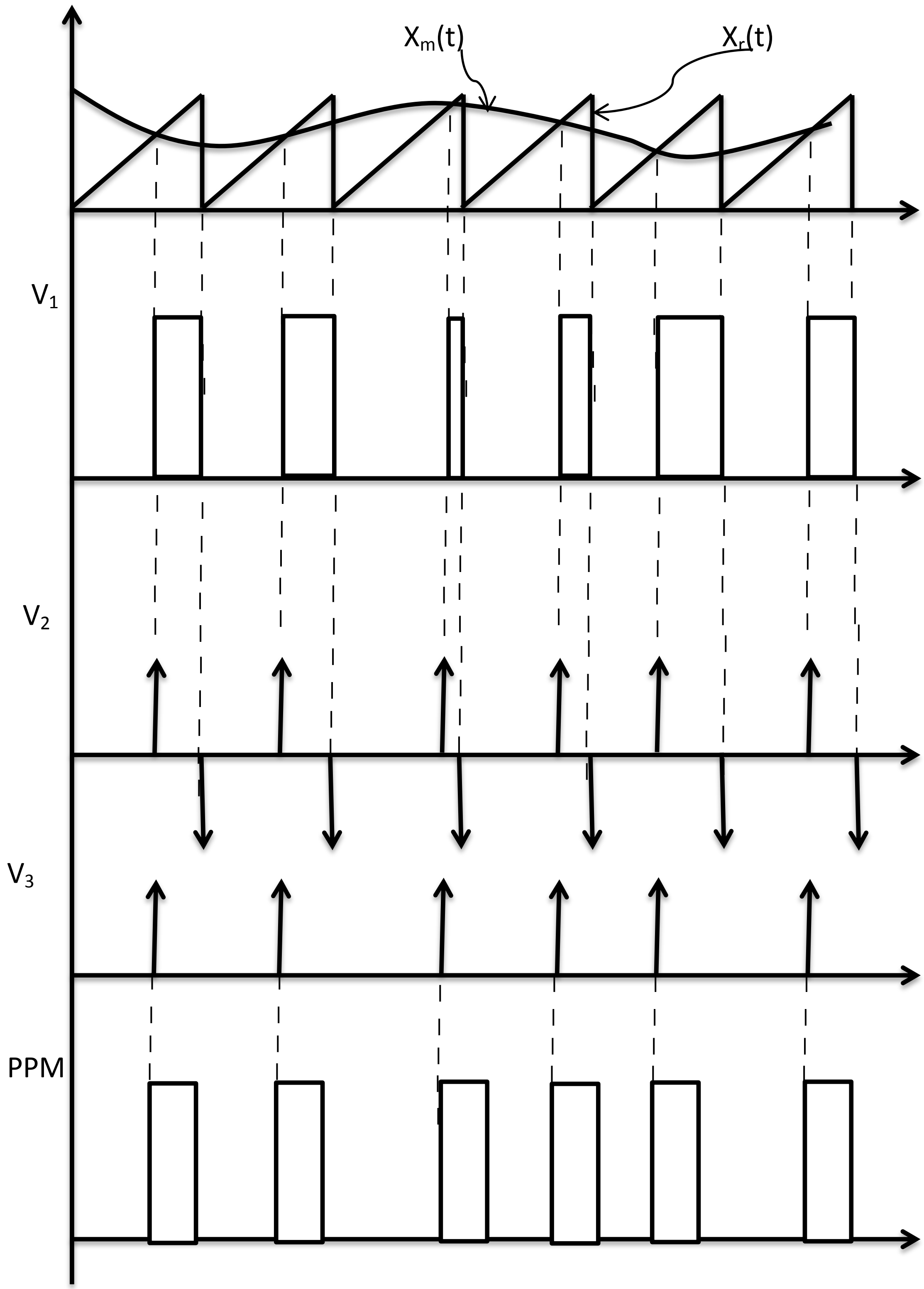
(5-3-2-1)Generation of (PWM and PPM)



(Generation of (PWM)

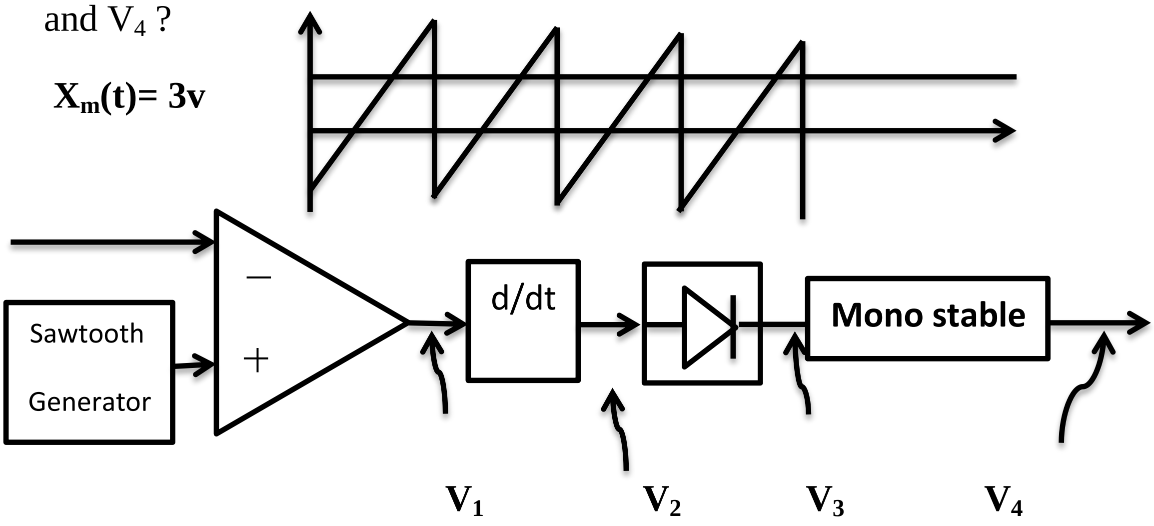


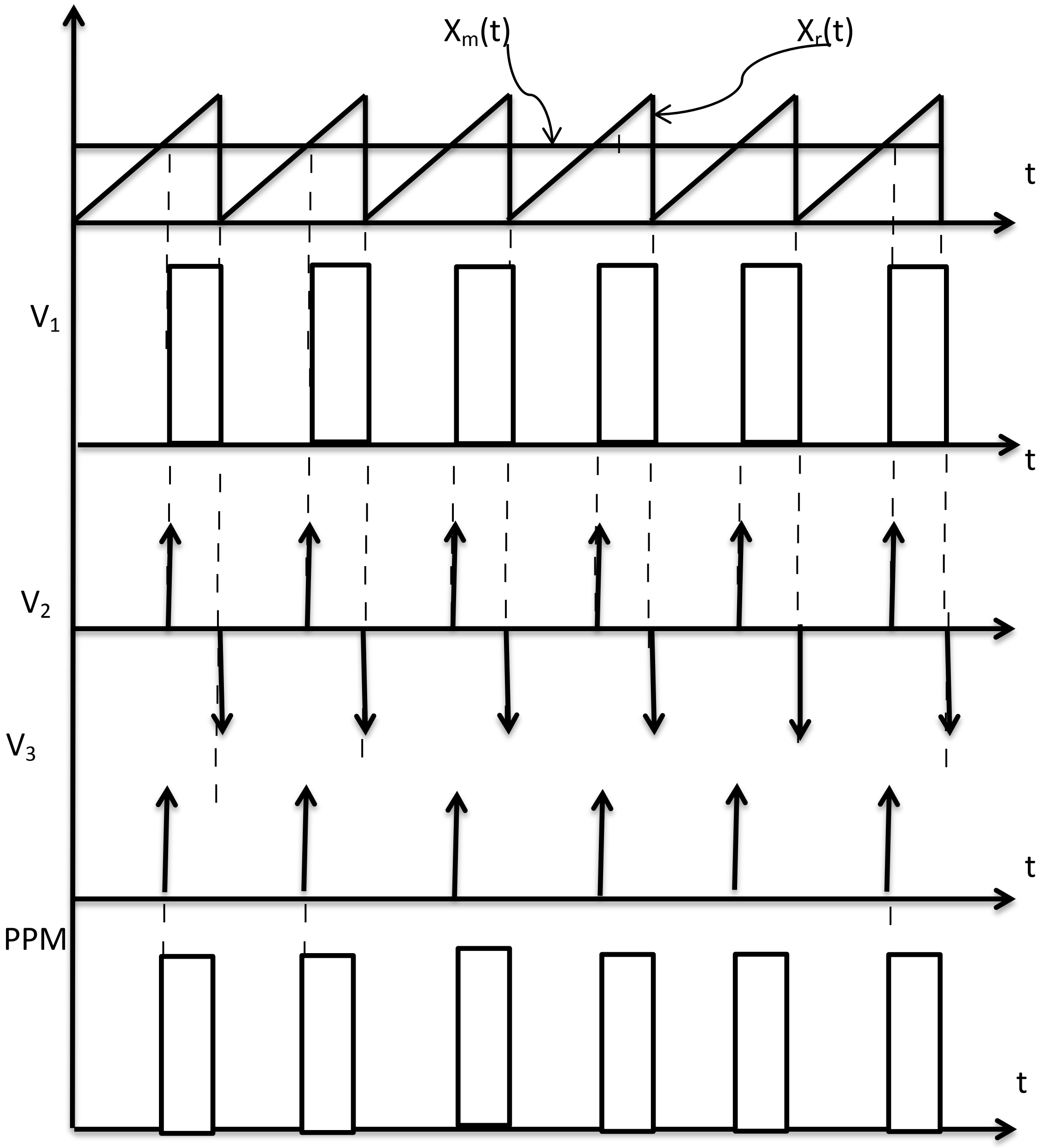
(Generation of (PPM)



Wave form of Pulse – (PWM),(PPM)

Q3)(**14/05/2014**) At the figure shown. Sketch the waveform at V_1, V_2, V_3, and V_4 ?

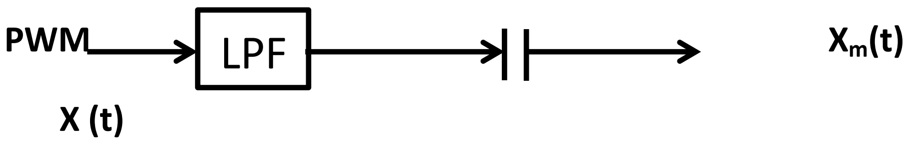




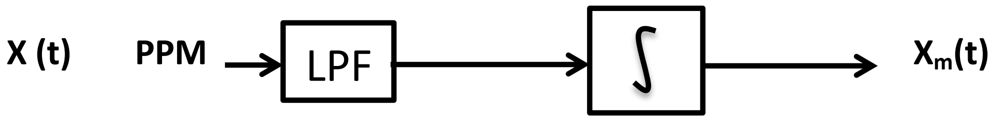
Note:

PPM signal has constant pulse width for all generated pulses this means much power can be transmitted for the same number of pulses compared to PWM .

<u>(6-3-2-2)Detection of Pulse – width Modulation</u>



<u>(6-3-2-3)Detection of Pulse–Position Modulation</u>



<u>Note:</u>

The pulse power of pulse-time modulation is "wasted" power, and it would be more efficient to suppress the pulses and just transmit the edges! Of course we cannot transmit edges without transmitting pulses to define them. But we can send very short pulses indicating the position of the edges, a process equivalent to PPM. The reduced power required for PPM is a fundamental advantage over PDM, an advantage that becomes more apparent when we examine the signal-to-noise ratios.

<u>Note:</u>

The PAM signal can be directly transmitted along a pair of wires. But it cannot be easily transmitted by electromagnetic wave in free space, because the spectrum is transmitted to higher frequencies by AM .

6-4) Properties and aplication of Analogue Pulse (Modulation

1- It is a simple system from the point of view of construction of transmitter and receiver.

2- It is used for transmission of information from near places (like a connection between the place of measurement and the control unit)

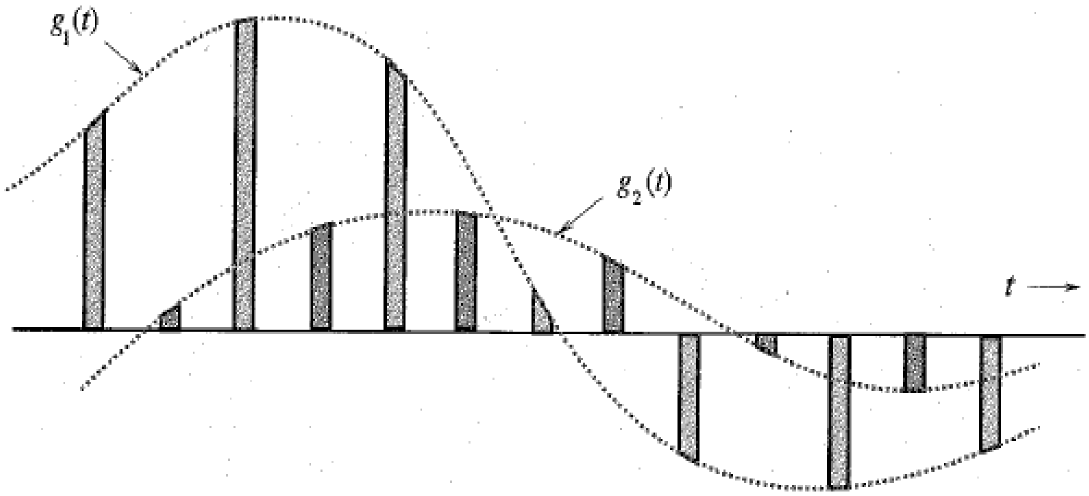
3- It is used in the transmission more than one channel (at the same time period on the same band) this is called **Time Division Multiplexing** (TDM).

(6-5) Time Division Multiplexing (TDM)

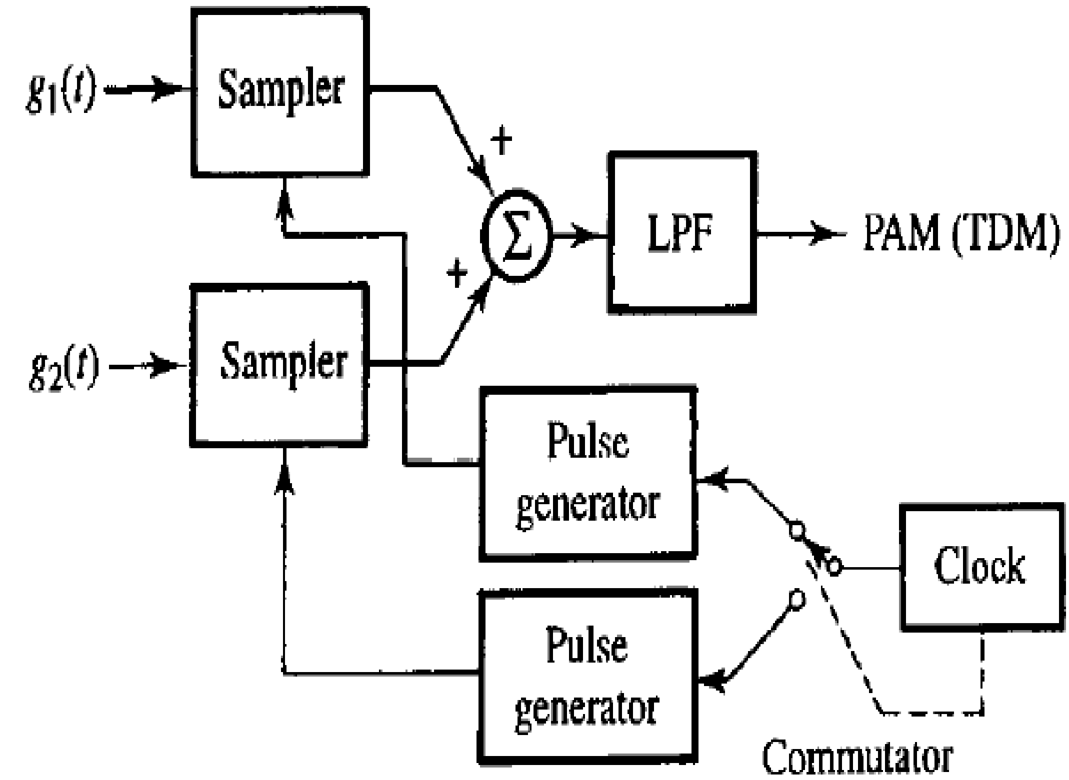
A sampled waveform is "off' most of the time, leaving the time between samples available for other purposes. In particular, sample values from several different signals can be interlaced into a single waveform. This is the principle of **time-division multiplexing** (TDM) .

(6-6) Type of Time Division Multiplexing (TDM)

1- TDM of the same sampling frequency .

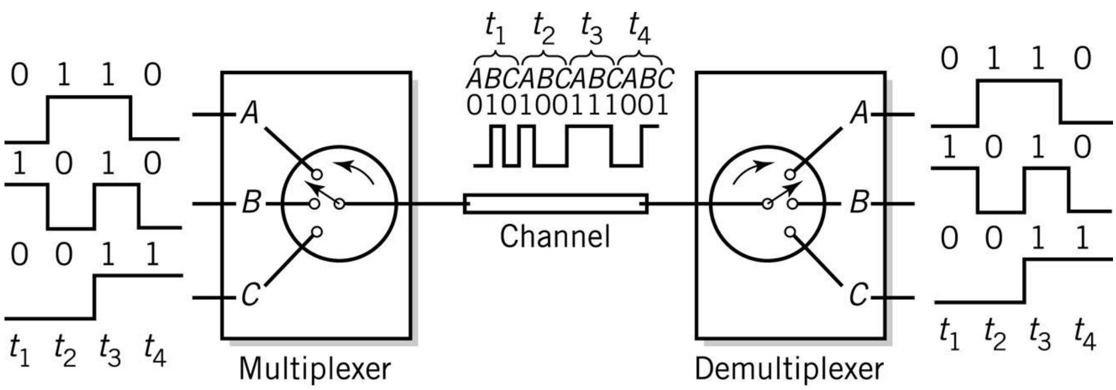


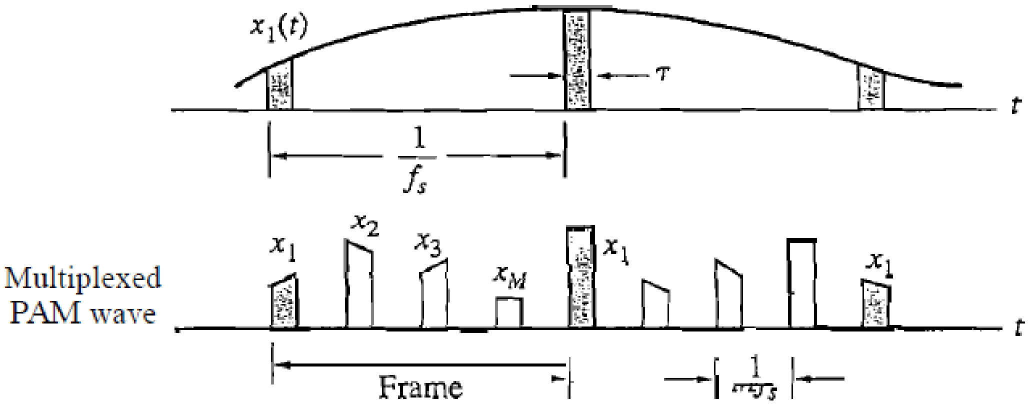
Time-division multiplexing of two signals.



Time division multiplexing of two pulse amplitude modulated signals.

2- TDM of the same sampling frequency(Multi Signal)
In this system we need **A commutator** in input and **decommutator** at the output ,and synch pulse .

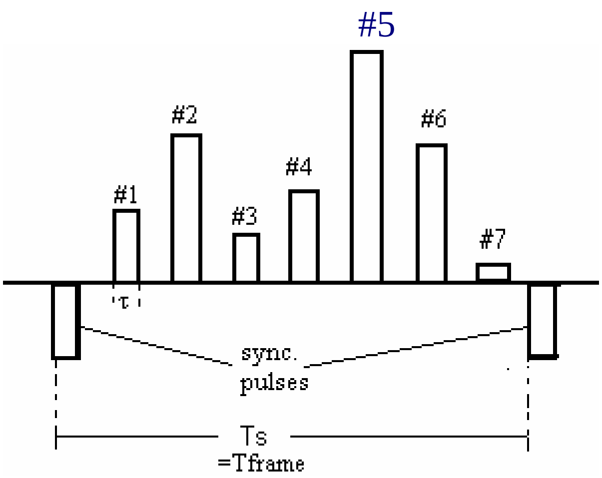




(b)

TDM system. (a)Block diagram; (b)waveforms.

Example: packet switching on the Internet Use digital channels



3-TDMCarrying multiple messages over channels simultaneously (PAM)

Amplitude of periodic pulse train is varied with a sampled message signal m(t).

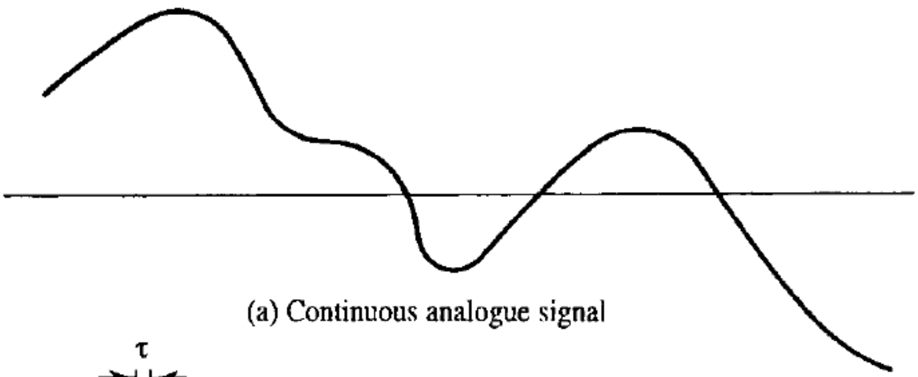
(Digital PAM: coded pulses of the sampled and quantized message signal

(Analog PAM: periodic pulse train with period Ts is the carrier below).

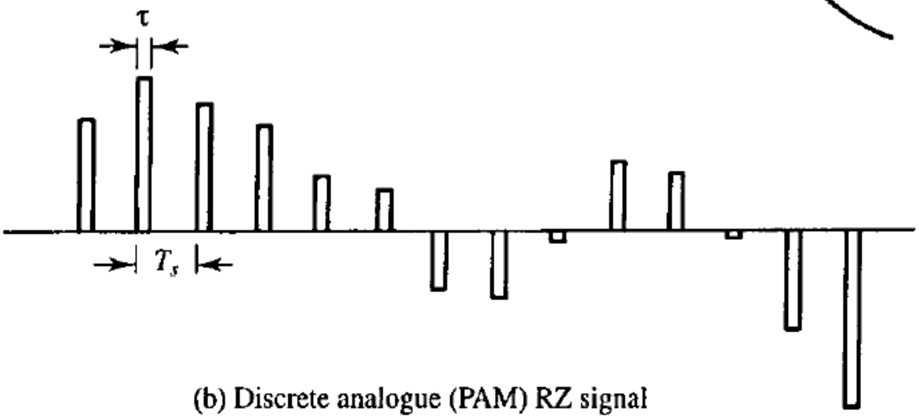
CH-6-

Digital Pulse Modulation

(6-1)Pulse Code Modulation(PCM)

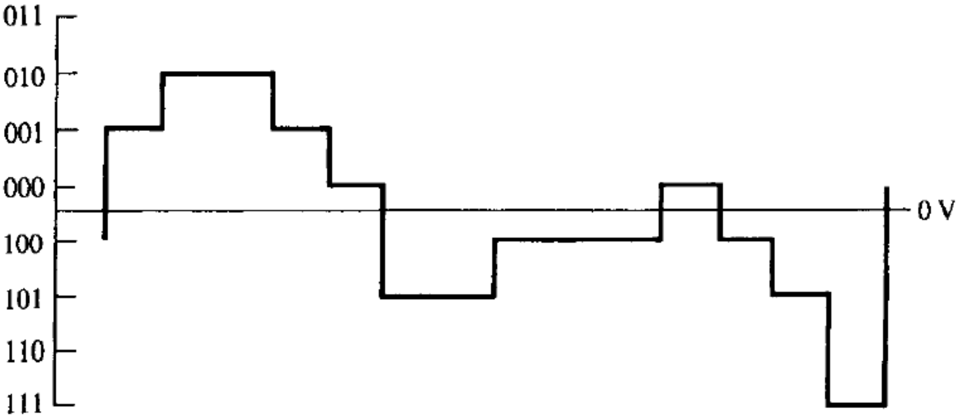


(a) Continuous analogue signal



(b) Discrete analogue (PAM) RZ signal

RZ Return to zero



(c) Discrete digital (quantised PAM) NRZ signal

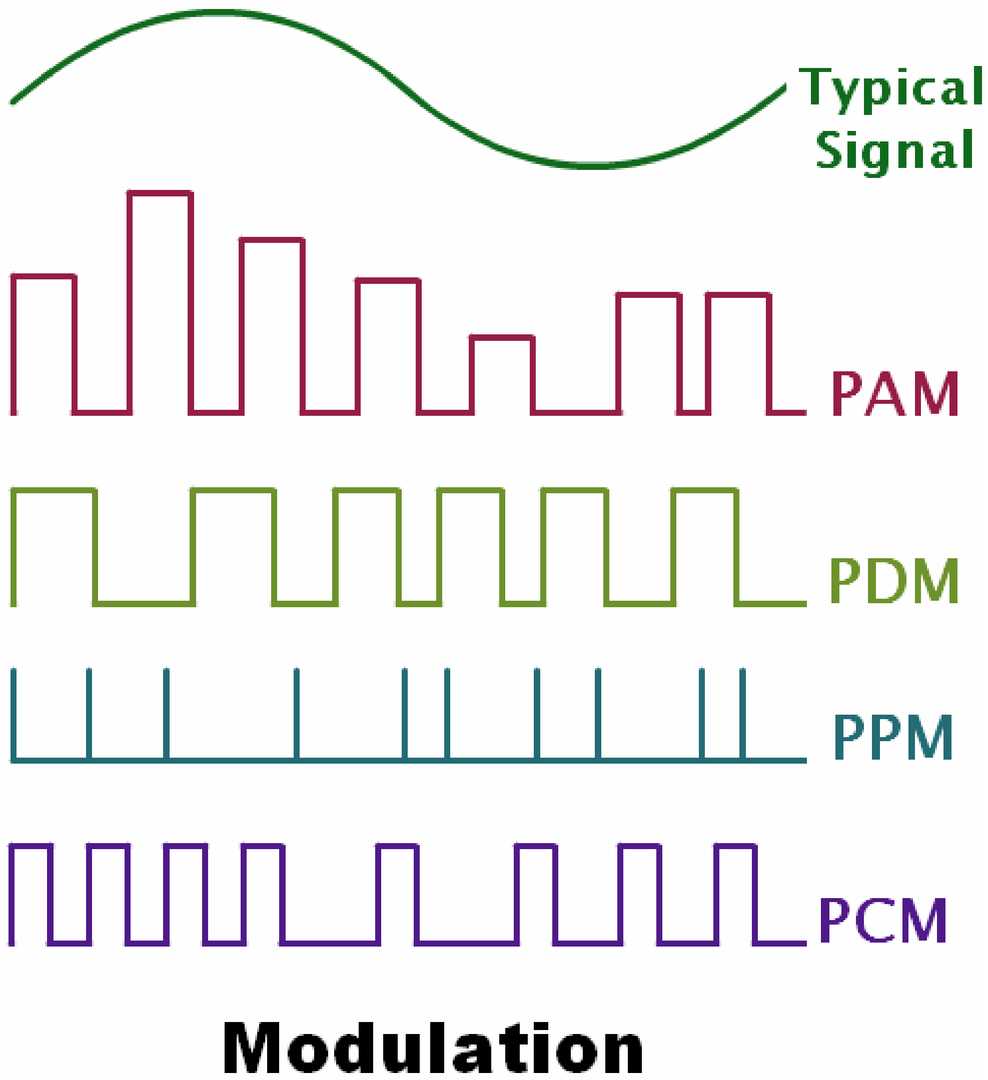
NRZ Non-return to zero

· 001 · 010 · 010 · 001 · 000 · 101 · 101 · 100 · 100 · 100 · 000 · 100 · 101 · 111

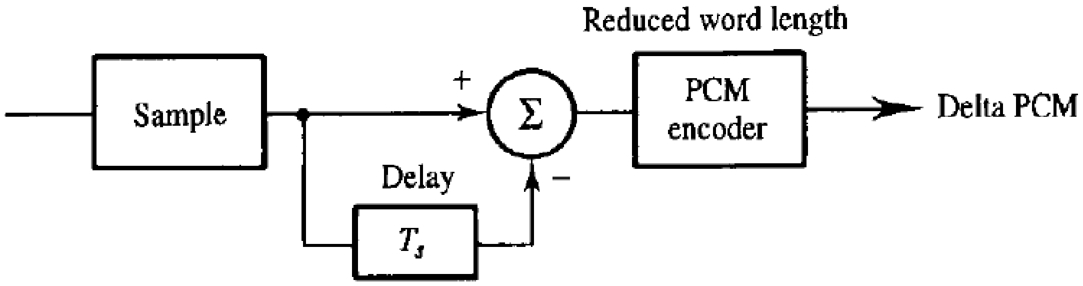
(d) Binary coded (quantised) PAM

(e) PCM NRZ signal

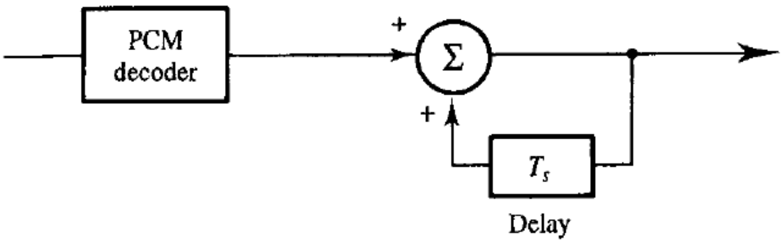
Relationship between PAM, quantised PAM and PCM signal.



(6-2) Delta Pulse Code Modulation(DPCM)



(a) Delta PCM encoder



(b) Delta PCM decoder

Delta PCM transmitter and receiver.

(6-3)Differential Pulse Code Modulation(DPCM)

(6-4) Delta Modulation(DM)

CH-7-
Angle Modulation

(7-1)Angle Modulation and Instantaneous Frequency

This section introduces the concepts of instantaneous phase and frequency for the definition of PM and FM signals

$$V(t) = E_C \cos[\theta(t)]$$

$$\theta(t) = 2\pi f_C + \Phi(t)$$

$$V(t) = E_C \cos[2\pi f_C + \Phi(t)]$$

Where $\phi(t)$: is the angle of sinusoidal wave

$$\omega_i(t) = \frac{d\theta(t)}{dt}$$:The instantaneous radian frequency

$$\omega_i(t) = \omega_C + \frac{d\phi(t)}{dt}$$

Where:

$$\omega_C = 2\pi f_C$$ The instantaneous Deviation of the phase

$$\frac{d\phi(t)}{dt}$$ The instantaneous deviation of the frequency

(7-2)Phase and Frequency Modulation (PM and FM):

(7-2-1)Phase Modulation (PM) and modulation index:

The phase of the carrier is varied instead of its frequency .

In effect , PM is a modified version of FM , because any change in phase

Is related to a change in frequency .

$$\phi(t) = \kappa_\rho V_m(t)$$

κ_ρ $\frac{radian}{Volts}$

κ_ρ : The constant instantaneous Deviation of the phase

$$V_{PM}(t) = E_C \cos[2\pi f_C t + \kappa_\rho V_m(t)]$$

OR $V_{PM}(t) = E_c \cos[w_c t + K_P V_m(t)]$

If the information signal sinusoidal wave $V_m(t)=V_m \sin w_m t$ in PM

Then :-

$V_{PM}(t) = E_c \cos[w_c t + K_P V_m \sin w_m t]$

$\beta = K_P V_m$

V_m : Max. amplitude of modulation signal

β : Modulation Index of PM [rad]

$$V_{PM}(t) = E_c \cos[w_c t + \beta \sin w_m t]$$

(7-2-2) Frequency Modulation and modulation index:

The instantaneous deviation is made proportional to the instantaneous value of the modulation signal (information signal($V_m(t)$)).

$$V(t) = E_C \cos[\theta(t)]$$

$$V(t) = E_C \cos[2\pi f_C + \Phi(t)]$$

$$\frac{d\phi(t)}{dt} = \kappa_f V_m(t)$$

$$\phi(t) = \kappa_f \int_{to}^{t} V_m(\lambda) d\lambda + \phi(t_o)$$

κ_f : $\frac{hz}{v}$

K_f : The constant instantaneous deviation of the frequency

$\phi(t_o)$: Primary phase at zero

$$V_{FM}(t) = E_C \cos\left[2\pi f_C t + \kappa_f \int_{-\infty}^{t} V_m(\lambda) d\lambda\right]$$

$$\omega_{i(FM)}(t) = \omega_C + \kappa_f V_m(t)$$

$V_{FM}(t) = E_c \cos [\, w_c t + K_f \int V_m(t)dt]$

If the information signal sinusoidal wave $V_m(t)=V_m \cos w_m t$ in FM

$V_{FM}(t) = E_c \cos [\, w_c t + K_f \int V_m \cos w_m t \, dt]$

$V_{FM}(t) = E_c \cos [\, w_c t + (K_f . V_m / w_m) \sin w_m t \,]$

V_m : Max. amplitude of modulation signal

$$\beta = \frac{\kappa_f V_m}{f_m}$$

$$\Delta f = \kappa_f V_m$$

$$\beta = \frac{\Delta f}{f m}$$

When :-

$\beta = (K_f . V_m / f_m) = (\Delta f / f_m) = (\Delta w / w_m)$

$$V_{FM}(t) = E_c \cos [\, w_c t + \beta \sin w_m t]$$

Example: Find the modulation index of the modulation signal

$V(t) = 2\cos(2\pi\ 2000t)$ where $K_P = 1.5$ [rad/volt].

Solution:

$$\beta = K_P\ V_m = 1.5 \times 2 = 3 \text{ [rad]}$$

Example: Find the modulation index of the modulation signal

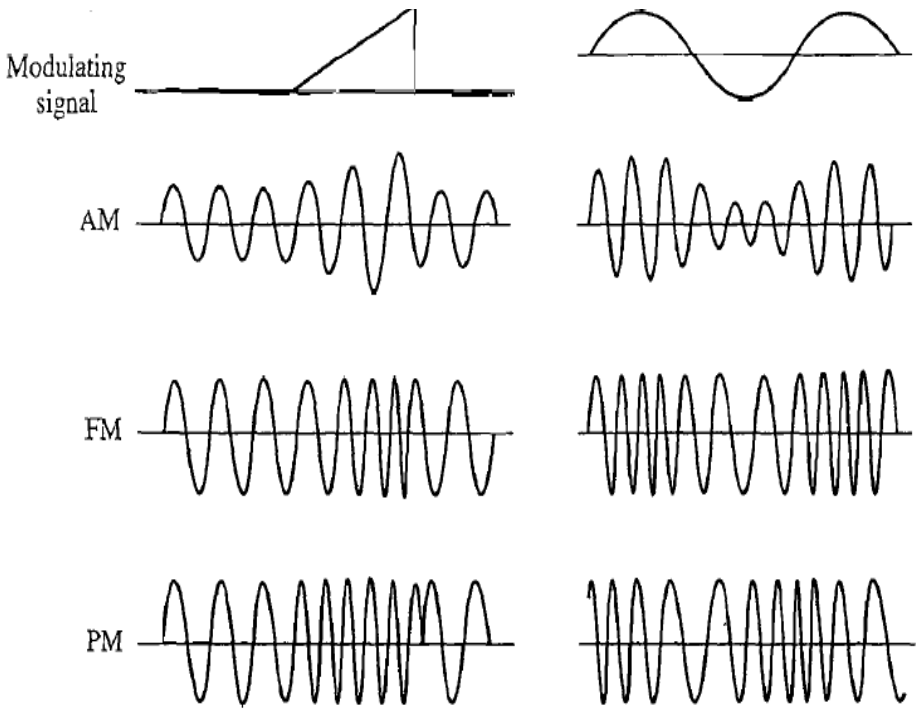
$V(t) = 2\cos(2\pi\ 2000t)$ where $K_f = 5$ [KHz/volt].

Solution:

$$\Delta f = K_f V_m$$

$$\Delta_f = K_f V_m = 5 \times 2 = 10 \text{ KHz}$$

$$\beta = \frac{\Delta_f}{f_m} = \frac{10000}{2000} = 5$$



Wave form of AM , PM , FM

(7-3)Type of Frequency Modulation(FM) :

(7-3-1)Narrow Band Frequency Modulation(NBFM) :

When $\beta << 1$

$V_{FM}(t)= E_c \cos [w_c t + \beta \sin w_m t]$

Where

$$\cos(A+B) = \cos A \cos B - \sin A \sin B$$

$= E_c [\cos w_c t \cos (\beta \sin w_m t) - \sin w_c t \sin(\beta \sin w_m t)]$....equ(1)

$= E_c [\cos w_c t - \sin w_c t \sin (\beta \sin w_m t)]$

Where:- $(\beta \sin w_m t)=0$, $\cos 0=1$

$\sin(\beta \sin w_m t)= (\beta \sin w_m t)$ if the angle is very small

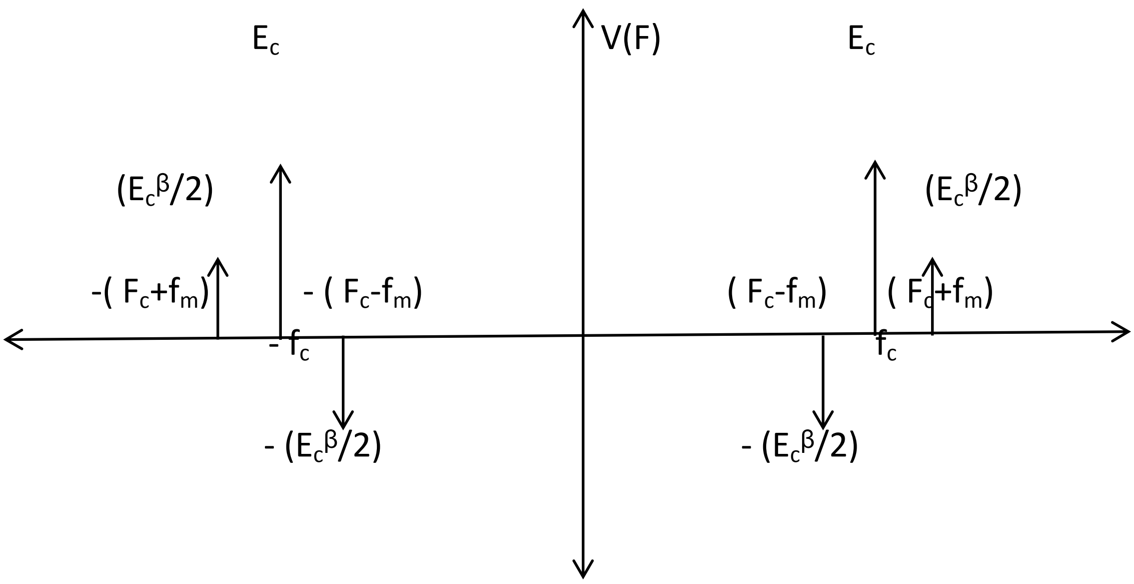
$V_{FM}(t)= \underbrace{E_c [\cos w_c t}_{\text{Carrier}} - \underbrace{\sin w_c t\, \beta \sin w_m t}_{\text{DSB}}]$

$V_{FM}(t)= E_c \cos w_c t - E_c \beta \sin w_c t \sin w_m t]$

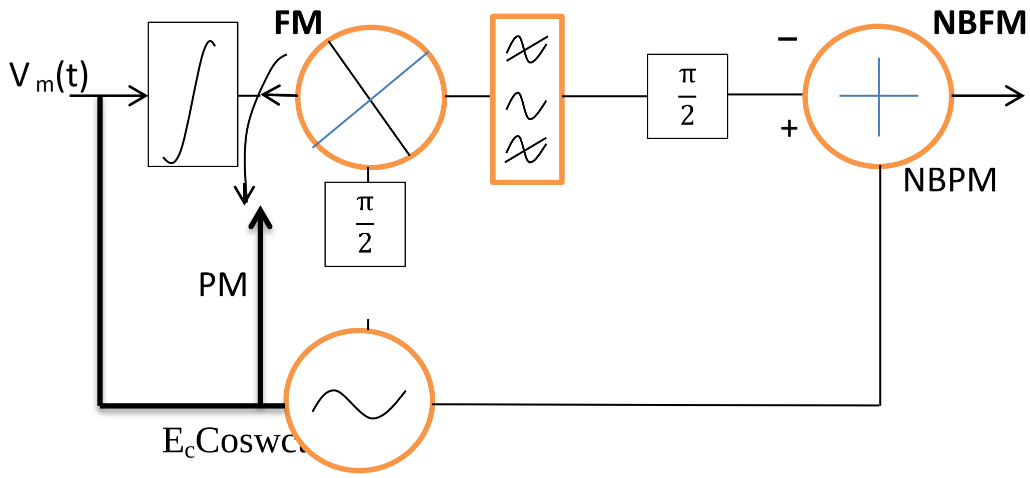
Where: $\sin A \sin B =0.5 [\cos(A-B)-\cos(A+B)]$

$V_{FM}(t)= E_c \cos w_c t – (E_c\beta/2)[\cos(w_c-w_m) t - \cos(w_c+w_m) t]$

$V_{FM}(t)= \underbrace{E_c \cos w_c t}_{\text{Carrier}} – \underbrace{(E_c\beta/2)[\cos(w_c-w_m) t}_{\text{LSB}} + \underbrace{(E_c\beta/2)[\cos(w_c+w_m) t]}_{\text{USB}}$

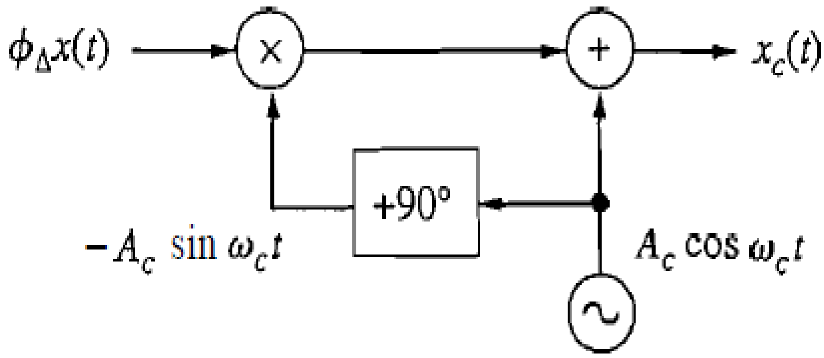


Line spectrum of NBFM



Block diagram of NBPM and NBFM

(7-3-2)Narrow Band Phase Modulation(NBPM) :



Narrowband phase modulator.

(7-3-3)wide Band Frequency Modulation(WBFM) :

Then we use the fact that, even though V(t) is not necessarily periodic, the

terrns cos (**β** sin w_mt) and sin (**β**sin w_m t) are periodic and each can be expanded as a trigonometric Fourier series with fo = f_m. Indeed, a well-known result from applied mathematics states that

$$\cos(\beta \sin \omega_m t) = J_0(\beta) + \sum_{n\ \text{even}}^{\infty} 2 J_n(\beta) \cos n\omega_m t$$

…………equ(2)

$$\sin(\beta \sin \omega_m t) = \sum_{n\ \text{odd}}^{\infty} 2 J_n(\beta) \sin n w_m t$$

Where :-

$J_n(\beta)$: Is the nth degree of Bessal function

where *n* is positive and

$$J_n(\beta) \triangleq \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{j(\beta \sin \lambda - n\lambda)} \, d\lambda$$

The coefficients Jn(**β**) are Bessel functions of the first kind, of order *n* and argument

β.

Substituting Eq. (2) into Eq. (1) and expanding products of sines and cosines
finally yields

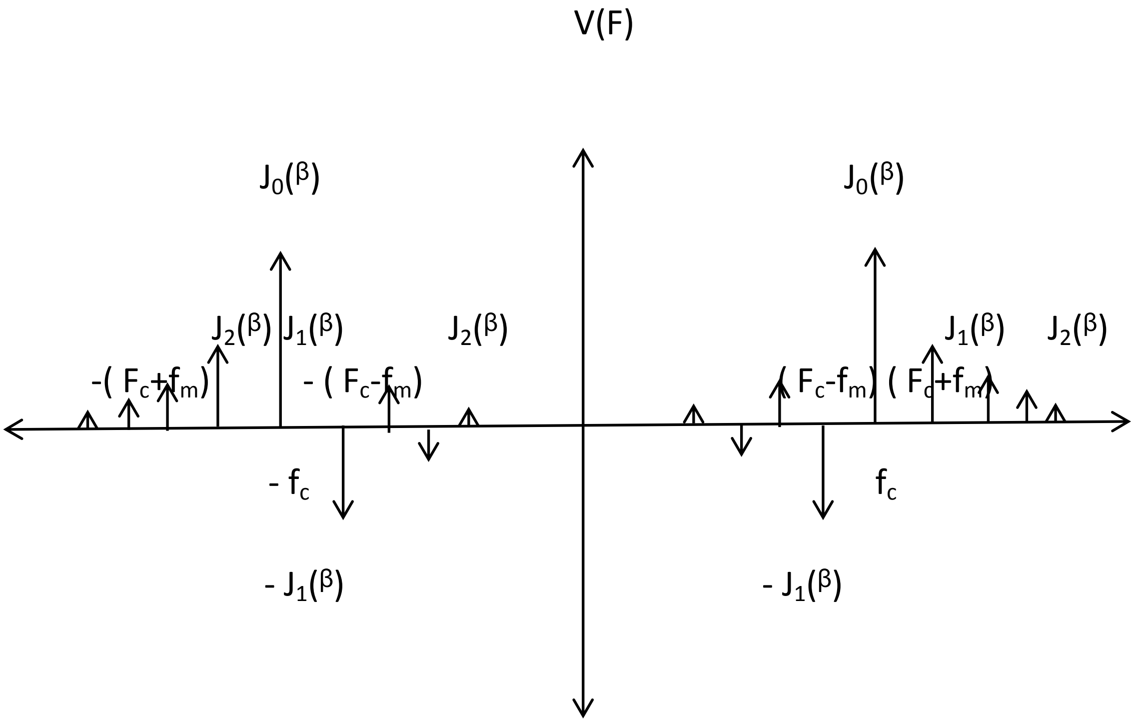
$V_{FM}(t) = E_c [\cos w_c t \cos(\beta \sin w_m t) - \sin w_c t \sin(\beta \sin w_m t)]$

………………

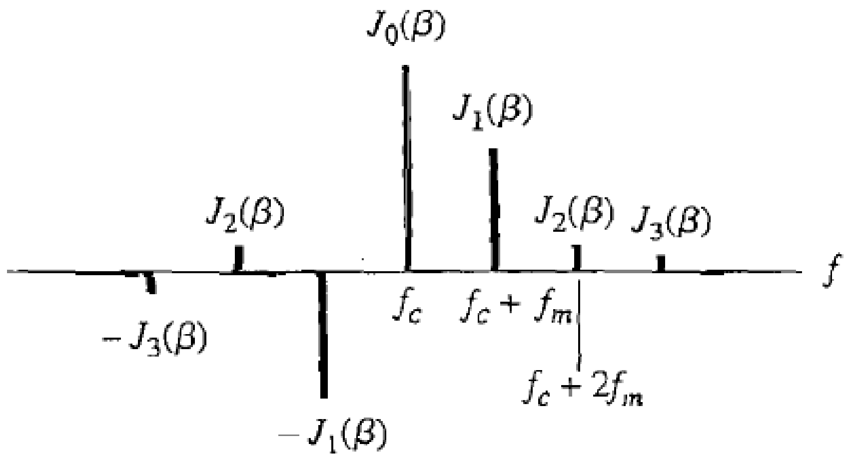
$$V(t) = E_C \left\{ \begin{array}{l} J_o(m)\cos\omega_C t + J_1(m)\left[\cos(\omega_C + \omega_m)t + \dfrac{\pi}{2}\right] - \\ J_1(m)\left[\cos(\omega_C - \omega_m)t - \dfrac{\pi}{2}\right] + J2(m)\left[\cos(\omega_C + \omega_m)t + \dfrac{\pi}{2}\right] - \\ J2(m)\left[\cos(\omega_C - \omega_m)t - \dfrac{\pi}{2}\right] + \ldots \end{array} \right\}$$

Where :-

Constant from the table Bessel function $J_{2(m)}, J_{1(m)}$

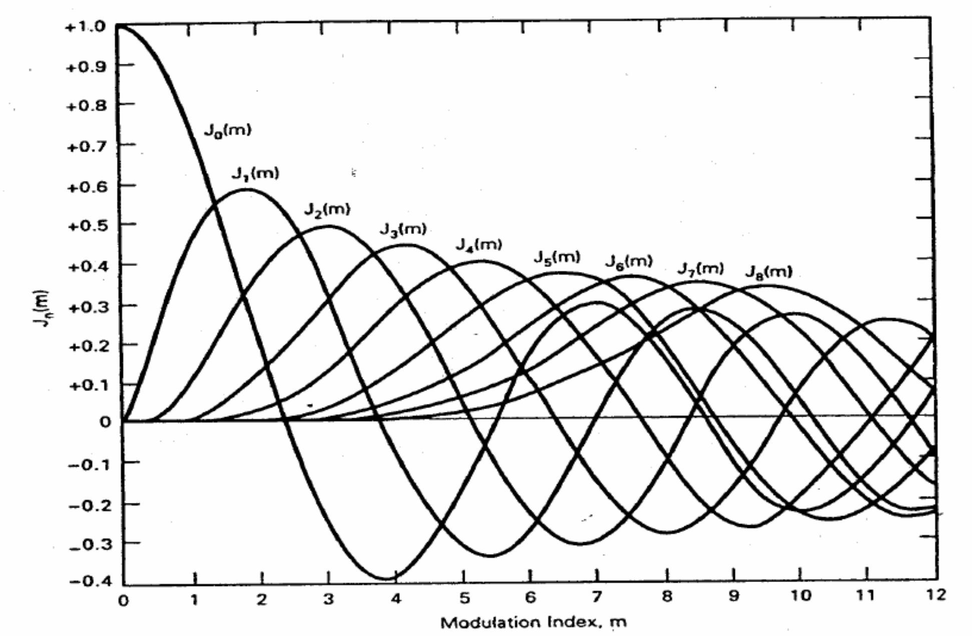


Line spectrum of WBFM with tone modulation



Line spectrum of FM with tone modulation.

m	J_o	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}
0.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.25	0.98	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-
0.5	0.94	0.24	0.03	-	-	-	-	-	-	-	-	-	-	-	-
1.0	0.77	0.44	0.11	0.02	-	-	-	-	-	-	-	-	-	-	-
1.5	0.51	0.56	0.23	0.06	0.01	-	-	-	-	-	-	-	-	-	-
2.0	0.22	0.58	0.35	0.13	0.03	-	-	-	-	-	-	-	-	-	-
2.4	0.00	0.52	0.43	0.20	0.06	0.02	-	-	-	-	-	-	-	-	-
2.5	- 0.05	0.5	0.45	0.22	0.07	0.02	0.01	-	-	-	-	-	-	-	-
3.0	- 0.26	0.34	0.49	0.31	0.13	0.04	0.01	-	-	-	-	-	-	-	-
4.0	- 0.04	- 0.07	0.36	0.43	0.28	0.13	0.05	0.02	-	-	-	-	-	-	-
5.0	- 0.18	- 0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	-	-	-	-	-	-
6.0	0.15	- 0.28	- 0.24	0.11	0.36	0.36	0.25	0.13	0.06	0.02	-	-	-	-	-
7.0	0.30	0.00	- 0.30	- 0.17	0.16	0.35	0.34	0.23	0.13	0.06	0.02	-	-	-	-
8.0	0.17	0.23	- 0.11	- 0.29	- 0.10	0.19	0.34	0.32	0.22	0.13	0.06	0.03	-	-	-
9.0	- 0.09	0.25	0.14	- 0.18	- 0.27	- 0.06	0.20	0.33	0.31	0.21	0.12	0.06	0.03	0.01	-
10.0	- 0.25	0.05	0.25	0.06	- 0.22	- 0.23	- 0.01	0.22	0.32	0.29	0.21	0.12	0.06	0.03	0.01

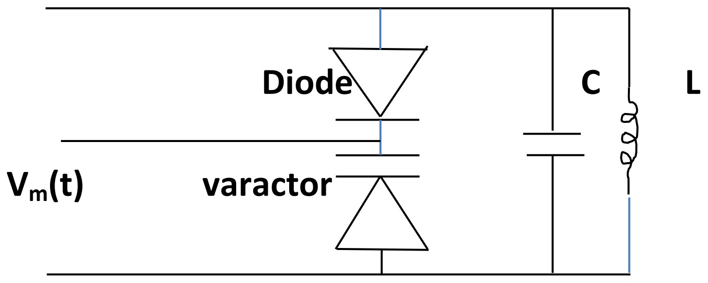


محاضرات اتصالات ٢٠١٧/٢٠١٦ مدرس المادة : محمود فاخر محمد

(7-4) Generation of (WBFM) :

(7-4-1) Direct method (WBFM) :

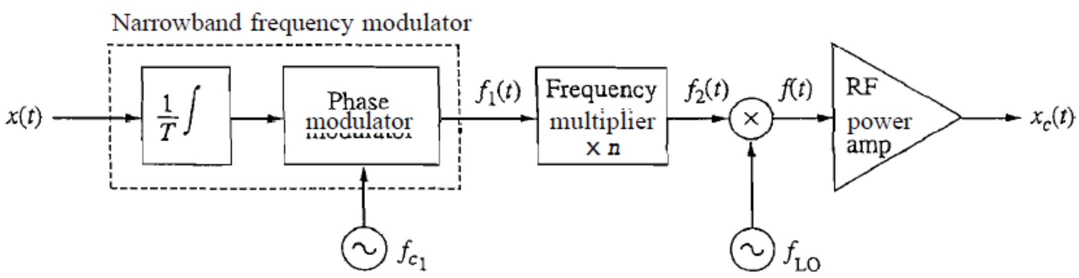
In this type we control either L or C a high quality LC oscillator .



Circuit diagram of voltage control oscillator(VCO)

$$F_C = \frac{1}{2\pi\sqrt{LC}}$$

(7-4-2) Indirect method (WBFM) :



Indirect FM transmitter

(7-5) Band width in FM(B_T) :

For small : β

$B_T = 2f_m$

For Large :
β

$B_T \cong 2\,\beta\, f_m = 2\,\frac{\Delta f}{fm}\, f_m$

$B_T = 2\Delta f$

For anther value of β we use

$B_T = 2nf_m$

تجريبي مقترحة

There is an empirical formula proposed by J.R Carlson

$B_T \cong 2(\Delta f + f_m) \cong 2\, f_m\, (\beta+1)$

Example: If FM signal f_c=10MHz , , $\Delta f = 50KHz$ find B_T , if :-

a) f_m=500KHz
b) f_m=0.5KHz
c) f_m=10KHz
Solution:

a)

$\beta = (\Delta f / f_m) = (50/500) = 0.1$ is small NBFM
$B_T = 2f_m = 2X500X10^3 = 1MHz$
b)

$\beta = (\Delta f / f_m) = (50/0.5) = 100$ is large WBFM
$B_T \cong 2\,\beta\, f_m = 2\,\frac{\Delta f}{fm}\, f_m$

$= 2X100X0.5X10^3 = 100KHz$

$B_T = 2\Delta f$

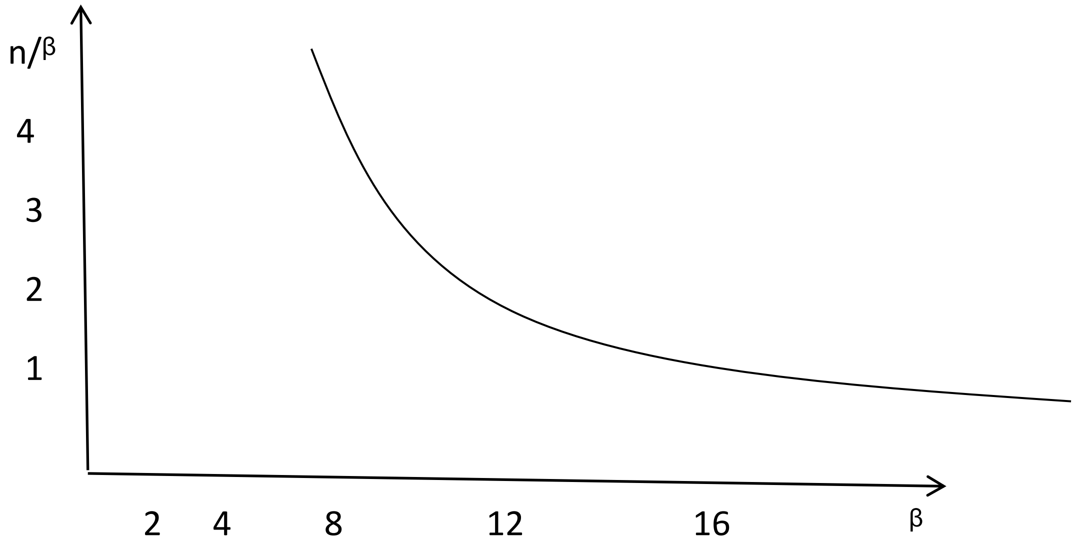
$= 2X50X10^3 = 100KHz$

c)

$\beta = (\Delta f / f_m) = (50/10) = 5$

$B_T = 2nf_m$

$B_T = 2nf_m = 2X8X10X10^3 = 160KHz$ Where n= 8 from the curve



(7-6) Avarage power in FM and PM :

$P_T = \langle \mathrm{I}\, V(t)\, \mathrm{I}^2 \rangle = (E_c)^2/2$

P_T not depend on β because each component cancel the ether .

Example : FM transmitter with carrier frequency of 100MHz and single tone modulation of 1kHz , the modulation index is 0.5 . find the band width?

Solution:

From the curve n= 2

$B_T = 2nf_m$

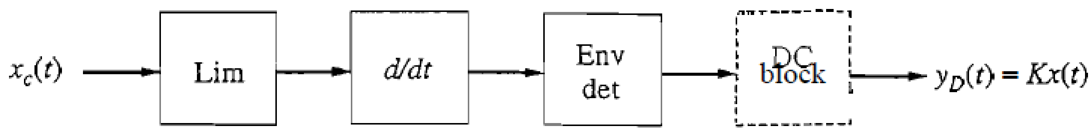
$B_T = 2nf_m = 2X2X1X10^3 = 4kHz$

(7-7) Frequency Detection:

A **frequency detector,** often called a **discriminator,** produces an output voltage that should vary linearly with the instantaneous frequency of the input. There are perhaps as many different circuit designs for frequency detection as there are designers who have considered the problem. However, almost every circuit falls into one of the following four operational:-

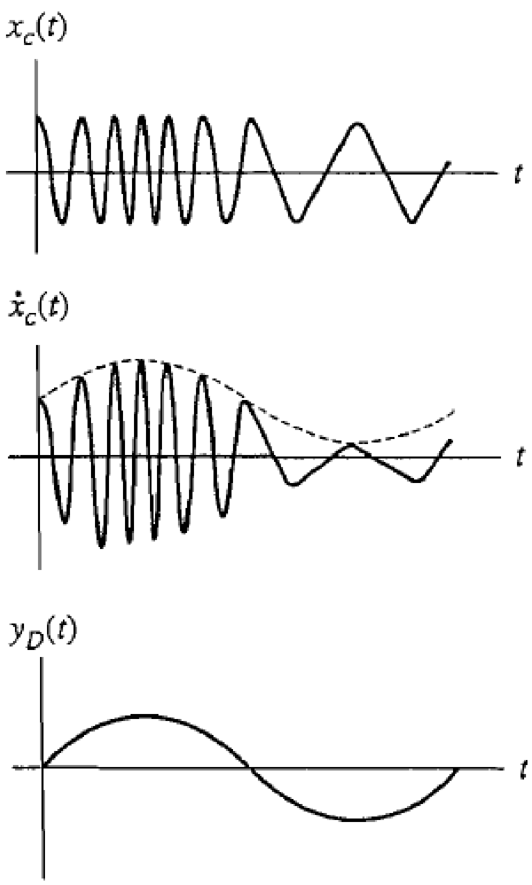
1. FM-to- AM conversion(slope detector)
2. Phase-shift discrimination (Balance discrimination) (Balance slope detector).
3. Zero-crossing detection
4. Frequency feedback **(Foster-Seeley discriminator**)
5. Ratio detector
6.Phase look-loop

(7-7-1) FM-to- AM conversion (slope detector):

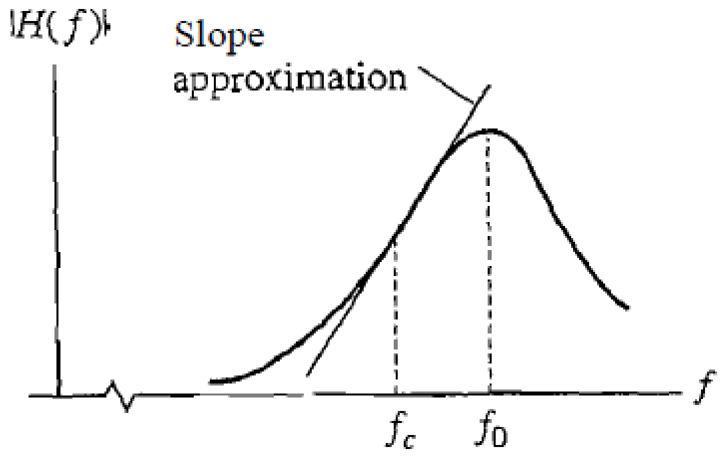


Frequency detector with limiter and FM-to-AM conversion:

OR (Block Diagram of slope detector)

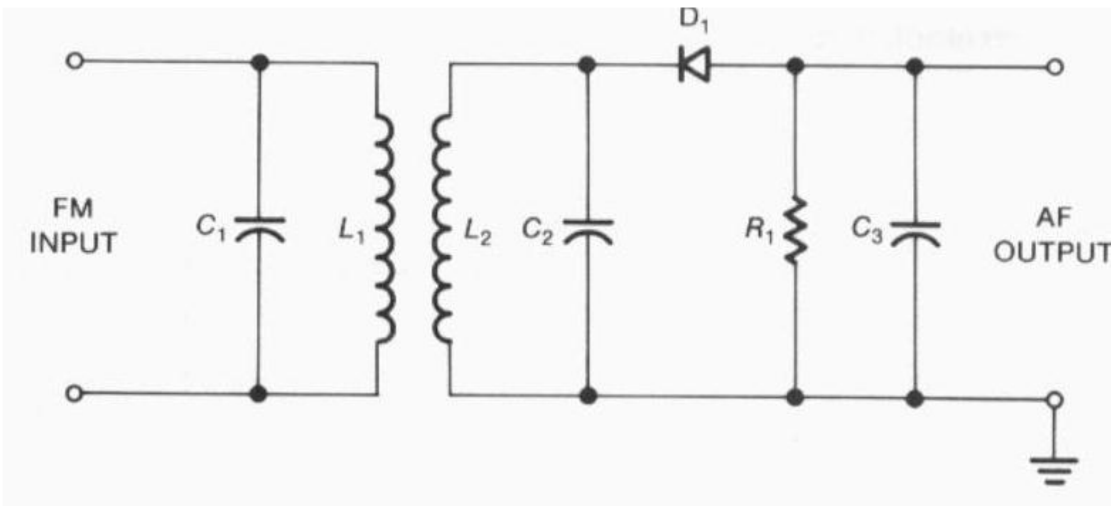


Wave Form of slope detector



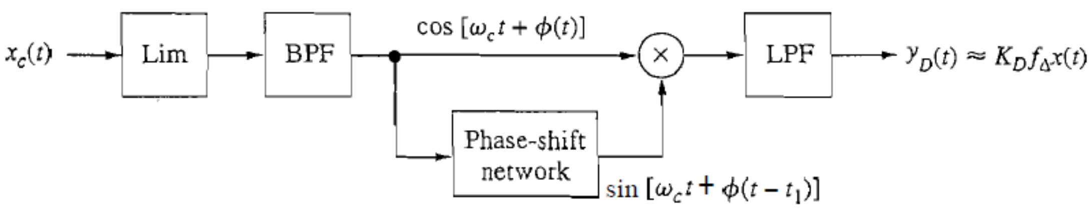
Slope detection with o tuned circuit

frequency-to-voltage characteristic.

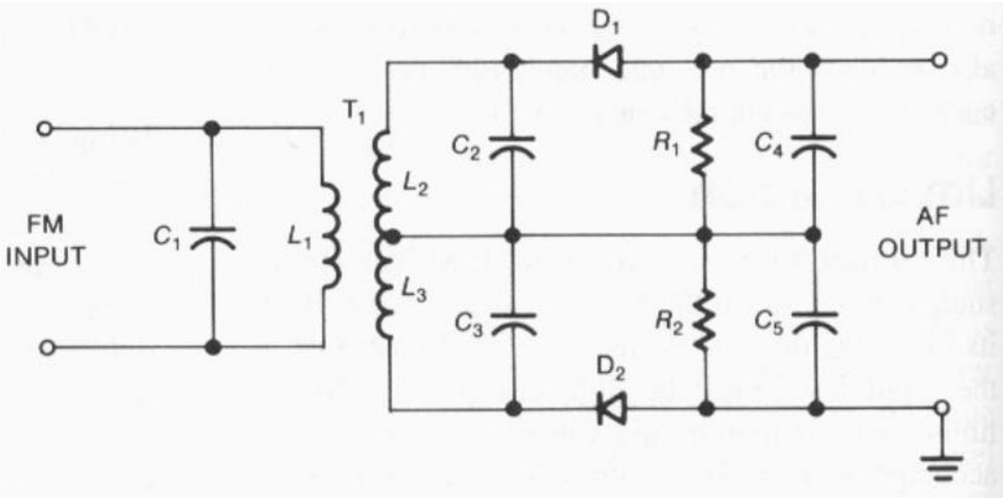


Circuit Diagram of Slop Detector

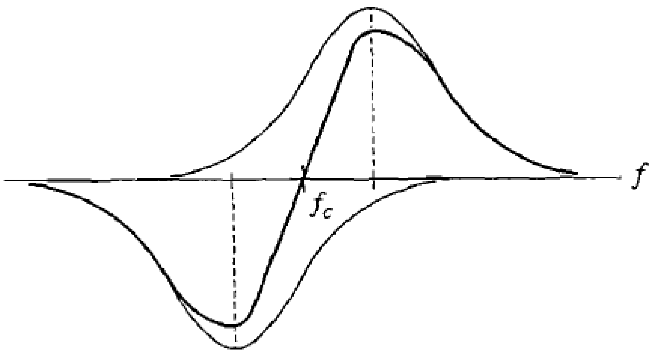
(7-7-2) Phase-shift discrimination(Balance discrimination):



Phase-shift discriminator or quadrature detector.

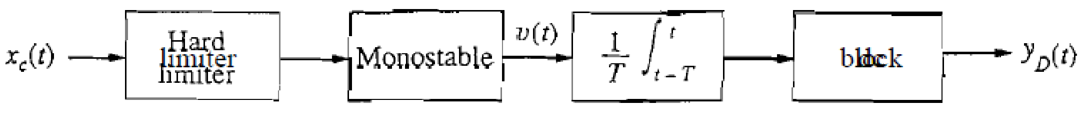


balanced discriminator circuit



frequency-to-voltage characteristic.

(7-7-3) Zero-crossing detection:



Block Diagram of Zero-crossing detector

(7-7-4) Foster-Seeley discriminator :

The Foster –Seeley converts into Audio voltage the frequency or phase variations brought into the receiver on the FM or PM waves . Because the circuit is also sensitive to amplitude variations in the FM wave .

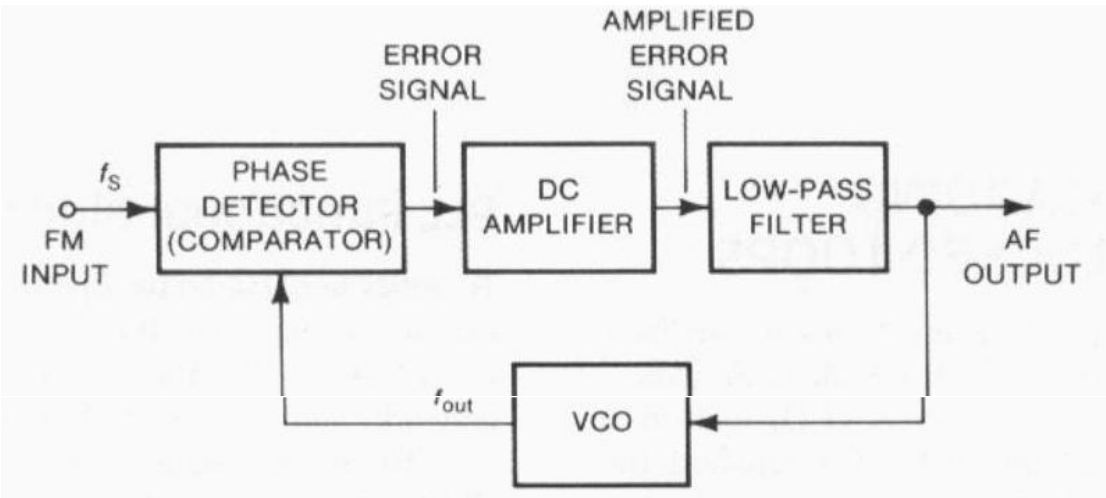
(7-7-5) Ratio detector:

An improvement over the Foster-Seeley discriminator is the (ratio detector) . The primary advantage of the ratio detector is its self-limiting action , that is , it requires no preceding limiter stage .

(7-7-6) Phase –Locked Loop Demodulator (PLL):

The PLL offers many advantages :-

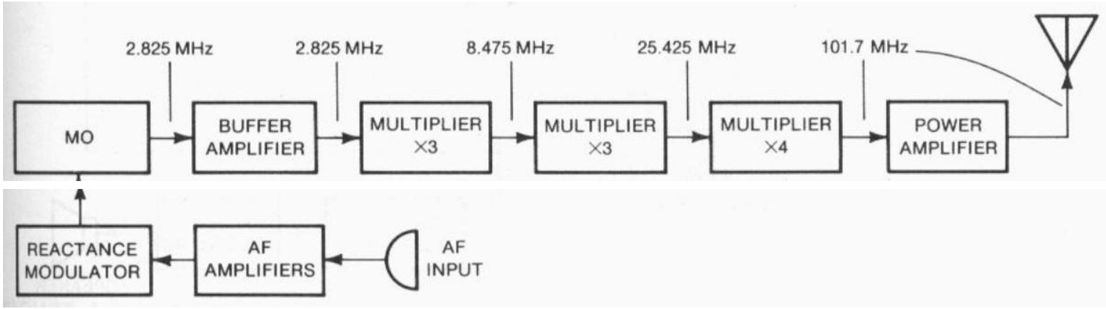
1. It requires no costly inductors or transformers, eliminating the need for intricate and time-consuming coil adjustments.
2. It produces excellent performance at low cost with a minimum of external components.
3. It can be used in many other electronics system applications.



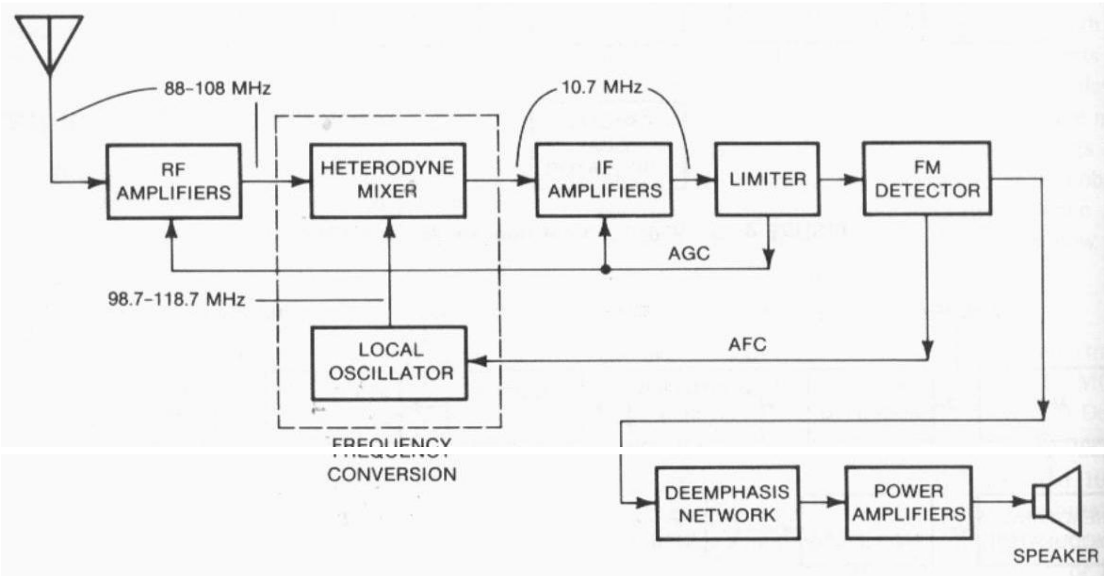
Block Diagram of Phase –Locked Loop Demodulator

(7-8) Application of FM and PM:

1. FM Transmitter and Receiver (FM Radio)

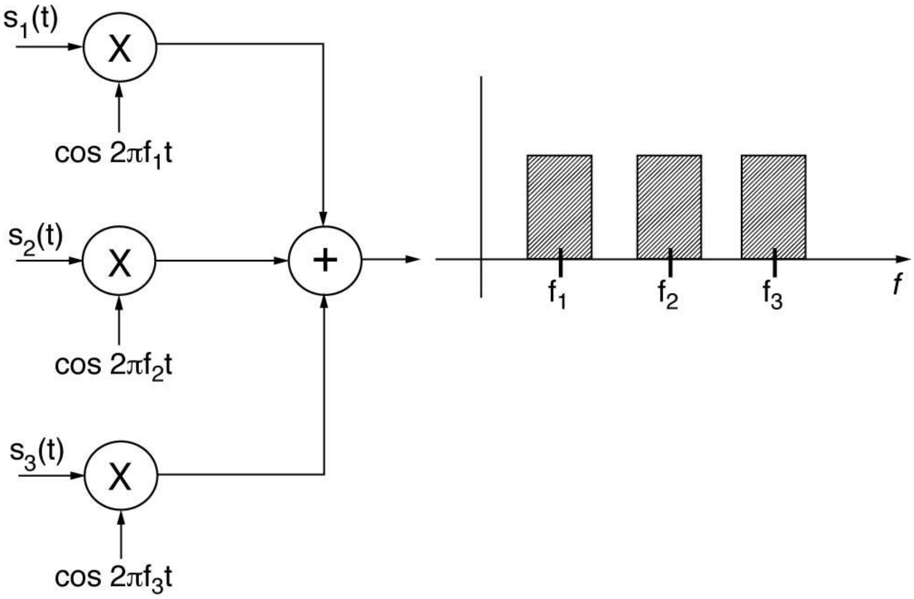


Block diagram of an FM transmitter with multipliers

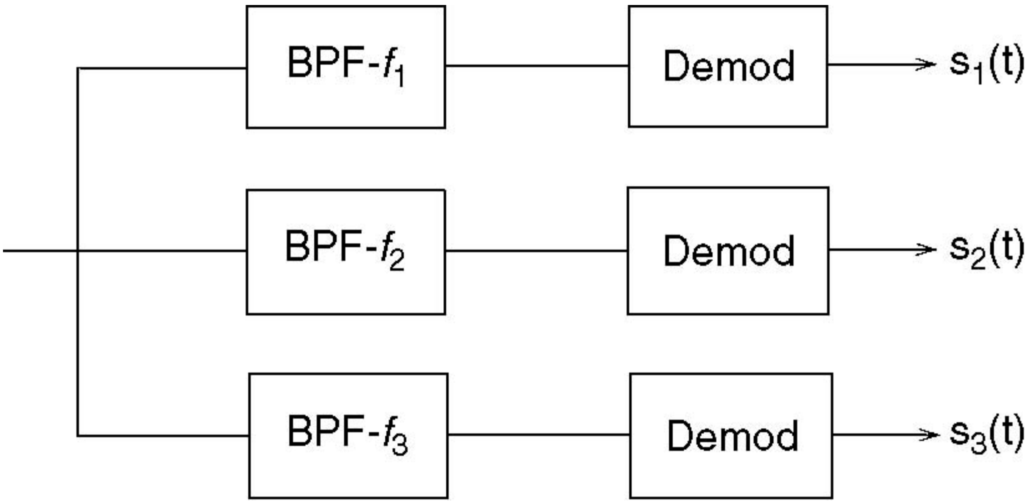


Block diagram of a broadcast FM receiver

2. FM Modulator of sound in TV system
3. NBFM and WBFM are used in telemetry system
4. FM Multiplexer (Frequency Division Multiplexer)
   It is process to transmit more than signal at the same transmission medium at the same time.



Block Diagram of Frequency-division multiplexing



Block Diagram of Demodulation multiplexing of FDM

FDM : Example: Cable TV , Analog channels

Example: FM transmitter of modulation index 1 , the information signal $V_m(t) = E_m \sin(2\pi 1000t)$ V , and the carrier wave $V_c = 10 \sin(2\pi 5X10^5 t)$ V , Find :-

1-Number of significant side band .

2- Average amplitude of carrier and side band.

3-Draw the frequency spectrum of relative amplitude .

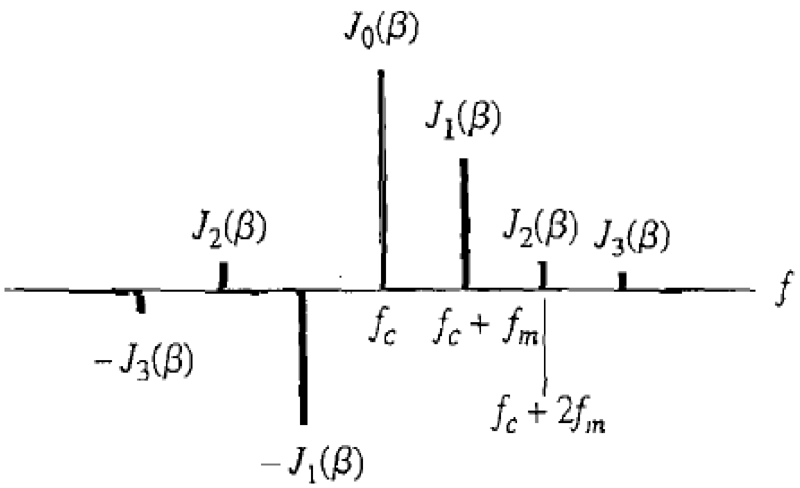
Solution:

1- Number of significant side band 3 from the table .

2-

$J_0 = 0.77\ (10) = 7.7\ V$
$J_1 = 0.44\ (10) = 4.4\ V$
$J_2 = 0.11\ (10) = 1.1\ V$
$J_3 = 0.02\ (10) = 0.2\ V$

3-



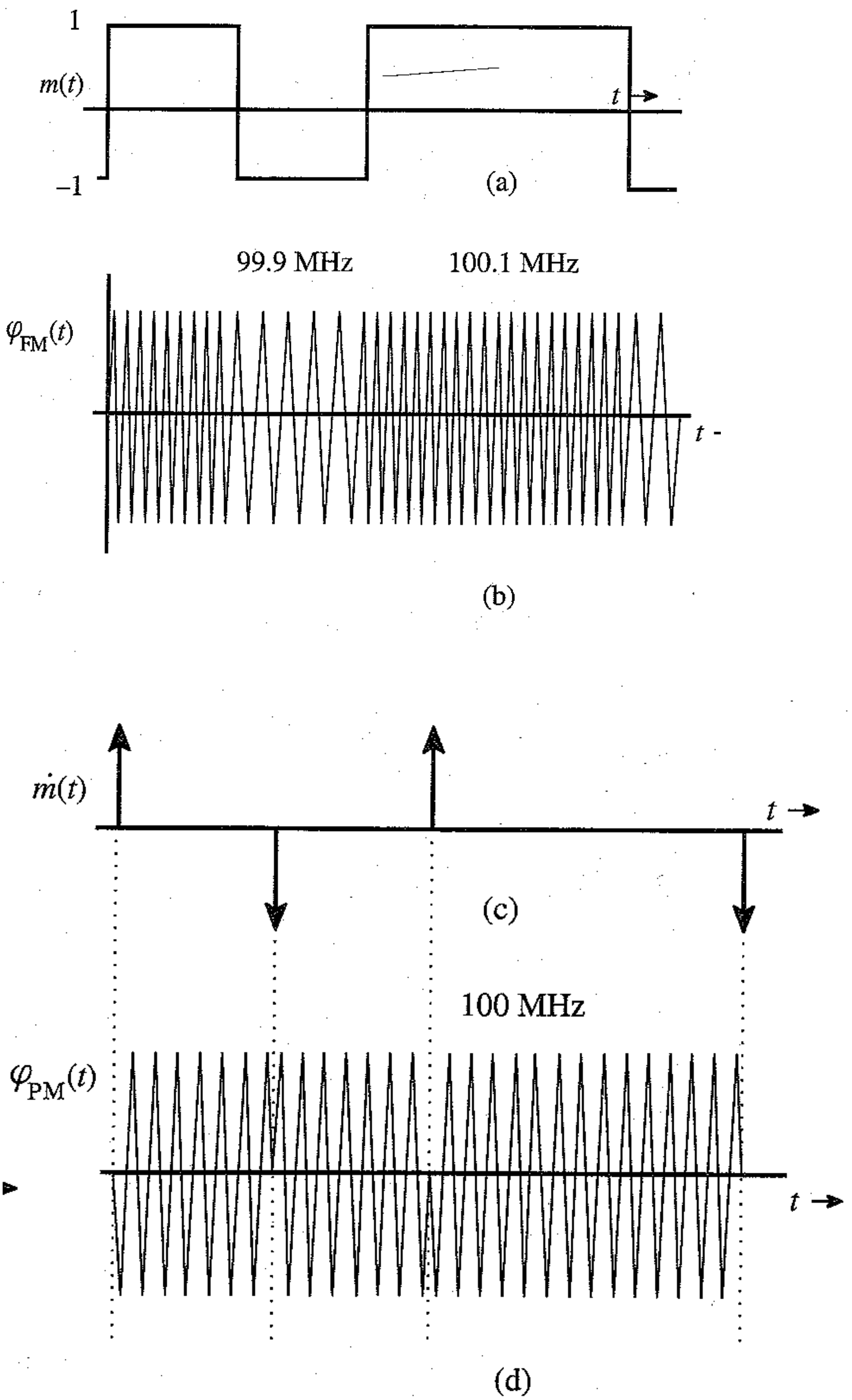
Line spectrum of FM with tone modulation.

EX:

Sketch FM and PM waves for the digital modulating signal $m(t)$ shown in Fig. constants k_f and k_p are $2\pi \times 10^5$ and $\pi/2$, respectively, and $f_c = 100$ MHz.

Solution:

$K_f = 2\pi X 10^5$, $K_p = \pi/2$, $f_c = 100MHz$


1
m(t)
t
−1
(a)
99.9 MHz
100.1 MHz
φFM(t)
t
(b)
ṁ(t)
t
(c)
100 MHz
φPM(t)
t
(d)

CH-8-

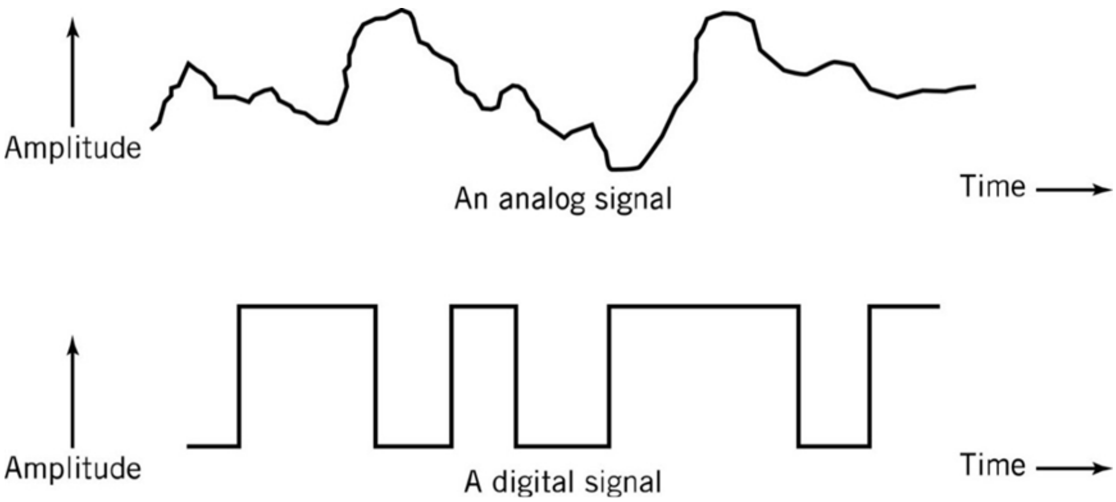
(8) Digital Modulation

The modulating signal is respresented as a time-sequence of symbols or pulses.

Analog: continuous varying waveforms to carry data, or continuous values Representation of a signal shown as a function of time

Digital: Two different values of electrical voltage or current or On/off light source.

Data represented by changes in the signal as a function of time Range of values.

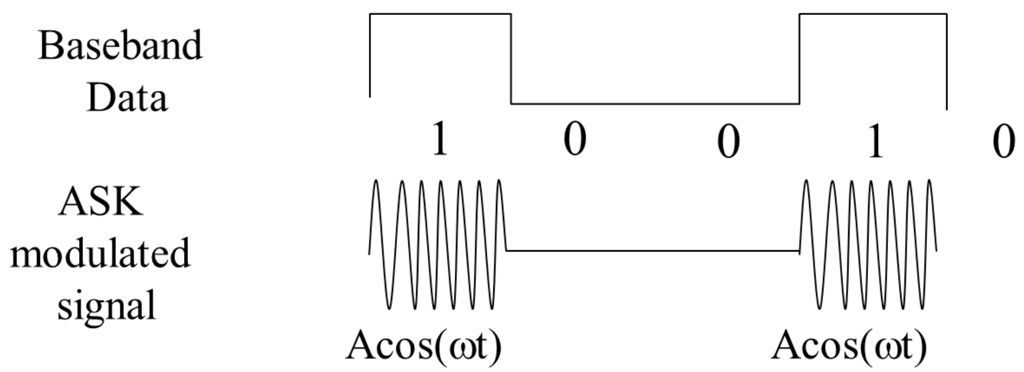


(8-1) Types of Digital Modulation

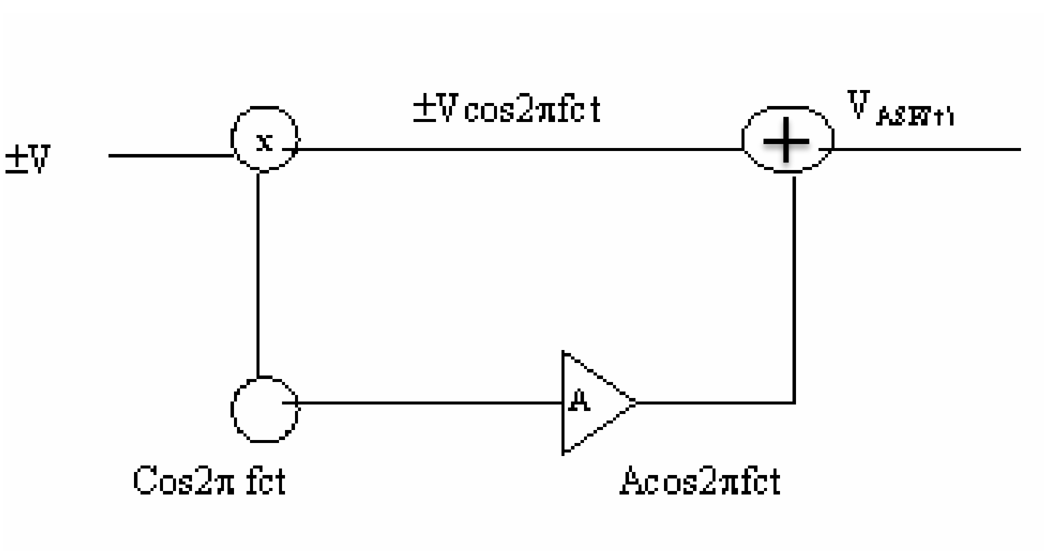
1-Amplitude Shift Keying (ASK):

Represents data by holding the frequency constant while varying the amplitude.

The most basic (binary) form of ASK involves the process of switching the carrier either on or off, in correspondence to a sequence of digital pulses that constitute the information signal. One binary digit is represented by the presence of a carrier, the other binary digit is represented by the absence of a carrier. Frequency remains fixed.



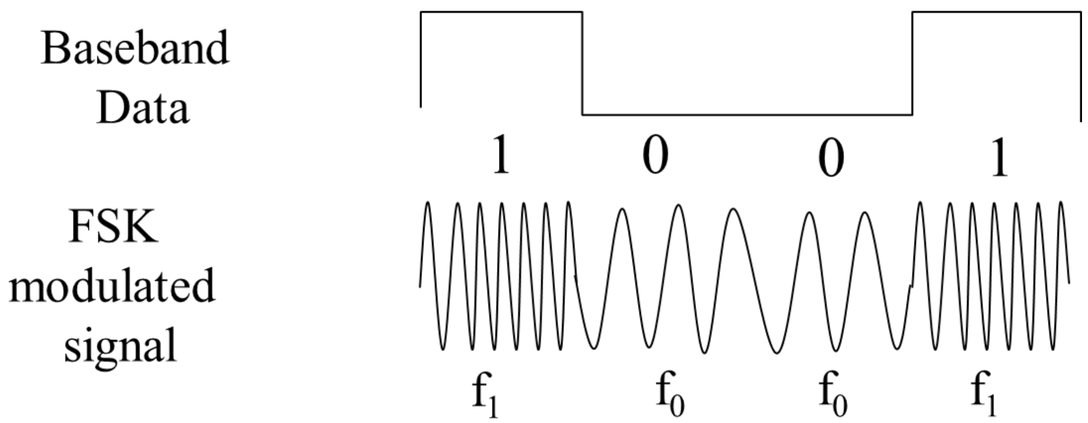
Generation of Ask :



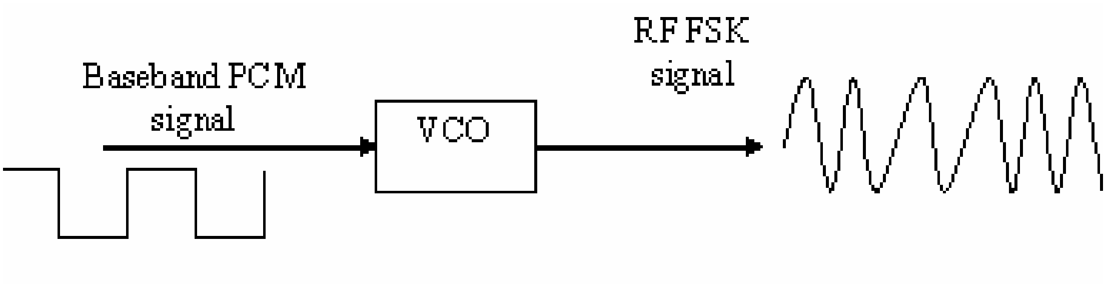
2-Frequency Shift Keying (FSK):

Represents data by holding the amplitude constant while varying the frequency.

The most basic (binary) form of FSK involves the process of varying the frequency of a carrier wave by choosing one of two frequencies (binary FSK) in correspondence to a sequence of digital pulses that constitute the information signal. Two binary digits are represented by two frequencies around the carrier frequency. Amplitude remains fixed.

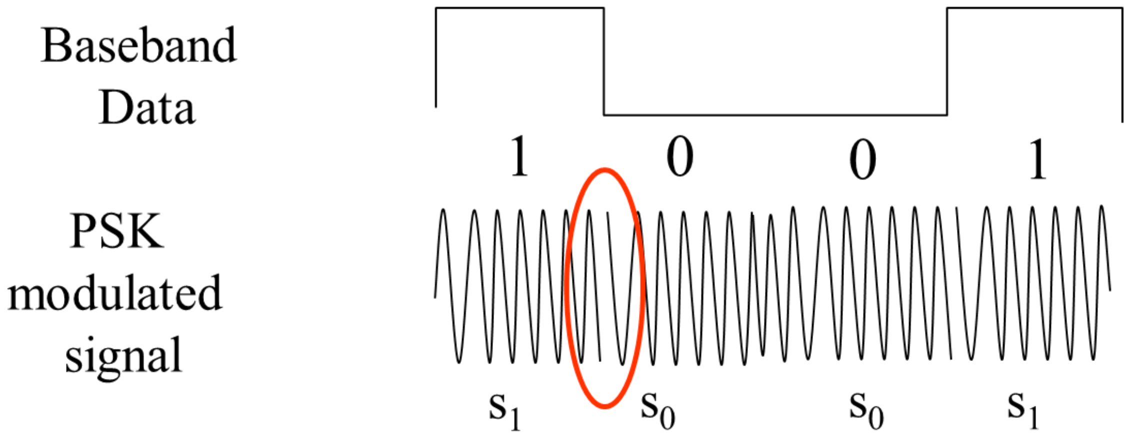


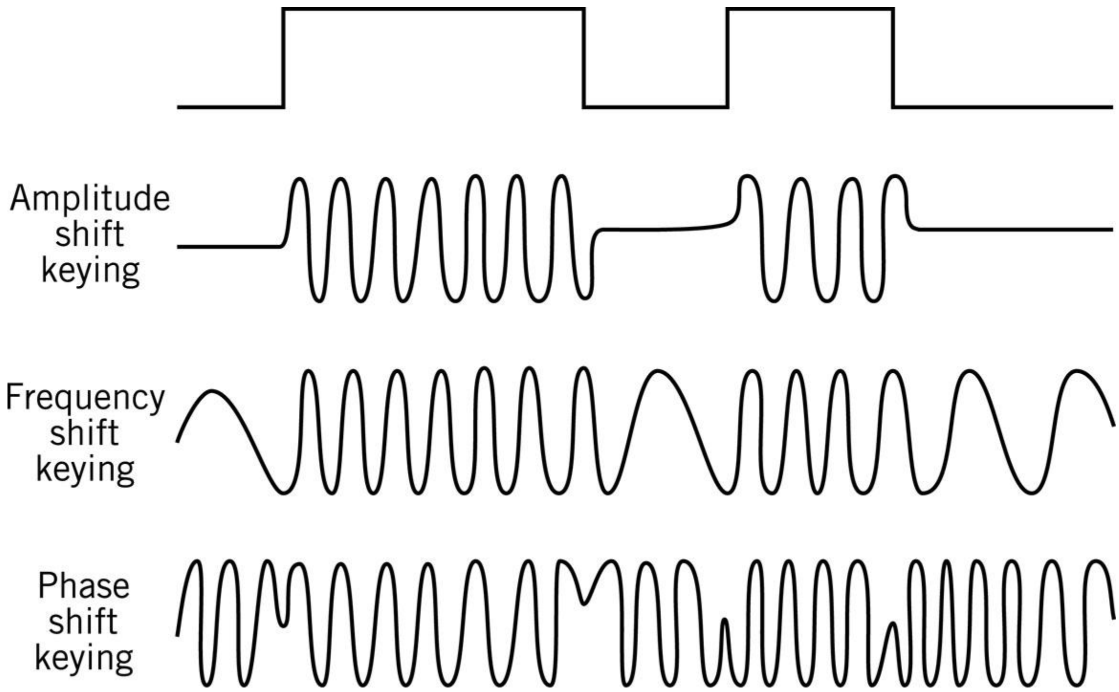
Generation of FSK:



3-Phase Shift Keying (PSK):

Represents data by an instantaneous shift in the phase or a switching between two signals of different phases.





4-Binary Phase Shift Keying

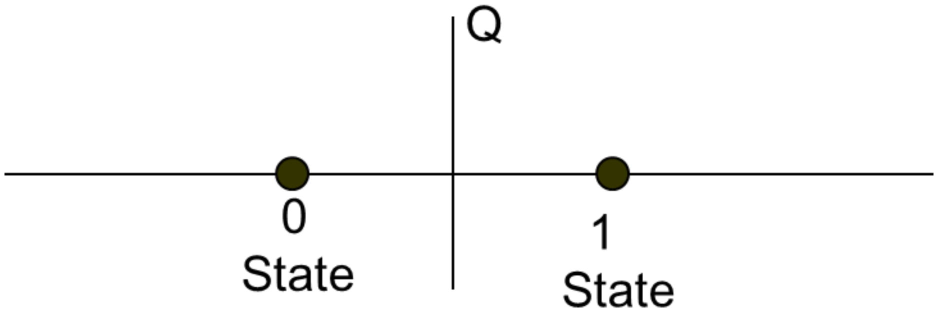
Use alternative sine wave phase to encode bits

.Phases are separated by 180 degrees

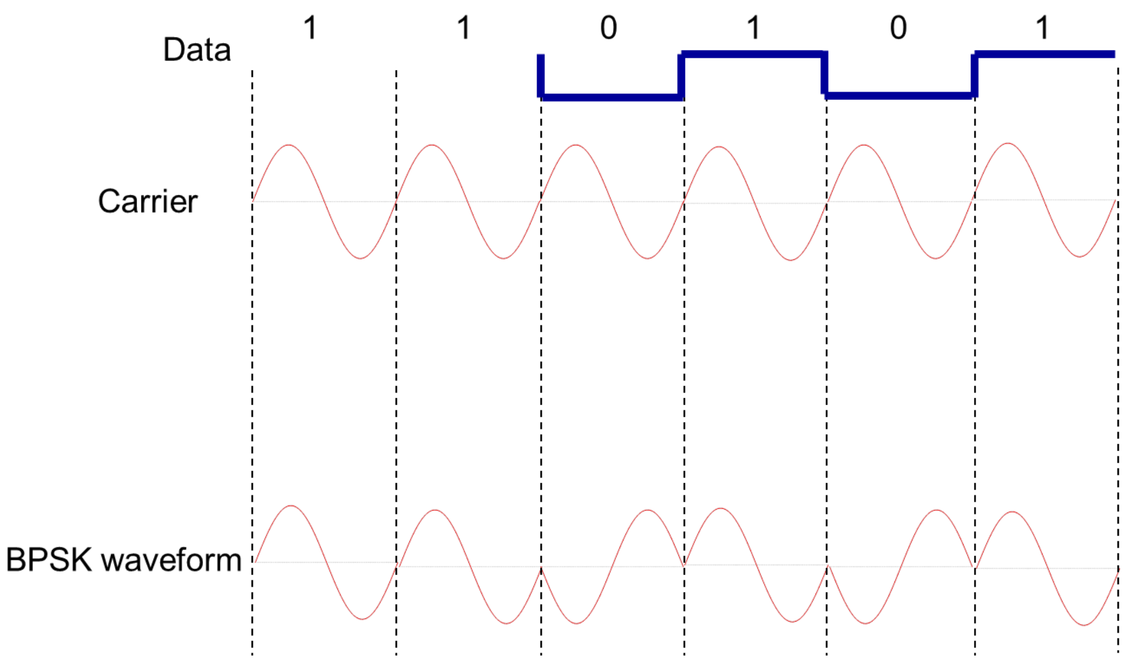
.Simple to implement, inefficient use of bandwidth

Very robust, used extensively in satellite communication

$$s_1(t) = A_c \cos(2\pi f_c + \theta_c) \quad \text{binary 1}$$
$$s_2(t) = A_c \cos(2\pi f_c + \theta_c + \pi) \quad \text{binary 0}$$



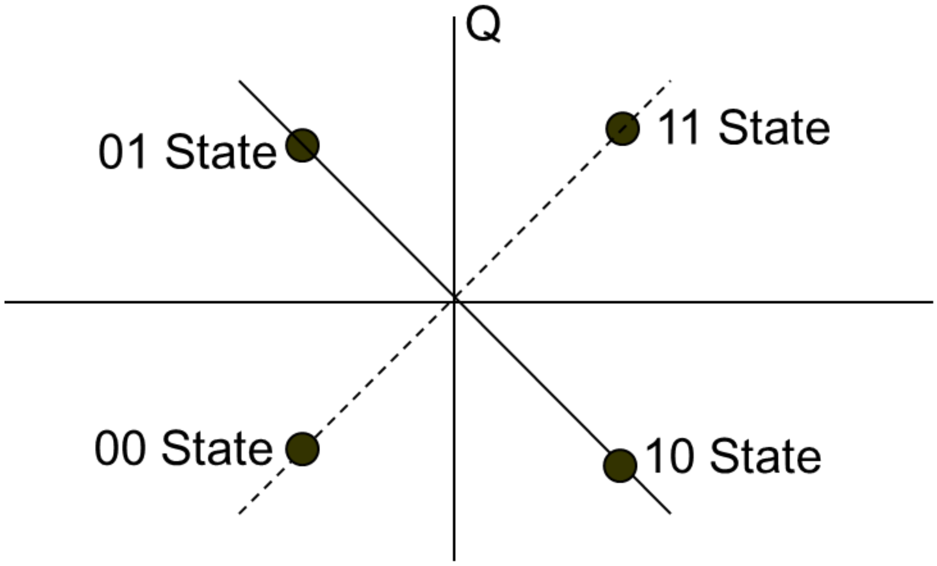
BPSK Example



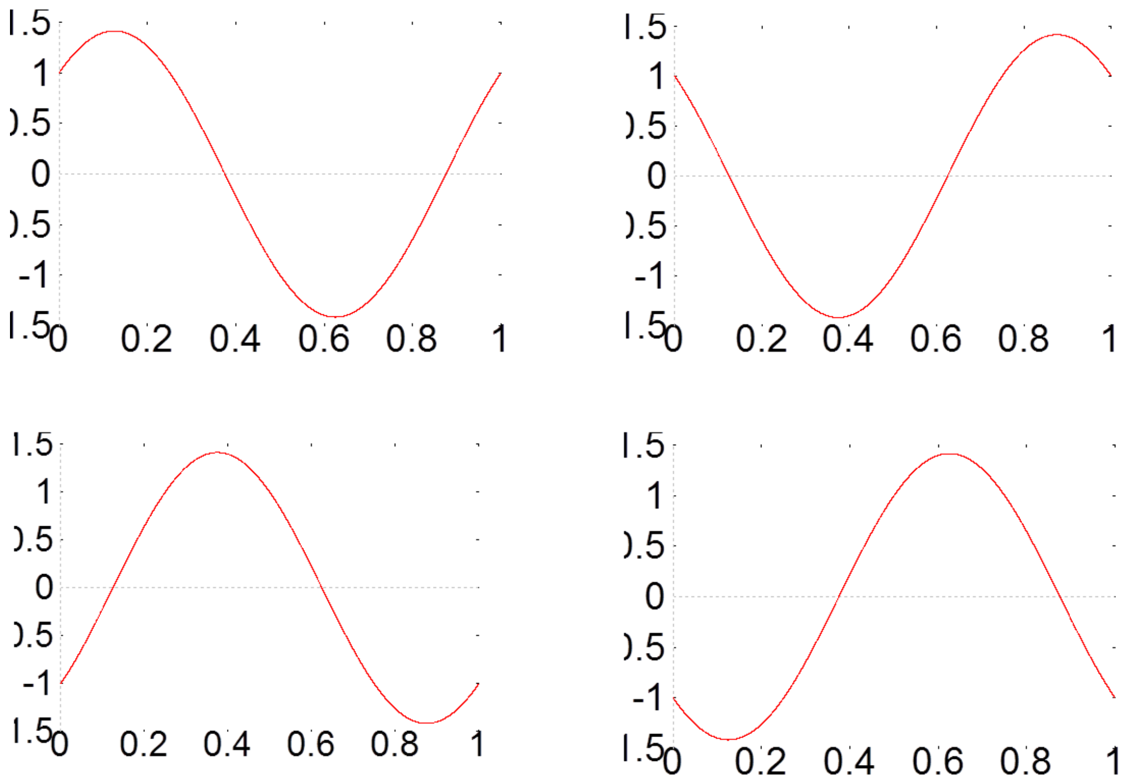
5 - Quadrature Phase Shift Keying (QPSK) :

- Quadrature Phase Shift Keying (QPSK) can be interpreted as two independent BPSK systems (one on the I-channel and one on Q), and thus the same performance but twice the bandwidth efficiency
- Large envelope variations occur due to abrupt phase transitions, thus requiring linear amplification

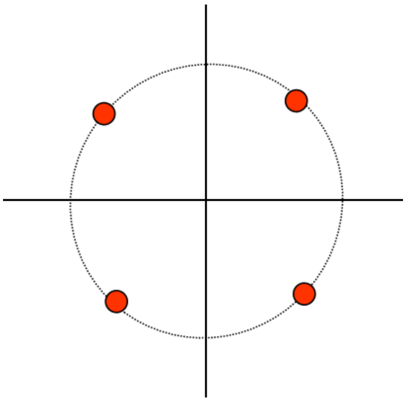
- Multilevel Modulation Technique: 2 bits per symbol
- More spectrally efficient, more complex receiver.
- Two times more bandwidth efficient than BPSK



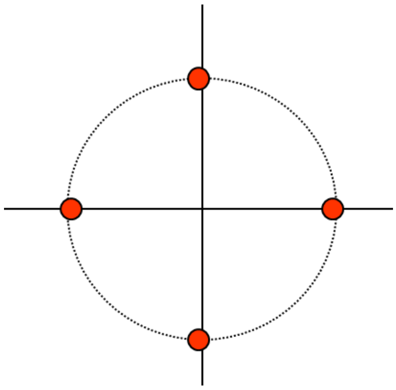
Phase of Carrier: π/4, 2π/4, 5π/4, 7π/4



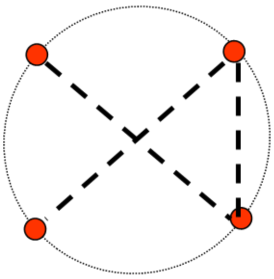
QPSK Constellation Diagram



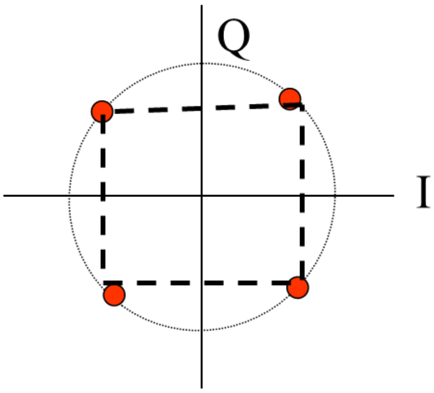
Carrier phases
{π/4, 3π/4, 5π/4, 7π/4}



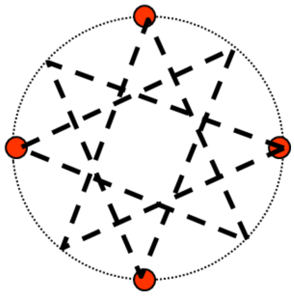
Carrier phases
{0, π/2, π, 3π/2}



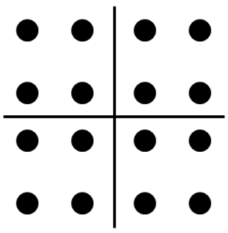
Conventional QPSK



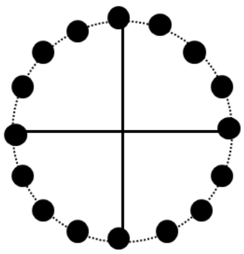
Offset QPSK



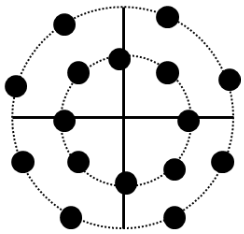
π/4 QPSK



16 QAM

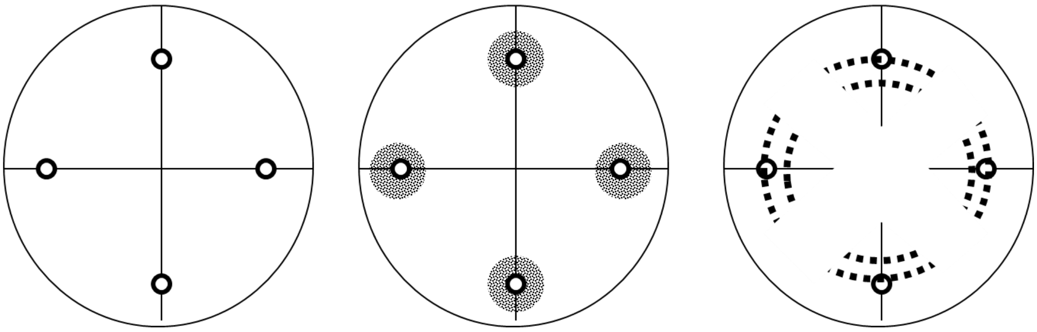


16 PSK



16 APSK

Distortions



(8-2)Demodulation & Detection

Demodulation: Is process of removing the carrier signal to obtain the original signal wave form.

Detection : extracts the symbols from the waveform.

A - Coherent detection

1. Phase Shift Keying (PSK)
2. Frequency Shift Keying (FSK)
3. Amplitude Shift Keying (ASK)
4. Binary Phase Shift Keying(BPSK)
5. Quadrature Phase Shift Keying (QPSK)

B - Non-coherent detection (envelope detection)

1. Frequency Shift Keying (FSK)
2. Amplitude Shift Keying (ASK)