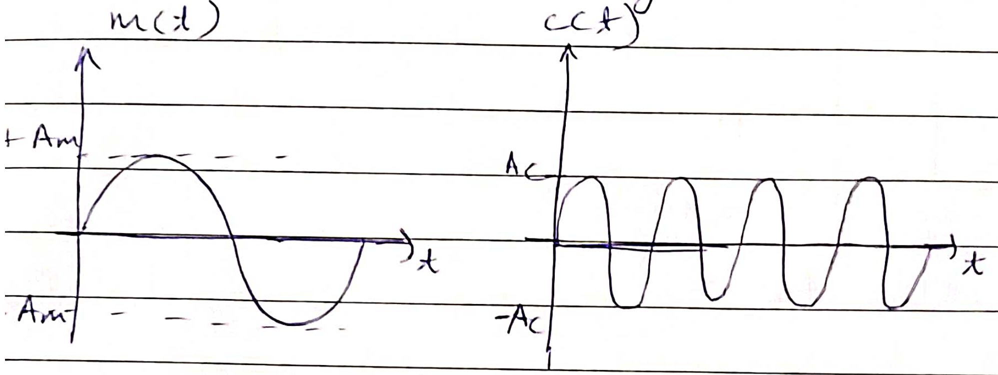
Amplitude Modulation

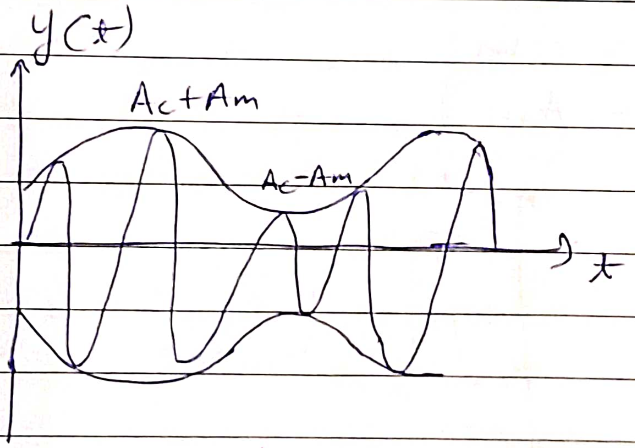
It is the process in which the amplitude of carrier signal changes wrt message (modulating) signal.

$\boxed{\text{DSB - FC}}$

Let $m(t)$ = modulating signal = $A_m \sin \omega_m t$

$c(t)$ = carrier signal = $A_c \sin \omega_c t$





Amplitude Modulated Signal (DSB - FC)

$$y(t) = A' \sin \omega_c t$$

$$= (A_c + m(t)) \sin \omega_c t$$

$$= (A_c + A_m \sin \omega_m t) \sin \omega_c t$$

$$= A_c\left(1 + \frac{A_m}{A_c} \sin \omega_m t\right) \sin \omega_c t$$

$$\mu = \frac{A_m}{A_c} = \text{Modulation index}$$

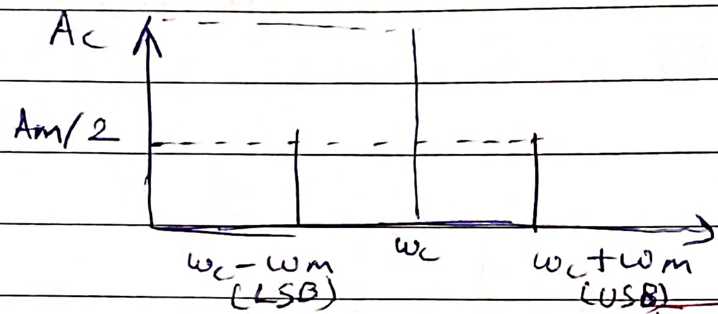
$$\boxed{y(t) = A_c(1 + \mu \sin \omega_m t) \sin \omega_c t}$$

$$y(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2} 2 \sin \omega_m t \sin \omega_c t$$

$$y(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2}\left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t\right]$$

$$\text{Sideband amplitude} = \frac{\mu A_c}{2} = \left(\frac{A_m}{A_c} \times \frac{A_c}{2}\right)$$

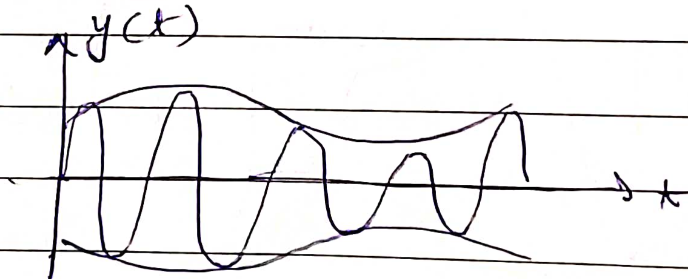
$$= \frac{A_m}{2}$$



Bandwidth (BW) = $\boxed{2\omega_m}$

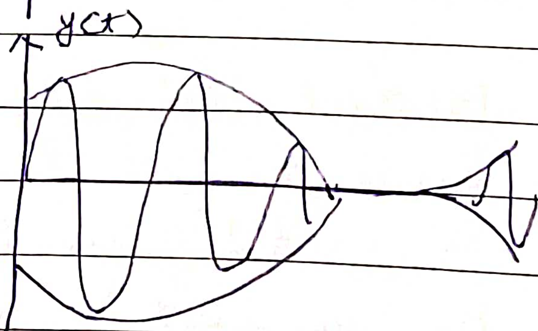
$$\boxed{\begin{aligned} A_{max} &= A_c + A_m \\ A_{min} &= A_c - A_m \end{aligned}}$$

If $\mu < 1$



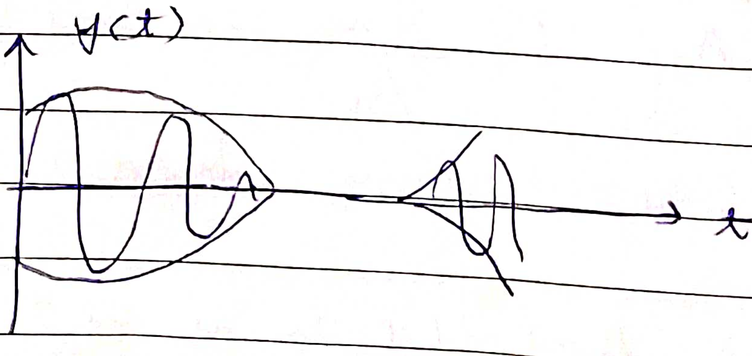
If $\mu = 1$

Modulated signal's output = 0



If $\mu > 1$

Distortion will occur



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

Total transmitted power $P_t = P_c + P_{USB} + P_{LSB}$

Carrier power, $P_c = \frac{A_c^2}{2}$

$$= \frac{1}{2}\left(\frac{\mu A_c}{2}\right)^2 = \frac{\mu^2 A_c^2}{8}$$

Total sideband power $= P_{USB} + P_{LSB} = P_S$

$$\frac{\mu^2 A_c^2}{8} + \frac{\mu^2 A_c^2}{8} = \frac{\mu^2 A_c^2}{4}$$

$$P_t = P_c + P_s$$

$$= \frac{A_c^2}{2} + \frac{\mu^2 A_c^2}{4}$$

$$= \frac{A_c^2}{2}\left(1 + \frac{\mu^2}{2}\right)$$

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

Sideband carrier information
carrier signal doesn't carry information.

Efficiency, $\eta = \frac{P_s}{P_t} = \frac{P_c \mu^2/2}{P_c\left(1+\frac{\mu^2}{2}\right)} = \frac{\frac{\mu^2}{2}}{1+\frac{\mu^2}{2}}$

$$\boxed{\eta = \frac{\mu^2}{\mu^2+2}}$$

Multiple Tone Amplitude Modulation

$m(t) = A_1 \sin \omega_1 t + A_2 \sin \omega_2 t + A_3 \sin \omega_3 t$

so AM signal will be

$$y(t) = A' \sin \omega_c t$$

$$= (A_c + m(t)) \sin \omega_c t$$

$$= A_c\left(1 + \frac{A_1}{A_c} \sin \omega_1 t + \frac{A_2}{A_c} \sin \omega_2 t + \frac{A_3}{A_c} \sin \omega_3 t\right) \sin \omega_c t$$

$= A_c(1 + \mu_1 \sin \omega_1 t + \mu_2 \sin \omega_2 t + \mu_3 \sin \omega_3 t) \sin \omega_c t$

$= A_c \sin \omega_c t + \frac{\mu_1 A_c}{2}[\cos(\omega_c - \omega_1)t - \cos(\omega_c + \omega_1)t]$

$+ \frac{\mu_2 A_c}{2}[\cos(\omega_c - \omega_2)t - \cos(\omega_c + \omega_2)t] +$

$\frac{\mu_3 A_c}{2}[\cos(\omega_c - \omega_3)t - \cos(\omega_c + \omega_3)t]$

Total transmitted power, $P_t = P_c + P_s$

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

$P_s = \frac{\mu_1^2 A_c^2}{4} + \frac{\mu_2^2 A_c^2}{4} + \frac{\mu_3^2 A_c^2}{4}$

$= \frac{P_c}{2}(\mu_1^2 + \mu_2^2 + \mu_3^2)$

$P_s = \frac{P_c}{2}\mu^2$

where $\boxed{\mu = \sqrt{\mu_1^2 + \mu_2^2 + \mu_3^2}}$

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

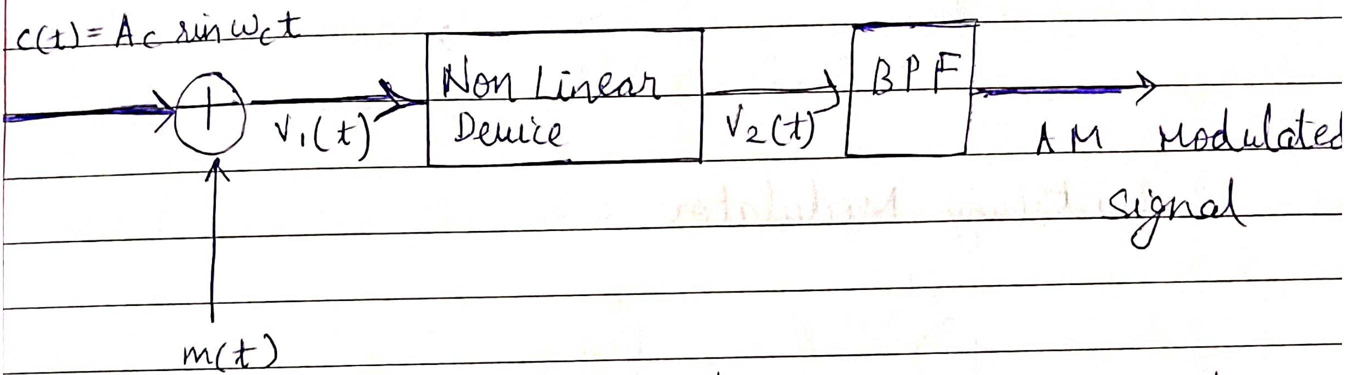
$= P_c\left(1 + \frac{\mu_1^2}{2} + \frac{\mu_2^2}{2} + \frac{\mu_3^2}{2}\right)$

Data Types in VHDL

VHDL data types are classified into five data types:

Scalar types: It includes numerics data types and enumerated data types.

Square Law Modulator



Square law modulator has three major parts

1) Adder
2) Non Linear Device
3) Bandpass Filter

After Adder

$$v_1(t) = c(t) + m(t)$$

$$v_1(t) = A_c \sin \omega_c t + m(t)$$

After passing through non linear device

$$V_2(t) = a v_1(t) + b v_1^2(t)$$

$$V_2(t) = a\left(A_c \sin \omega_c t + m(t)\right) + b\left(A_c \sin \omega_c t + m(t)\right)^2$$

$$= aA_c \sin \omega_c t + a m(t) + b\left(A_c^2 \sin^2 \omega_c t + (m(t))^2 + 2A_c \sin \omega_c t \, m(t)\right)$$

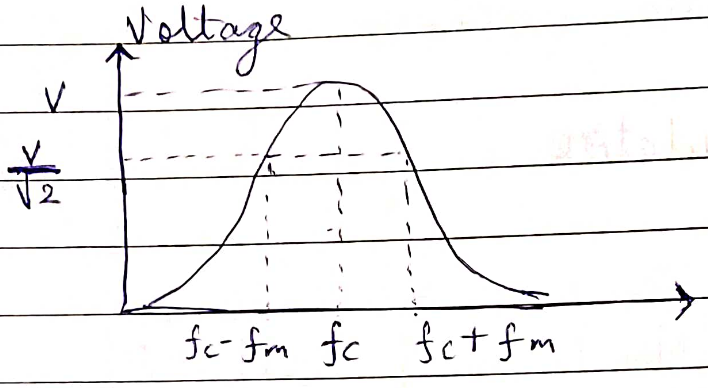
$$= a m(t) + b m^2(t) + bA_c^2 \sin^2 \omega_c t + \boxed{aA_c \sin \omega_c t + 2bA_c \sin \omega_c t \, m(t)}$$

Useful Component

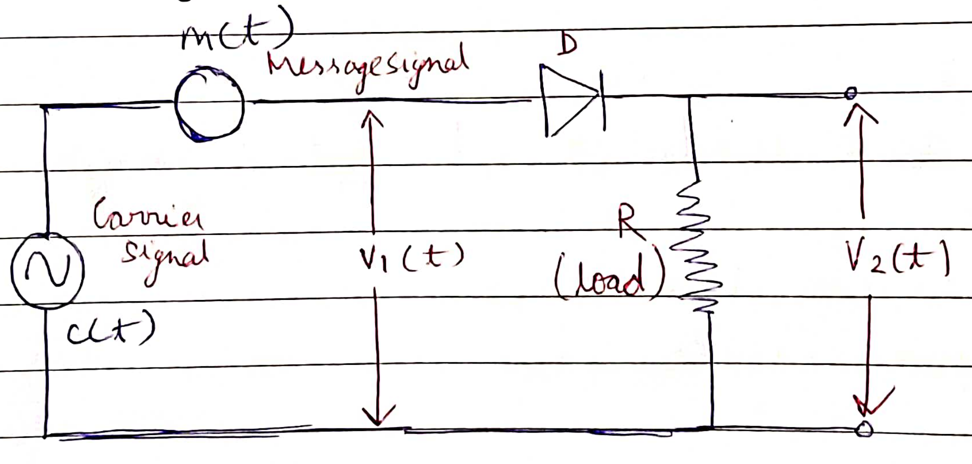
→ After Bandpass Filter

$$a A_c \sin \omega_c t + 2 b A_c \sin \omega_c t \, m(t)$$

$$= a A_c \left(1 + \frac{2b}{a} m(t) \right) \sin \omega_c t$$



Switching Modulator

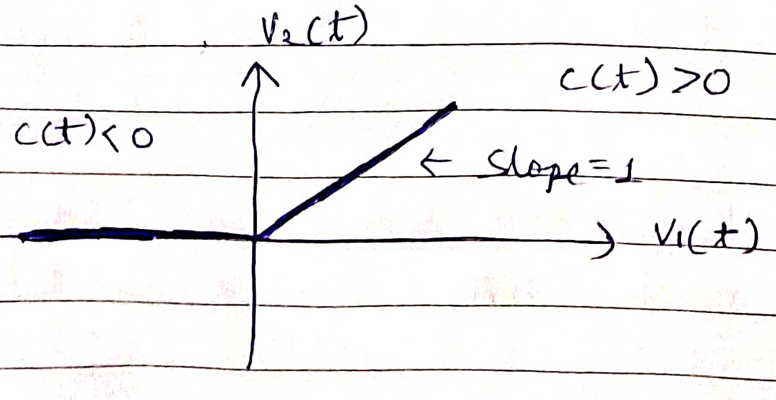


→ $c(t)$ and $m(t)$ are connected in series

$$V_1(t) = c(t) + m(t)$$

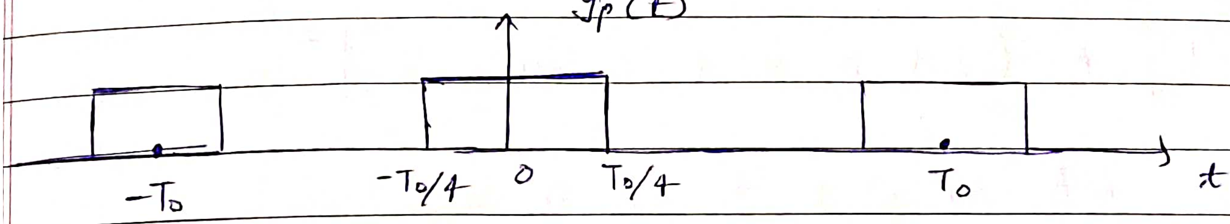
$$= m(t) + A_c \cos \omega_c t$$

→ Amplitude of $c(t)$ is very greater than $m(t)$. So ON and OFF of diode depends on $c(t)$.



Output, $V_2(t) = V_1(t)\, g_p(t)$

$g_p(t)$ is periodic pulse train of duty cycle equal to half period of $T_0/2$



$$\boxed{g_p(t) = \frac{1}{2} + \frac{2}{\pi}\cos\omega_c t} + \text{odd harmonics}$$

$$V_2(t) = \left(m(t) + A_c \cos\omega_c t\right)\left(\frac{1}{2} + \frac{2}{\pi}\cos\omega_c t\right)$$

$$= \frac{m(t)}{2} + \boxed{\frac{A_c}{2}\cos\omega_c t + \frac{2}{\pi} m(t)\cos\omega_c t} \text{ AM signal}$$

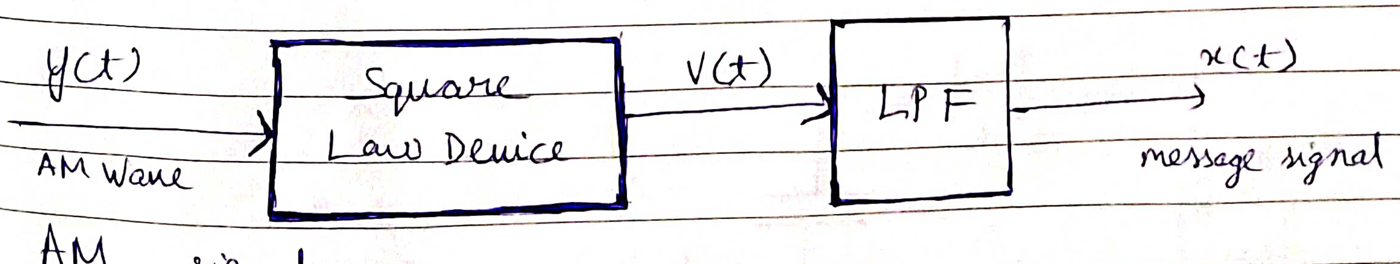
$$+ \frac{2A_c}{\pi}\cos^2\omega_c t$$

After BPF

$$y(t) = \frac{A_c}{2}\cos\omega_c t + \frac{2}{\pi} m(t)\cos\omega_c t$$

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

Square Law Detector



AM signal

$$y(t) = A_c\left(1 + m\, x(t)\right)\sin\omega_c t$$

Output of square law device, $V(t)$ is given by

$$v(t) = a\,y(t) + b\,y^2(t)$$

$$v(t) = a\left[A_c(1 + m\,x(t))\sin w_c t\right]$$

$$+\, b\left[A_c(1 + m\,x(t))\sin w_c t\right]^2$$

$$v(t) = aA_c \sin w_c t + aA_c m\,x(t)\sin w_c t$$
$$+\, bA_c^2 \sin^2 w_c t + bA_c^2 m^2 x^2(t)\sin^2 w_c t$$
$$+\, 2bA_c^2 m\,x(t)\sin^2 w_c t$$

$$v(t) = aA_c \sin w_c t + aA_c m\,x(t)\sin w_c t$$
$$+\, bA_c^2 m\,x(t)\left[1 - \cos 2w_c t\right] +$$
$$bA_c^2 \sin^2 w_c t + bA_c^2 m^2 x^2(t)\sin^2 w_c t$$

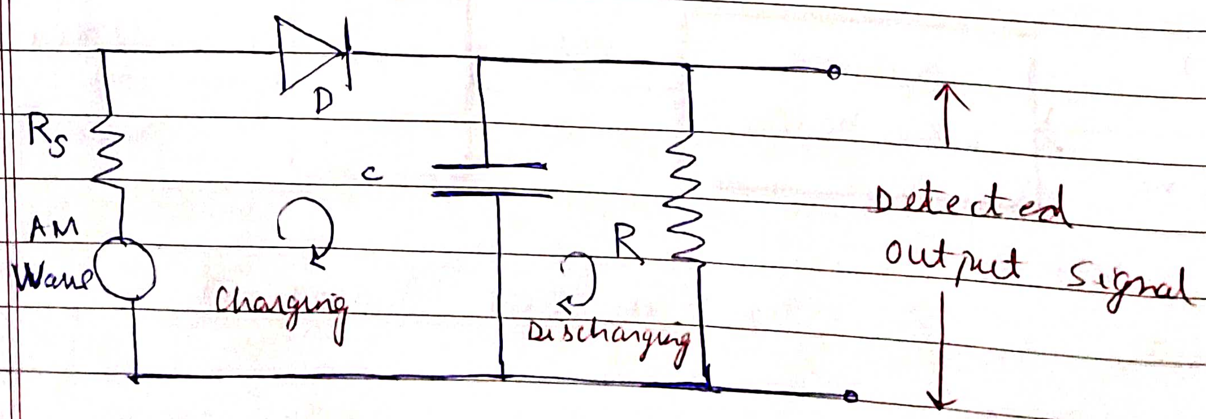
$$v(t) = aA_c \sin w_c t + aA_c m\,x(t)\sin w_c t +$$
$$\cancel{+mbA_c^2 x(t)}\; bA_c^2 \sin^2 w_c t +$$
$$bA_c^2 m^2 x^2(t)\sin^2 w_c t - m\,bA_c^2\,x(t)\cos 2w_c t$$

$$+\; \boxed{mbA_c^2\,x(t)}$$

→ After Low Pass Filter

$$mbA_c^2\,x(t)$$

✓ Envelope Detector



→ During Charging

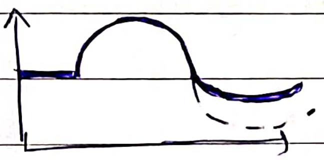
$$R_s C << \frac{1}{f_c}$$

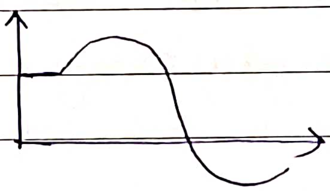
→ During Discharging

$$\frac{1}{f_c} << RC < \frac{1}{f_m}$$

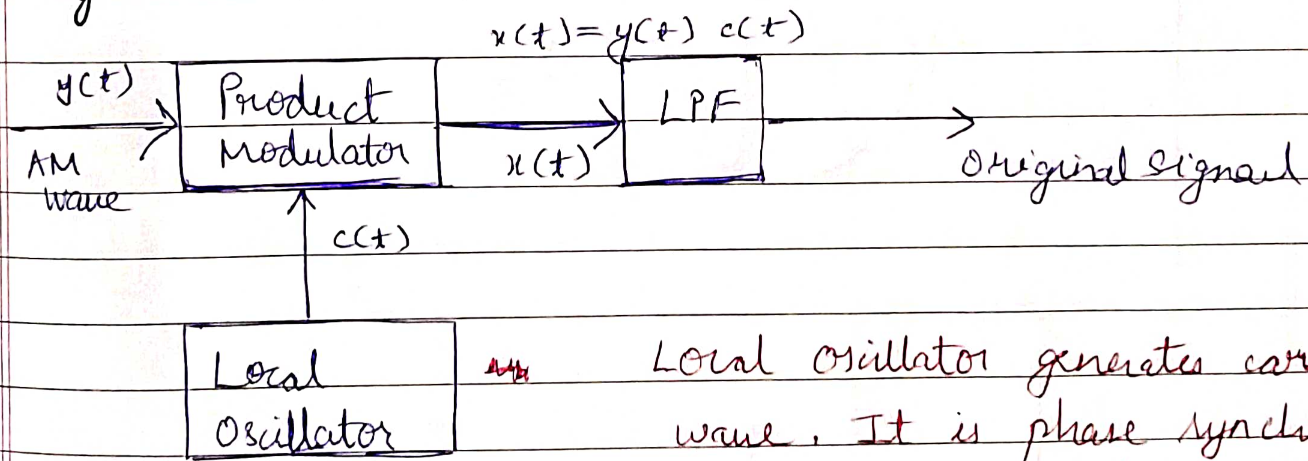
Two problems that occur during detection are

(i) Diagonal Clipping (ii) Negative Cycle Clipping





Synchronous Detection



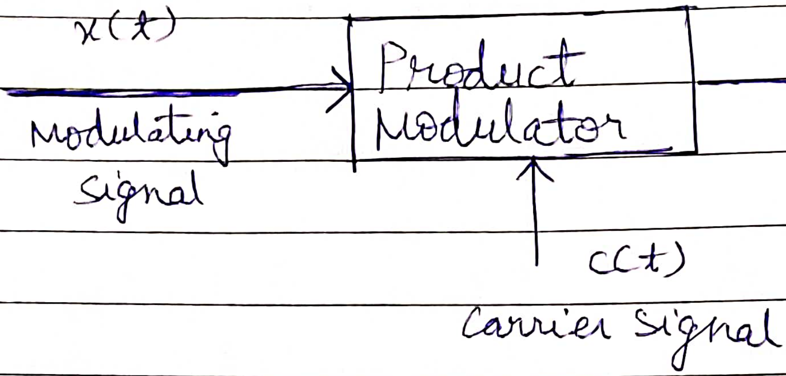
Local oscillator generates carrier wave. It is phase synchronous by transmitter and receiver.

Advantages
→ Better quality
→ Less effected by noise

Drawbacks
→ More complexity
→ Phase and frequency error may get generated
→ Synchronization of transmitter and receiver is required.

DSB-SC

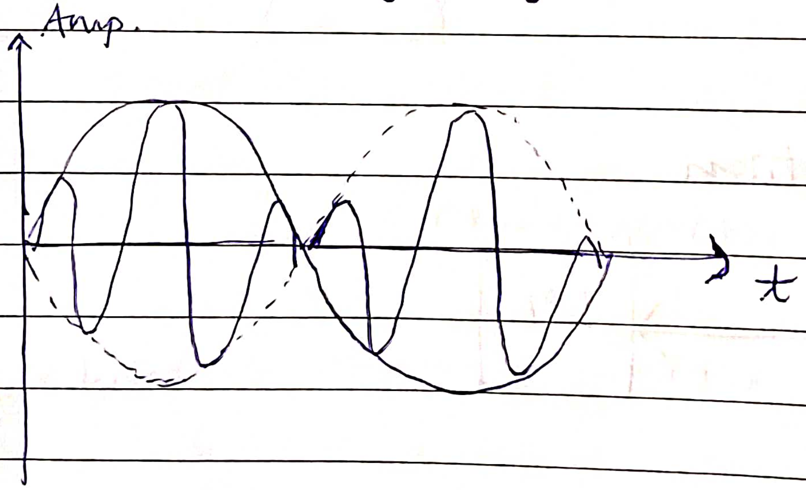
Block Diagram

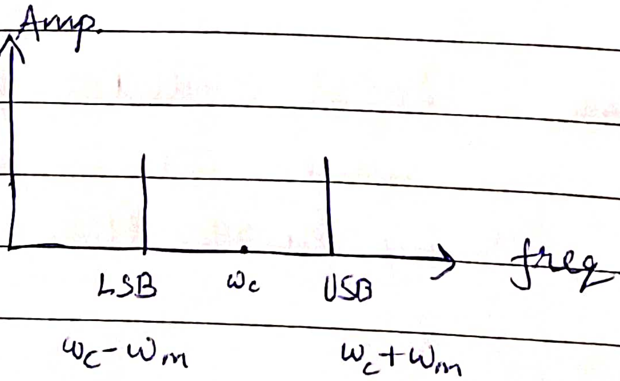


$y(t) = x(t)\,c(t)$
$= A_c \cos w_c t \; x(t)$

∴ In DSB-SC

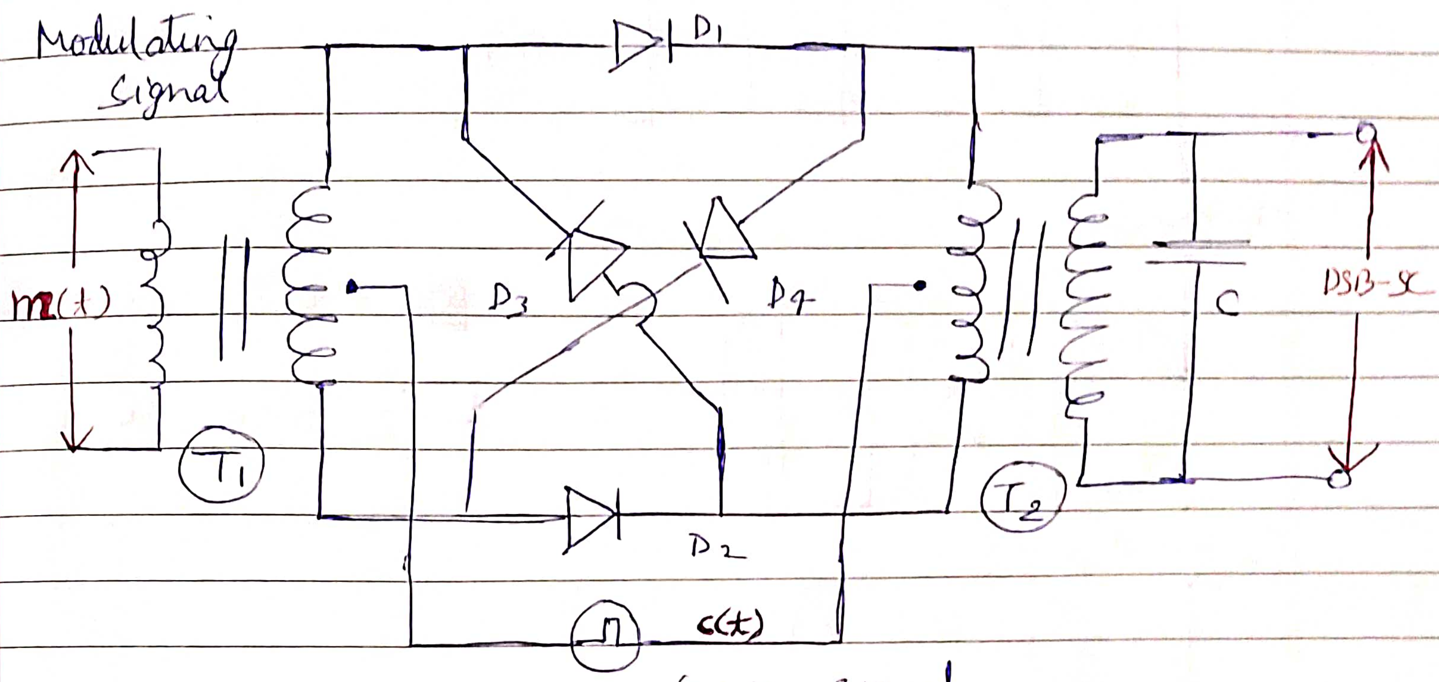
- We don't send carrier signal
- Only LSB and USB signals are present
- It has 180° phase reversal at zero crossing of modulating signal





$B.W = 2w_m$

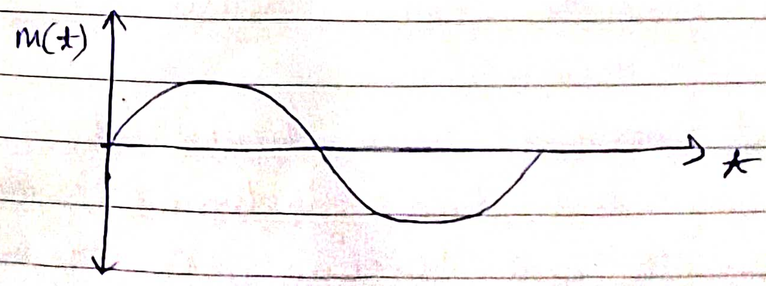
Ring Modulator or Chopper Modulator

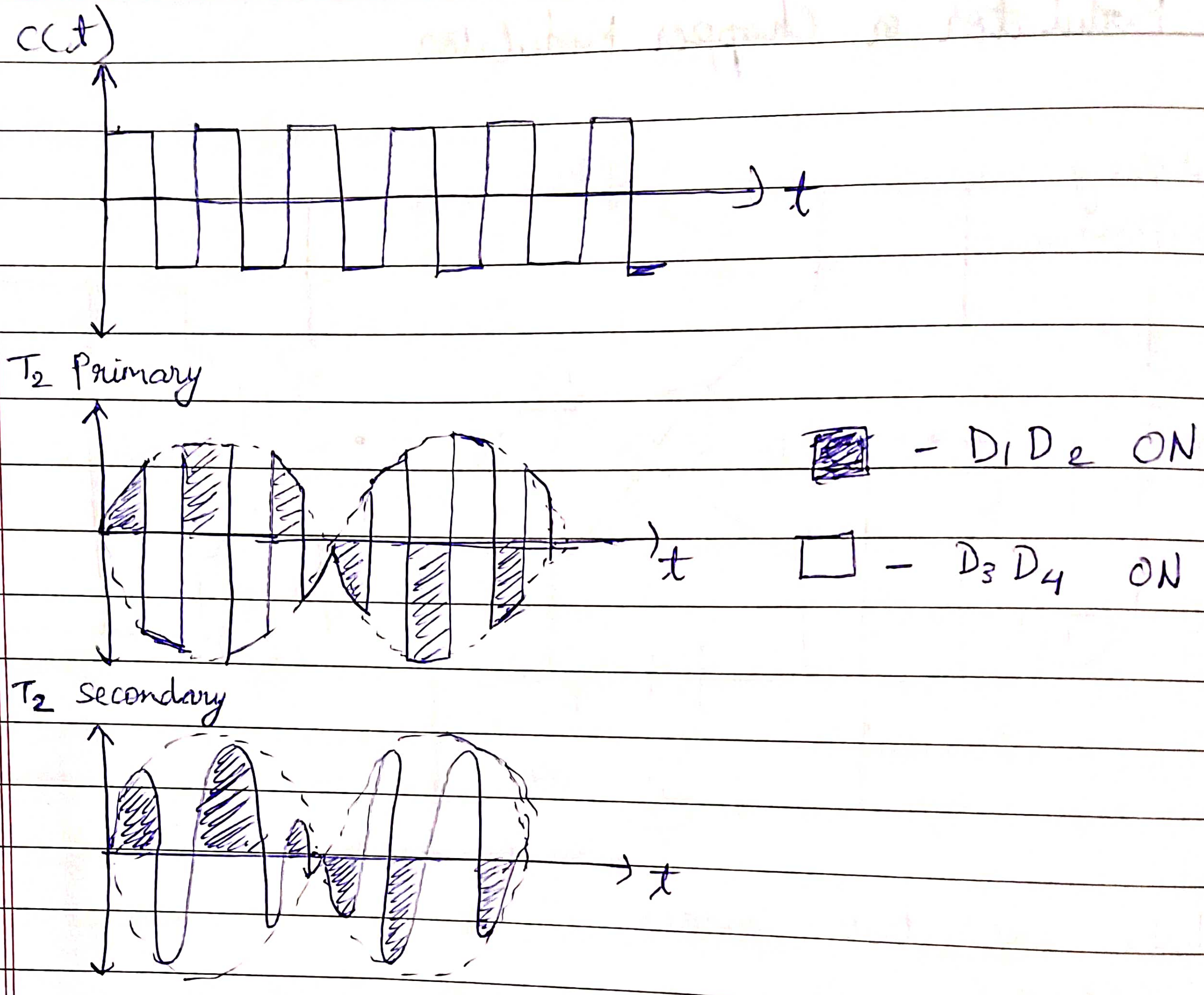


There are two modes
① $m(t) = 0$
② $m(t) \neq 0$

Modulating Signal	Carrier Signal	Output Cycle
+	+	+
+	−	−
−	+	−
−	−	+

→ Carrier signal decides biasing of diodes



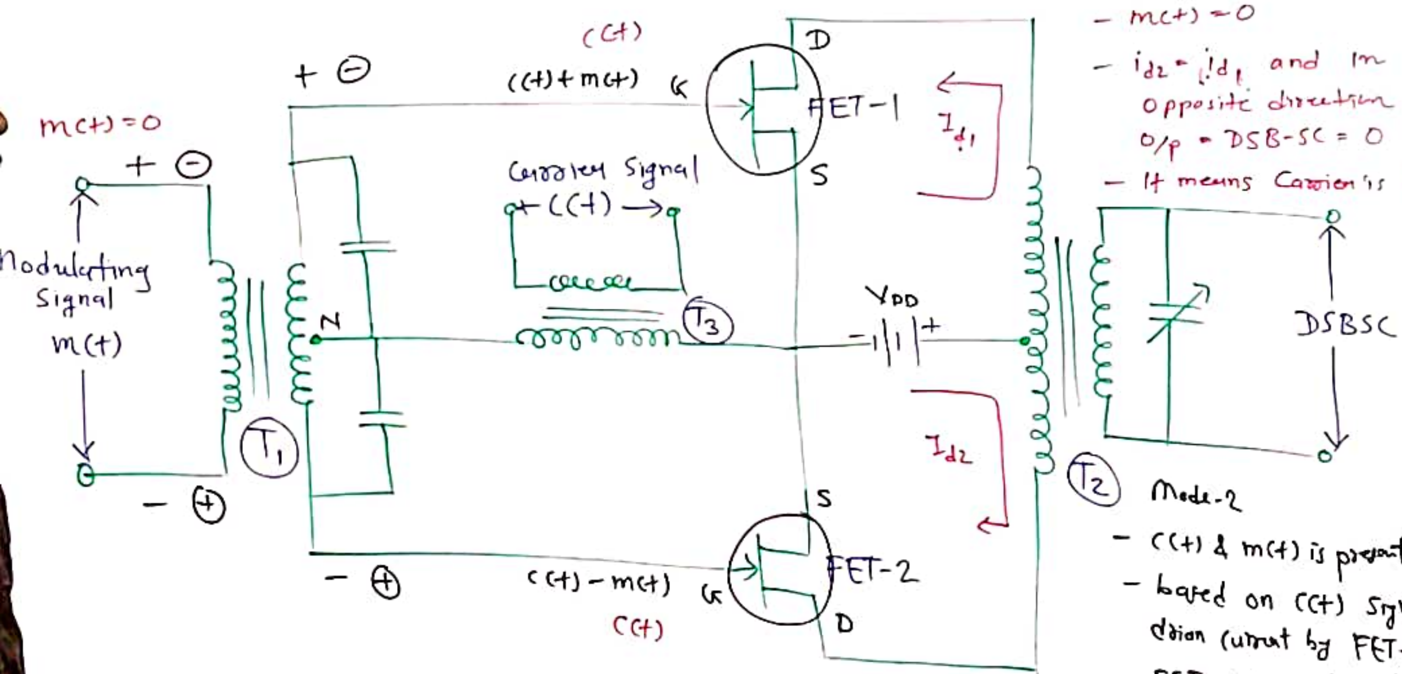


c(t)
t
T2 Primary
t
- D1 D2 ON
- D3 D4 ON
T2 secondary
t

Balanced Modulator using FET (DSB-SC)

Mode-1

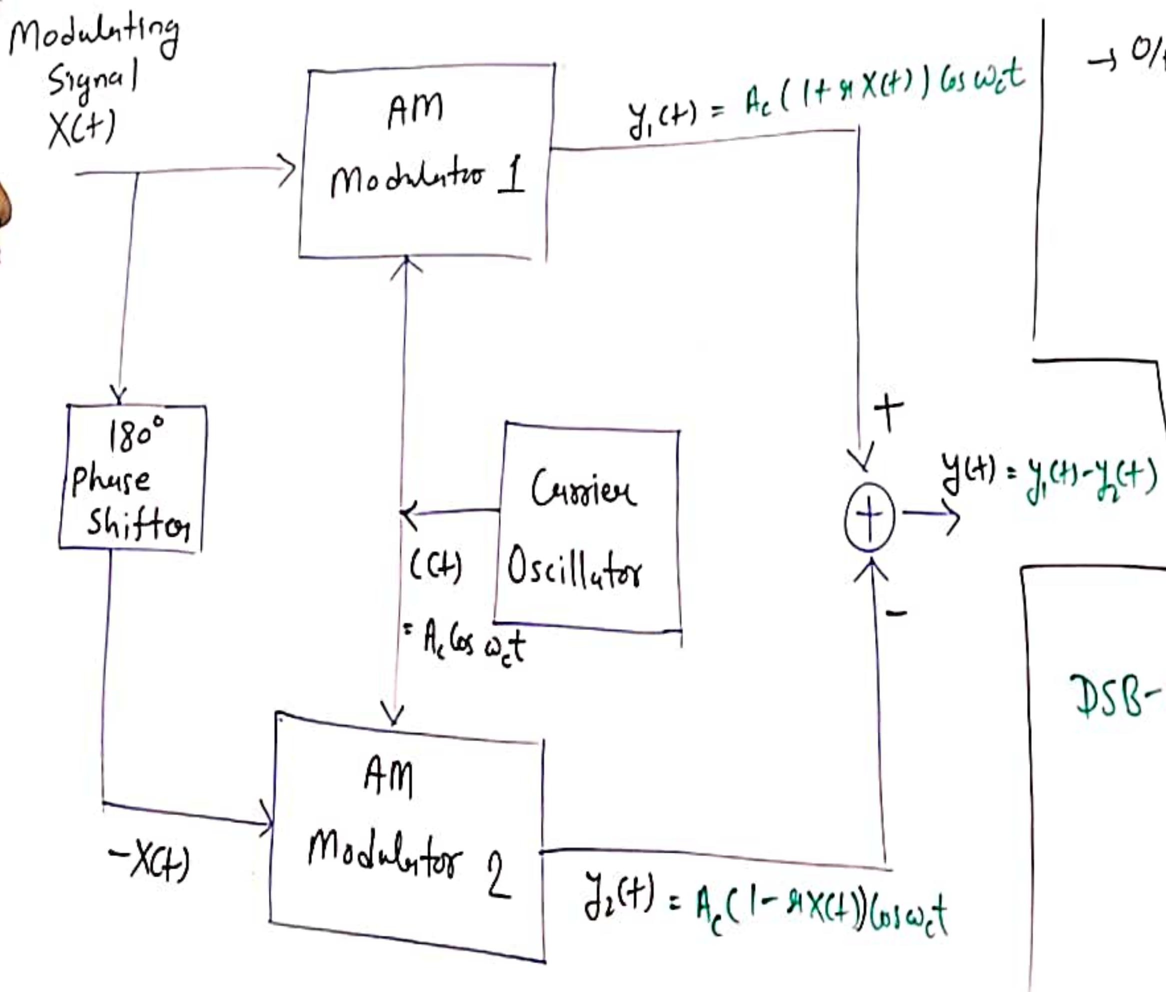
- $m(t) = 0$
- $i_{d2} = i_{d1}$ and in opposite direction
  o/p = DSB-SC = 0
- It means Carrier is Suppressed



Mode-2

- c(t) & m(t) is present
- based on c(t) signal drain current by FET-1 & FET-2 is equal and cancelled.

Balanced Modulator using AM Modulators for DSBSC generation



$\rightarrow$ O/p $= y(t)$

$= y_1(t) - y_2(t)$

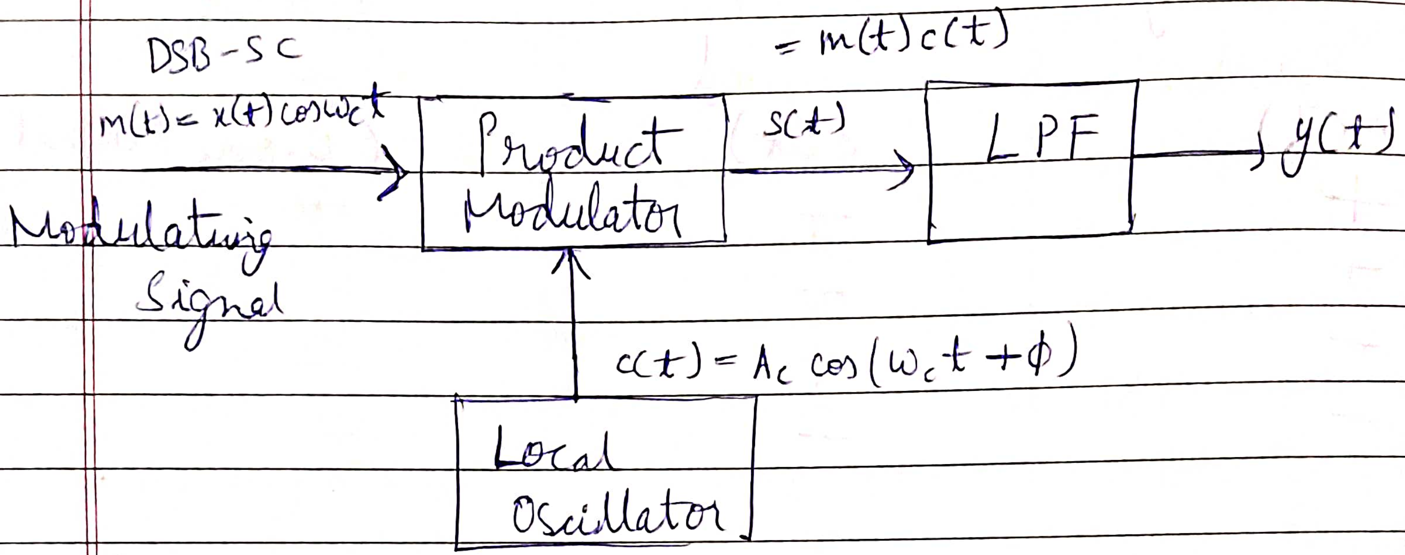
$= A_c(1+\mu X(t))\cos\omega_c t - A_c(1-\mu X(t))\cos\omega_c t$

$= \underline{A_c\cos\omega_c t} + \mu A_c X(t)\cos\omega_c t \underline{- A_c\cos\omega_c t} + \mu A_c X(t)\cos\omega_c t$

$= \boxed{2\mu A_c X(t)\cos\omega_c t}$

DSB-SC $= \underline{X(t)\cos\omega_c t}$

Coherent Detection of DSB-SC



→ It generates carrier wave

→ That carrier wave should be frequency and phase synchronised at transmitter and receiver, else there can be frequency or phase error

→ Output of Product Modulator

$$s(t) = m(t)\, c(t)$$

$$= \left(x(t) \cos \omega_c t\right)\left(A_c \cos(\omega_c t + \phi)\right)$$

$$= \frac{A_c x(t)}{2}\left(2 \cos \omega_c t \cos(\omega_c t + \phi)\right)$$

$$2 \cos A \cos B = \cos(A+B) + \cos(A-B)$$

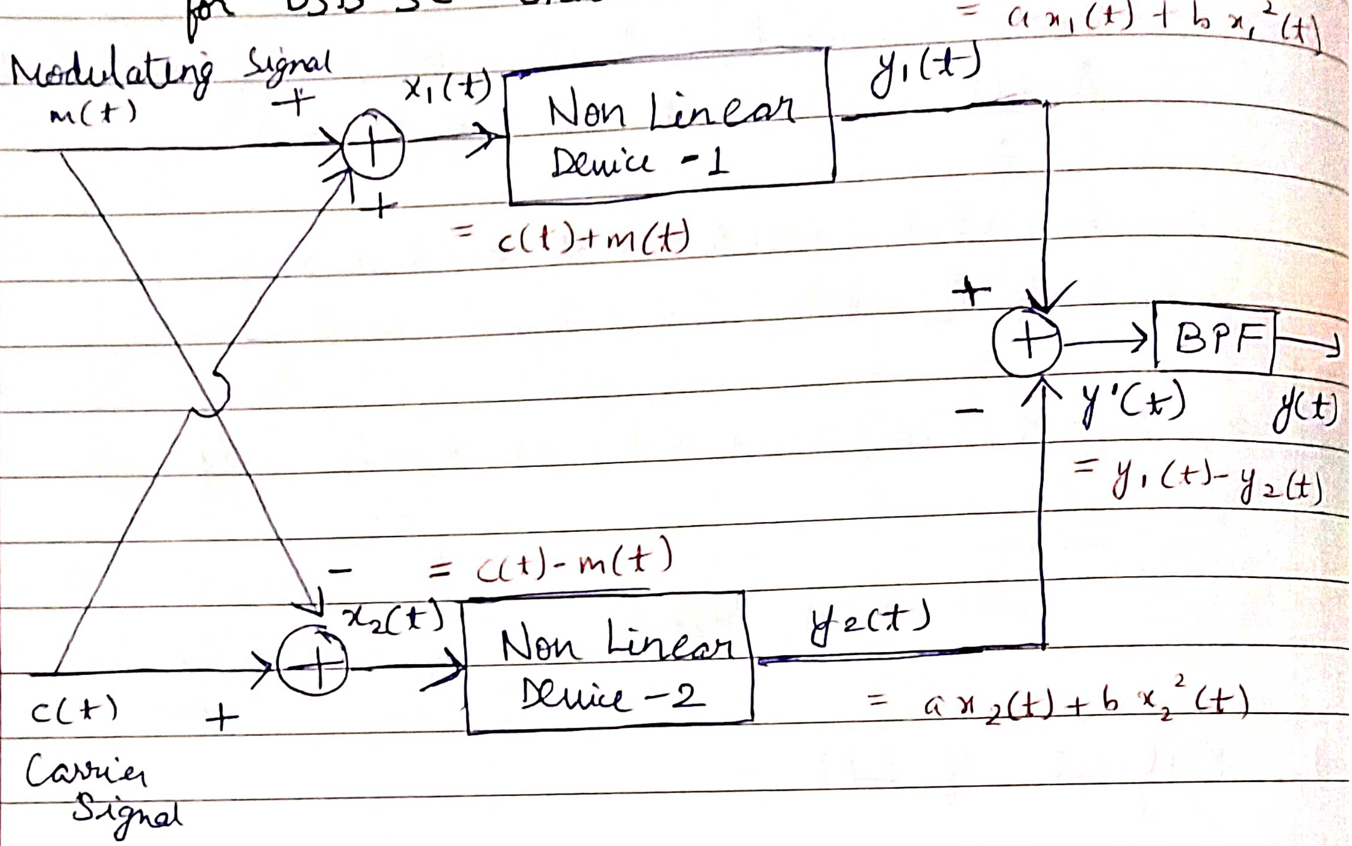
$$= \frac{A_c x(t)}{2}\left[\cos(2\omega_c t + \phi) + \cos\phi\right]$$

$$= \underbrace{\frac{A_c x(t)}{2} \cos(2\omega_c t + \phi)}_{\text{Unwanted signal}} + \underbrace{\frac{A_c x(t)}{2} \cos\phi}_{\text{Low Frequency Original signal}}$$

Output of LPF

$$y(t) = \frac{A_c x(t)}{2} \cos\phi$$ ← Constant Phase Error

Balanced Modulator using Non Linear Device for DSB-SC Generation



→ Output of Adder 1

$x_1(t) = A_c \cos\omega_c t + m(t)$

→ Output of Adder 2

$x_2(t) = A_c \cos\omega_c t - m(t)$

→ Output of Non Linear Device 1

$y_1(t) = a x_1(t) + b x_1^2(t)$

$= a(A_c \cos\omega_c t + m(t)) +$

$b[A_c \cos\omega_c t + m(t)]^2$

$\cancel{a A_c \cos\omega_c t + a m(t) +}$

→ Output of Non Linear Device 2

$y_2(t) = a x_2(t) + b x_2^2(t)$

$= a(A_c \cos\omega_c t - m(t))$

$+ b(A_c \cos\omega_c t - m(t))^2$

→ $y'(t) = y_1(t) - y_2(t)$

$y'(t) = a(2m(t)) + b[4 A_c \cos\omega_c t \; m(t)]$

$$y'(t) = \underbrace{2a\,m(t)}_{\text{Message signal}} + \underbrace{4b A_c m(t) \cos\omega_c t}_{\text{DSB-SC signal}}$$

Output of Bandpass Filter

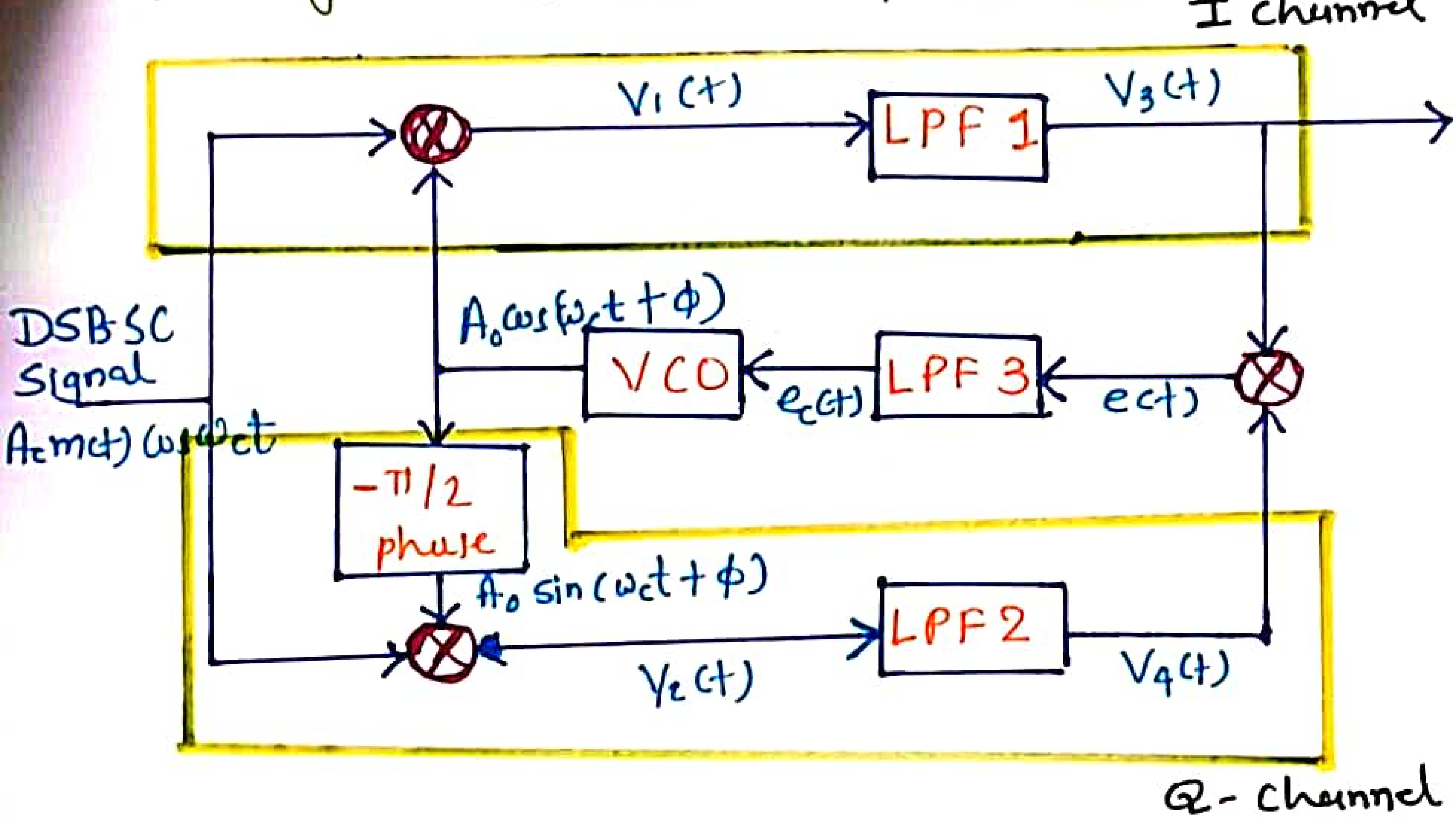
$$y(t) = 4bA_c\, m(t) \cos \omega_c t$$

Costas Loop receiver for DSB-SC demodulation

basics of Costas loop receiver

- In Coherent detection, at receiving end a Carrier is req.^rd that should be phase Coherent with the transmitter Carrier.
- It can be possible, If we transmit a Carrier component with the modulated signal.
- But DSB-SC signal has no Such component.
- Costas loop has the capability to generate a coherent carrier at the receiver and therefore used for the demodulation of DSB-SC signals.

Blockdiagram of Costas loop receiver



Case-1 : Let's assume that freq and phase of VCO output are same as that of incoming carrier, then

$$(VCO)_{O/P} = A_0 \cos \omega_c t$$

- signal $V_1(t)$

$$V_1(t) = (A_c m(t) \cos \omega_c t)(A_0 \cos \omega_c t)$$

$$= \frac{A_c A_0 m(t)}{2} (1 + \cos 2\omega_c t)$$

$$= \frac{A_c A_0 m(t)}{2} + \frac{A_c A_0 m(t)}{2} \cos(2\omega_c t)$$

- Output of LPF

$$V_3(t) = \frac{A_c A_0 m(t)}{2}$$

- Similarly, Signal $V_2(t)$

$$V_2(t) = (A_c m(t) \cos \omega_c t)(A_0 \sin \omega_c t)$$

$$= \frac{A_c A_0 m(t)}{2} \sin(2\omega_c t)$$

- Output of LPF 2

$$V_4(t) = 0$$

Error Signal $= V_3(t) V_4(t)$

$$= 0$$

Case-2 Assume $(VCO)_{O/P} = A_0 \cos(\omega_c t + \phi)$

[Non phase Synchronization]

- signal $V_1(t)$

$$V_1(t) = (A_c m(t) \cos \omega_c t)(A_0 \cos(\omega_c t + \phi))$$

$$= \frac{A_c A_0 m(t)}{2} [\cos(2\omega_c t + \phi) + \cos \phi]$$

$$= \frac{A_c A_0 m(t)}{2} \cos(2\omega_c t + \phi) + \underbrace{\frac{A_c A_0 m(t)}{2} \cos \phi}_{\text{Low Freq. component}}$$

- Output of LPF 1

$$V_3(t) = \frac{A_c A_o m(t)}{2} \cos\phi$$

- Signal $V_2(t)$

$$V_2(t) = (A_c m(t) \cos \omega_c t)(A_o \sin(\omega_c t + \phi))$$

$$V_2(t) = \frac{A_c A_o m(t)}{2} [\sin(2\omega_c t + \phi) + \sin\phi]$$

$$V_2(t) = \frac{A_c A_o m(t)}{2} \sin(2\omega_c t + \phi) + \underbrace{\frac{A_o A_c m(t)}{2} \sin\phi}_{\text{Low Freq component}}$$

- Output of LPF 2

$$V_4(t) = \frac{A_c A_o m(t)}{2} \sin\phi$$

- So error signal

$$e(t) = V_3(t) V_4(t)$$

$$= \left(\frac{A_c A_o m(t)}{2} \cos\phi\right)\left(\frac{A_c A_o m(t)}{2} \sin\phi\right)$$

$$= \frac{1}{4} (A_c A_o m(t))^2 \sin\phi \cos\phi$$

$$= \underbrace{\boxed{\frac{1}{8} (A_c A_o m(t))^2}}_{\text{constant}} \sin 2\phi$$

- Output of LPF 3

$$C = \frac{1}{8} (A_c A_o m(t))^2$$

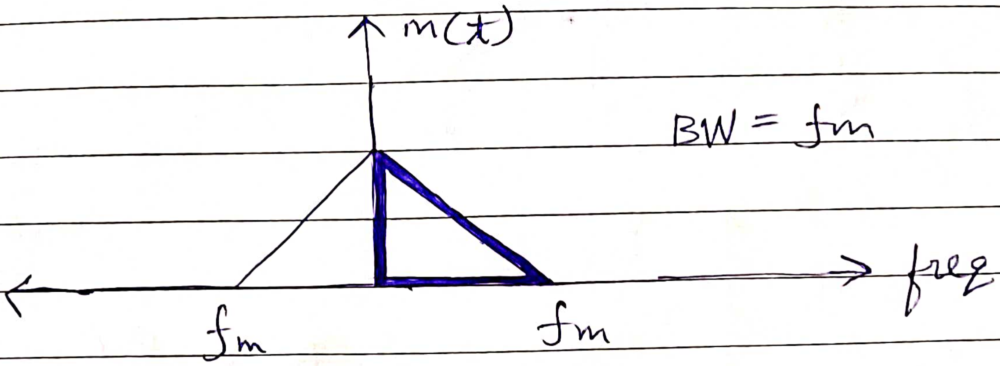
$$e_c(t) = C \sin 2\phi$$

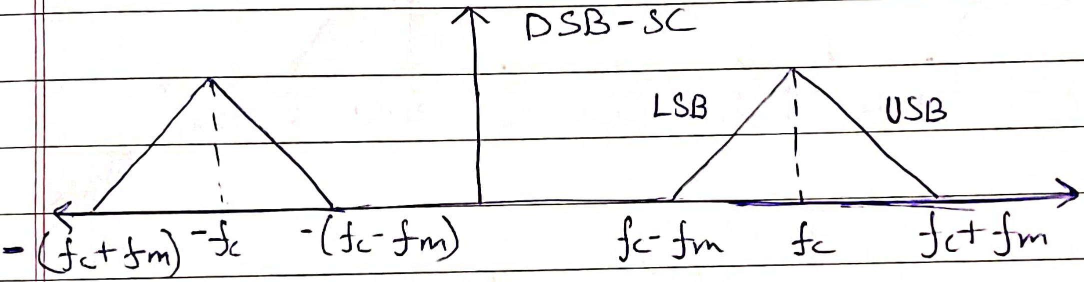
This DC output control voltage ensures that the VCO output is coherent with the carrier used for modulation.

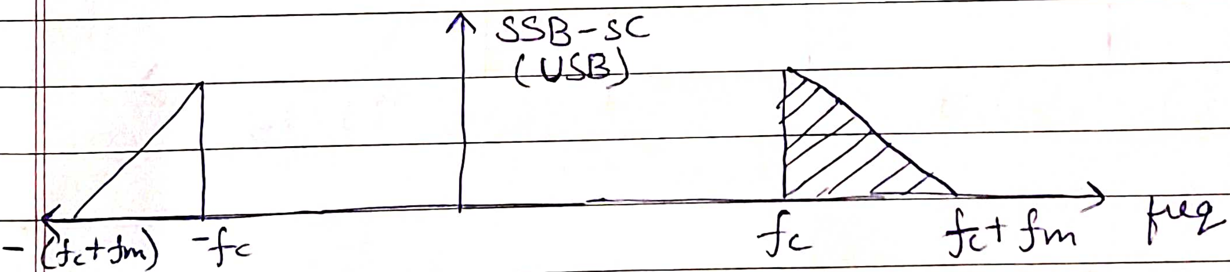
SSB-SC (Single Sideband Suppressed Carrier)

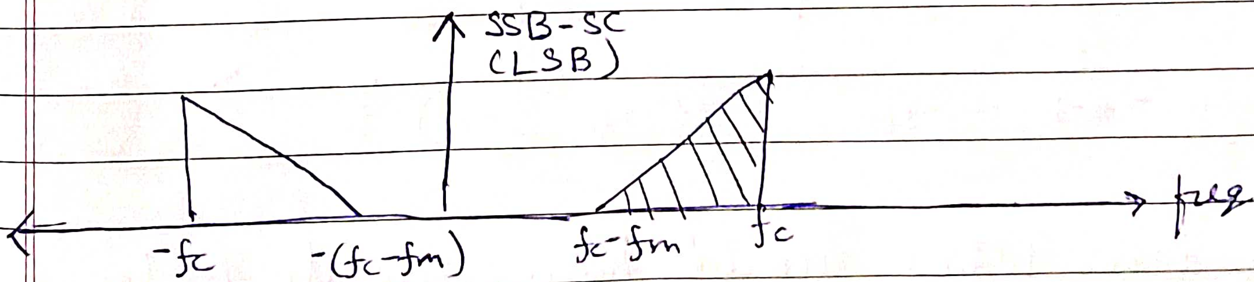
Bandwidth = f_m

Power Transmission = $\frac{\mu^2 P_c}{4}$

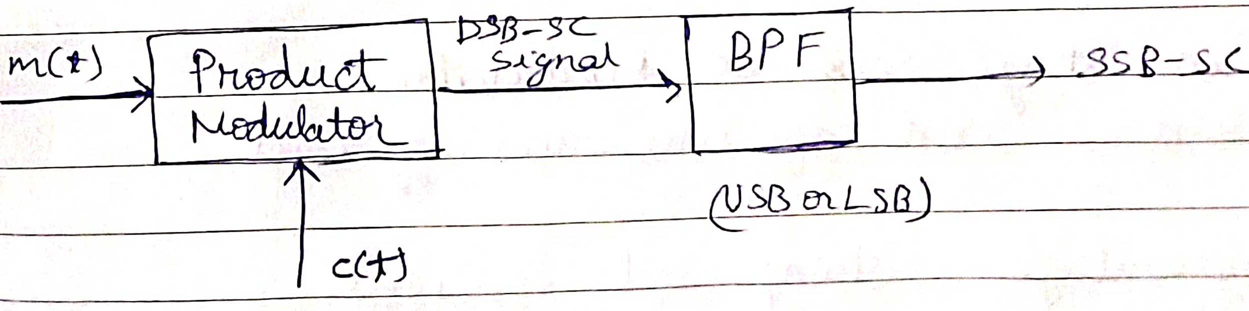




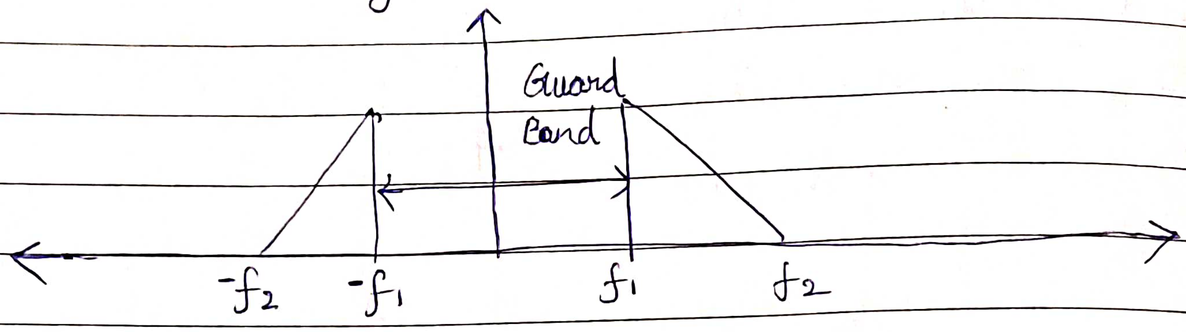


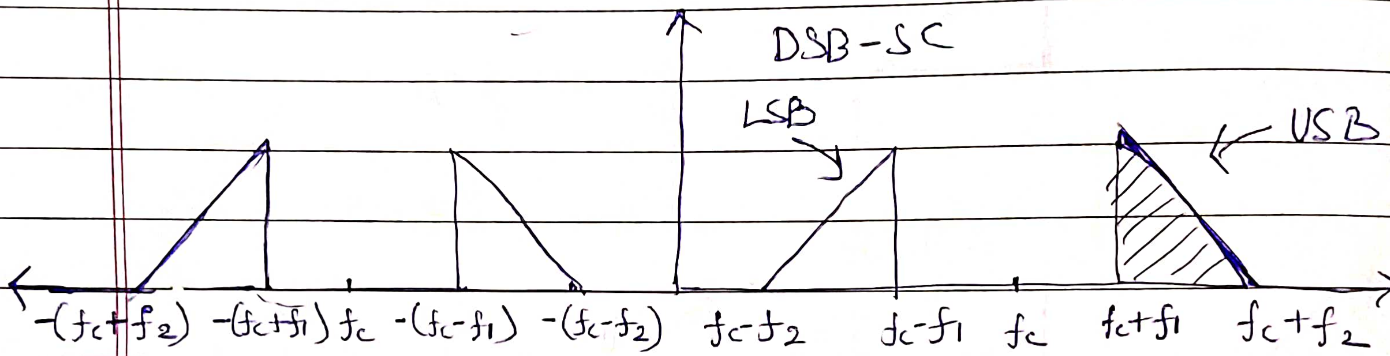


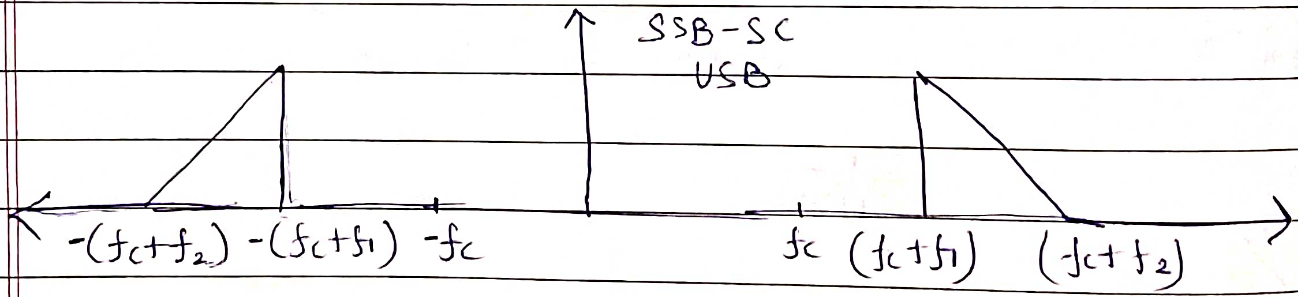
Block Diagram

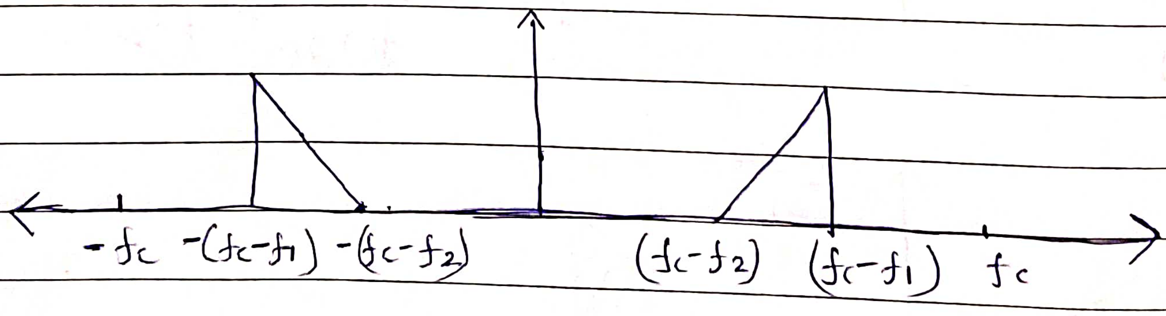


As the band pass filter don't have sharp edge so we use guard band







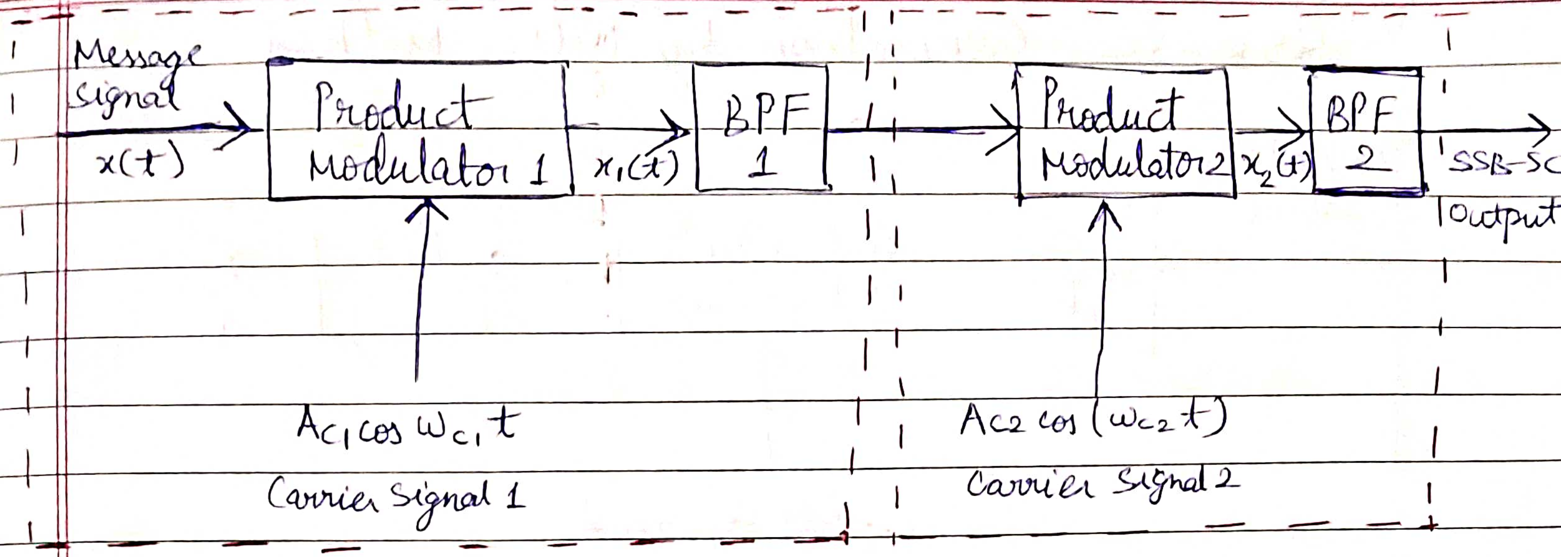


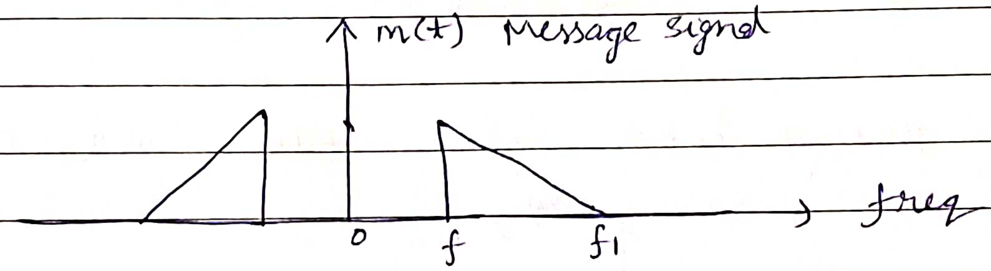
Bandpass filter should have quality factor between 1000 and 2000

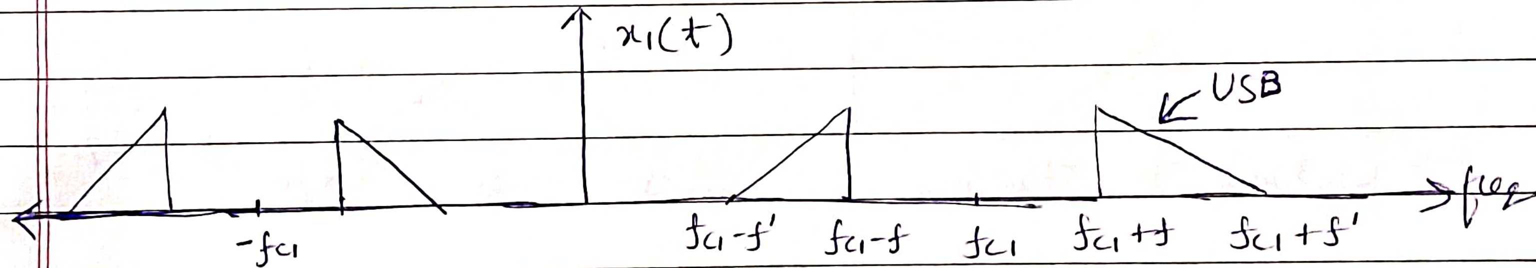
Two Stage SSB-SC Modulator

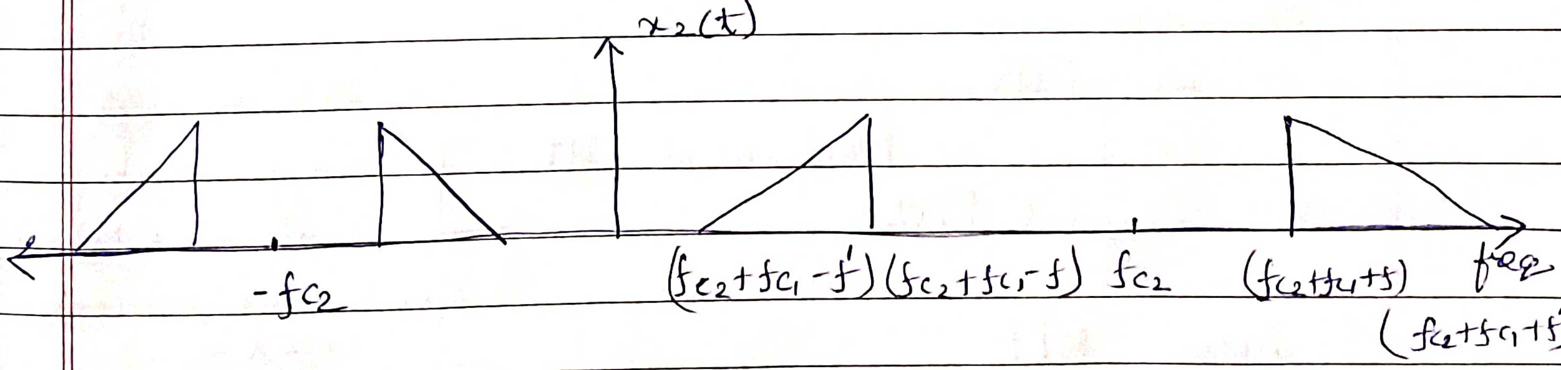
Needs cost effective and efficient

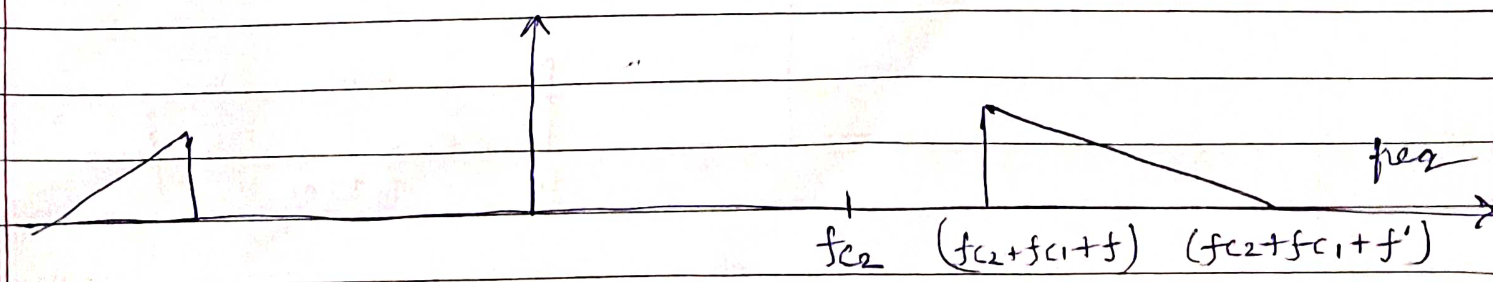
Advantage: cheap and efficient





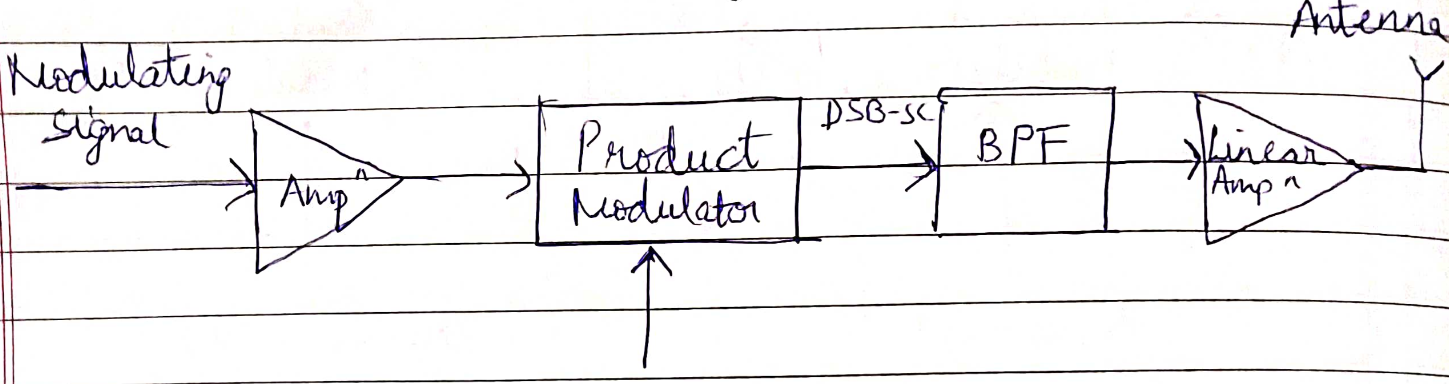






Guard Band = 2f

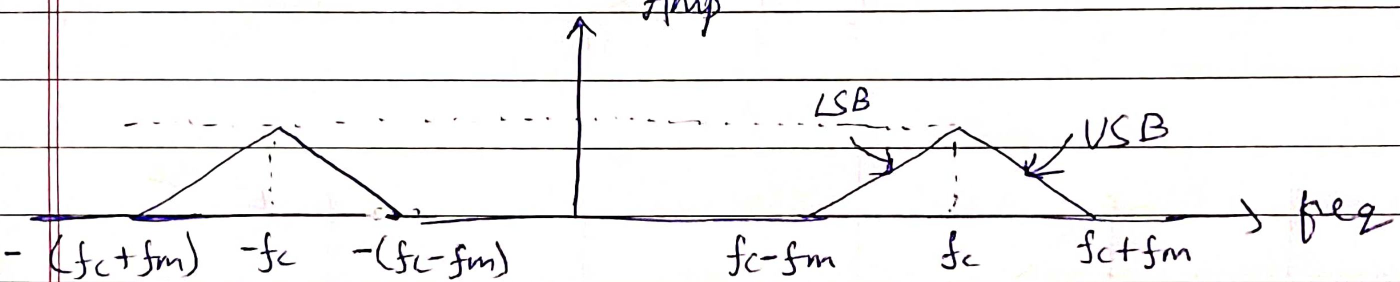
SSB-SC Generation by Filter Method



Carrier Signal

$c(t) = A_c \cos W_c t$

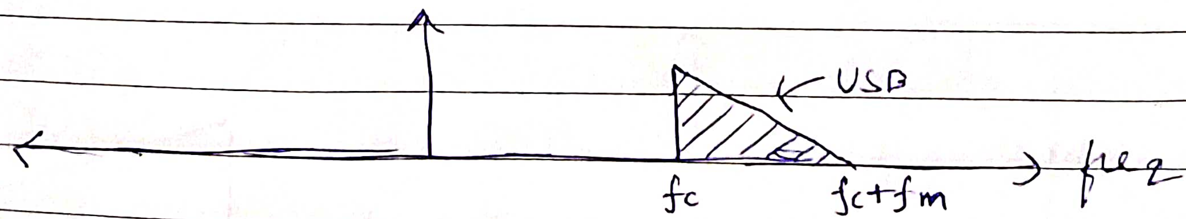
Frequency band after product modulator



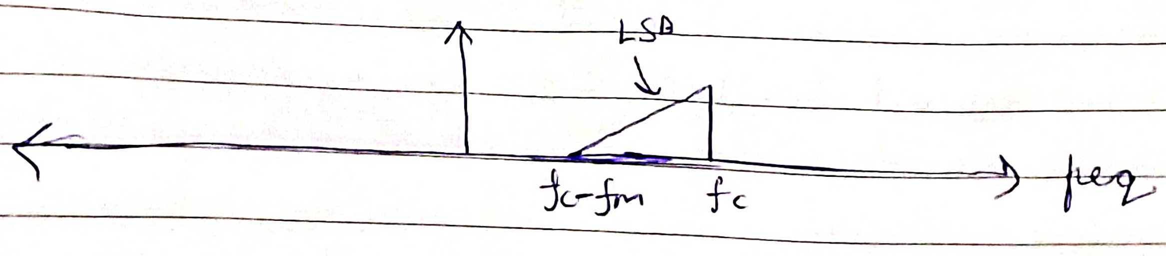
We can use
- LC Filter — Size is less
- Ceramic or Mechanical Filter
- Crystal Filter

] – Used for high freq (above 1 MHz)
– Good passband characteristics

After BPF

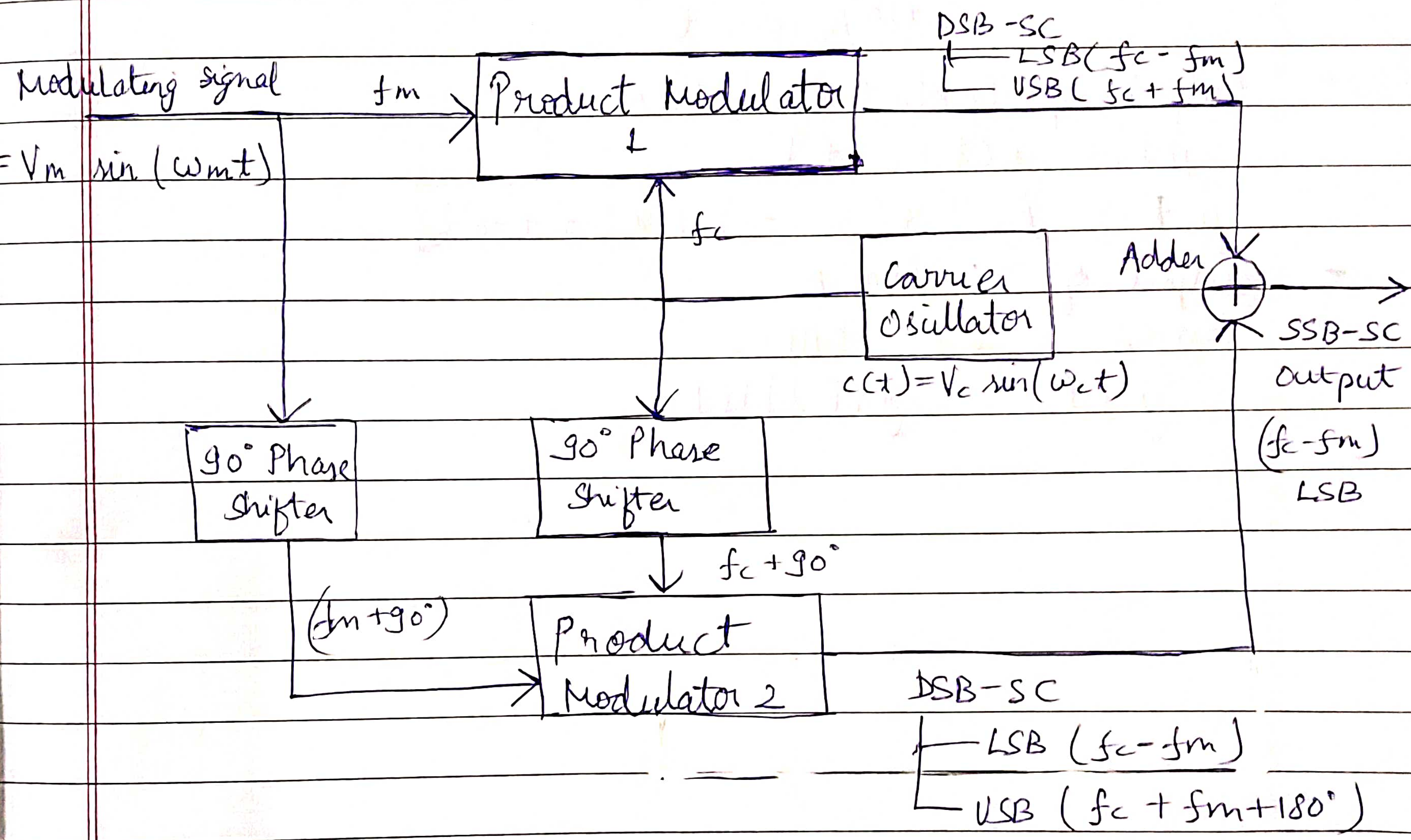


OR

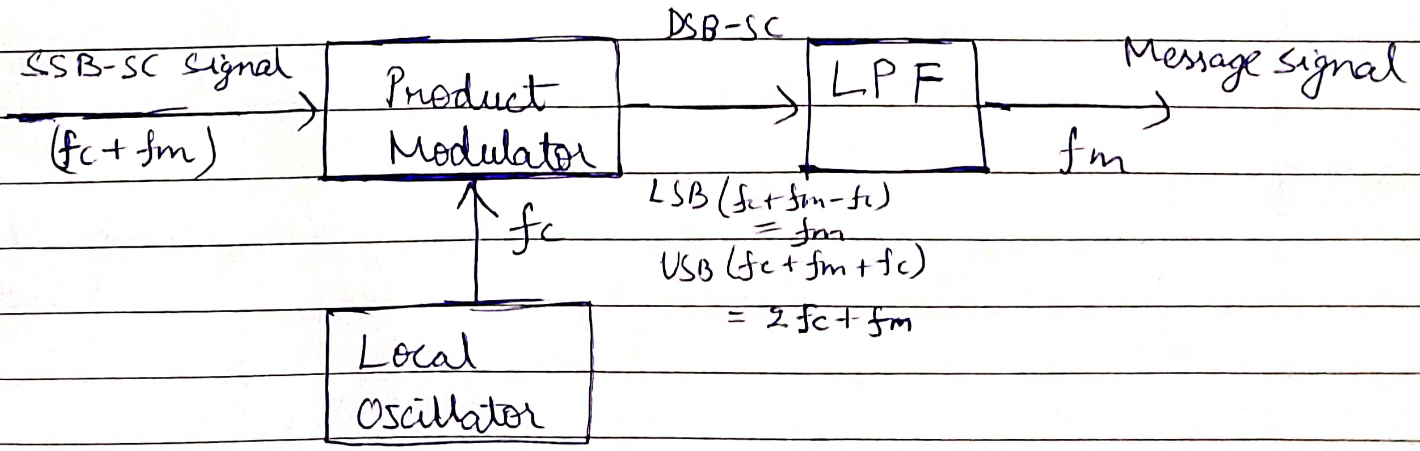


We don't use SSB-SC in broadcasting because
- freq. stability
- costly tunnable filter

SSB-SC Generation by Phase Shift Method

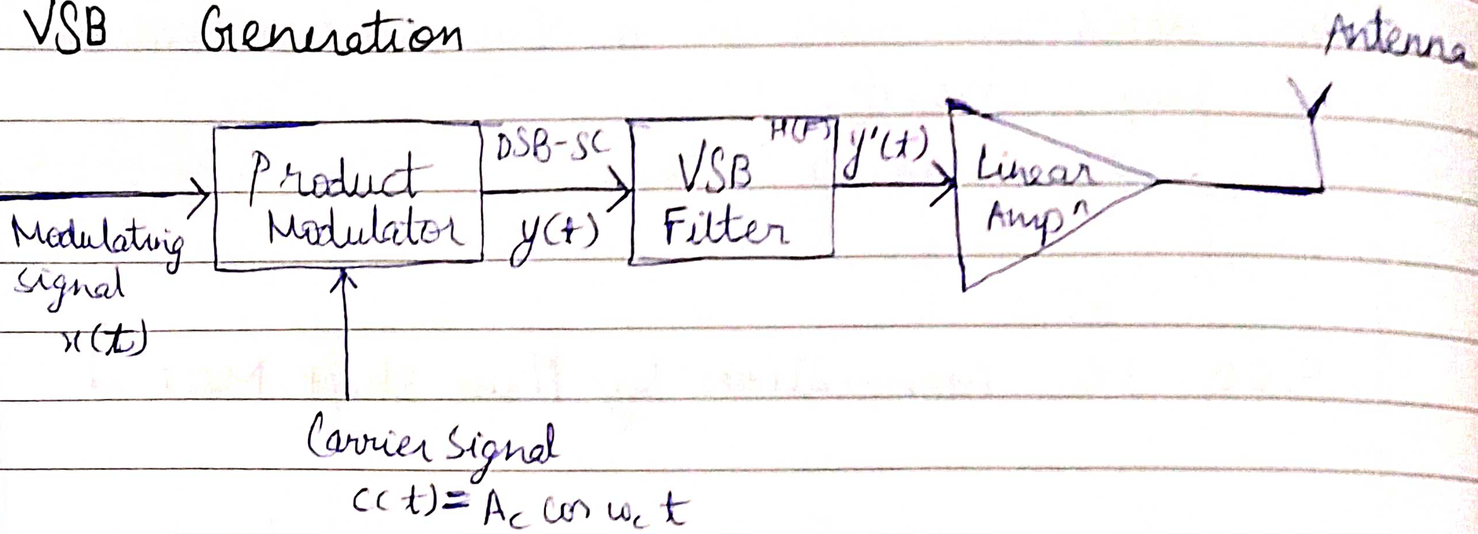


SSB-SC Demodulation



- To generate carrier signal
- It should be synchronized by frequency and phase at transmitter and receiver

VSB Generation



- Output of Product Modulator

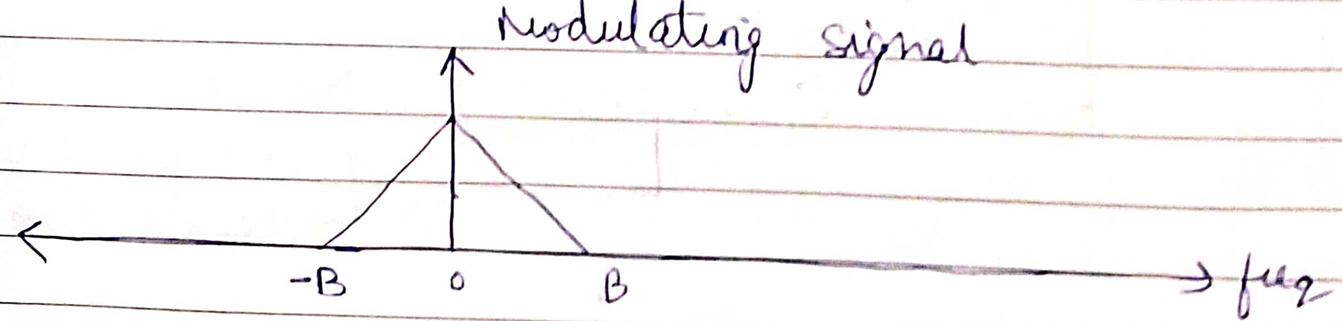
$$y(t) = x(t)\,c(t)$$

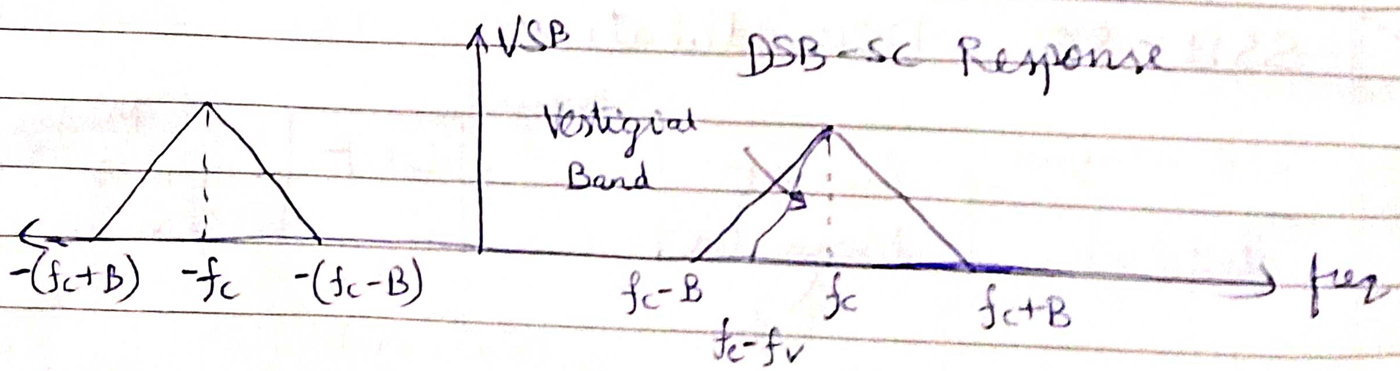
$$y(F) = \frac{A_c}{2}\left[x(f_c - f_0) + x(f_c + f_0)\right]$$

- Output of VSB Filter

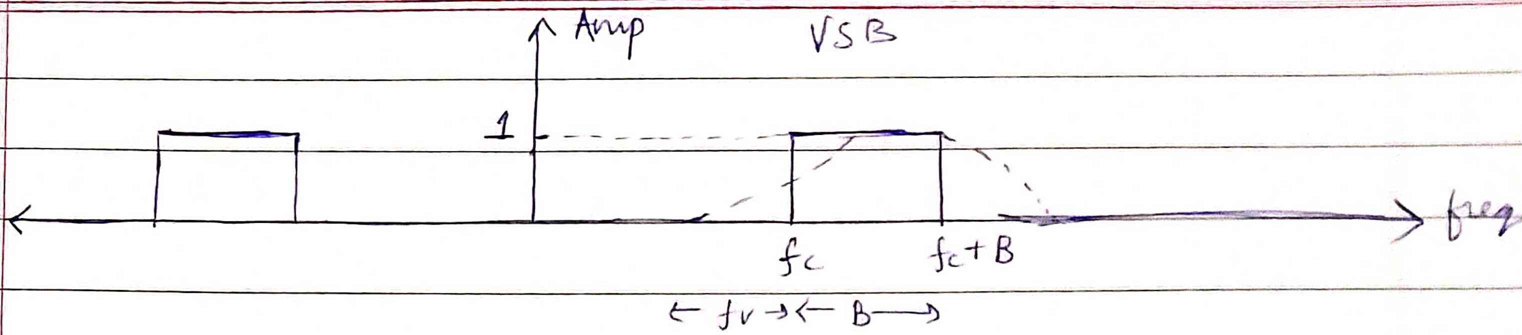
$$y'(F) = y(F)\,H(F)$$

$$= \frac{A_c}{2}\left[x(f_c - f_0) + x(f_c + f_0)\right] H(F)$$





Total BW = $B + f_v$

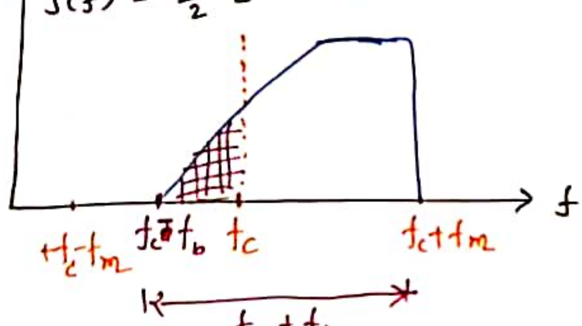


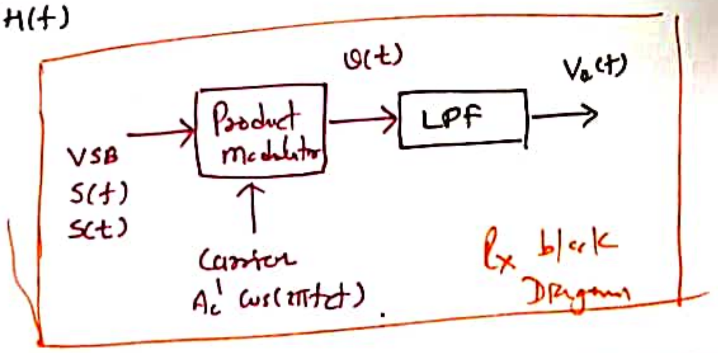
$BW = B + f_v$

Vestigial BW is about 25 to 30 % of one side band

Application : In TV transmission

$$S(f) = \frac{A_c}{2}\left[M(f+f_c) + M(f-f_c)\right]H(f)$$





$$\boxed{V_0(t) = \frac{A_c A_c'}{4}\left[H(f-f_c) + H(f+f_c)\right]M(f)}$$

→ Output of Product Modulator $v(t)$

$$v(t) = s(t)\left(A_c' \cos(2\pi f_c t)\right).$$

→ In freq domain

$$V(f) = \frac{A_c'}{2}\left[S(f-f_c) + S(f+f_c)\right].$$

$$= \frac{A_c'}{2}\left[\frac{A_c}{2}\left(M(f-\underline{f_c+f_c}) + M(f-\underline{f_c-f_c})\right)\right]H(f-f_c) + \frac{A_c}{2}\left(M(f+\underline{f_c+f_c}) + \underline{M(f+f_c-f_c)}\right)H(f+f_c)\Big]$$

$$= \boxed{\frac{A_c' A_c}{4}\underbrace{\left[H(f-f_c) + H(f+f_c)\right]M(f)}_{LPF}} + \frac{A_c A_c'}{4}\underbrace{M(f-2f_c)H(f-f_c)}_{\times} + \frac{A_c A_c'}{4}\underbrace{M(f+2f_c)H(f+f_c)}_{\times}$$

1. A modulating signal of frequency 5 kHz and peak voltage of 6V is used to modulate a carrier of frequency 10 MHz and peak voltage of 10 V. determine (1) Modulation index, (2) Frequency of LSB and USB, (3) Amplitude of LSB and USB.

→ $f_m = 5\ \text{KHz}$, $A_m = 6\text{V}$

$f_c = 10\ \text{MHz}$, $A_c = 10\text{V}$

→ $m = \frac{A_m}{A_c} = \frac{6}{10} = 0.6 = 60\%$

→ $USB = f_c + f_m = 10\ \text{MHz} + 0.005\ \text{MHz}$

$= 10.005\ \text{MHz}$

$LSB = f_c - f_m = 10\ \text{MHz} - 0.005\ \text{MHz}$

$= 9.995\ \text{MHz}$

→ Amplitude of LSB & USB $= \frac{m A_c}{2} = \frac{A_m}{2} = 3$ Volt

2. For an amplitude modulated wave, the maximum amplitude is found to be 10V while the minimum amplitude is found to be 6V. Determine the modulation index (%) and amplitude of original carrier frequency.

$\rightarrow$ $A_{max} = 10\,V = A_c + A_m$

$A_{min} = 6\,V = A_c - A_m$

$\Rightarrow 16 = 2A_c$

$\Rightarrow \boxed{A_c = 8\ \text{Volt}}$, $\boxed{A_m = 2\ \text{Volt}}$

$\rightarrow$ $\mu = \dfrac{A_m}{A_c} = \dfrac{2}{8} = 0.25 = 25\%$.

3. If the frequency of 3 kHz signal has to be transmitted through amplitude modulation. Which of the following frequency should use as a carrier frequency?
   a. 30 Hz ✗
   b. 300 Hz ✗
   c. 3000 Hz ✗
   d. $\boxed{\text{3 MHz}}$ ✓

→ $f_m = 3\ kHz$

→ $f_c >> f_m$

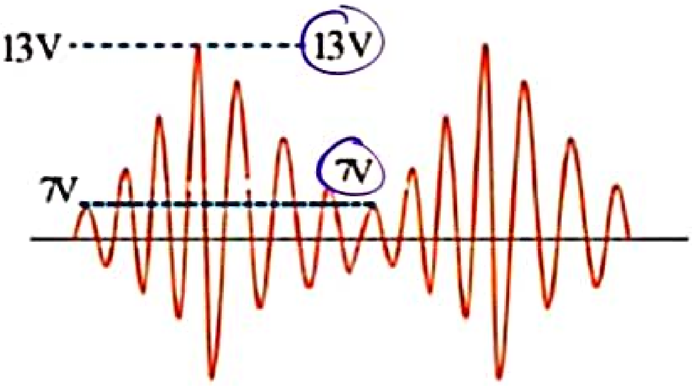
4. What will be the modulation index of the following AM wave?

a. 6%

b. 20%

c. 30%

d. 50%



$A_{max} = 13V = A_c + A_m$

$A_{min} = 7V = A_c - A_m$

$\Rightarrow 20 = 2A_c$

$\Rightarrow \boxed{A_c = 10 \text{ Volt}}$

$\Rightarrow \boxed{A_m = 3 \text{ Volt}}$

→ Modulating Index

$$\mu = \frac{A_m}{A_c} = \frac{3}{10} = 0.3 = 30\%$$

5. A carrier wave of 2 MHz is amplitude modulated by a modulating wave of 2 kHz. Which of the following frequencies will be present in AM wave?
   a. 2 MHz, 2 kHz
   b. 2 kHz, 2.002 MHz, 1.998 MHz
   c. 2 MHz, 2.002 MHz, 1.998 MHz
   d. 2.002 MHz, 1.998 MHz

→ Am wave f_c, $\underbrace{f_c - f_m}_{LSB}$, $\underbrace{f_c + f_m}_{USB}$

→ $f_c = 2\ MHz$

$f_m = 2\ KHz = 0.002\ MHz$

→ 2 MHz, 1.998 MHz, 2.002 MHz

6. The maximum amplitude of carrier wave is 12 V. What should be the amplitude of modulating signal in order to have a modulation index of 75%?

$\rightarrow A_c = 12\,V$

$\mu = 75\% = 0.75$

$\rightarrow \mu = \dfrac{A_m}{A_c} \Rightarrow A_m = \mu A_c$

$= 0.75 \times 12$

$\boxed{A_m = 9 \text{ Volt}}$

7. The equation of AM wave is, $e = 100(1 + 0.6 \sin 6280t)\sin(2\pi \times 10^6 t)$. Calculate, (1) modulation index, (2) Frequency of carrier wave, (3) Frequency of modulating wave and (4) Frequency of LSB and USB.

$\rightarrow e = 100(1 + 0.6 \sin 6280t)\sin(2\pi \times 10^6 t)$

$= A_c(1 + \mu \sin \omega_m t)\sin(\omega_c t)$

$\rightarrow A_c = 100$ Volt

$\boxed{\mu = 0.6}$

$\omega_m = 6280 \Rightarrow f_m = \frac{\omega_m}{2\pi} = \frac{6280}{2\pi} = \boxed{1000\ Hz}$

$\omega_c = 2\pi \times 10^6 \Rightarrow f_c = \frac{\omega_c}{2\pi} = 10^6 = \boxed{1\ MHz}$

$\rightarrow$ LSB $= f_c - f_m = 1\ MHz - 0.001\ MHz$

$= 0.999\ MHz$

$\rightarrow$ USB $= f_c + f_m = 1\ MHz + 0.001\ MHz$

$= 1.001\ MHz$

1. Find total modulated power, side power and net modulation index for the AM signal, expressed in volts.

$$y = 10\cos(2\pi \times 10^6 t) + 5\cos(2\pi \times 10^6 t)\cos(2\pi \times 10^3 t) + 2\cos(2\pi \times 10^6 t)\cos(4\pi \times 10^3 t)$$

$\rightarrow y = \underline{\underline{10}} \cos(2\pi \times 10^6 t)\left(1 + \underline{0.5}\cos(2\pi \times 10^3 t) + \underline{0.2}\cos(4\pi \times 10^3 t)\right)$

$\rightarrow A_c = 10$ volt

$\mu_1 = 0.5$

$\mu_2 = 0.2$

$\rightarrow P_c = \dfrac{A_c^2}{2}$

$= \underline{50\ W}$

$\rightarrow P_t = P_c\left(1 + \dfrac{\mu_1^2}{2} + \dfrac{\mu_2^2}{2}\right)$

$= 50\left(1 + \dfrac{0.5^2}{2} + \dfrac{0.2^2}{2}\right)$

$= 57.25\ W$

$\Rightarrow P_t = P_c + P_s$

$\Rightarrow P_s = P_t - P_c$

$= 57.25 - 50$

$= 7.25\ W$

$\rightarrow \mu = \sqrt{\mu_1^2 + \mu_2^2}$

$= \sqrt{0.5^2 + 0.2^2}$

$= 0.539$

2. An Amplitude modulated amplifier has radio frequency output of 50W at 100% modulation index with internal loss in modulator is 10W.
   a. What is the unwanted carrier power?
   b. What power output is required from the modulator (baseband signal)?
   c. If the percentage modulation is reduced to 75%, how much output is needed from modulator (baseband signal)?

$\rightarrow P_t = P_r + P_{loss}$

$= 50 + 10$

$= 60\,W$

$\Rightarrow P_t = P_c(1 + \mu^2/2)$

$\rightarrow 60 = P_c(1 + 1/2)$

$\Rightarrow 60 = P_c(1.5)$

$\rightarrow \boxed{P_c = 40\,W}$

$\Rightarrow P_t = P_c + P_s$

$\Rightarrow P_s = P_t - P_c$

$= 60 - 40$

$= 20\,W$

$\rightarrow \mu = 0.75$

$\Rightarrow 60 = P_c(1 + 0.75^2/2)$

$\Rightarrow \boxed{P_c = 46.82\,W}$

$\Rightarrow P_t = P_c + P_s$

$\Rightarrow \boxed{P_s = 13.18\,W}$

3. The Modulation index of an AM wave is changed from 0 to 1. The transmitted power is

   a. Unchanged
   b. Halved
   c. Increased by 50%
   d. Quadrupled

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

$\rightarrow$ for $m = 0$

$\Rightarrow P_t = P_c(1+0)$

$\Rightarrow \boxed{P_t = P_c}$

$\rightarrow$ for $m = 1$

$\Rightarrow P_t = P_c(1+1/2)$

$\Rightarrow \boxed{P_t = 1.5\, P_c}$

$\rightarrow$ It changes from P_c to $1.5\, P_c$

4. An AM wave is given by

$$y(t) = \underline{10}(1 + 0.4\cos(10^3 t) + 0.3\cos(10^4 t))\cos(2\pi \times 10^6 t)$$

The modulation index of the envelope is

a. 0.4
b. 0.5
c. 0.3
d. 0.9

$\rightarrow \mu_1 = 0.4$

$\rightarrow \mu_2 = 0.3$

$\rightarrow \mu = \sqrt{\mu_1^2 + \mu_2^2}$

$= \sqrt{0.4^2 + 0.3^2}$

$= 0.5$

5. The most suitable method for detecting a modulated signal $(2.5 + 5\cos(w_m t))\cos(w_c t)$

a. Envelope detector
b. Synchronous detector
c. Radio detector
d. Both a and b

$\Rightarrow y(t) = (2.5 + 5 \cos \omega_m t) \cos \omega_c t$

$= 2.5 (1 + 2 \cos \omega_m t) \cos \omega_c t$

$\rightarrow \boxed{\mu = 2}$

$\rightarrow$ Asynchronous detection $\mu \in (0, 1)$

Synchronous detection $\mu > 1$

1. Prove that in an AM, maximum average Power transmitted by AM is 1.5 times the carrier power.

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

$\rightarrow$ for max. power, $\mu = 1$

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

$\Rightarrow \boxed{P_t = 1.5\, P_c}$

2. The Antenna current of an AM broadcast transmitter, modulated to a depth of 40% by an audio sine wave is 11 amp. It increases to 12 amp as a result of simultaneous modulation by another audio sine wave. Find the modulation index due to this second sine wave.

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

$P \propto i^2$

$\Rightarrow \boxed{i_t^2 = i_c^2 \left(1 + \frac{\mu^2}{2}\right)}$

$\rightarrow \mu_1 = 40\% = 0.4$

$i_t = 11 \text{ amp}$

$\Rightarrow i_c = i_t / \sqrt{1 + \frac{0.4^2}{2}}$

$\Rightarrow \boxed{i_c = 10.58 \text{ amp}}$

$\rightarrow$ After add another Signal

$i_t = 12 \text{ amp}$

$\Rightarrow 12^2 = 10.58^2 \left(1 + \frac{\mu^2}{2}\right)$

$\Rightarrow \frac{12^2}{10.58^2} = 1 + \frac{\mu^2}{2}$

$\Rightarrow \boxed{\mu = 0.7533}$ ✓

$\Rightarrow \mu^2 = \mu_1^2 + \mu_2^2$

$\Rightarrow \mu_2^2 = \mu^2 - \mu_1^2$

$\Rightarrow \mu_2^2 = 0.7533^2 - 0.4^2$

$\Rightarrow \boxed{\mu_2 = 0.643}$

3. Determine η and the percentage of the total power carried by sidebands of AM wave for tone modulation when μ = 1, 0.5 and 0.3

→ $\mu = 1$

→ $\eta = \dfrac{\mu^2}{2+\mu^2}$

$= \dfrac{1}{2+1}$

$= 0.3333$

$= 33.33\%$

→ Side band power

$= 33.33\%$

→ Carrier Power.

$= 66.67\%$

→ $\mu = 0.5$

→ $\eta = \dfrac{\mu^2}{2+\mu^2}$

$= \dfrac{0.5^2}{2+0.5^2}$

$= 0.1111$

$= 11.11\%$

→ Side Power

$= 11.11\%$

→ Carrier Power

$= 88.89\%$

→ $\mu = 0.3$

→ $\eta = \dfrac{\mu^2}{2+\mu^2}$

$= \dfrac{0.3}{2+0.3^2}$

$= 0.043$

$= 4.3\%$

→ Sideband Power

$= 4.3\%$

→ Carrier Power

$= 95.7\%$

Example of DSB-CS

– Calculate power saving by DSB-SC for modulating Index (a) 100 % (b) 50 %

(a) = 100 %

→ For AM wave

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

$$= 1.5\, P_c$$

→ For DSB-SC

$$P_t' = P_c\left(\frac{\mu^2}{2}\right)$$

$$= 0.5\, P_c$$

→ % Power by DSB-SC

$$= \frac{P_t'}{P_t}\times 100 = \frac{0.5 P_c}{1.5\, P_c}\times 100 = 33.33\ \%$$

→ % Power Saving by DSB-SC

$$= 100 - 33.33$$

$$= 66.67\ \%$$

% Power Saving by DSB-SC

$$= \frac{P_c}{P_t}\times 100$$

$$= \frac{P_c}{1.5 P_c}\times 100$$

$$= 66.67\ \%$$

(b) = 50 %

→ For AM wave

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

$$= P_c\left(1+\frac{0.5^2}{2}\right)$$

$$= P_c(1+0.125)$$

$$= 1.125\ P_c$$

% Power Saving by DSB-SC

$$= \frac{P_c}{P_t}\times 100$$

$$= \frac{P_c}{1.125 P_c}\times 100$$

$$= 0.8888 \times 100$$

$$= 88.88\ \%$$

SSB-SC Examples

Calculate the percent power saving for the SSB signal if the AM wave is modulated to a depth of (a) 100 %. (b) 50 %.

→ % Power Saving for SSB-SC

$$= \frac{P_c + P_{\text{one side band}}}{P_c + P_{\text{two side bands}}} \times 100$$

$$= \frac{P_c + \frac{\mu^2}{4} P_c}{P_c + \frac{\mu^2}{2} P_c} \times 100$$

$$= \frac{1 + \mu^2/4}{1 + \mu^2/2} \times 100$$

(a) $\mu = 1$

$$\Rightarrow \% \text{ Power Saving} = \frac{1 + 1/4}{1 + 1/2} \times 100$$

$$= \frac{1.25}{1.5} \times 100$$

$$= 83.33 \%$$

(b) $\mu = 0.5$

$$\Rightarrow \% \text{ Power Saving} = \frac{1 + 1/16}{1 + 1/8} \times 100$$

$$= \frac{1.0625}{1.125} \times 100$$

$$= 94.44 \%$$

The amplitude modulated wave from $s(t) = \boxed{A_c\left[1 + K_a m(t)\right]}\cos\omega_c t$ is fed to an ideal envelope detector. The maximum magnitude of $K_a m(t)$ is greater than 1. Which of the following could be the detector output?

(a) $A_c m(t)$

(b) $A_c^2\left[1 + K_a m(t)\right]^2$

(c) $\left|A_c\left[1 + K_a m(t)\right]\right|$

(d) $A_c\left[1 + K_a m(t)\right]^2$

→ If Modulating Index $K_a > 1$

→ By Envelope detector we should not detect signal. For that we should use Synchronous detector.

→ $\text{Envelope} = A_c[\underbrace{1}_{DC} + \underbrace{K_a m(t)}_{AC}]$

A message signal $m(t) = \cos 2000\pi t + 4\cos 4000\pi t$ modulates the carrier $c(t) = \cos 2\pi f_c t$ where $f_c = 1$ MHz to produce an AM signal. For demodulating the generated AM signal using an envelope detector, the time constant RC of the detector circuit should satisfy

(A) 0.5 ms $< RC <$ 1 ms

(B) 1 $\mu s << RC <$ 0.5 ms

(C) $RC <<$ 1 μs

(D) $RC >>$ 0.5 ms

$\rightarrow m(t) = \cos 2000\pi t + 4 \cos 4000\pi t$

$f_1 = 1000\,Hz$ $\quad$ $f_2 = 2000\,Hz$

$\rightarrow c(t) = \cos 2\pi \times 10^6 t$

$\boxed{f_c = 10^6\,Hz}$ $\quad$ $f_m = 2000\,Hz$

$\Rightarrow \frac{1}{f_c} << RC << \frac{1}{f_m}$

$\Rightarrow \boxed{1\,\mu sec << RC << 0.5\,msec}$

Suppose that the modulating signal is $m(t) = 2\cos(2\pi f_m t)$ and the carrier signal is $x_C(t) = A_C \cos(2\pi f_c t)$, which one of the following is a conventional AM signal **without** over-modulation?

(A) $\boxed{x(t) = A_c m(t) \cos(2\pi f_c t)}$ – DSBSC

(B) $\boxed{x(t) = A_c[1 + m(t)]\cos(2\pi f_c t)}$ – AM, $\mu = 2$

(C) $x(t) = A_c \cos(2\pi f_c t) + \frac{A_c}{4} m(t) \cos(2\pi f_c t)$ AM, $\mu = \frac{1}{2}$

(D) $x(t) = A_c \cos(2\pi f_m t) \cos(2\pi f_c t) + A_c \sin(2\pi f_m t) \sin(2\pi f_c t)$

→ AM Signal

→ $\mu < 1$

→ $m(t) = 2\cos(2\pi f_m t)$

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

→ $x(t) = A_c(1 + \mu x(t))\cos(2\pi f_c t)$

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

Consider the following Amplitude Modulated (AM) signal, where $f_m < B$

$X_{AM}(t) = 10(1 + 0.5 \sin 2\pi f_m t) \cos 2\pi f_c t$

1. The average side-band power for the AM signal given above is

(a) 25

(b) 12.5

(c) 6.25

(d) 3.125

→ Standard form

$$x(t) = A_c(1 + \mu x(t)) \cos \omega_c t$$

→ $A_c = 10$

$\mu = 0.5$

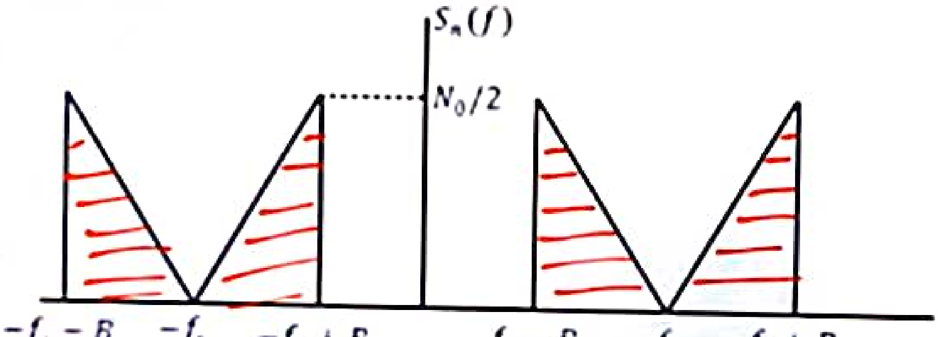
→ $P_s = \frac{\mu^2}{2} P_c$

→ $P_c = \frac{A_c^2}{2} = \frac{100}{2} = 50\ W$

→ $P_s = \frac{0.5^2}{2} \times 50$

$= \frac{50}{8} = \frac{25}{4} = 6.25\ W$

The AM signal gets added to a noise with Power Spectral Density $S_n(f)$ given in the figure below. The ratio of average sideband power to mean noise power would be:



(a) $\frac{25}{8N_0B}$

(b) $\frac{25}{4N_0B}$

(c) $\frac{25B}{2N_0B}$

(d) $\frac{25}{N_0B}$

$\rightarrow P_S = \frac{25}{4}$

$\rightarrow P_N = 4\left(\frac{1}{2} \times \frac{N_0}{2} \times B\right)$

$\Rightarrow P_N = N_0B$

$$SNR = \frac{P_S}{P_N} = \frac{25}{4(N_0B)}$$

A 1 MHz sinusoidal carrier is amplitude modulated by a symmetrical square wave of period 100µsec. Which of the following frequencies will NOT be present in the modulated signal?

(a) 990 KHz (b) 1010 KHz (c) 1020 KHz (d) 1030 KHz

→ $F_c = 1 \text{ MHz} = 1000 \text{ KHz}$

$F_m = \dfrac{1}{100 \mu sec} = 10 \text{ KHz}$

→ Symetrical Square wave Contains only odd harmonics. f_m, $3f_m$, $5f_m$, ...

→ In AM Signal

f_c, $f_c \pm f_m$, $f_c \pm 3f_m$, $f_c \pm 5f_m$

1000 KHz

990 KHz
1010 KHz

1030 KHz
970 KHz

1050 KHz
950 KHz

A DSB-SC signal is to be generated with a carrier frequency $f_c = 1\text{MHz}$ using a nonlinear device with the input-output characteristic

$v_0 = a_0 v_i + a_1 v_i^3$

where a_0 and a_1 are constants. The output of the nonlinear device can be filtered by an appropriate band-pass filter.

Let $v_i = A_c' \cos(2\pi f_c' t) + m(t)$ where m(t) is the message signal. Then the value of f_c' (in MHz) is

(a) 1.0 (b) 0.333 (c) 0.5 (d) 3.0

$- f_c = 1\text{MHz}$

$- V_o = a_0 V_i + a_1 V_i^3$

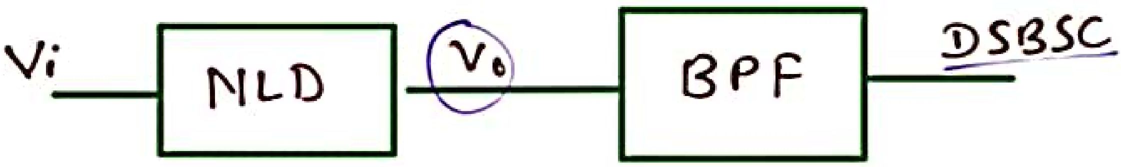
$\rightarrow V_i = A_c' \cos(2\pi f_c' t) + m(t)$

$\rightarrow V_o = a_0(A_c' \cos(2\pi f_c' t) + m(t)) + a_1(A_c' \cos(2\pi f_c' t) + m(t))^3$

$$\boxed{\begin{aligned} V_o = {} & a_0(A_c' \cos(2\pi f_c' t) + m(t)) + \\ & a_1(A_c'^3 \cos^3(2\pi f_c' t) + m^3(t) + \\ & 3A_c' \cos(2\pi f_c' t)\, m^2(t) + \\ & 3A_c'^2 \cos^2(2\pi f_c' t)\, m(t)) \end{aligned}}$$

$$V_0 = a_0\left(A_c' \cos(2\pi f_c' t) + m(t)\right) + a_1\left(A_c'^3 \cos^3(2\pi f_c' t) + m^3(t)\right.$$

$$\left. + \boxed{3 A_c'^2 \cos^2(2\pi f_c' t)\, m(t)} + 3 A_c' \cos(2\pi f_c' t)\, m^2(t)\right)$$



$$\rightarrow V_0 = 3 A_c'^2 a_1 \cos^2(2\pi f_c' t)\, m(t)$$

$$= \frac{3 A_c'^2 a_1}{2}\left(1 + \cos(2(2\pi f_c' t))\right) m(t)$$

$$= \frac{3 A_c'^2 a_1}{2} + \boxed{\frac{3 A_c'^2 a_1}{2}\left(m(t) \cos(4\pi f_c' t)\right)}$$

$$f_c = 2 f_c' = 1\,\text{MHz} \Rightarrow \boxed{f_c' = 0.5}$$

$$= 1\ f_c'$$

For a message signal $m(t) = \cos(2\pi f_m t)$ and carrier of frequency f_c, which of the following represents a single-side-band (SSB) signal ?

(A) $\cos(2\pi f_m t)\cos(2\pi f_c t)$

(B) $\cos(2\pi f_c t)$

(C) $\cos[2\pi(f_c + f_m)t]$

(D) $[1 + \cos(2\pi f_m t]\cos(2\pi f_c t)$

DSBSC

Carrier signal

USB (SSB-SC)

AM Standard form.

A message signal given by

$$m(t) = \left(\frac{1}{2}\right)\cos\omega_1 t - \left(\frac{1}{2}\right)\sin\omega_2 t$$

is amplitude-modulated with a carrier of frequency ω_c to generate

$$s(t) = [1 + m(t)]\cos\omega_c t$$

What is the power efficiency achieved by this modulation scheme ?

(A) 8.33 %
(B) 11.11 %
(C) 20 %
(D) 25 %

$\rightarrow s(t) = \left(1 + \underbrace{\left(\frac{1}{2}\right)\cos\omega_1 t}_{m_1 = 0.5} - \underbrace{\left(\frac{1}{2}\right)\cos\omega_2 t}_{m_2 = 0.5}\right)\cos\omega_c t$

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

$= \sqrt{(1/2)^2 + (1/2)^2}$

$= 1/\sqrt{2}$

$\rightarrow A_c = 1$

$\rightarrow P_c = A_c^2/2 = 1/2$

$\rightarrow P_s = \frac{\mu^2}{2} P_c$

$= \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$

$= \frac{1}{8}$

$\rightarrow \eta = \frac{P_s}{P_s + P_c}$

$= \frac{1/8}{1/2 + 1/8}$

$= \frac{1/8}{5/8}$

$= \frac{1}{5} \times 100$

$= 20\%$.

[redacted] A career signal $c(t) = 20\cos 2\pi 10^6 t$ is modulated by a message signal $m(t) = 20\cos 8\pi 10^3 t$ to generate DSB-SC , Calculate B.W. , Total Power and modulation Efficiency.

$\rightarrow$ $c(t) = \underline{20} \cos 2\pi \times 10^6 t \rightarrow f_c = 10^6$ Hz

$m(t) = \underline{20} \cos 8\pi \times 10^3 t \rightarrow f_m = 4 \times 10^3$ Hz

$\rightarrow$ $\left.\begin{array}{l} A_c = 20 \text{ Volt} \\ A_m = 20 \text{ Volt} \end{array}\right\} \rightarrow$ Modulating Index

$$m = \frac{A_m}{A_c} = 1$$

$\rightarrow$ for DSB-SC

$$BW = 2f_m = 2 \times 4 \times 10^3 = 8 \times 10^3 = 8 \text{ KHz}$$

$$P_t = P_s = \frac{1}{2}\mu^2 P_c = \frac{1}{2}\mu^2 \left(\frac{A_c^2}{2}\right) = \frac{1}{2} \times 1 \times \frac{20^2}{2}$$

$$= 100 \text{ W}$$

$\rightarrow$ for DSB-SC

$$\eta = \frac{P_s}{P_t} = \frac{P_s}{P_s} = 100\ \%$$

[redacted] In a double side-band (DSB) full carrier AM transmission system, if the modulation index is doubled, then the ratio of total sideband power to the carrier power increases by a factor of ________.

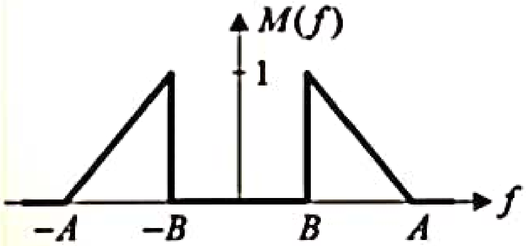
$\rightarrow \dfrac{P_s}{P_c} = \dfrac{\frac{1}{2}\mu^2 P_c}{P_c} = \dfrac{1}{2}\mu^2$ — (1)

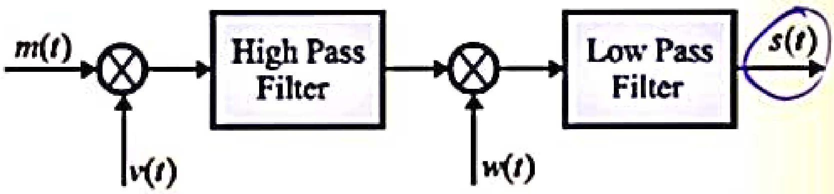
$\rightarrow$ If $\mu' = 2\mu$

$\rightarrow \left(\dfrac{P_s'}{P_c'}\right) = \dfrac{1}{2}\mu'^2 = \dfrac{1}{2}(2\mu)^2 = 4\left(\dfrac{1}{2}\mu^2\right)$ — (2)

$\rightarrow$ ratio $= \dfrac{4\left(\cancel{1/2\,\mu^2}\right)}{\cancel{1/2\,\mu^2}} = \underline{\underline{4}}$

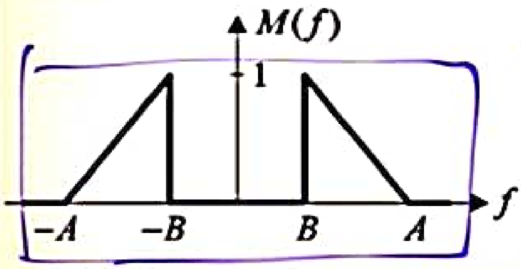
In the figure, $M(f)$ is the Fourier transform of the message signal $m(t)$ where A = 100 Hz and B = 40 Hz. Given $v(t)=\cos(2\pi f_c t)$ and $w(t)=\cos(2\pi(f_c+A)t)$ where $f_c > A$. The cut-off frequencies of both the filters are f_c. **[Set - 02]**

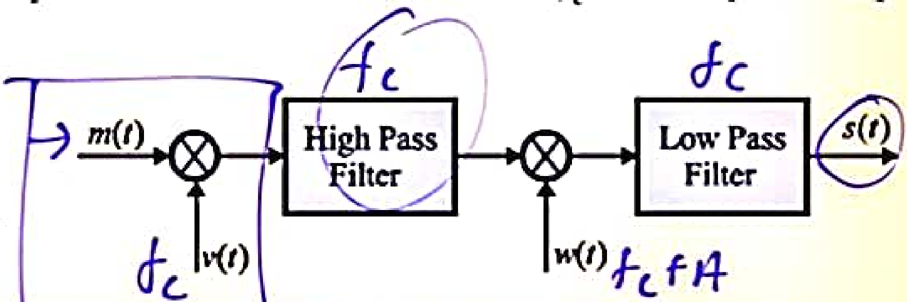




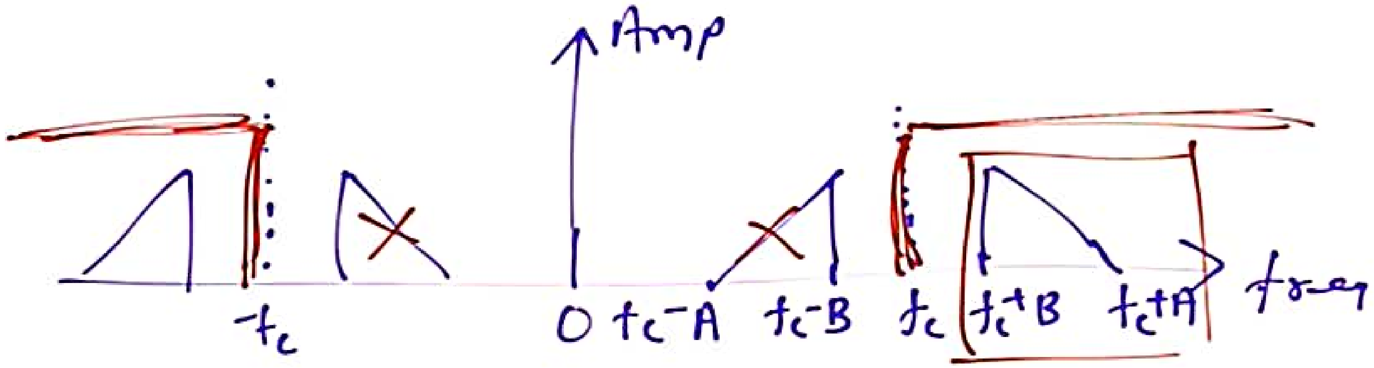
The bandwidth of the signal at the output of the modulator (in Hz) is __________.

In the figure, $M(f)$ is the Fourier transform of the message signal $m(t)$ where $A = 100$ Hz and $B = 40$ Hz. Given $v(t) = \cos(2\pi f_c t)$ and $w(t) = \cos(2\pi(f_c + A)t)$ where $f_c > A$. The cut-off frequencies of both the filters are f_c. **[Set - 02]**





The bandwidth of the signal at ~~the output of~~ the modulator (in Hz) is ________.



$A - B = 100 - 40 = 60$ Hz

[redacted] Which of the following analog modulation scheme requires the minimum transmitted power and minimum channel bandwidth ?

(A) VSB (B) DSB-SC

(C) $\boxed{\text{SSB}}$ (D) AM

→ VSB − $P_t = P_{LSB}$ or P_{USB} $+ P_{VB}$

$BW = f_m + f_v$

→ SSB

$P_t = P_{LSB}$ or P_{USB}

$BW = f_m$

→ DSB-SC

- $P_t = P_{LSB} + P_{USB}$
- $BW = 2f_m$

→ AM

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

$BW = 2f_m$

[redacted] The Hilbert transform of $\cos\omega_1 t + \sin\omega_2 t$ is

(A) $\sin\omega_1 t - \cos\omega_2 t$ (B) $\sin\omega_1 t + \cos\omega_2 t$

(C) $\cos\omega_1 t - \sin\omega_2 t$ (D) $\sin\omega_1 t + \sin\omega_2 t$

→ $s(t) = \cos\omega_1 t + \sin\omega_2 t$

→ for Hilbert transform

+ve freq → -90°

-ve freq → $+90^\circ$

→ $s_H(t) = \cos(\omega_1 t - 90) + \sin(\omega_2 t - 90)$

$= \boxed{\sin\omega_1 t - \cos\omega_2 t}$

[redacted] Consider sinusoidal modulation in an AM system. Assuming no overmodulation, the modulation index (μ) when the maximum and minimum values of the envelope, respectively, are 3 V and 1 V, is ______.

$\rightarrow A_{max} = 3\,V \Rightarrow A_c + A_m = 3\,V$

$A_{min} = 1\,V \Rightarrow A_c - A_m = 1\,V$

$\Rightarrow 2A_c = 4\,V$

$\Rightarrow \boxed{A_c = 2\,V}$

$\Rightarrow \boxed{A_m = 1\,V}$

$\rightarrow m = \dfrac{A_m}{A_c}$

$= \dfrac{1}{2} = \boxed{0.5}$

[redacted] The amplitude of a sinusoidal carrier is modulated by a single sinusoid to obtain the amplitude modulated signal $s(t) = 5\cos 1600\pi t + 20\cos 1800\pi t + 5\cos 2000\pi t$. The value of the modulation index is _0.5_.

$$s(t) = \underbrace{5\cos 1600\pi t}_{\text{LSB}} + \underbrace{20\cos 1800\pi t}_{\text{Carrier}} + \underbrace{5\cos 2000\pi t}_{\text{USB}}$$

$$\rightarrow y(t) = A_c(1 + \mu\cos\omega_m t)\cos\omega_c t$$

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

$$= \underbrace{A_c\cos\omega_c t}_{\text{Carrier}} + \frac{A_c\mu}{2}\underbrace{\cos(\omega_c+\omega_m)t}_{\text{USB}} + \frac{A_c\mu}{2}\underbrace{\cos(\omega_c-\omega_m)t}_{\text{LSB}}$$

$$\rightarrow A_c = 20$$

$$\rightarrow \frac{A_c\mu}{2} = 5 \Rightarrow \mu = \frac{10}{A_c} = \frac{10}{20} = \frac{1}{2} = \underline{0.5}$$

An AM transmitter radiates 50 W when the carrier is not modulated. Determine the total power radiate when the modulation index=1

a. 55 W
b. 60 W
c. 75 W
d. 100 W

→ $P_c = 50\,W$

$\mu = 1$

→ $P_t = P_c + P_s$

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

$= 50 + \frac{1}{2} \times 1 \times 50$

$= 75\,W$

Let $m(t) = \cos[(4\pi \times 10^3)\, t]$ be the message signal &
$c(t) = 5\cos[(2\pi \times 10^6\, t)]$ be the carrier.
$c(t)$ and $m(t)$ are used to generate an AM signal.
The modulation index of the generated AM signal is 0.5.
Then the quantity $\frac{\text{Total sideband power}}{\text{Carrier power}}$ is

(A) $\frac{1}{2}$

(B) $\frac{1}{4}$

(C) $\frac{1}{3}$

(D) $\frac{1}{8}$

$$\boxed{\eta = \frac{P_s}{P_t} = \frac{\mu^2}{2+\mu^2}}$$

$$\rightarrow \frac{P_s}{P_c} = \frac{\frac{1}{2}\mu^2 \cancel{P_c}}{\cancel{P_c}} = \frac{1}{2}\mu^2$$

$$= \frac{1}{2}\left(\frac{1}{2}\right)^2$$

$$= \frac{1}{8}$$

$A_m = 1$ volt

$A_c = 5$ volt

$\Rightarrow m = \frac{A_m}{A_c}$

$= \frac{1}{5}$

0.2

$$\frac{P_s}{P_c} = \frac{1}{2}\mu^2 = \frac{1}{2} \times \left(\frac{1}{5}\right)^2$$

$$= \frac{1}{50}$$