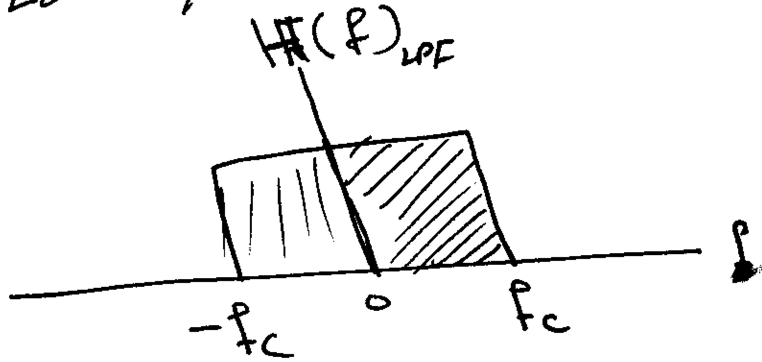
6- Filter type

Filter it's electrical element used to select same type of frequencyes than the ather. There are Foure type of filter

1- Low pass filter (LPF)

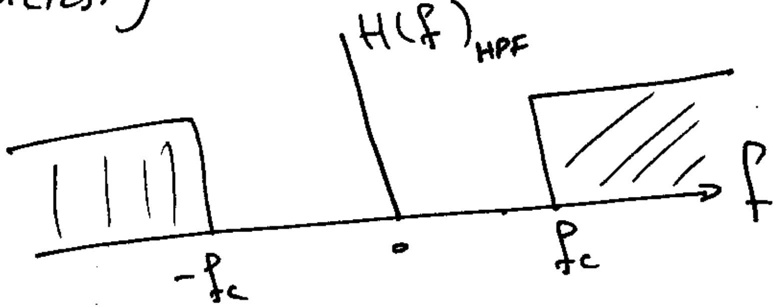
This filter pass only Low frequenices ~~as shown~~ Less than cutoff frequency

LPF



2- High pass filter (HPF)

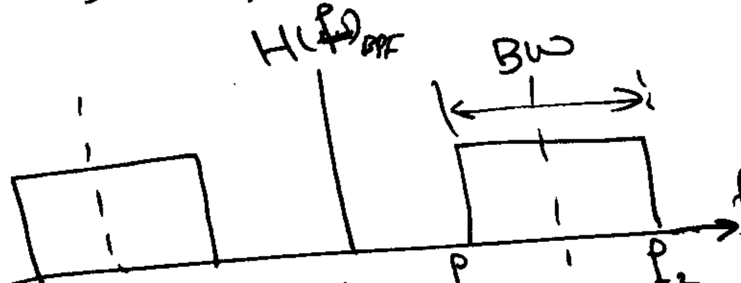
This filter pass frequienciest greater than cutoff freq. fc



3- Band pass filter (BPF)

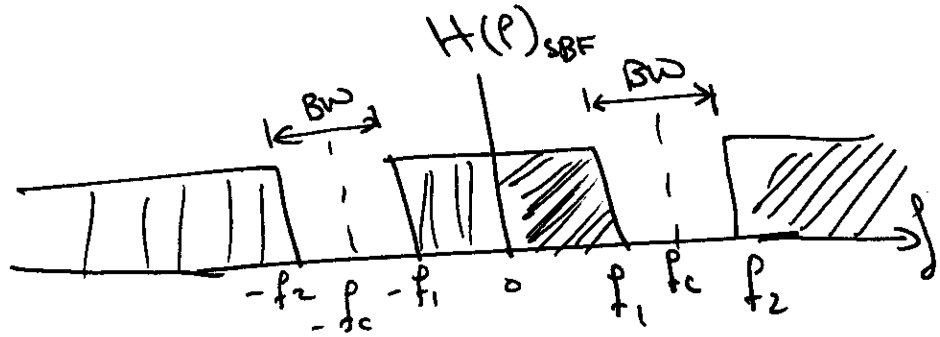
This filter select Band of frequenices between f_1 & f_2

$BW = f_2 - f_1$



4- Stop Band filter (SBF)

This filter reject only Band of frequencies than the ather



Convolution

The output of any system have by Convoluted Input with system Impulse responce

$f(t) \longrightarrow$ [$h(t)$] $\longrightarrow g(t)$

$$g(t) = f(t) \circledast h(t) \quad \text{--- (12)}$$

where

$$g(t) = \int_{-\infty}^{\infty} f(\tau) \cdot h(t-\tau)\, d\tau$$

$f(t)$: Input wave form

$h(t)$: System Impulse responce

$g(t)$: output wave Form

The output frequency domian done by mult Signal frequency ~~responce~~ Domian by system freq. responce

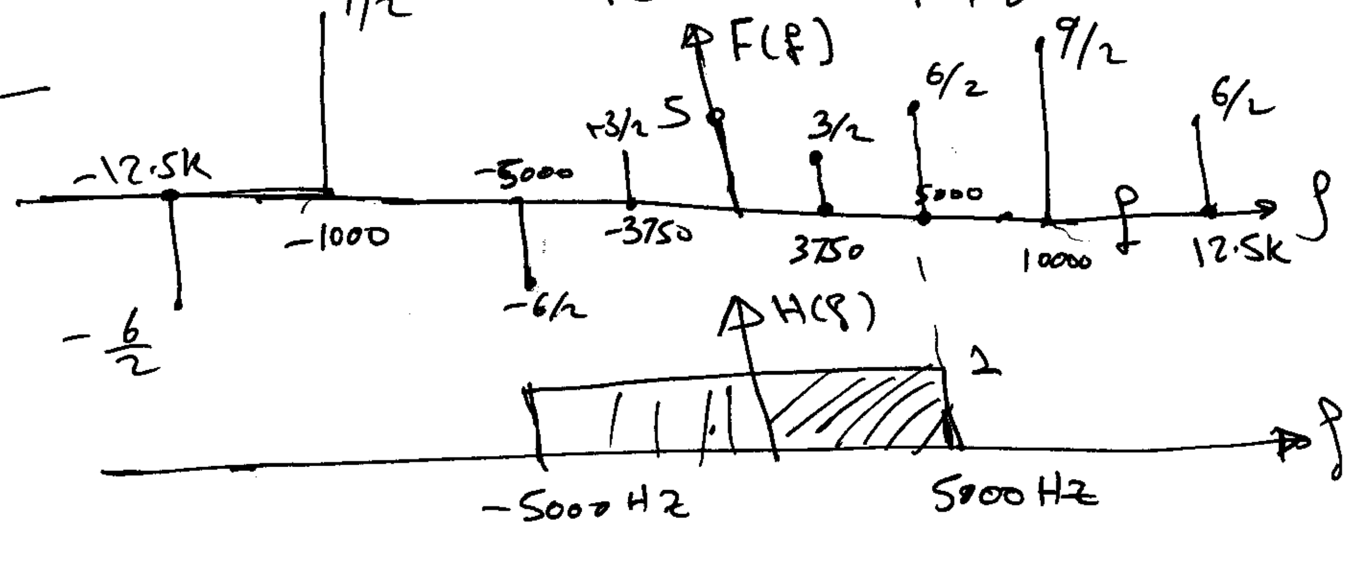
$$G(\omega) = F(\omega) * H(\omega) \quad \text{---(13)}$$

For that the output of any filter done by Multiply signal $F(\omega)$ spectran by filter spectran.

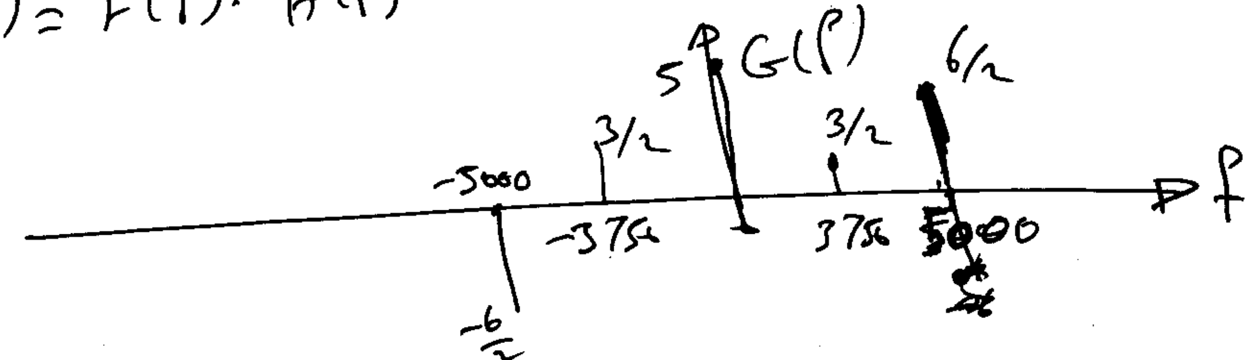
Exp/ an signal $f(t)$ Input through LPF of frequency 5000 Hz Find Power ratio between Input & output.

$$f(t) = 5 + 3\cos 7500\pi t + 6\sin 10000\pi t + 9\cos 20000\pi t + 6\sin 2500\pi t$$

Sol.



$$G(f) = F(f) \cdot H(f)$$



Input power (f(t))

$$Pav_{In} = \sum_{n=-\infty}^{\infty} |c_n|^2$$

$$= 5^2 + \frac{1}{2}(3^2 + 6^2 + 9^2 + 6^2) =$$

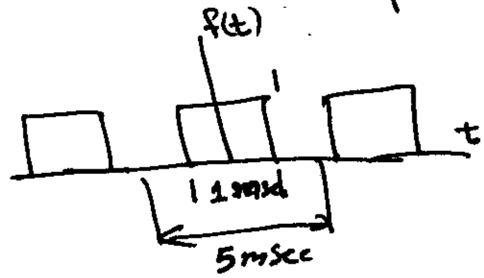
output power

$$Pav_{out} = 5^2 + \frac{1}{2}(3^2 + 6^2) = 115 \text{ watt}$$

$$\frac{P_{output}}{P_{In}} = \frac{115}{\quad} * 100\%$$

Exp / Trian of pulse shown f(t) pass through Block H(t) the output g(t). Find ratio between Input & output power

$$g(t) = 5 + 4.5\cos 400\pi t + 3.2\cos 600\pi t + 2.1\cos 800\pi t$$



Exp 8 / Draw spectram output of LPF (Wc = 100 rad/sec)
If Input frequency Domian $F(\omega) = 1/(5 + j\omega)$

2. Modulation Techniques

Modulation : Is that process by which a property or a parameter of a signal is varied in proportion to a second signal. The first signal call (Carrier).

- Carrier Signal $\phi(t) = A_c \cos w_c t$ (unmodulation signal)

A_c : carrier Amplitude (volt)

f_c : Carrier frequency $f_c = \frac{w_c}{2\pi}$ (Hz)

- Modulation Signal

$$\phi(t) = a(t) \cos(\theta(t))$$

In amplitude modulation (AM), $a(t)$ varies with Input signal when $\theta(t)$ Is fixed to carrier frequency $w_c t$

$$\phi_{Am}(t) = a(t) \cos(w_c t)$$

In frequency modulation (FM) & phase Modulation (PM) call angule modulation, $a(t)$ be constant at carrier Amplitude A_c and $\theta(t)$ will by varies with signal

$$\phi_{FM/PM}(t) = A_c \cos(\theta(t))$$

2-1 Amplitude Modulation (AM)

Transmitted of low pass signal waveform over the channel without modulation result probler In attunation Interferance & antenna design for that convert signal Into Band Pass signal (shift In frequency) by Modulation.

signal : $f(t)$
carrier : $A_c \cos w_c t$

$$\phi_{Am}(t) = (A_c + f(t)) \cos w_c t$$

The carrier Amplitude will by variaes with signal.

i- single tone signal

If $f(t) = A_m \cos w_m t$

A_m : ~~carrie~~ signal Amplitude
w_m : signal frequency

Then ~~mod~~ AM signal

$$\phi_{Am}(t) = (A_c + A_m \cos w_m t) \cos w_c t$$
$$= A_c (1 + m \cos w_m t) \cos w_c t$$

1) The ~~Bam~~ Low pass Signal

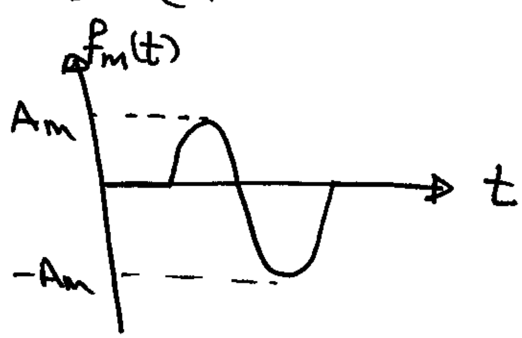
modulated signal $(f(t))$

$$\phi_{AM}(t) = A_c(1 + m f(t)) \cos w_c t$$

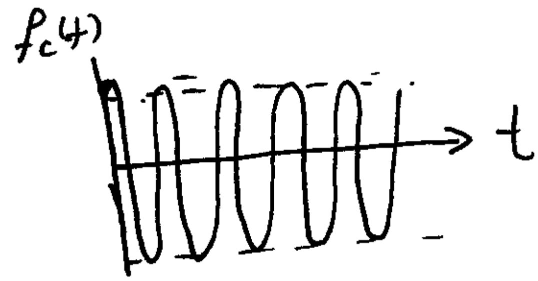
2-1.1 Time domian AM signal

Let ~~[illegible]~~ $f(t)$ unmodulated signal

& $f_c(t) = A_c \cos w_c t$



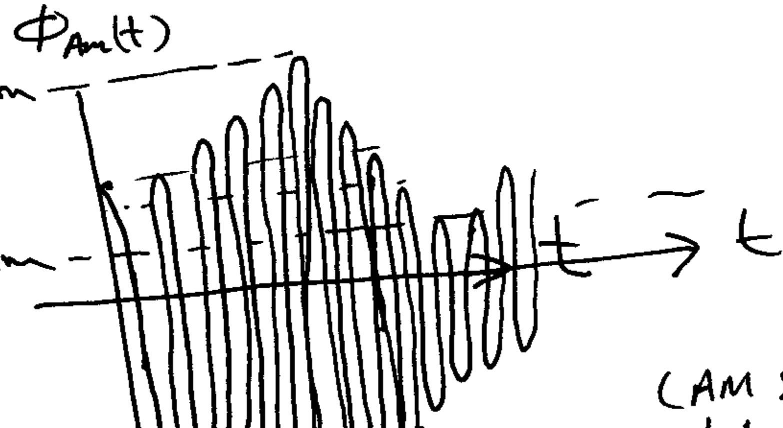
(signal)



(carrier)

$V_{max} = A_c + A_m$

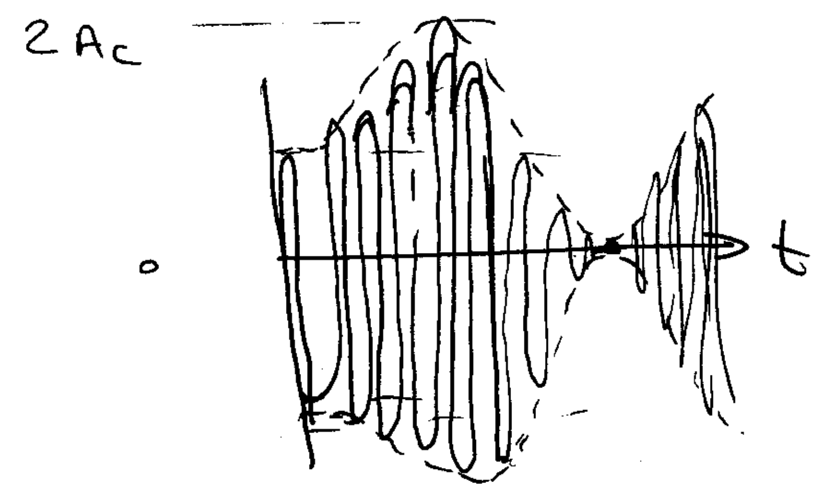
$V_{min} = A_c - A_m$



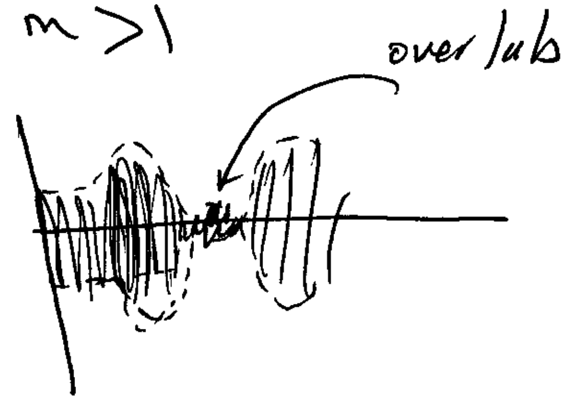
(AM signal)

$A_m \ldots V_{max} - V_{min}$

If $A_m = A_c$ $\quad m = 1$



If $A_m > A_c$ $\quad m > 1$



for that $m \leq 1$

2-1-2 AM spectrum & Bandwidth

i) For single tone signal $f_m(t) = A_m \cos w_m t$

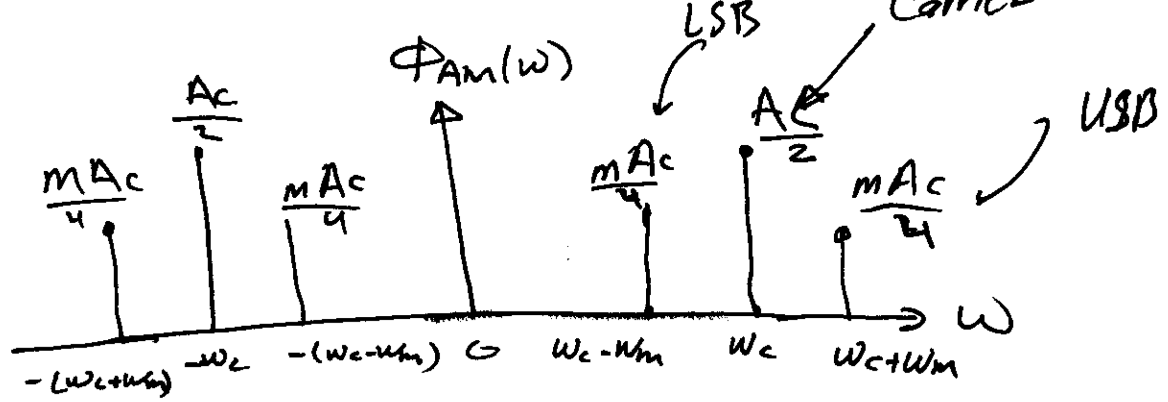
$$\phi_{Am}(t) = A_c(1 + m \cos w_m t) \cos w_c t$$

$$= A_c \cos w_c t + m A_c \cos w_c t \cos w_m t$$

$$= A_c \cos w_c t + \frac{m A_c}{2} \cos(w_c + w_m)t + \frac{m A_c}{2} \cos(w_c - w_m)t$$

$BW = 2 f_m$ Hz

For that spectram $\Phi_{AM}(w)$ will by



(AM spectram)

That compount call

carrier $(A_c \cos w_c t)$

upper side Band $\left(\frac{mA_c}{2} \cos(w_c + w_m)t\right)$ (USB)

Lower side Band $\left(\frac{mA_c}{2} \cos(w_c - w_m)t\right)$ LSB

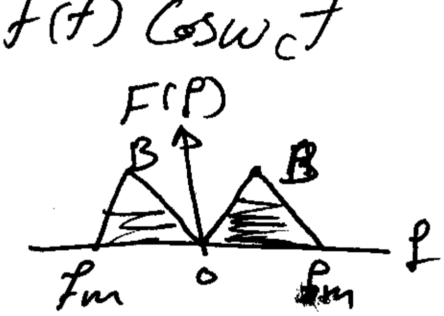
1B- spectram for pass Band signal (Low pass Signal)

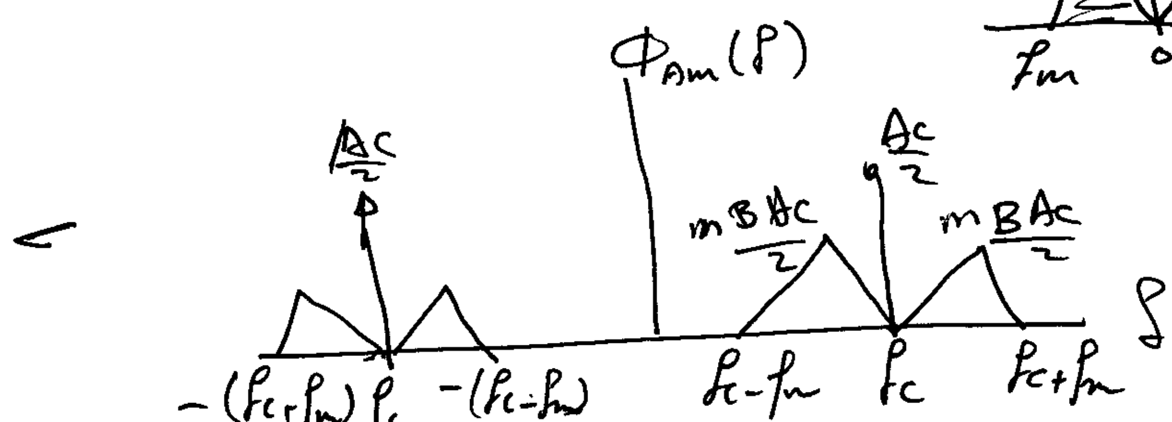
signal equation $f(t)$

$$\Phi_{Am}(t) = A_c(1 + m f(t)) \cos w_c t$$

$$= A_c \cos w_c t + m A_c f(t) \cos w_c t$$

signal spectram (can be as)





2.1.3 AM Power

The AM equation

$$\phi_{AM}(t) = \underbrace{A_c \cos w_c t}_{\text{Carrier}} + \underbrace{\frac{mA_c}{2}\cos(w_c+w_m)t}_{\text{USB}} + \underbrace{\frac{mA_c}{2}\cos(w_c-w_m)t}_{\text{LSB}}$$

$$P = \frac{V_{rms}^2}{R} = \frac{V_p^2}{2R}$$

Cos OR Sine Signal $V_{rms} = \frac{V_p}{\sqrt{2}}$

- The Carrier Power

$$P_c = \frac{A_c^2}{2R}$$

- Side Band Power (USB OR LSB)

$$P_{side} = \frac{\left(\frac{mA_c}{2}\right)^2}{2R} = \frac{m^2 A_c^2}{8R} = P_c \frac{m^2}{4}$$

- Sides Bands Power

$$P_{sides} = 2P_{side} = \frac{m^2 A_c^2}{4R} = P_c \frac{m^2}{2}$$

- Total power

$$P_T = P_c + P_{sides} \qquad P_T = P_c\left(1 + \frac{m^2}{2}\right)$$

- Modulation efficiency $\eta = \frac{P_{sides}}{P_T} = \frac{m^2}{2+m^2}$

Hint: If signal Consist of mult. tone modulation index used In equation m_{eff} (affective mod-Index)

m_{eff} ... $m_1 =$ ...

Exp/ an modulated signal $f(t) = 5\cos 5000\pi t$ modulated In AM signal with carrier $f_c(t) = 20\cos 500000\pi t$

Find
① AM equation
② Draw AM spectrum & find Bandwidth
③ Calculate P_C, P_T, m
④ If signal change $f_2(t) = 3\cos 5000\pi t$ + 6 sin 5500πt + 10 cos 5900πt

Find P_T and

Sol

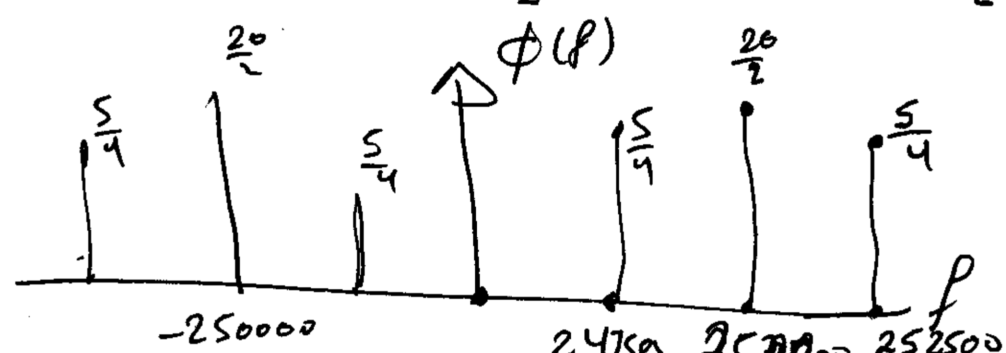
$$\phi_{AM}(t) = (20 + 5\cos 5000\pi t)\cos 5\pi \times 10^5 t$$

$$= 20\,(1 + 0.25\cos 5000\pi t)\cos 5\pi \times 10^5 t$$

$A_c = 20$
$m = 0.25$
$\omega_c = 5\pi \times 10^5$ rad/sec $\qquad f_c = 2.5 \times 10^5$ Hz
$W_m = 5000\pi$ rad/sec $\qquad f_m = 2500$ Hz

② AM spectrum

$$\phi_{AM}(t) = 20\cos 5\pi \times 10^5 t + \frac{5}{2}\cos(5\times10^5 + 5\times10^3)\pi t + \frac{5}{2}\cos(5\times10^5 - 5\times10^3)\pi t$$



$BW = 2f_m = 2 \cdot 2500 = 5000$ Hz

$$P_c = \frac{\left(\frac{20}{2}\right)^2}{2R} = 50 \text{ watt} \qquad R \approx 1$$

$$P_T = P_c \left(1 + \frac{m^2}{2}\right) = 51.5625 \text{ watt}$$

$$P_{side} = 2 P_{USB} = P_T - P_c = 1.5625 \text{ watt}$$

$$\eta = \frac{P_{USB}}{P_T} = \frac{m^2}{2 + m^2} = 1.5625 \%$$

(4) $f_2(t) = 3 \cos 5000\pi t + 6 \sin 5500\pi t + 10 \cos 5900\pi t$

$$m_{eff} = \sqrt{m_1^2 + m_2^2 + m_3^2}$$

$$m_1 = \frac{3}{20} = 0.15$$

$$m_2 = \frac{6}{20} = 0.3$$

$$m_3 = \frac{10}{20} = 0.5$$

$$m_{eff} = \sqrt{0.15^2 + 0.3^2 + 0.5^2} = 0.602$$

$$P_T = P_c \left(1 + \frac{m_{eff}^2}{2}\right) = 59.0601 \text{ watt}$$

Exp_1 / an modulating signal shown Find P_T & Draw spec.

$$\phi(t) = 10(1 + 0.2 \sin 500\pi t) \cos 5000\pi t$$

what type of mod.? why?

Exp_2 / an AM waveform equal to 500W is 75% modulated Calculate the transmitting power? If antenna Resistance 50 Ω Find all spectrum Compounent voltage (peak voltage).

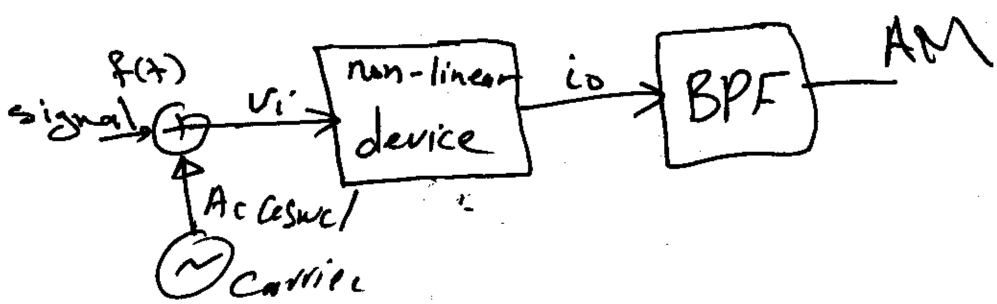
2.1.4 AM modulater

There are two type of AM generator

1- non Linear AM generator (modulator)
2- Linear AM generator (chopper)

dependent of element characteristics of material used In circut.

i) non Linear AM modulator



non linear device equation

$$i_o = a_0 + a_1 v_i + a_2 v_i^2 + ---$$

$a_0, a_1, -- a_N$: element parameter

Exp/

$$i_o = a_0 + a_1 v_i + a_2 v_i^2 \qquad v_i = f(t) + A_c \cos w_c t$$

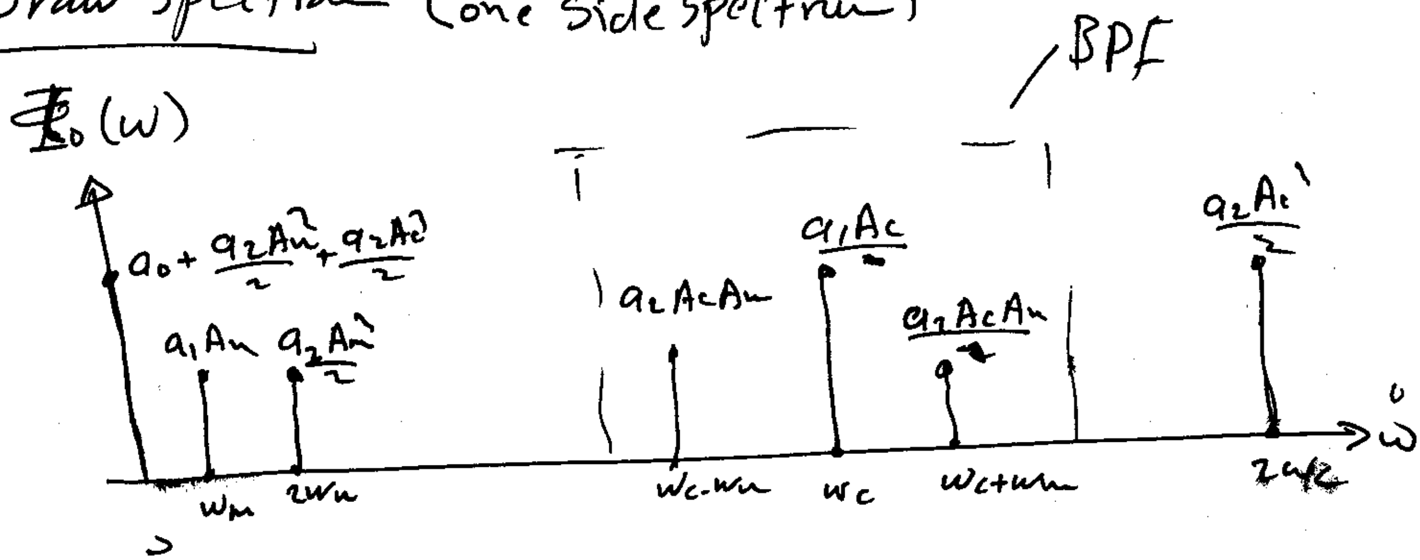
$$i_o = a_0 + a_1 (f(t) + A_c \cos w_c t) + a_2 (f(t) + A_c \cos w_c t)^2$$

let $f(t) = A_m \cos w_m t$ single tone

$$i_o = a_0 + a_1 A_m \cos w_m t + a_1 A_c \cos w_c t + a_2 (\ldots$$

$$i_o = a_0 + a_1 A_m \cos w_m t + a_1 A_c \cos w_c t + \frac{a_2 A_m^2}{2} + \frac{a_2 A_m^2}{2}\cos 2w_m t$$
$$+ \frac{2a_2 A_c A_m}{2}\cos(w_c + w_m)t + \frac{2a_2 A_c A_m}{2}\cos(w_c - w_m)t + \frac{a_2 A_c^2}{2} + \frac{a_2 A_c^2}{2}$$
$$\cos 2w_c t$$

(ii) Draw spectrum (one side spectrum)



after used BPF of $f_{center} = f_c$

$$2f_m \leq BW < (2f_c - 2f_m)$$

The output will be

$$V_o(t) = a_1 A_c + a_2 A_c A_m \cos(w_c + w_m)t + a_2 A_c A_m \cos(w_c - w_m)$$
$$= a_1 A_c \left(1 + \frac{2a_2}{2a_1} A_m \cos w_m t\right) \cos w_c t$$

for that modulation index In this cel-

can by know as

2.1.5 - Double side Band SUPPRESSED CARRIER DSB-SC

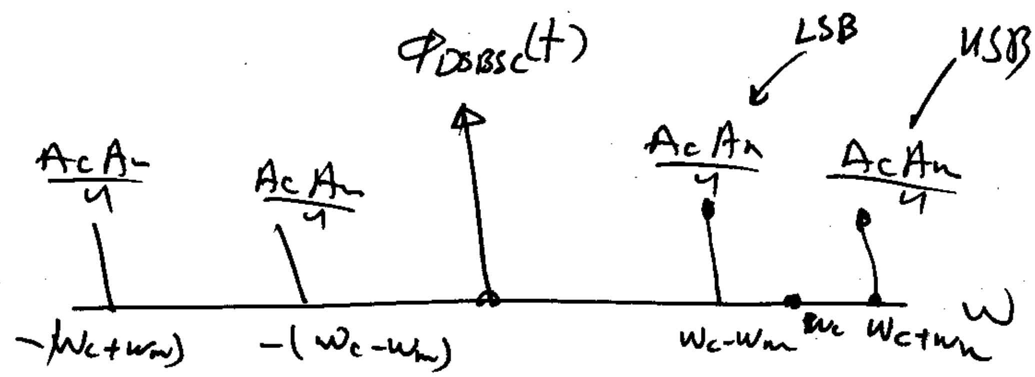
This type of AM Contian USB, LSB without Carrier because all Information headed In sides and carrier dont have any Information

$$\Phi_{DSBSC}(t) = f(t) * A_c \cos w_c t$$

i) Single tone Signal

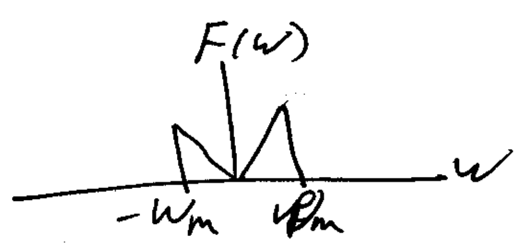
$$f(t) = A_m \cos w_m t$$

$$\Phi_{DSBSC}(t) = \frac{A_m A_c}{2} \cos(w_c + w_m)t + \frac{A_m A_c}{2} \cos(w_c - w_m)t$$

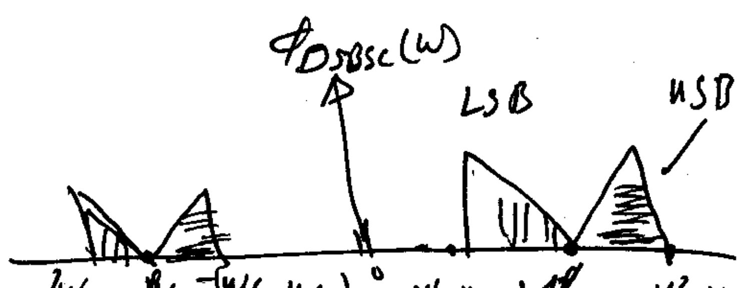


ii) Lowpass signal

$f(t)$



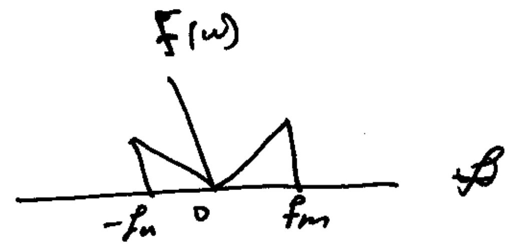
$$\Phi_{DSBSC}(t) = f(t) \cos w_c t$$



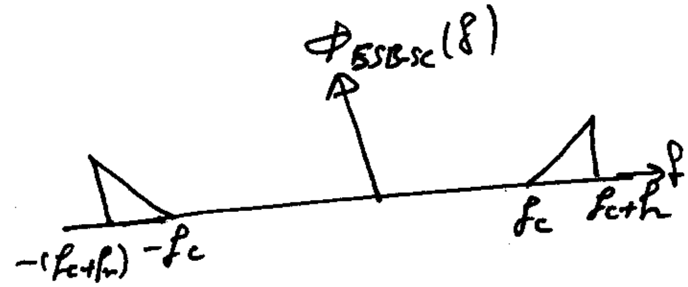
21.6 Single Side Band suppressed Carrier (SSB-SC)

This type of AM contian only at USB or LSB only by this way power will used to Transmit one side with min Band width To transmitted signal.

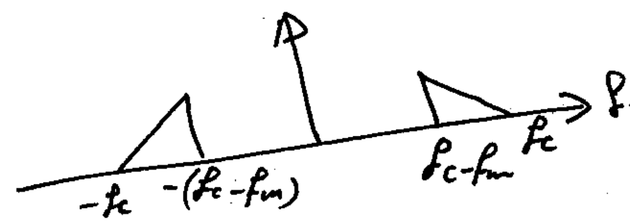
SSB-SC spectrum



SSB-SC (USB)



SSB-SC (LSB



$\Phi_{SSB-SC}(t) = f(t)\cos w_c t + \hat{f}(t)\sin w_c t$ (USB)

$\Phi_{SSB-SC}(t) = f(t)\cos w_c t - \hat{f}(t)\sin w_c t$ (LSB)

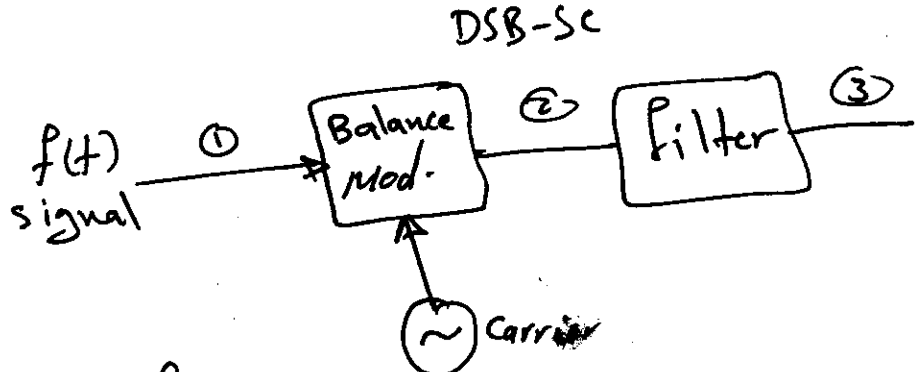
$$BW_{SSB-SC} = f_m$$

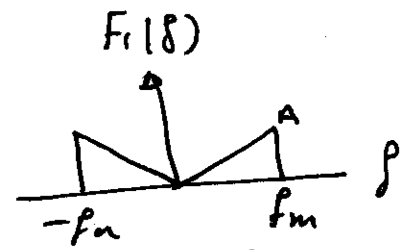
2.1.6.1 SSB-SC Modulator

There are two methods

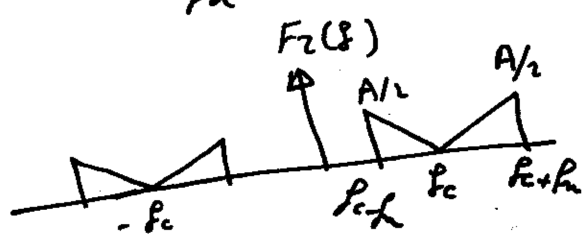
i- Filter method

used DSB-sc modulator than used filter to select one ~~meth~~ side



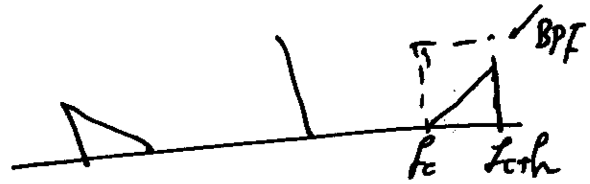


$f_2(t) = f(t) \cos w_c t$



generate SSB-SC

$f_3(t) =$

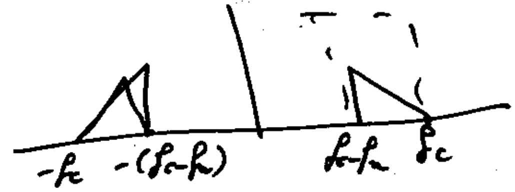


USB

BPF of ~~fcenter~~ $f_1 = f_c$
$f_2 = f_c + f_m$

oR used HPF $f_c \geq f_c$

(LSB)

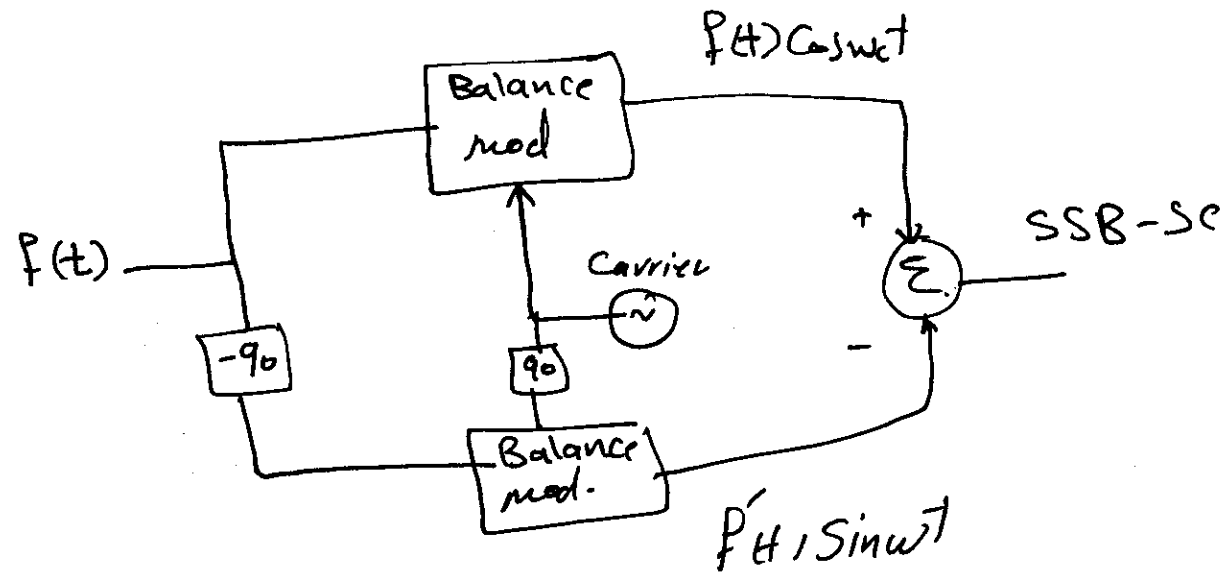


BPF of $f_1 = f_c - f_m$
$f_2 = f_c$

oR LBF $f_{cut} = f_c$

$BW = f_m$

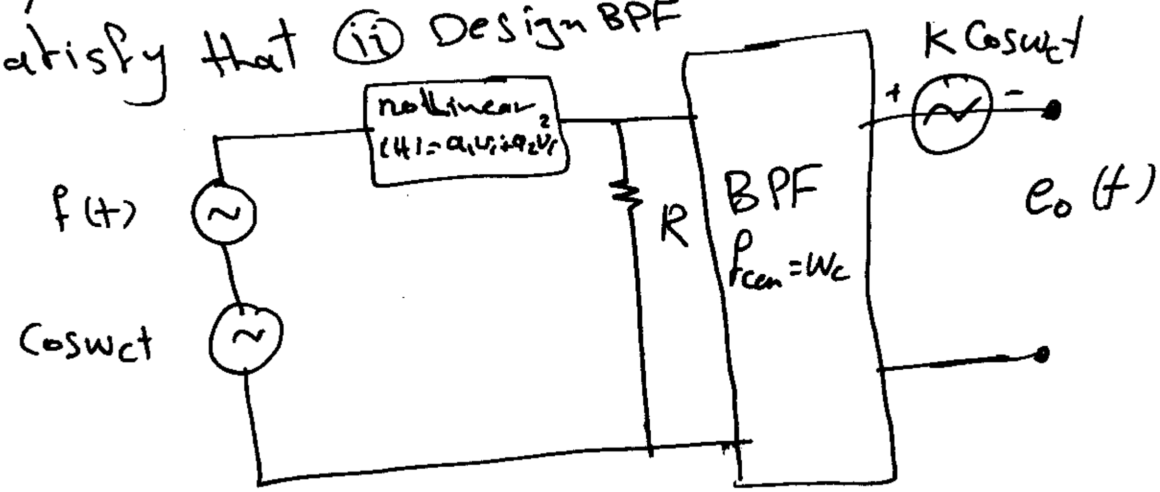
ii) phase shift methods



$\Phi_{USB}(t) = f(t)\cos\omega_c t + f'(t)\sin\omega_c t$

$\Phi_{LSB} = f(t)\cos\omega_c t - f'(t)\sin\omega_c t$

Exp/ (i) The model to generat DSB-SC find value of k to satisfy that (ii) Design BPF

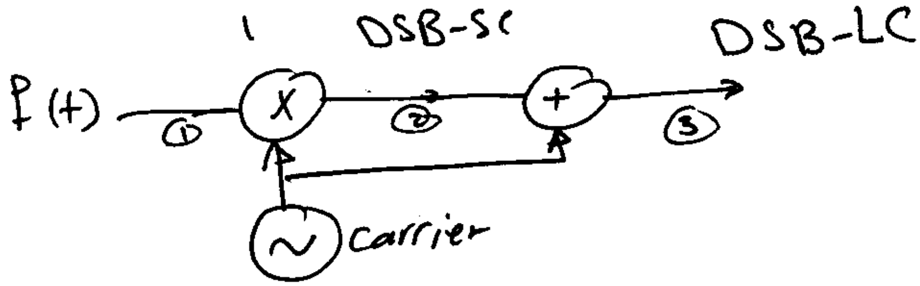


Exp₂/ SSB-SC Modulator (filter method) Design all circut & filter to generat USB If Input signal

$f(t) = 2\cos 500\pi t + 3\cos 1000\pi t$

2.17 Generation of DSB-LC (Double Side Band - Large Carrier)

first generat DSB-SC then add some carrier this carrier help Receiver to synchrononsied the carrier of Receiver

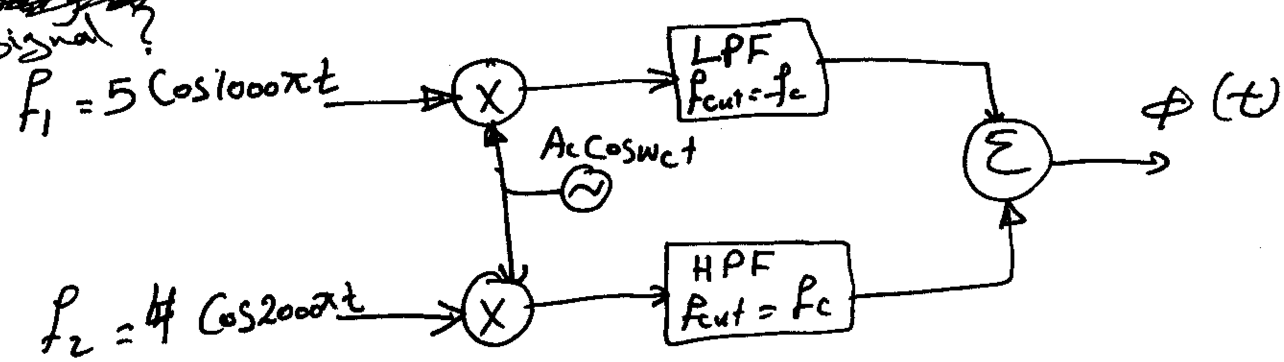


① $f_1(t)$

$f_2(t) = A_c f(t) \cos w_c t$

$f_3(t) = A_c f(t) \cos w_c t + A_c \cos w_c t = A_c (1 + f(t)) \cos w_c t$

Exp/ The system shown below generated two signal of SSB-SC can transmitted at the same channel find spectrum at every point ①, ②, ③, ④, ⑤ & 6 + time domain signal?



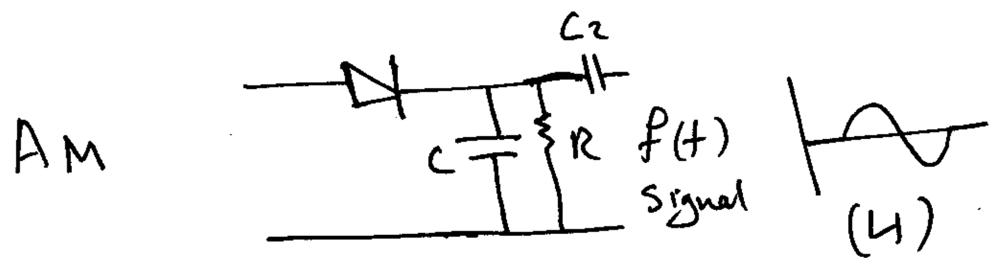
2.18 AM - Demodulator

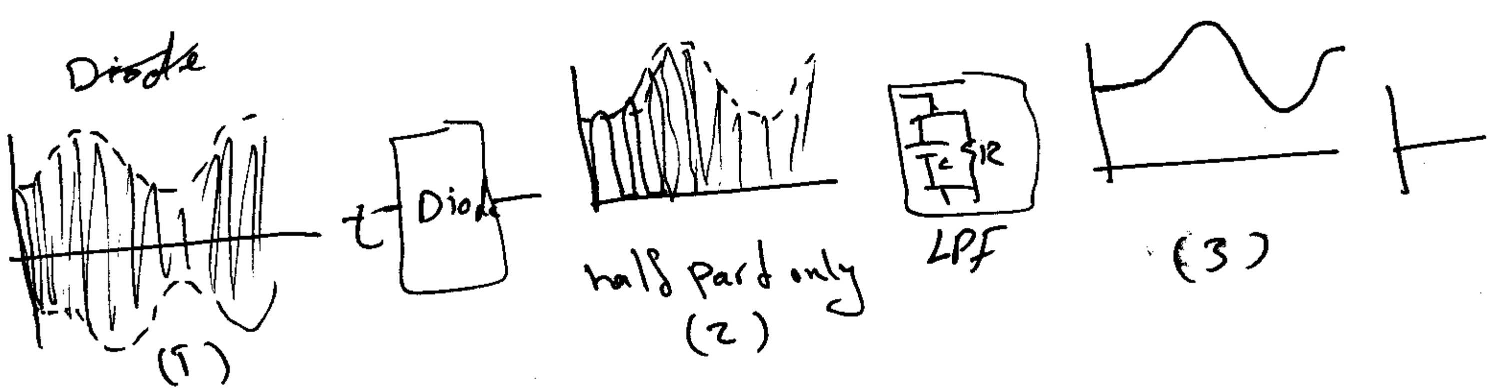
This sircut used In Receiver and can detect Signal (massage) from Modulated Signal.

There are two method to detect AM signal and ather type of AM (DSB-SC, SSB-SC, DSB-LC)

i- non-Linear demodulator or (Squar Low detector)

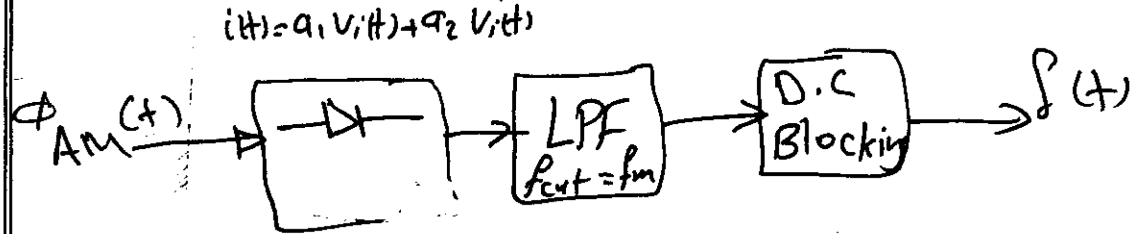
This method used diode (non Linear device) & LPF as shown





- by diode half part of signal used
- by RC (LPF) charge and discharge signal to generat Low pass Signal
- by used C_2 (D.C Blocking) Remoived D.C Signal from result Signal

Nonlinear demodulator Block Diagram

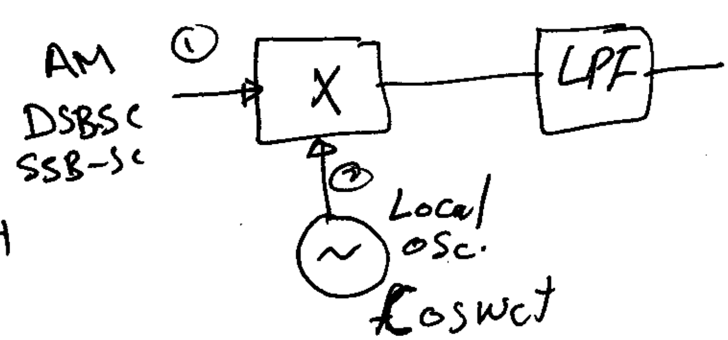


Exp/ For the Block Diagram shown upper If Input Signal $\phi_{AM}(t) = A_c(1 + m\cos w_m t)\cos w_c t$ prove all part work? by spectrum Drawing

Exp$_2$/ Prove by using nonlinear device Can not detect DSB-SC

ii) synchronous Demodulator

This type of demodulator used Mixer to detect signal and Can detect AM, DSB-SC OR SSB-SC

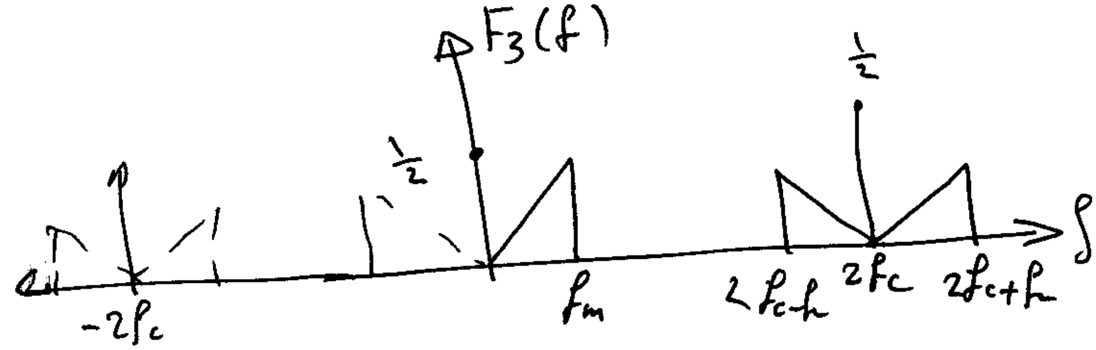


$f_1(t) = \cos w_c t + f(t)\cos w_c t$

$f_2(t) = \cos w_c t$

$f_3(t) = f_1(t) \cdot f_2(t)$

$(\cos w_c t + f(t)\cos w_c t) \cdot \cos w_c t = \frac{1}{2} + \frac{1}{2}\cos 2w_c t + \frac{f(t)}{2} + \frac{f(t)}{2}$



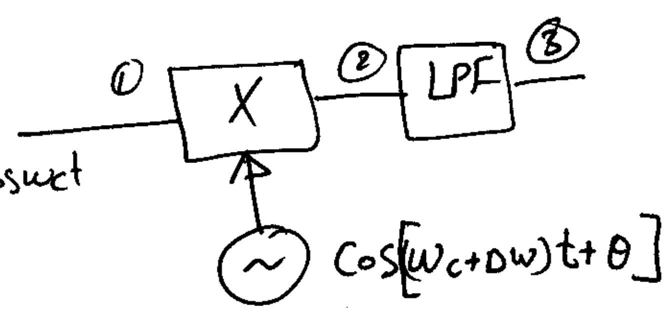
by using LPF $f_m \le f_{cut} < 2f_c - f_m$

can reject signal

$$f_4(t) = \frac{1}{2} + \frac{1}{2} f(t)$$

This Modulation call synchronous because the carrier generated from Local osc. must by equal In frequency and phase different to the modulation carrier

DSB-SC



$$f_1(t) = f(t)\cos w_c t$$

$$f_2(t) = f(t)\cos w_c t \cdot \cos(w_c+\Delta w)t+\theta$$

$$= \frac{1}{2} f(t)\cos(\Delta w t+\theta) + \frac{1}{2} f(t)\cos[(2w_c+\Delta w)t+\theta]$$

after LPF

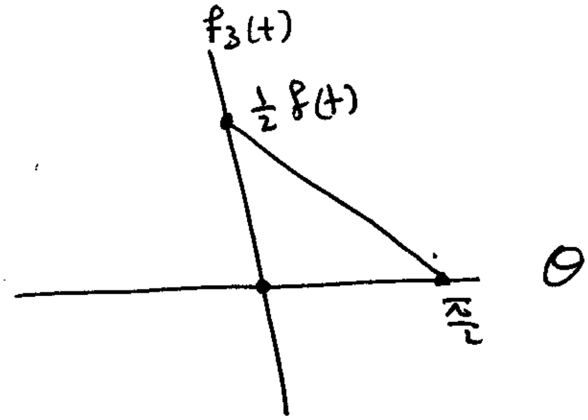
$$f_3(t) = \frac{1}{2} f(t)\cos(\Delta w t+\theta)$$

① If $\Delta w = 0$ phase different only

$$f_3(t) = \frac{1}{2} f(t)\cos\theta$$

If phase different by $\theta = \frac{\pi}{2}$ the output = 0

$f_3(t) = 0$



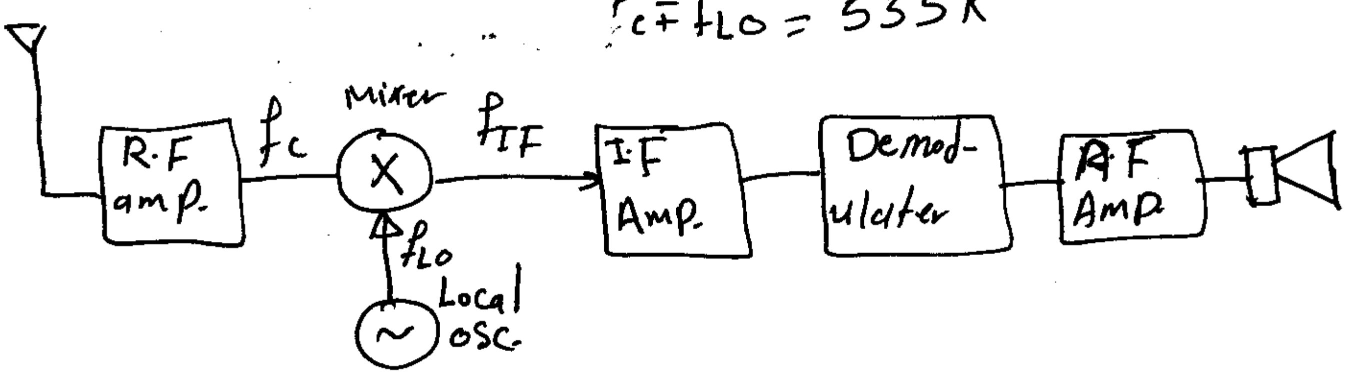
② $\theta = 0$. only different In freq. $\Delta\omega$

$f_3(t) = \frac{1}{2} f(t) \cos \Delta\omega t$

this $\cos\Delta\omega t$ will reduce and attunate the output by noise.

AM Receiver Block Diagram

$f_c \mp f_{LO} = 535K$



Three stage

① RF (Radio frequency) f_c

② IF (Intermidant freq) $f_{IF} = 535$ KHz

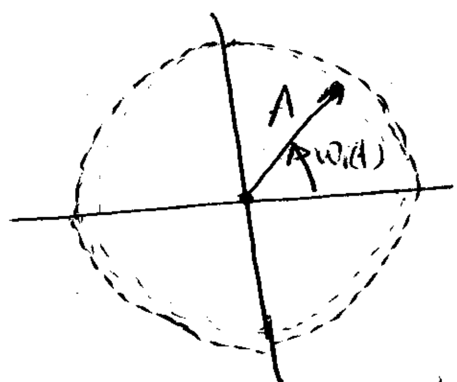
$f_{IF} = f_c \mp f_{Local\,osc.}$

③ AF (Audio frequency) hair Signal

3- Angle Modulation

In angle modulation the phase angle is Varied in proportion to f(t) (signal).

The phasor representation of a Constant-amplitude sinusoid is shown below.



If the angular rate is not Constant, we can still write a relation between the Instantaneous angular rate $w_i(t)$ and $\theta(t)$

$$w_i(t) = \frac{d\theta}{dt} \Rightarrow \theta(t) = \int w_i(t)\,dt$$

In Angle modulation modulated Signal equation

$$\phi(t) = A_c \cos\theta(t)$$

The Instanouse frequency $w_i(t)$

3-1 FM (frequency mod.)

$$w_i(t) = w_c + K_f f(t) \quad \text{For FM}$$

K_f: FM Constant rad/volt·sec

$$\text{If } f(t) = A_m \cos w_m t \quad (\text{single tone})$$

$$w_i(t) = w_c + K_f A_m \cos w_m t$$

$$\theta(t) = \int w_i(t)\, dt$$

$$\theta(t) = w_c t + \frac{k_f A_m}{w_m} \sin w_m t$$

Then the FM equation

$$\phi_{FM}(t) = A_c \cos[w_c t + m_f \sin w_m t]$$

m_f = modulation Index $= \frac{\Delta f}{f_m} = m_f$

Δf : frequency diviation $2\pi \Delta f = k_f \cdot A_m$

$\Delta w = k_f A_m$

General FM equation

$$\phi_{FM}(t) = A_c \cos[w_c t + k_f \int f(t)\, dt]$$

3.2 PM (phase modulation)

$$\theta(t) = w_c t + k_p f(t)$$

k_p: PM constant

for single tone

$$\phi_{pm}(t) = A_c \cos[w_c t + \Delta\phi \cos w_m t]$$

$\Delta\phi$: ~~phase deviation~~ Max phase diviation $\Delta\phi = k_p \cdot A_m$

General Equation of PM

Example 1 an angle Modulator (FM, PM) of unmodulated Carrier $f_c(t) = 100\cos 50\times10^5\pi t$ and Input signal $f_m(t) = 3\cos 5000\pi t$ If modulator have $k_f = 500\pi$ rad/sec $K_p = 10$ Find FM & PM equation

sol.

FM output

$$f_m(t) = 3\cos 5000\pi t$$

$$\omega_i(t) = \omega_c + k_f f(t)$$

$$= 50\times10^5\pi + 500\pi * 3\cos 5000\pi t$$

$$\theta_i(t) = 50\times10^5\pi t + \frac{1500\pi}{5000\pi}\sin 5000\pi t$$

$$\phi_{FM}(t) = 100\cos[50\times10^5\pi t + 0.3\sin 5000\pi t]$$

$$m_f = 0.3$$

PM output

$$\theta_i(t) = \omega_c t + k_p \cdot f(t)$$

$$= 50\times10^5\pi t + 10 * 3\cos 5000\pi t$$

$$= 50\times10^5\pi t + 30\cos 5000\pi t$$

$$\phi_{PM}(t) = 100\cos[50\times10^5\pi t + 30\cos 5000\pi t]$$

$$\Delta\phi = 30$$

Q1 / Find the outputs of that systems If signal by ① $f_m(t) = 10e^{-50t}$ ② $f_m(t) = 30t^2 + 5t + 3$ than Find Instanous frequency & phase at time $t = 5$ msec.

Example 3

An FM modulator have input signal voltage 5 volt and 3 KHz have max. frequency divation 30 KHz. If the signal change as shown calculate modulation index

1. signal frequency doubled
2. signal voltage by 15 volt
3. signal voltage 15 volt signal freq. 10 KHz

Sol / Hint from the equation $\Delta f = \frac{K_f A_m}{2\pi}$ Hz

Δf undependent of signal frequency fm but on signal amplitude only

① $m_f = \frac{\Delta f}{f_m} = \frac{30K}{6K} = 5$

② $K_f = \frac{\Delta f * 2\pi}{A_m} = \frac{30K * 2\pi}{5 \text{ volt}} = 12K\pi$

$\Delta f_{new} = \frac{K_f \cdot A_m}{2\pi} = \frac{12K\pi * 15}{2\pi} = 90 \text{ KHz}$

$m_f = \frac{\Delta f}{f_m} = \frac{90K}{3K} = 30$

③ Δf_{new} for $A_m = 15V$ $= 90 \text{ KHz}$

$m_f = \frac{90K}{10K} = 9$

3.2 Narrowband FM [redacted]

For small value of modulation index m_f

If single tone $f(t) = A_m \cos\omega_m t$

$$\phi_{FM}(t) = A_c \cos[\omega_c t + m_f \sin\omega_m t)$$

$$\phi_{FM}(t) = A_c\left[\cos\omega_c t \cos[m_f \sin\omega_m t] + \sin\omega_c t \sin(m_f \sin\omega_m t)\right]$$

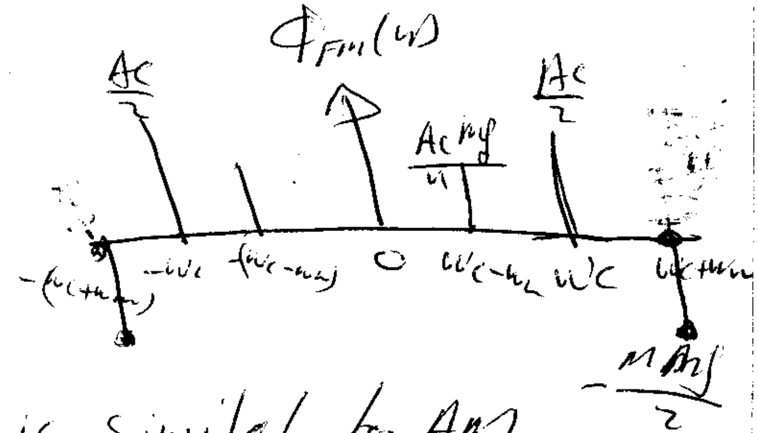
For small m_f

$\cos\theta = 1$
$\sin\theta = \theta$ } $\lim \theta \to 0$

$$\phi_{FM}(t) = A_c \cos\omega_c t + A_c \sin\omega_c t \cdot m_f \sin\omega_m t$$

$$= A_c \cos\omega_c t + \frac{A_c m_f}{2}\cos(\omega_c + \omega_m)t - \frac{A_c m_f}{2}\cos(\omega_c - \omega_m)t$$

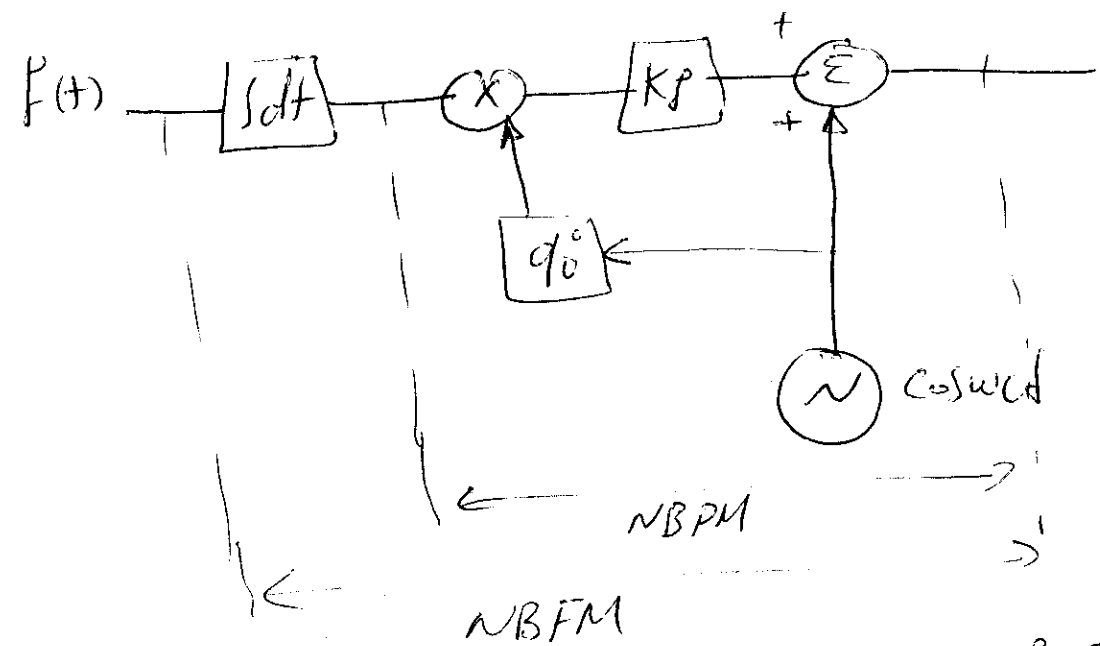
Spectrum of NBFM



- For that spectrum of NBFM is similar to AM except phase shift in USB by 90°

$$BW_{NBFM} = 2 f_m \quad (1\text{-}12) \qquad \text{for } m_f < 0.2$$

The FM (NBFM) generator



This system work to generate NBFM If Integration Remove the curcuit by NBPM If remove 90° phase shift by DSB-LC (AM).

3.3 Wide Band Frequency Modulation WBFM

3.3 The FM Signal

$$\phi_{FM}(t) = A_c \left[\cos\omega_c t + m_f \sin\omega_m t \right]$$

Expanding the exponential modulation term in series

$$\phi_{FM}(t) = A e^{j\omega_c t} \left(1 + j m_f \sin\omega_m t - \frac{1}{2!} m_f^2 \sin(\omega_m)t^2 - j\frac{1}{3!} m_f^3 \right.$$
$$\left. \sin^3\omega_m t + \cdots \right.$$

at using numerical soultion

$$\phi_{FM}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(m_f) \cos(w_c + n w_m)t$$

where $J_n(m_f)$ is Bessel function of n order depend on m_f (modulation index)

$$\phi_{FM}(t) = A_c J_0(m_f) \cos w_c t + J_1(m_f)\left[\cos(w_c + w_m)t - \cos(w_c - w_m)t\right]$$
$$+ J_2(m_f)\left[\cos(w_c + 2w_m)t - \cos(w_c - 2w_m)t\right]$$

⋮

all value of $|J_n(m_f)| \geq 0.01$ when the other nuclacted to approximate signal by 1%

~~[illegible]~~

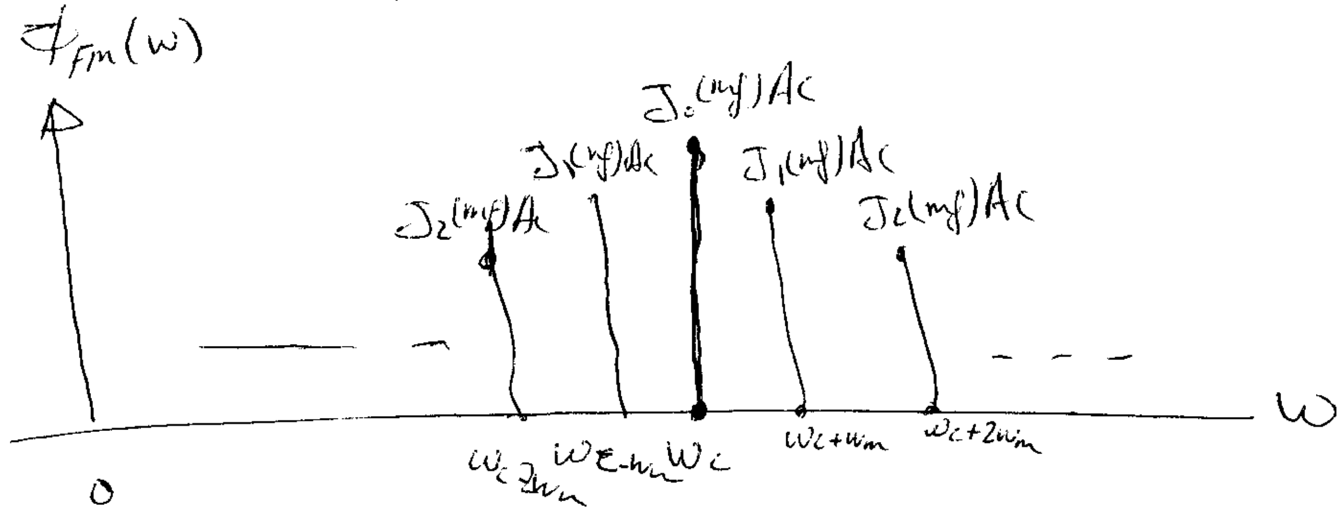
The characteristics of Bessel function?

1- $J_n(m_f)$ are real valued
2- $J_n(m_f) = J_{-n}(m_f)$ for even
3- $J_n(m_f) = -J_{-n}(m_f)$ for odd
4- $\sum_{n=-\infty}^{\infty} J_n^2(m_f) = 1$

as shown In figure (6-9) P.292 stremidl

3.4 FM spectrum

The FM spectrum depend on m_f and Bessel value $J_n(m_f)$



Exact FM Bandwidth

$$BW_{exact} = 2 \cdot n \cdot f_m$$

n; max value of m_f

approximate FM BW

$m_f < 0.2$ for NBFM $\quad BW = 2f_m$

$0.2 < m < 30$ for WBFM $\quad BW \approx 2f_m(m_f + 1)$

for Large m_f $\quad BW = 2\Delta f$

Average Power in FM

The single tone signal have modulating signal

$$\phi_{FM}(t) = A_c \cos(w_c t + m_f \sin w_m t)$$

by using series analysis

$$\phi_{FM}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(m_f) \cos(w_c + n w_m)t$$

- The unmodulated carrier power $\boxed{P_{cun.} = \frac{A_c^2}{2R}}$
- when modulated signal power

$$\boxed{P_T = P_{cun.} \left[J_0^2(m_f) + 2\left(J_1^2(m_f) + J_2^2(m_f) + \cdots \right) \right]}$$

when $\sum_{n=-\infty}^{\infty} J_n^2(m_f) \approx 1$

$$P_T \approx P_{cun.}$$

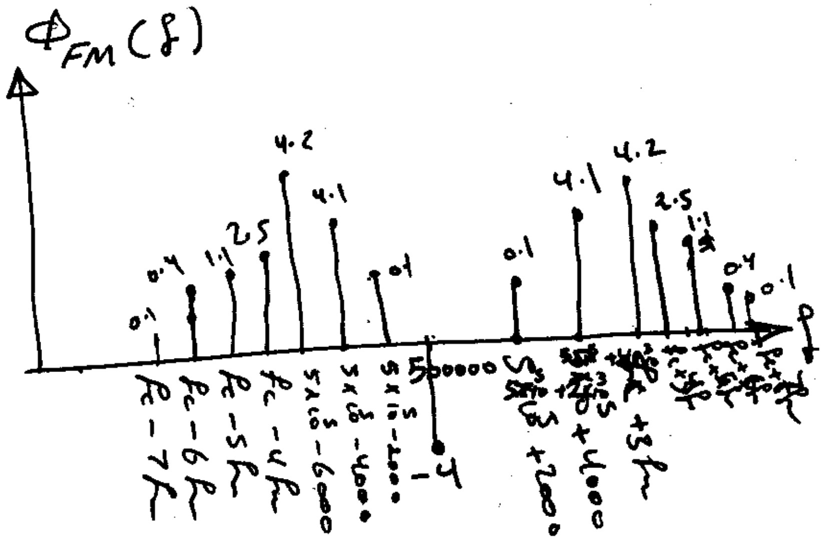
Exp./ show that r.m.s value of FM signal by

$$\phi_{rms}(t) = \sqrt{\overline{\phi^2(t)}} = A_c \sqrt{\frac{J_0^2(m_f) + 2\sum_{n=1}^{\infty} J_n^2(m_f)}{2}}$$

Exp/ an FM signal shown

$$\phi_{FM}(t) = 10\cos[10^6\pi t + 3.8\cos 4000\pi t]$$

① Draw Modulation signal spectrum
② Calculate Modulation index and max. freq. divation
③ Exact Band width and approximat Band width
④ unmodulated carrier power into 50 Ω resistive Load
⑤ second and third sides power
⑥ peak voltage of the Fourth side haramonic



Sol.

$m_f = 3.8$

$J_0(3.8) = -0.4$
$J_1(3.8) = 0.01$
$J_2(3.8) = 0.41$
$J_3(3.8) = 0.42$
$J_4(3.8) = 0.25$
$J_5(3.8) = 0.11$
$J_6(3.8) = 0.04$
$J_7(3.8) = 0.01$

②

$m_f = 3.8$

$$\Delta f = m_f \cdot f_m = 3.8 * 2000 = 7.6\,\text{kHz}$$

③ $BW_{exact} = 2f_m \cdot n = 2*2000*7 = 28000\,\text{Hz} = 28\,\text{kHz}$

$BW_{approximated} = 2f_m(\beta+1) = 2*2k(3.8+1) = 19.2\,\text{kHz}$

④ $$P_{C_{un.}} = \frac{A_c^2}{2R} = \frac{(10)^2}{2\times 50} = 1\,\text{watt}$$

⑤ $P \; + P \; = 2 \cdot P \; [J_2^2(3.8) + J_3^2(3.8)]$

6) $V_{Fourth} = A_c J_4(3.8)$ (peak)

$= 10 * 0.25$

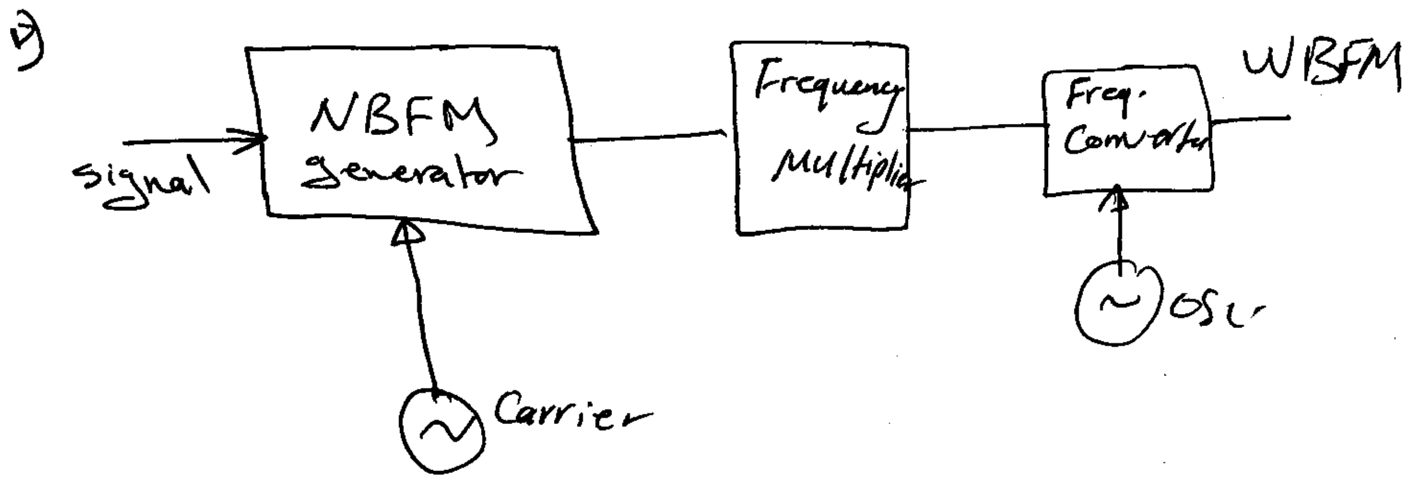
$V_{Fourth} = 2.5$ volt.

Generation of WBFM

There are two method to generate WBFM (wide Band frequency Modulation)

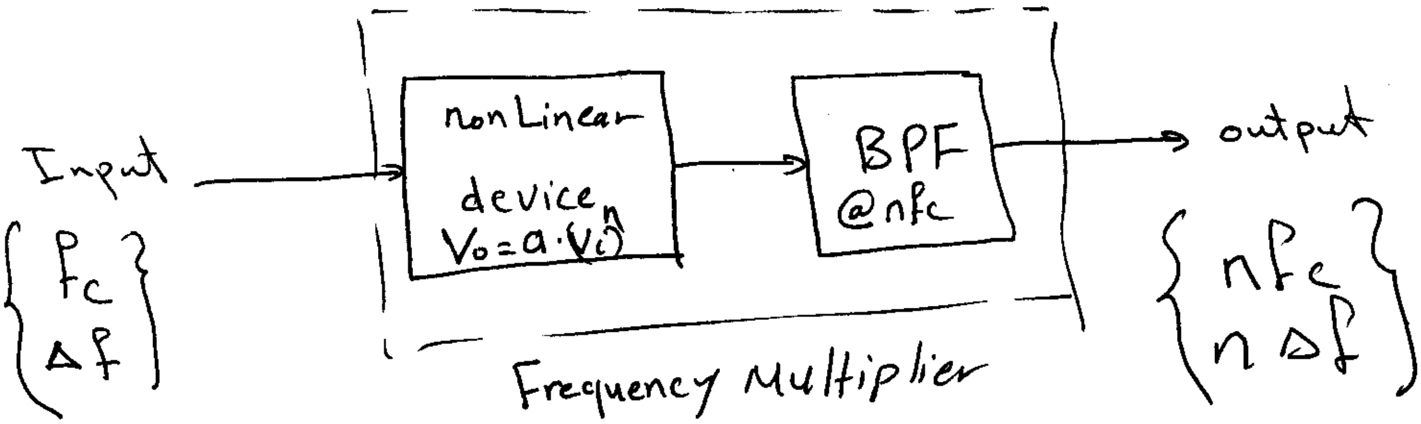
i) In direct method

By this method NBFM by generated then Increasing Bandwidth by using (Frequency Multiplier) and shifted carrier by (frequency Converter) to generate WBFM.



1) Frequency Multiplier

It's non Linear device and BPF that used to Multipliy frequency (carrier) by a factor (n)



Frequency Multiplier by n

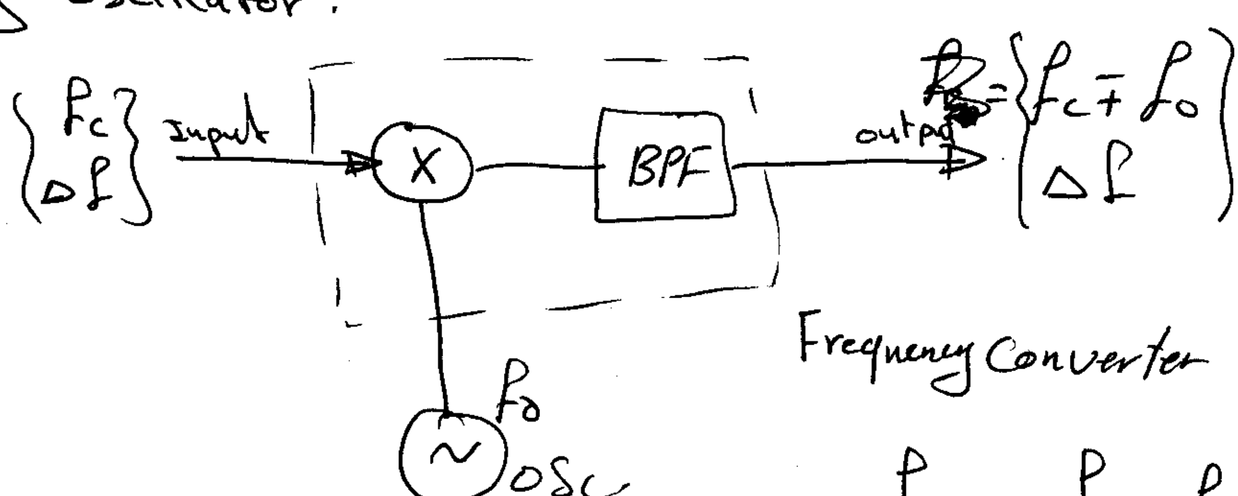
both (f_c & Δf) by growing and multipliy by (n)

$$f_{c_{out}} = n f_{c_{In}}$$

$$\Delta f_{out} = n \Delta f_{In}$$

2) Frequency Converter

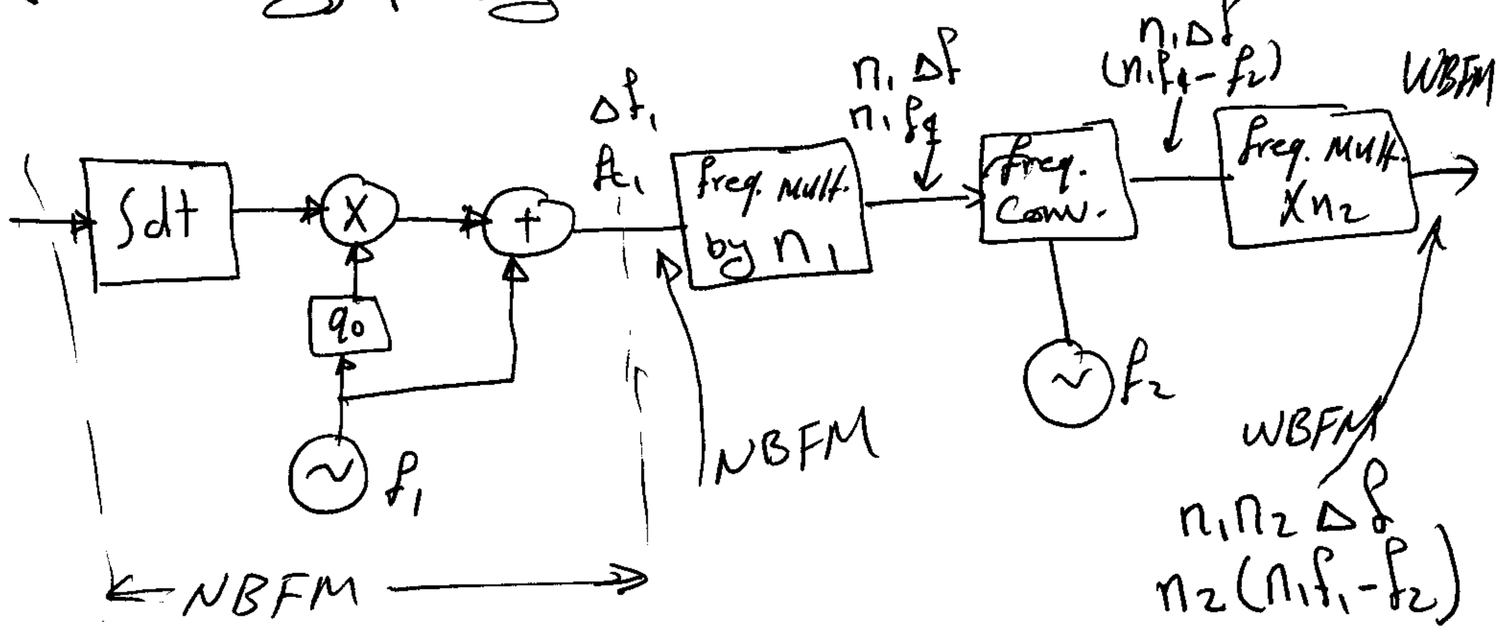
This device Convert carrier of Signal to new freq. by using oscillator.



Frequency Converter

$$f_{c_{out}} = f_{c_{In}} \mp f_o$$

The Block diagram of an Indirect FM generator (Armstrong) FM generater shown below



ii) Direct FM Modulator

In the direct method of generating FM the modulating signal directly controls the carrier frequency. An attempt is usually to generated WBFM.

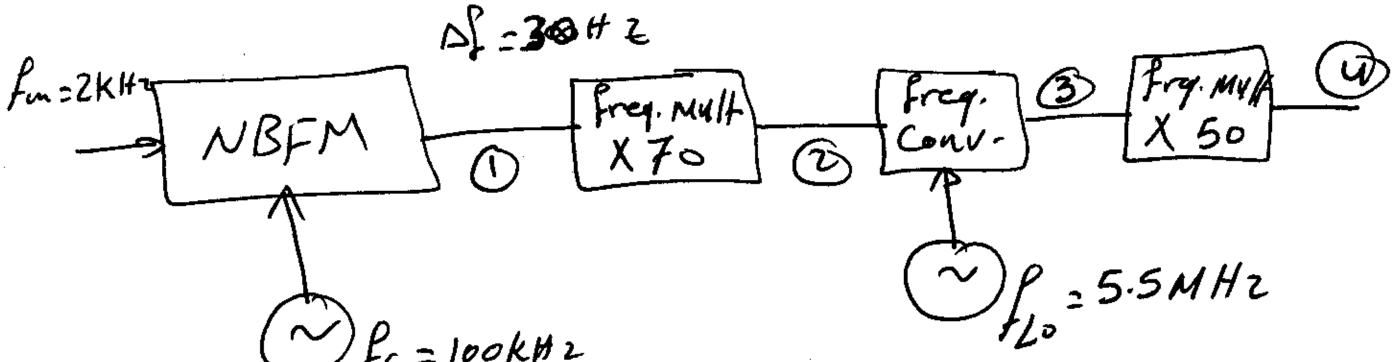
To generate FM direct used Inductive and capacitor (oscillator)

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

Then controll by Input signal at capacitor to generated FM Signal. Examples used

1) Varactor diode
2) FET

Example For the Block Diagram shown Find : carrier frequency, Δf, and Band width If signal frequency $f_m = 2KHz$



sol.

① Point (1)

$\Delta f = 30 Hz$

$f_c = 100 KHz$

$BW = 2 f_m = 4KHz$ (NBFM)

$m_f = \frac{30}{2K}$ 0.015

② $\Delta f = 70 * 30 = 2.1 KHz$

$f_c = 70 * 100k = 7MHz$

$m_f = 1.05$

$BW = 2 f_m (m_f + 1) = 8.2 KHZ$

③ $\Delta f = 2.1 kHz$

$f_{c_3} = f_{c_2} - f_{Lo} = 1.5 MHZ$

$m_f = 1.05$

$BW = 8.2 KHz$

④ $\Delta f = 50 * 2.1K = 105 KHZ$

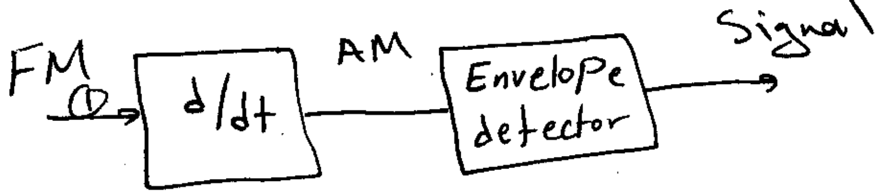
$f_{c4} = f_{c_3} * 50 = 75 MHZ$

Demodulation of FM signal

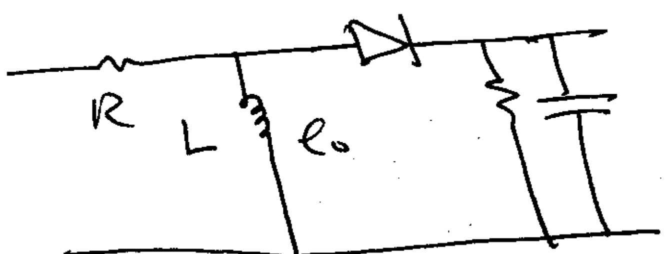
There are two methods, depend on type of detection

i) Direct method

one method is to use some system which has a linear frequency-to-voltage transfer characteristic call *frequency Discriminator*.



Differentiator



R-L discriminator

Point 1 FM equation

$$\phi_{FM}(t) = A_c \cos\left[w_c t + k_f \int f(t)\, dt\right]$$

Point 2

$$\frac{d\phi_{FM}(t)}{dt} = -A_c \left[w_c + k_f f(t)\right] \sin\left[w_c t + k_f \int f(t)\, dt\right]$$

This signal $\left(\frac{d\phi_{FM}(t)}{dt}\right)$ Contian Information variance In amplitude & frequency

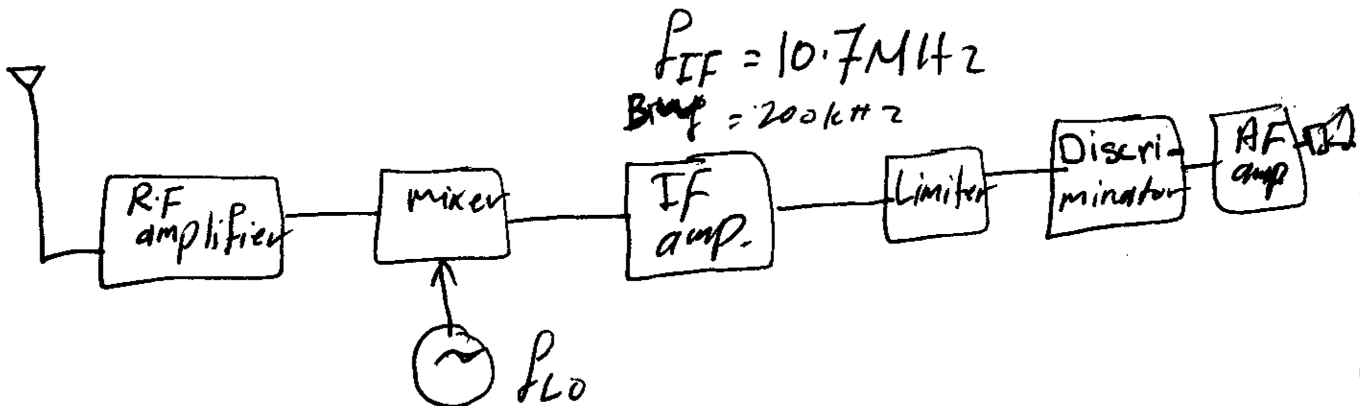
$$\ldots = A_c w_c \left[1 + \frac{k_f}{\ldots} f(t)\right]$$

$$f_3(t) = A_c w_c + A_c k_f \, f(t)$$

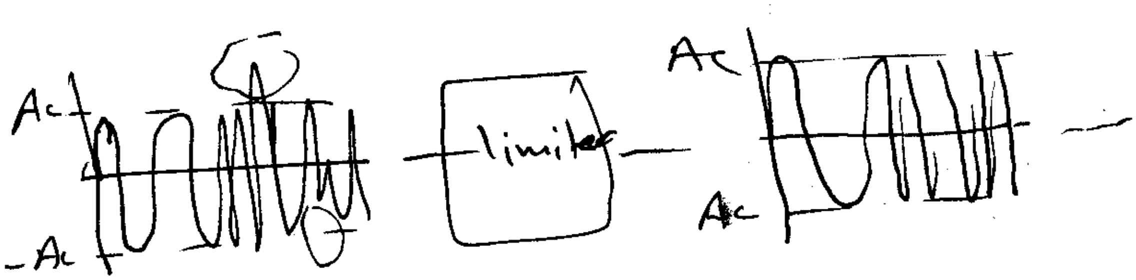
by using D.C Blocking to Remove $A_c w_c$

$$f_3(t) = A_c k_f \, f(t)$$

FM Receiver



- I.F frequency In FM (10.7MHz)
- Limiter; used to Remove any noise In Amplitude and fixed it at Ac



F.M Receiver have high Quality Signal ~~for that used~~ Transmitted by using UHF 88-108 MHz

(fm)

Frequency Division Multiplixing (FDM)

It's possible to send several signals simultaneously by choosing a different carrier frequency for each signal.

These carrier frequencies are chosen so that the signal spertra are not ~~overlabing~~ overlapping.

There are two type of carrier
1. main carrier (main modulation)
2. sub carrier (sub modulation)

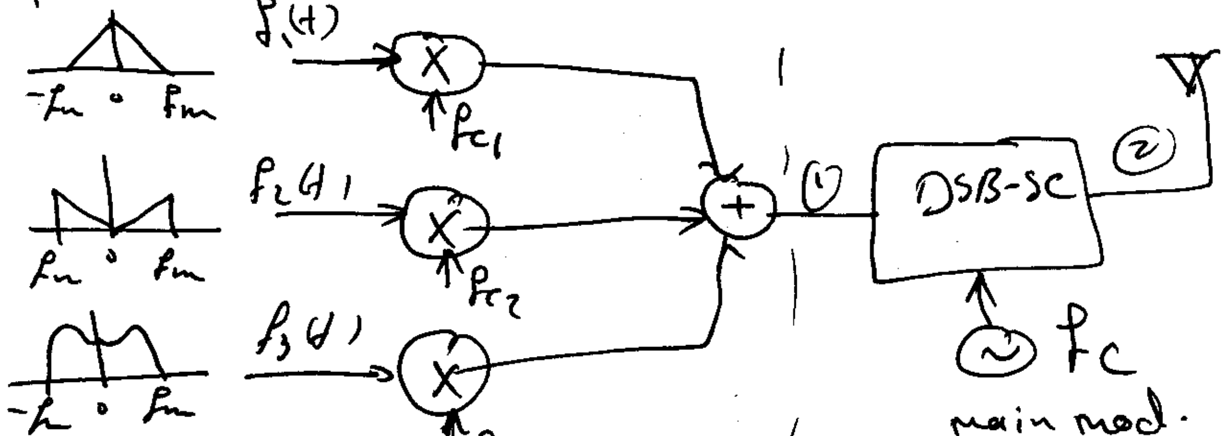
$$\text{Total Bandwidth} = n\,(BW_{signal} + f_g)$$

n: no. of channel (FDM)

BW_{signal} : sub modulation Bandwidth

f_g : guard frequency

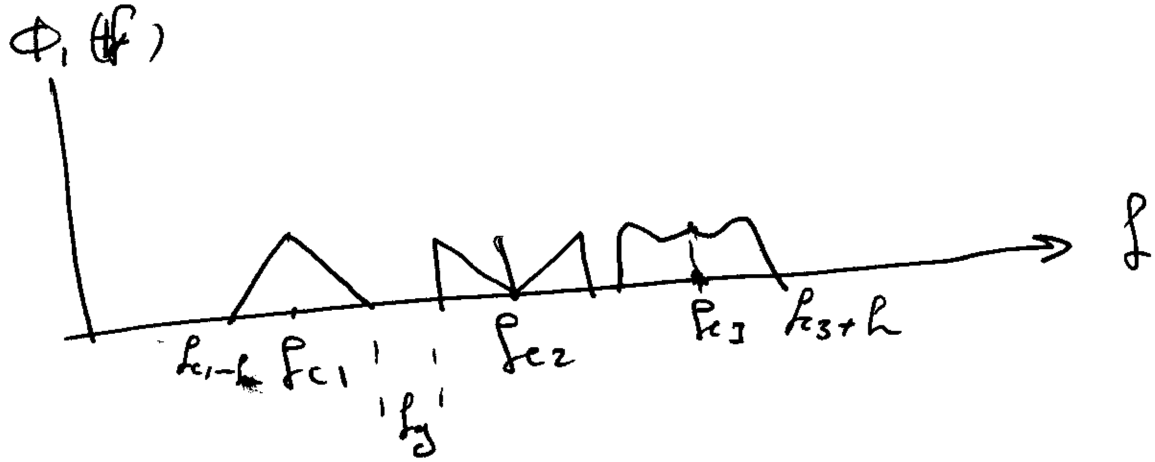
Exp/ used Three signal shown to draw output spetram



sub carrier frequency

f_{c1}, f_{c2}, f_{c3}

no. of subcarrier = 3



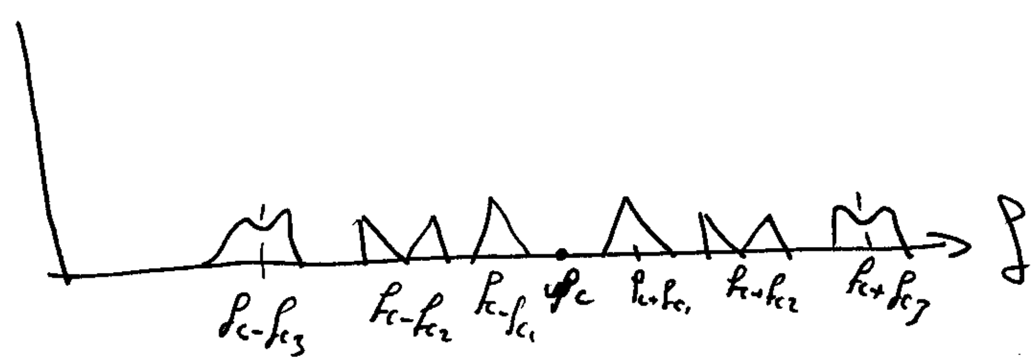
$BW_{T_{sub.}} = 3(2f_m + f_g)$

when signal

$\Phi_1(t) = f_1(t)\cos w_{c1}t + f_2(t)\cos w_{c2}t + f_3(t)\cos(w_{c3}t)$

after main modulation

$\Phi_T(t) = \Phi_1(t) \cdot \cos w_c t$ $\qquad f_c > f_{c3} > f_{c2} \dots$



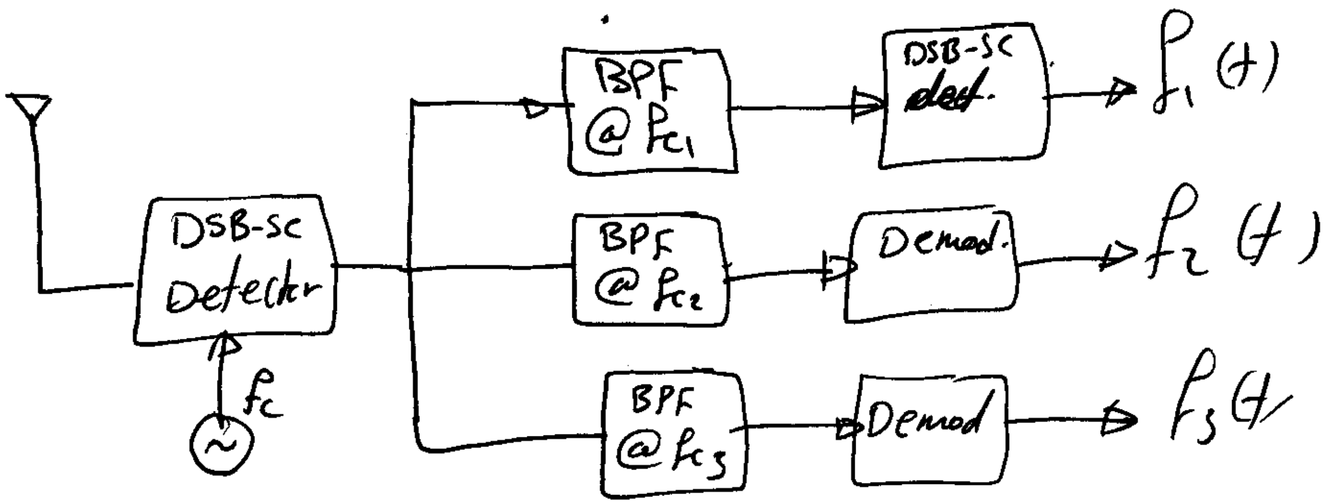
$BW_T = 2\, BW_1$

$= 6(2f_m + f_g)$

FDM Receiver

To Received FDM used Mult- stag

1. used BPF with different carrier frequency
2. Detected In main modulation
3. Detect sub modulation



by using BPF with different center frequency Caud sperated every multiplixing System.

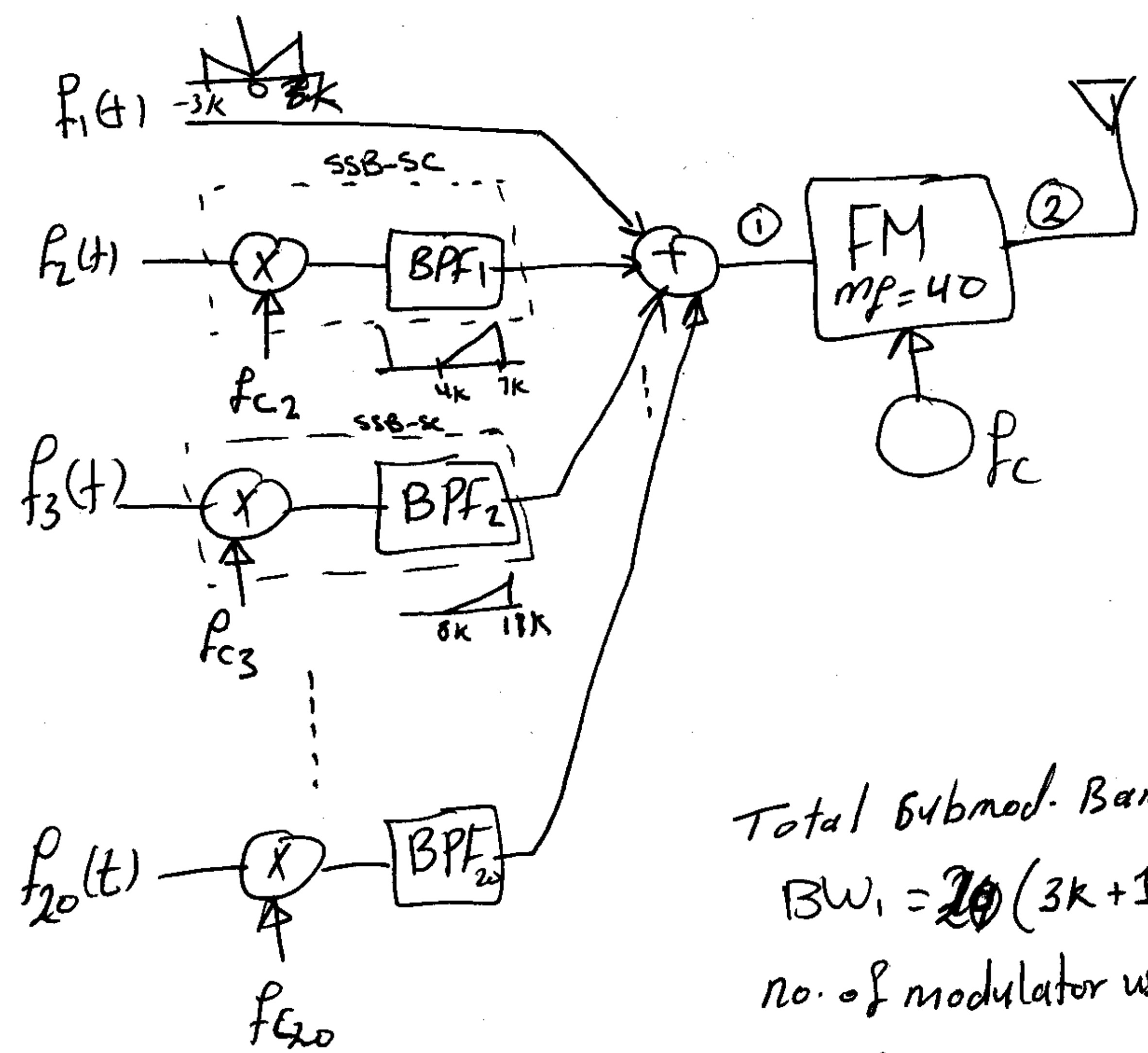
Hint

- Main & sub modulation Can used any type of analoge oR Digital Modulation Like (AM, DSB-SC, SSB-SC & FM)
- In Exchanger used SSB-SC as ~~main~~ submodulator and FM as main modulated.

Exp/ Design FDM system to Multiplixed 20 channel used SSB-SC (USB) as sub carrier and FM of $m_f = 40$ as main modulation (Hint: Signal Low pass Signal of $f_m = 3kHz$ & gard frequency $f_g = 1kHz$, $f_{c_1} = 0Hz$)

Sol.

① Design sub modulation to mod. SSB-SC

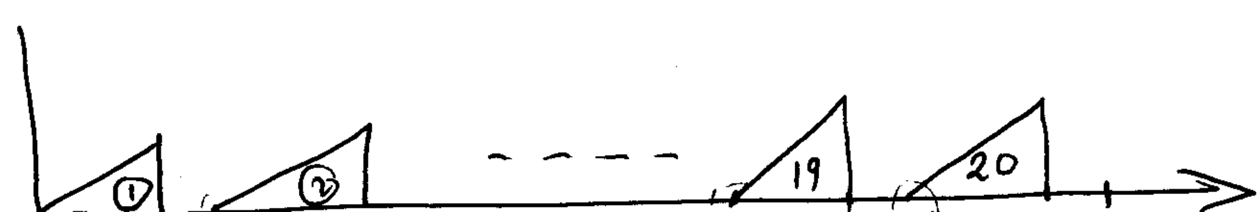


Total Submod. Bandwidth

$BW_1 = 20(3k + 1k) = 80kHz$

no. of modulator used $= n-1 = 20-1 = 19$

no. of carrier used $= 19$



From spectral

$f_{c2} = 4KHz$ $\quad f_{c7} = 24KHz$ $\quad f_{c20} = 76KHz$

$f_{c3} = 8KHz$ $\quad f_{c8} = 28KHz$

$f_{c4} = 12KHz$ $\quad f_{c9} = 32KHz$

$f_{c5} = 16KHz$

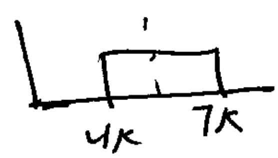
$f_{c6} = 20KHz$

(B) Design BPF for modulator

BPF1/

$BW_2 = 3KHz$

$f_{cen_2} = 5.5KHz$



BPF2/ $BW_3 = 3KHz$

$f_{cent_2} = 9.5KHz$

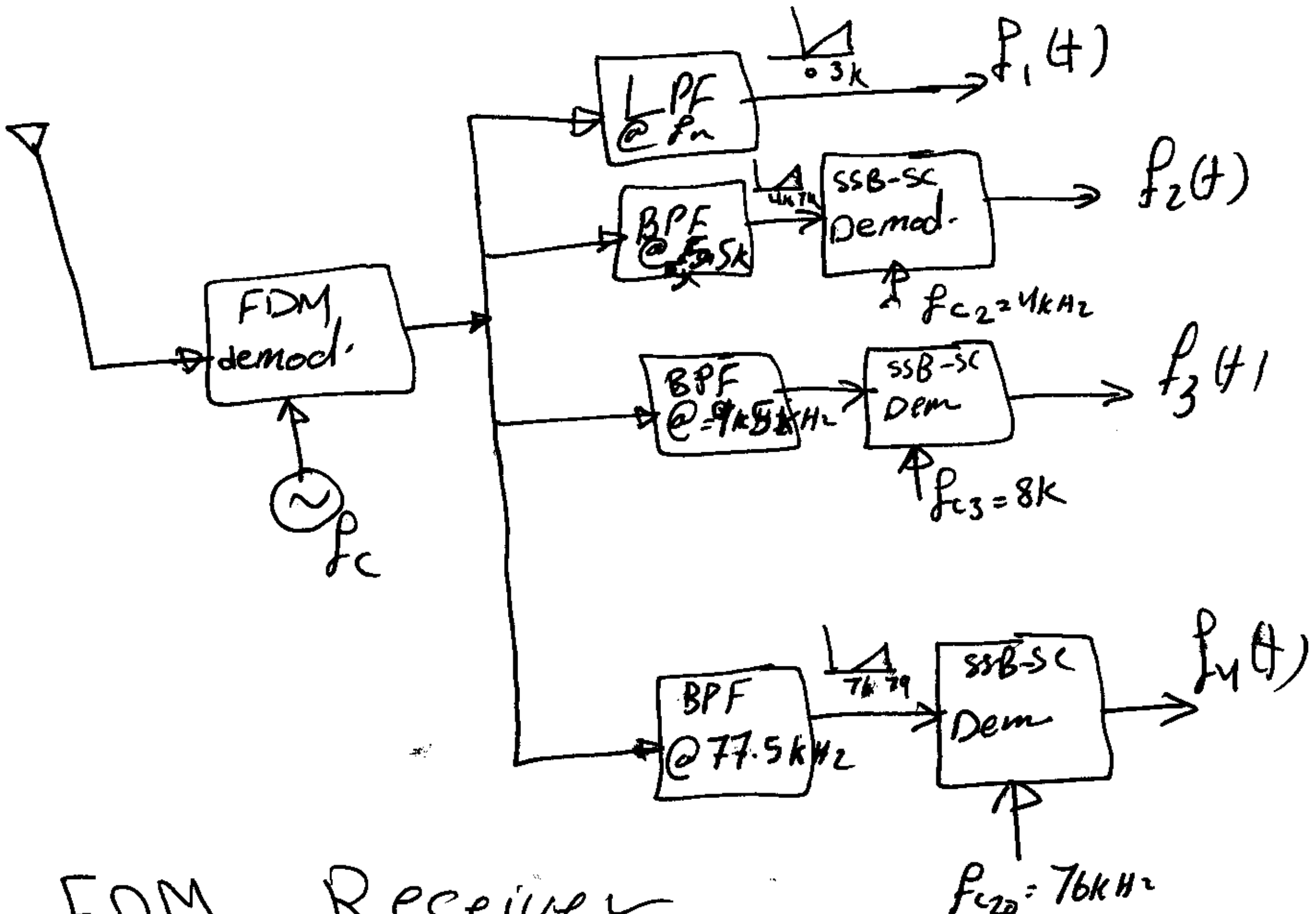
Total Bandwidth

$BW_{FM} = 2BW_1(M_f + 1)$

$= 2 \cdot 80KHz\,(4+1) =$

De

Design FDM Receiver



FDM Receiver

Q/ An FDM system have 100 channel In Exchanger used (SSB-SC) (USB) as submodulater & DSB-SC as main modulater of carrier f_c = 4MHz if channel have Low Pass Signal $f_m = 4\ KHz$ & guard freq. $f_g = 1KHz$). Draw spectrum at every part of T&R?