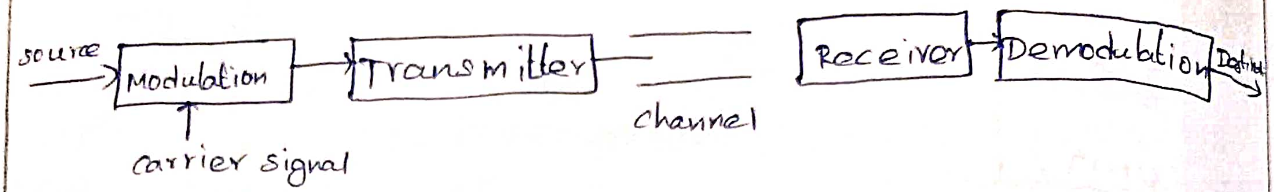
30.1.23

Modulation:

process of placing message signal over some carrier to make it suitable for transmission over long distance.



Demodulation:

process of separting message signal from the modulated carrier signals

Analog and digital communication

=> Less data loss

=> speed

=> small size

=> clarity.

Need for modulation

=> High range transmission

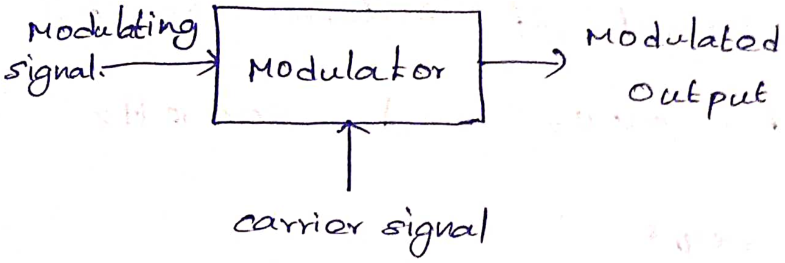
-> Quality transmission

=> To avoid overlaping of signals.

=> Data loss is due to

- Additive noise interference
- signal attenuation.
- Amplitude & phase distorsion.
- Multipath distorsion

2.2.23



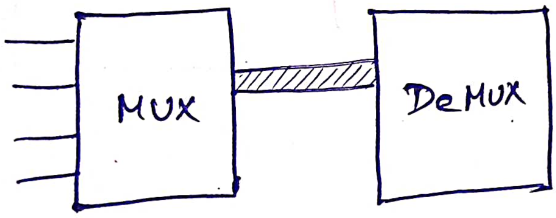
Classification of Modulation.

- ⇒ Analog Modulation.
- ⇒ Pulse Modulation
- ⇒ Digital Modulation.

Analog Modulation

- Amplitude Modulation.
- Angle Modulation.
  - phase Modulation
  - Frequency modulation.

1) Multiplexing:



2) Transmission Antenna Height

$h = \lambda/2$, $\lambda = c/f$

1. calculate the height of Antenna to be installed if frequency $f = 5KHz$ and $500 kHz$

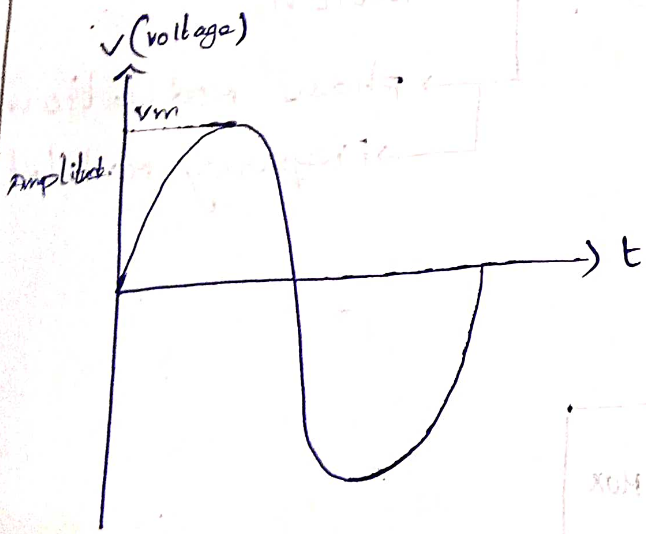
$f = 5kHz$

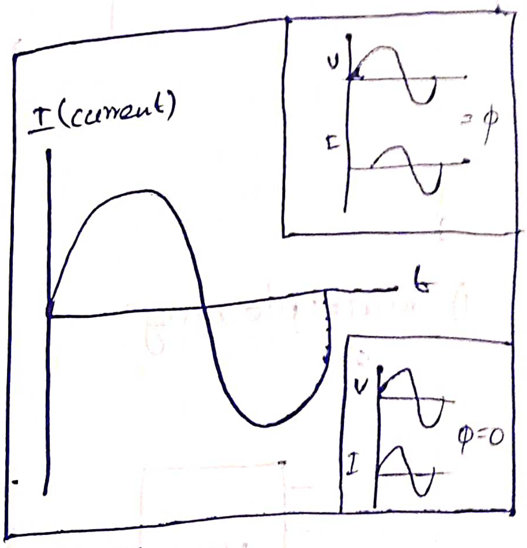
$$\lambda = c/f = \frac{3\times10^8}{5\ kHz}$$

$$h = \frac{c}{2f} \Rightarrow \lambda/2 = \frac{c/f}{2} = \frac{3\times10^8}{2\times5\times10^3} = \frac{3\times10^5}{10} = 30000m$$

$f = 500kHz$

$$h = \frac{c}{2f} \Rightarrow \frac{\lambda}{2} = \frac{c/f}{2} = \frac{3\times10^8}{2\times500\times10^3} = \frac{3\times10^5}{1000} = \frac{300000}{1000} = 300m$$





$V = V_m \sin\omega t$

↳ peak voltage. (or) Maximum voltage.

V_{p-p} peak to peak voltage.

1. For a sin signal find max value if $V_{p-p} = 10V$. Also find the value of voltage at $\theta = 90^\circ$ and 45°

$$V_m = \frac{V_{p-p}}{2} = \frac{10}{2} = 5V$$

$\because \omega t = \theta$

i) $\theta = 90^\circ \Rightarrow v = 5\sin 90^\circ$

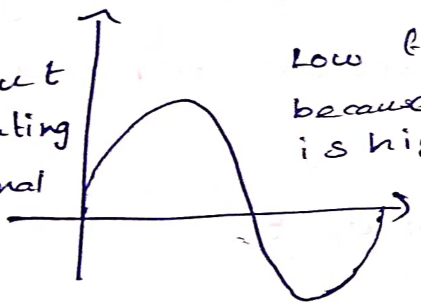
$= 5V$

ii) $\theta = 45^\circ \Rightarrow v = 5\sin 45^\circ$

$= 5/\sqrt{2} = \frac{5}{1.414} = 3.536V$

3.2.23 **Amplitude Modulation:**

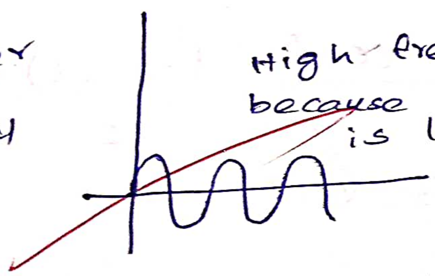
input modulating signal



Low frequency because time is high.

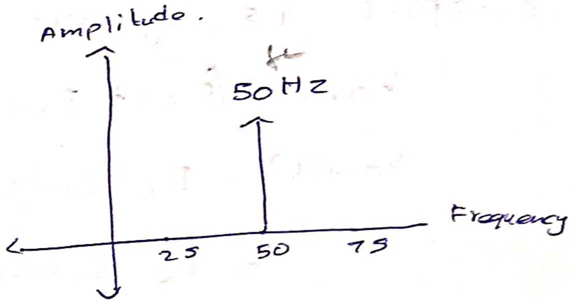
+

carrier signal



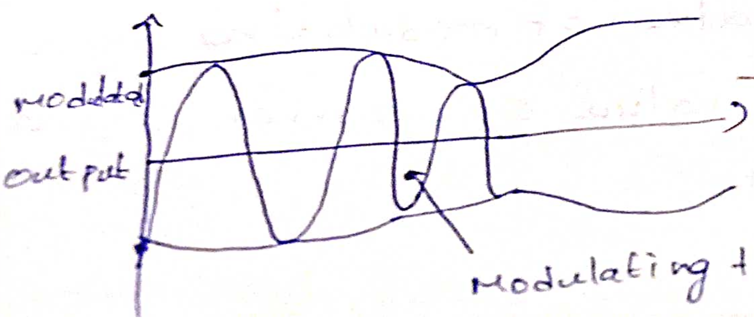
High frequency because time is low.

Spectrum:

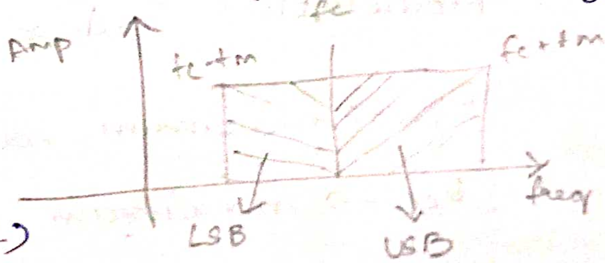


$\rightarrow$ with high frequency amplitude. (super-imposing signal)

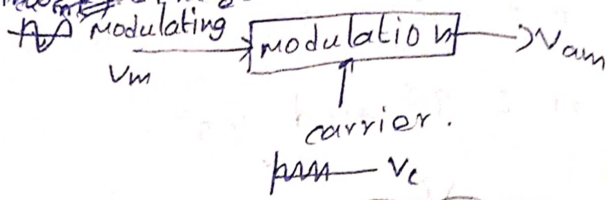
super-imposing signal



Modulating + carrier.



4.2.23



$V_m = E_m \sin\omega_m t$

$V_m = E_m \sin 2\pi f_m t$

or

$\omega_m t$

$V_c = E_c \cdot \sin\omega_c t$

$V_c = E_c \cdot \sin 2\pi f_c t$

m → modulating signal

f_m → frequency of modulating.

c → carrier signal.

f_c → frequency of carrier signal

The process of changing the characteristics (amplitude) of carrier signal with respect to instantaneous change in modulating signal is known as amplitude modulation. As modulating signal is super imposed with carrier signal to get modulated output, the equation for modulated output is given by

$$V_{am} = (E_c + E_m \sin\omega_m t)\sin\omega_c t$$

$$V_{am}(t) = E_c \sin\omega_c t + E_m \sin\omega_m t \cdot \sin\omega_c t$$

$$= E_c \sin\omega_c t + E_m \frac{\cos(\omega_c t - \omega_m t) - \cos(\omega_m t + \omega_c t)}{2} \quad \text{—— } ①$$

$$\sin A \cdot \sin B = \frac{\cos(A-B) - \cos(A+B)}{2}$$

modulation index, $m = \frac{E_m}{E_c}$

E_m → maximum value of modulating signal.

E_c → maximum value of carrier signal.

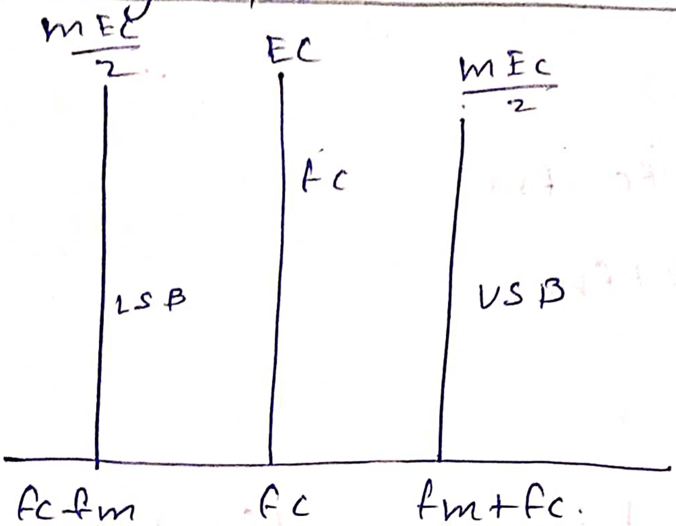
$m = \frac{E_m}{E_c}$, $\omega = 2\pi f$

$E_m = m \cdot E_c$

$$① \Rightarrow V_{AM} = E_c \sin 2\pi f_c t + \frac{mE_c}{2} \cos 2\pi \overbrace{(f_c - f_m)}^{f_{LSB}} t$$

$$- \frac{mE_c}{2} \cos 2\pi \overbrace{(f_m + f_c)}^{f_{USB}} t$$

<u>Frequency Spectrum of AM:</u>



<u>Bandwidth</u> $= f_{USB} - f_{LSB}$

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

$= f_m + \cancel{f_c} - \cancel{f_c} + f_m$

$= 2 f_m$

Upper side Band $\rightarrow$ USB

Lower side Band $\rightarrow$ LSB.

Bandwidth [(B) or (BW)]

=) The difference between upper side band frequency and lower side band frequency is called Bandwidth.

$B = (USB) - (LSB)$

$B = (f_c + f_m) - (f_c - f_m)$

$= f_c + f_m - f_c + f_m$

$= 2f_m.$

Modulation envelope

=) The shape of modulation signal (modulate waveform) is called modulation Envelope.

Modulation index (or) coefficient

=) The amount of amplitude change (modulation) present in an output of modulation waveform is termed as modulation coefficient.

$m = \frac{E_m}{E_c}$ E_m → Maximum value of modulating signal. E_c → Maximum value of carrier signal

---

1. For an amplitude modulated wave carrier signal frequency is 200 kHz and modulated frequency is 6 kHz. Find (i) Frequency limits (upper and Lower side band) (ii) Bandwidth. (iii) Draw the frequency spectrum.

i) Frequency limits.

$f_c = 200\,kHz, \quad f_m = 6\,kHz$

$USB = f_c + f_m = 200 + 6 = 206\,kHz.$

$LSB = f_c - f_m = 200 - 6 = 194\ kHz$

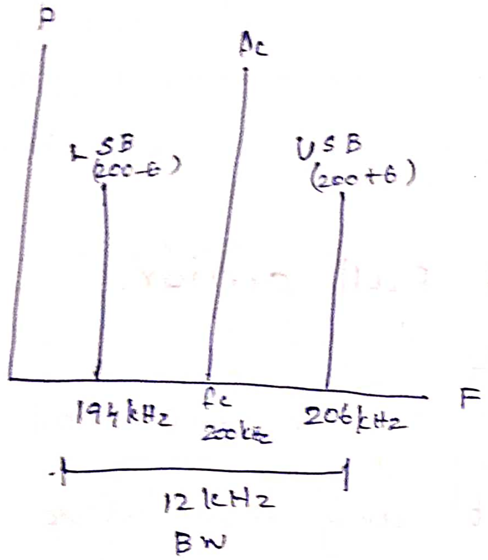
ii) Bandwidth

$BW = 2f_m$

$= 2 \times 6$

$B = 12\ kHz$

iii) frequency spectrum



2. For Amplitude modulation, carrier frequency = 400 kHz with 20 v maximum and modulating frequency = 8kHz with 8.5v max. Find side band limits and modulation coefficient.

frequency limits. $f_c = 400\ kHz$, $f_m = 8\ kHz$

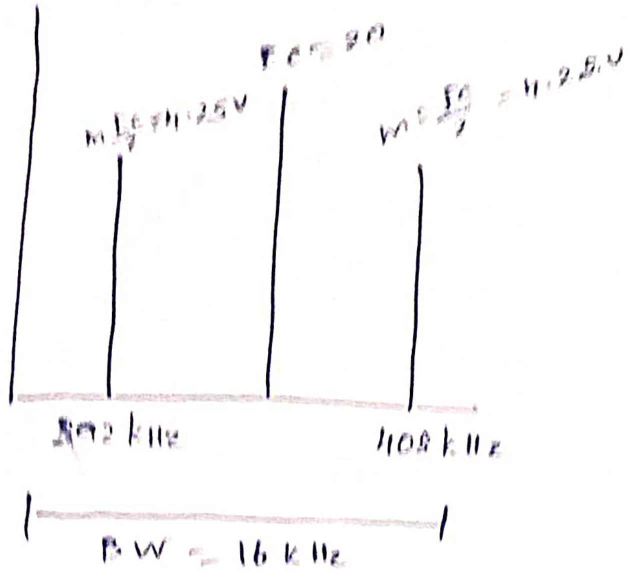
$USB = f_c + f_m = 400 + 8 = 408\ kHz$

$LSB = f_c - f_m = 400 - 8 = 392\ kHz.$

modulation coefficient.

$E_c = 20v$, $E_m = 8.5v.$

$$m = \frac{E_m}{E_c} = \frac{8.5}{20} = 0.425$$



DSBFC

⇒ Double side Band Full carrier.

Tutorial:-

1. Amplitude Modulation DSBFC is modulated with a carrier of 60 $\sin\omega_c t$ and modulating signal of 30 $\sin\omega_m t$. determine the modulation index and percentage modulation.

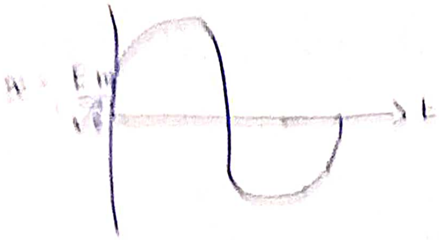
2. Define Amplitude modulation and mention the need for modulation.

3. show the amplitude modulation envelope.

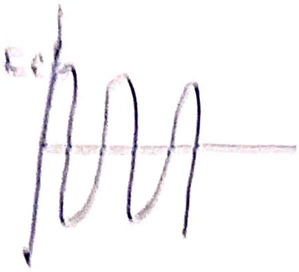
4. Draw the frequency spectrum for LSB = 121 kHz and USB 139 kHz with Ec = 8 V and m = 0.4.

5. Derive the amplitude modulation output with voltage equations.

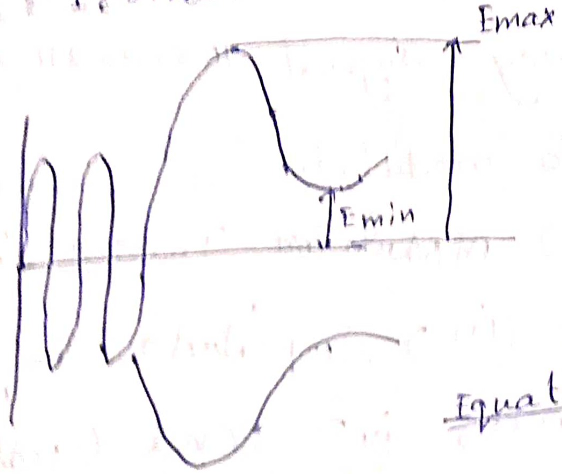
Modulation index for modulated waveform



$e_m = E_m \sin \omega_m t$



$e_c = E_c \sin \omega_c t$



Equation for modulation:

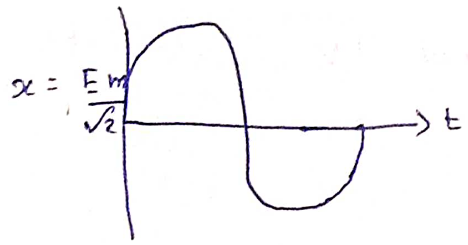
$$E_m = \frac{E_{max} - E_{min}}{2}$$

$$E_c = \frac{E_{max} + E_{min}}{2}$$ (modulated & unmodulated)

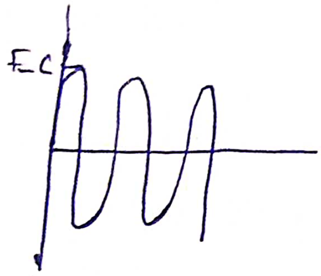
$$m = \frac{E_m}{E_c} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$ (Percentage modulation)

3.2.23

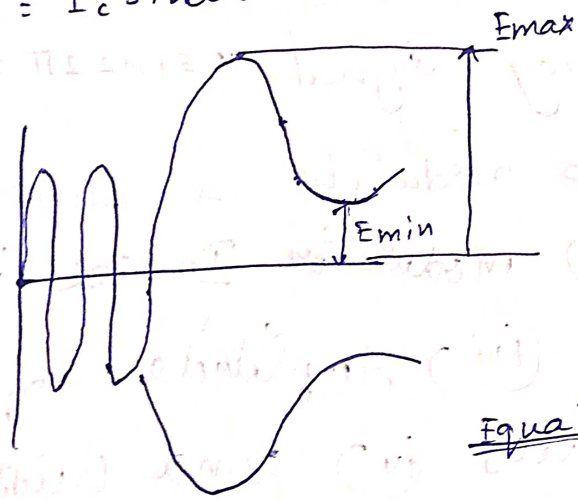
modulation index for modulated waveform



$e_m = E_m \sin \omega t$



$e_c = E_c \sin \omega t$



Equation for modulation.

$$E_m = \frac{E_{max} - E_{min}}{2}$$

$$E_c = \frac{E_{max} + E_{min}}{2}$$ (modulated & Unmodulated

/ Percentage modulation

$$m = \frac{E_m}{E_c} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}.$$

1. The carrier Amplitude after Amplitude modulation varies between 4 V and 1V. Calculate the depth of modulation.

$E_{max} = 4V$, $E_{min} = 1V$

$$\text{depth} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$

$$= \frac{4-1}{4+1}$$

$$= \frac{3V}{5V} = 0.6$$

2. An Audio frequency signal $10 \sin 2 2\pi \times 500t$ is used to amplitude modulate a carrier of $50 \sin 2\pi \times 10^5 t$ (i) Modulation Index (ii) Side Band frequencies (iii) Amplitude of side Band frequencies (iv) Band width

i) Modulation index

$E_m = 10$, $E_c = 50$

$$m = \frac{10}{50}$$

$$\boxed{m = \frac{1}{5}} = 0.2 = 20\%$$

ii) Side Frequencies.

$USB = f_c + f_m$

$= 100000 + 500$ Hz

Hz → kHz, divide by 1000

$= 100 + 0.5$ kHz

$= 100.5\ kHz.$

$LSB = f_c - f_m$

$= 100 - 0.5\ kHz$

$= 99.5\ kHz.$

iv) Band ~~frequence~~ width

$= 2f_m$

$= 2 \times 0.5\ kHz$

$= 1\ kHz$

iii) Amplitude $= \frac{mE_c}{2}\ V$

$= \frac{0.2 \times \cancel{50}^{25}}{\cancel{2}}$

$= 5\ V$

1.2.23

AM power distribution:

$\boxed{P = V \cdot I}$

$$V_{AM}(t) = \underbrace{E_c \sin\omega_c t}_{\text{carrier}} + \underbrace{\frac{mE_c}{2} \cos 2\pi(f_c - f_m)t}_{LSB} - \underbrace{\frac{mE_c}{2} \cos 2\pi(f_c + f_m)t}_{USB}$$

From the given AM voltage equation, the signal has 3 component - i) carrier signal.

ii) LSB

iii) USB.

Hence total power is given by

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

$\frac{V^2}{R} \to \frac{V_{RMS}^2}{R} = \left(\frac{V_m}{\sqrt{2}}\right)^2 / R$ $\qquad \left[\because V_{RMS} = \frac{V_m}{\sqrt{2}}\right]$

$$P_c = \left(\frac{V^2}{R}\right) = \frac{\left(\frac{E_c}{\sqrt{2}}\right)^2}{R}$$

$$\boxed{P_c = \frac{E_c^2}{2R}} \quad \text{—— ①}$$

power of side band signals given by

$$P_{LSB} = P_{USB}$$

$$= \frac{V_{RMS}^2}{R}$$

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

$$\boxed{P_{LSB} = P_{USB} = \frac{m^2 E_c^2}{8R}} \quad \text{—— ②.}$$

substituting equations ① and ② in P_{total},

we get

(carrier + side bands)

$$P_{Total} = \frac{E_c^2}{2R} + \frac{m^2 E_c^2}{8R} + \frac{m^2 E_c^2}{8R}.$$

$$= \frac{E_c^2}{2R}\left[1 + \frac{m^2}{4} + \frac{m^2}{4}\right]$$

$$= \frac{E_c^2}{2R}\left[1 + \frac{\cancel{2}m^2}{{}_2\cancel{4}}\right]$$

$$= \frac{E_c^2}{2R}\left[1 + \frac{m^2}{2}\right]$$

$$\boxed{P_{Total} = P_c\left[1 + \frac{m^2}{2}\right]} \qquad \left[\because P_c = \frac{E_c^2}{2R}\right]$$

1. Find the total power delivered to the load 600 ohms. For $E_c = 50 \sin 2\pi \times 10^5 t$, $E_m = 10 \sin 2\pi \times 500 t$

$$P_{Total} = \left[P_c\left(1 + \frac{m^2}{2}\right)\right]$$

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

$E_c = 50$, $R = 600$ ohms, $E_m = 10$

$$P_c = \frac{50^2}{2 \times 600} = \frac{250\cancel{0}}{120\cancel{0}}$$

$$P_c = \frac{25}{12} = 2.08$$

$$m = \frac{E_m}{E_c} = \frac{10}{50}$$

$$\boxed{m = 1/5} = 0.2$$

$$P_{Total} = P_c\left[1 + \frac{m^2}{2}\right]$$

$$= \frac{25}{12}\left[1 + \frac{(0.2)^2}{2}\right]$$

$$= \frac{25}{12}\left[\frac{2 + 0.04}{2}\right]$$

$$= \frac{25}{12}\left[\frac{2.04}{2}\right]$$

$$= \frac{51}{24}$$

$$\boxed{P_{Total} = 2.125} \, W$$

2. A 400 w carrier is modulated to a depth of 80%. calculate the total power.

$$P_{Total} = P_c\left[1 + \frac{m^2}{2}\right]$$

$P_c = 400$ w, $m = 80\% = 0.8$

$$P_{Total} = 400\left[\frac{1 + (0.8)^2}{2}\right]$$

$$= 400\left[\frac{1 + 0.64}{2}\right]$$

$$= 400\left[\frac{2 + 0.64}{2}\right]$$

$$= 400(1.32)$$

$$= 528 \text{ w}$$

16.2.23

1. For an AM envelope $V_{max} = 30\,V_p$ and $V_{min} = 10\,V_p$.

Find a) unmodulated carrier amplitude.

b) modulated carrier amplitude.

c) percentage modulation.

2. AM amplitude modulation DSBFC peak unmodulated carrier voltage $E_c = 15$ v and load resistance $R_c = 15\Omega$. Determine the following for $m = 1$, $m = 0.5$

a) power of carrier

b) upper and lower side band

c) Total side band power

d) Total power.

1. $V_{max} = 30V_p$; $min = 10V_p$

a) $E_c = \frac{V_{max} + V_{min}}{2} = \frac{30+10}{2} = 20V$

b) $E_c = 20V$ $\boxed{\because E_c \text{ will not change}}$

c) $E_m = \frac{V_{max} - V_{min}}{2} = \frac{30-10}{2} = 10$

$m = \frac{E_m}{E_c} = \frac{10}{20} = \frac{1}{2} = 50\%$.

2. $E_c = 15V$, $R = 15\Omega$

a) $P_c = \frac{E_c^2}{2R} = \frac{15^2}{2(15)} = \frac{225}{30}$

$P_c = \frac{45}{6} = 7.5W$

b) LSB and USB

$m = 1$

$\Rightarrow \frac{m^2 E_c^2}{8R} = \frac{225}{120} = 1.875W$

$m = 0.5$

$\Rightarrow \frac{(0.5)^2 (225)}{120} = 0.468W$

c) Total side band power. $\boxed{\text{Total SBP} = 4.686W}$

$m = 1 \Rightarrow 1.875 + 1.875 = 3.75W$.

$m = 0.5 \Rightarrow 0.468 + 0.468 = 0.936W$.

d) Total power: $P_{total} = P_c \left[1 + \frac{m^2}{2}\right]$

$m = 1 \Rightarrow 7.5\left[1 + \frac{1^2}{2}\right] = (1.5) \times 7.5 = 11.25$.

$m = 0.5 \Rightarrow 7.5\left[1 + \frac{0.25}{2}\right] \Rightarrow (1.125) \times 7.5 = 8.4375$.

17.2.23

categories of modulation index (m)

=) critical modulation, $m=1$ also $E_m = E_c$

-) Under modulation, $E_m < E_c$

=) Over modulation, $E_m > E_c$

↳ In over modulation condition, the amplitude of message signal is greater than the amplitude of carrier signal. so, the envelope no longer resembles the modulating signal. Hence, the information cannot be retrived also. the information is lost to some extent in this case.

-) when modulating signal has several frequencies with one carrier signal we have combined co-efficient as the sequence of quadratic sum of individual modulating indexes

$$m_1 = \frac{E_{m1}}{E_c}, \quad m_2 = \frac{E_{m2}}{E_c}$$

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

$$P_c = \frac{E_c^2}{2R}, \quad P_{USB} = P_{LSB} = \frac{m_1^2 E_c^2}{8R} \Rightarrow P_{USB1} = P_{USB2} = \frac{m_1^2 E_c^2}{8R}$$

$$\boxed{P_{Total} = P_c + P_{LSB_1} + P_{USB_1} + P_{LSB_2} + P_{USB_2} + \dots}$$

17.2.23

1. For the given signals $E_c = 10 \sin \omega t$, $E_{m_1} = 25 \sin \omega t$, $E_{m2} = 15 \sin \omega t$, $E_{m3} = 12 \sin \omega t$. Find the modulation indexes

$$m_1 = \frac{E_{m1}}{E_c} = \frac{25}{10} = 2.5$$

$$m_2 = \frac{E_{m2}}{E_c} = \frac{15}{10} = 1.5$$

$$m_3 = \frac{E_{m3}}{E_c} = \frac{12}{10} = 1.2$$

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

$$= \sqrt{(2.5)^2 + (1.5)^2 + (1.2)^2}$$

$$= \sqrt{6.25 + 2.25 + 1.44}$$

$$= \sqrt{9.94}$$

$$= 3.152$$

2. In an AM wave carrier power $P_c = 150\,W$ it is simultaneously with 3 modulating signals with $m_1 = 0.3$, m_2, 0.4, m_3, 0.5. i) Find Total coefficient of modulation, ii) Total side band power iii) Total transmitted power, $E_c = 15\,v$, $R = 100\Omega$

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

i) $$m = \sqrt{m_1^2 + m_2^2 + m_3^2}$$

$$= \sqrt{(0.3)^2 + (0.4)^2 + (0.5)^2}$$

$$= \sqrt{0.9 + 0.16 + 0.25}$$

$$= \sqrt{0.50}$$

$$\boxed{m = 0.707}$$

iii) $P_T = P_C\left(1 + \frac{m^2}{2}\right)$

$$P_T = P_C\left(1 + \frac{(\sqrt{0.50})^2}{2}\right)$$

$$= 150\left(1 + \frac{0.50}{2}\right)$$

$$= 150(1.25)$$

$$\boxed{P_T = 187.5}$$

ii) $P_{LSB1} = P_{USB1} = \frac{m_1^2 E_c^2}{8R}$

$$= \frac{(0.3)^2 (15)^2}{8(100)} = \frac{(0.9)(225)}{800} = 0.025$$

$$P_{LSB2} = P_{USB2} = \frac{m_2^2 E_c^2}{8R}$$

$$= \frac{(0.4)^2 (15)^2}{8 \times 100} = \frac{(0.16)(225)}{800} = 0.045$$

$$P_{LSB3} = P_{USB3} = \frac{m_3^2 E_c^2}{8R}$$

$$= \frac{(0.5)^2 (15)^2}{8 \times 100} = \frac{(0.25)225}{800} = 0.070.$$

Total side band power:

m = 0.3 => 0.025 + 0.025 = 0.05

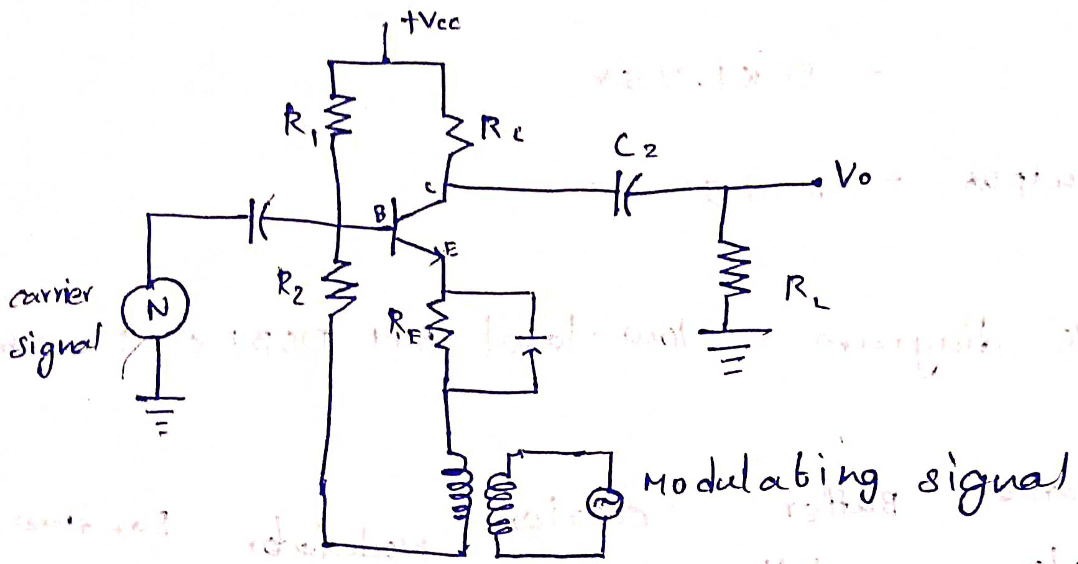
m = 0.4 => 0.045 + 0.045 = 0.09

m = 0.5 => 0.070 + 0.070 = 0.14

0.05 + 0.09 + 0.14 = 0.28 W

Nilesh 18/2/23

21.2.23 Low level AM circuits:



=> The modulating signal is applied through isolat transformer to the emitter of transistor Q.

=> And carrier signal is applied to the base

=> with emitter modulation, the amplitude of output signal depends on amplitude of input carrier and voltage gain of the amplifier.

=> The coefficient of modulation depends entirely on amplitude of modulating signal.

⇒ The primary disadvantage of emitter modulation is the amplifier operates at class A which is extremely inefficient also emitter modulator are incapable of producing high power output waveforms.

1. Find the output of amplifier circuit if gain is 5 and input voltage is 1.75 V

output = gain × input voltage

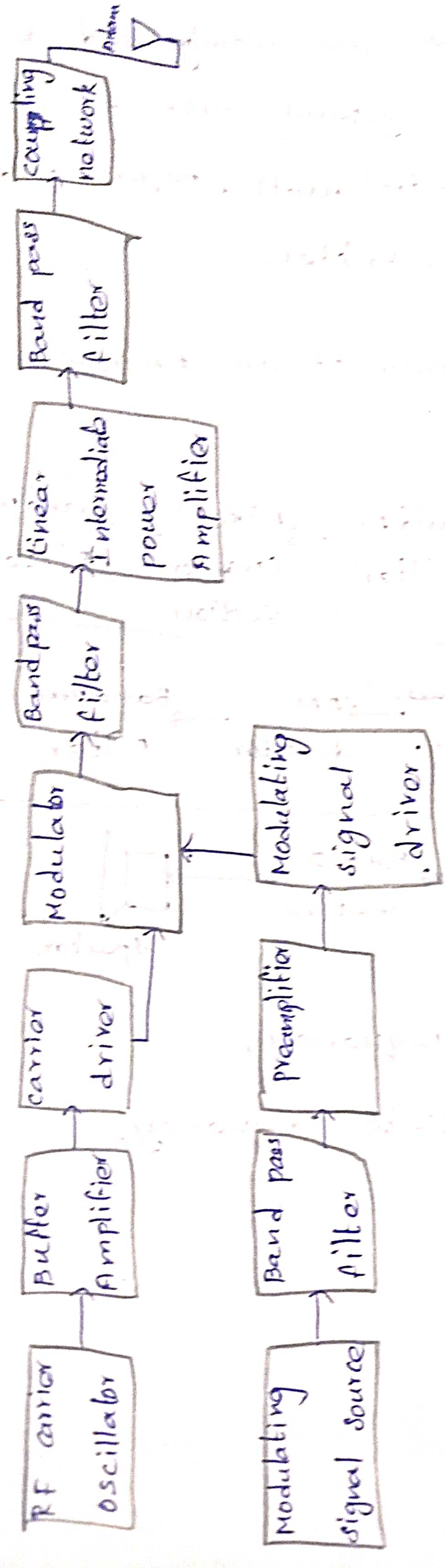
= 5 × 1.75 V

output = 8.75 V

Block diagram of low level AM DSBFC Transmitter

RF carrier oscillator | Buffer Amplifier | Carrier driver | Modulator | Bandpass filter

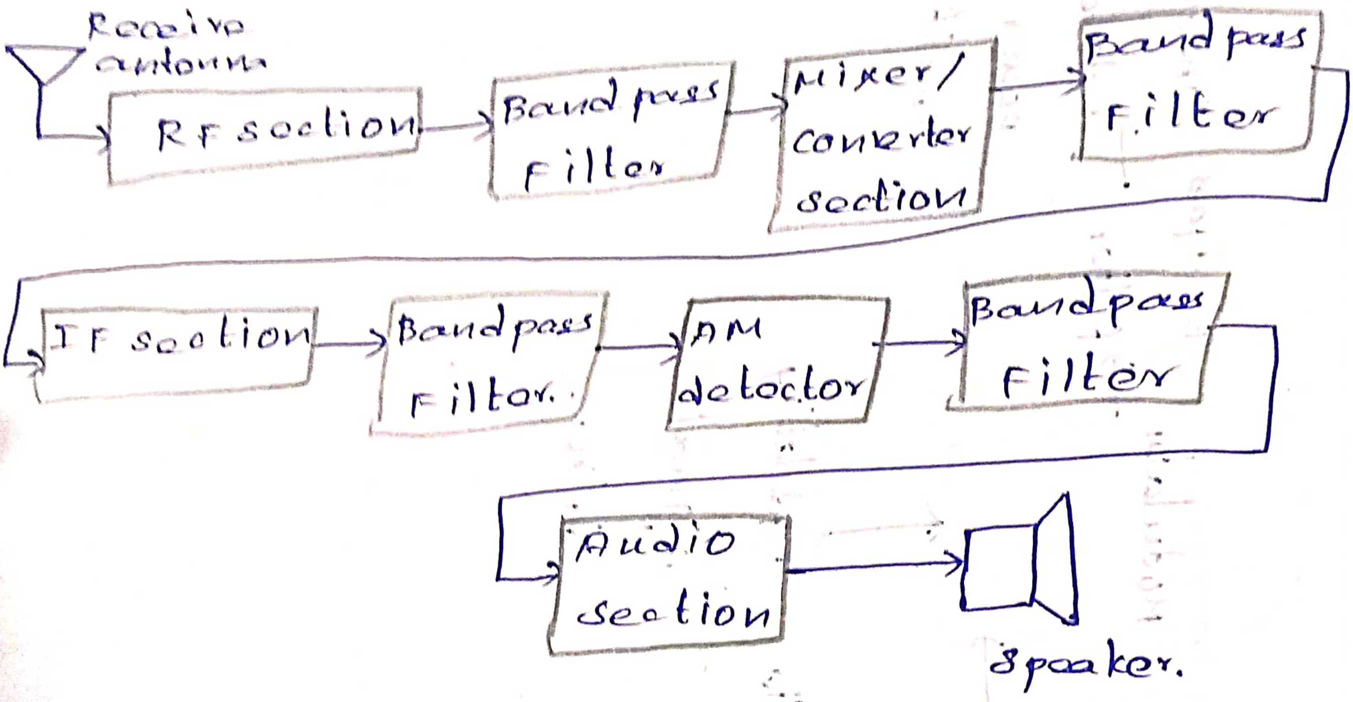
Block diagram of low level AM DSBFC Transmitter



Application

Low level transmitters are mainly used for low power, low capacity systems such as wireless intercoms, remote control units, pagers and short range walkie - talkies.

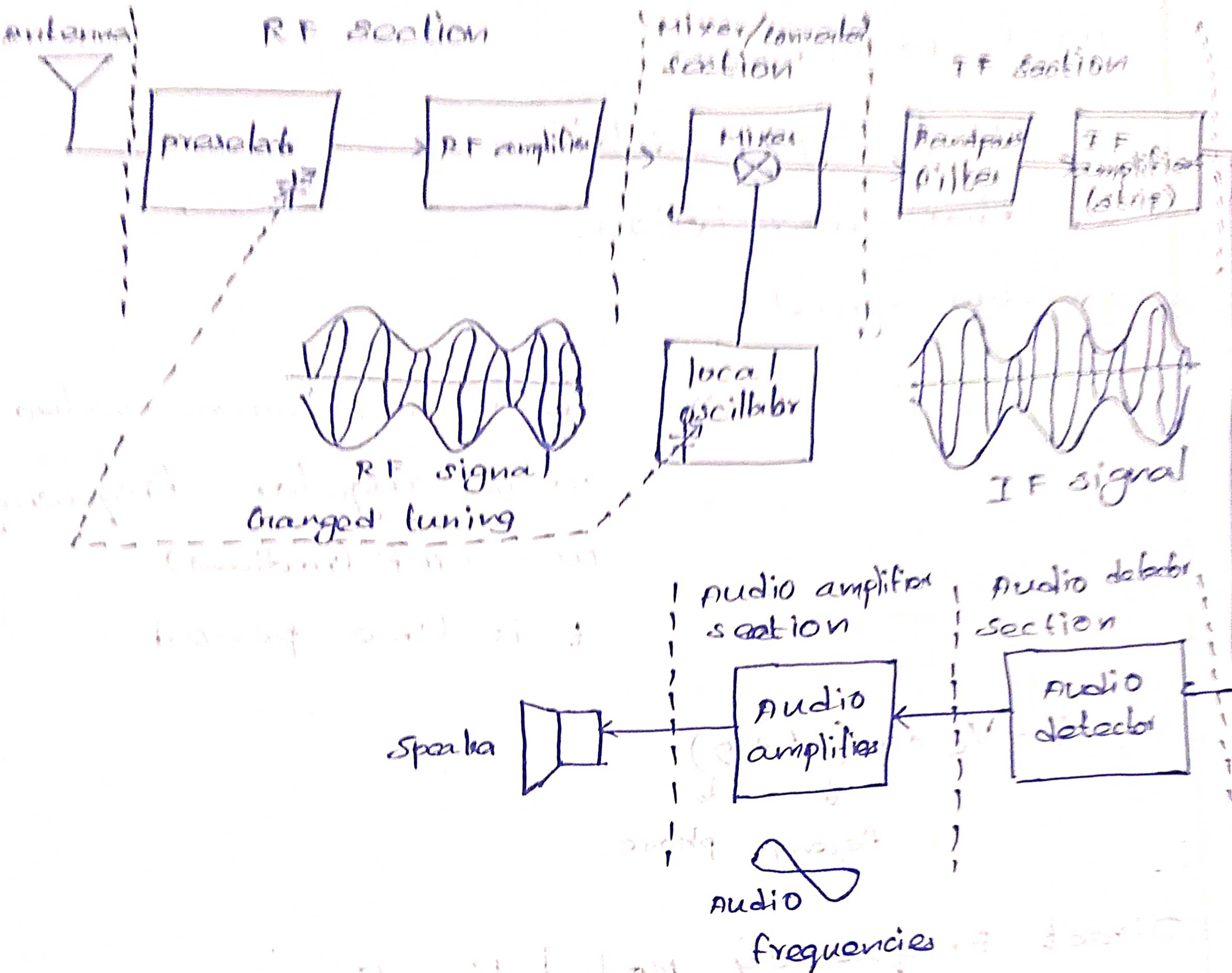
simplified block diagram of an AM receiver.



∴ RF → Radio Frequency,

∴ IF → Intermediate frequency.

AM superheterodyne receiver block diagram:



UNIT-2: ANGLE MODULATION

ANGLE MODULATION

⇒ Frequency modulation

⇒ phase modulation

Modulating signal

$= V_m \sin \omega t$, where V_m is maximum value

ω is angular frequency

$\omega = 2\pi f$ (radians)

t is time period

$$V_c = V_c \cos(\underbrace{\omega_c t}_{\text{frequency}} + \underbrace{\theta}_{\text{phase}})$$

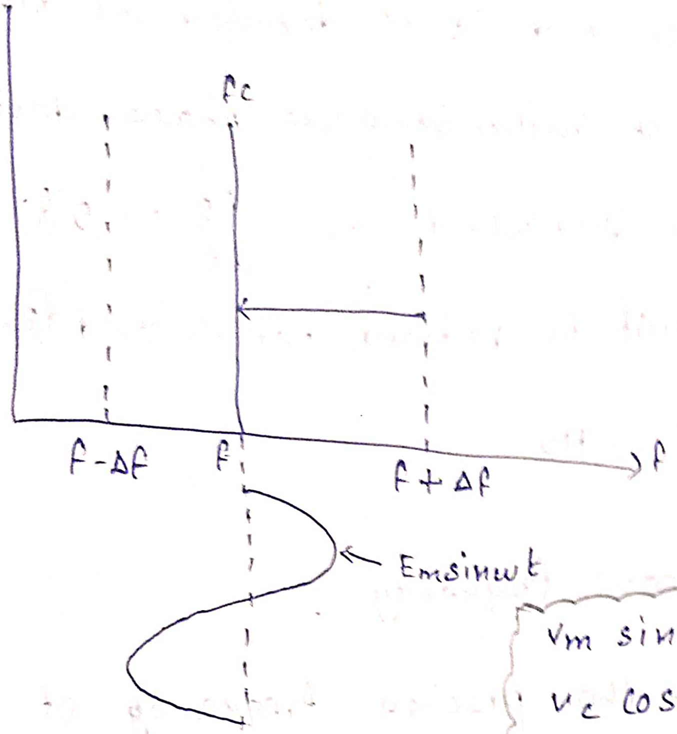
Direct Frequency Modulation [FM]

varying the frequency of constant amplitude carrier directly proportional to amplitude of the modulating signal at a rate equal to the frequency of modulating signal.

Direct phase modulation [PM]

varying the phase of constant amplitude carrier directly proportional to amplitude of modulating signal at a rate equal to the frequency of modulating signal.

Direct phase Modulation



$V_m \sin \omega_m t$

$V_c \cos \omega_c t$

$V_c \cos[\omega_c t + \theta(t)]$

3.2.23

Instantaneous phase deviation

⇒ It is the instantaneous change in phase of carrier signal at a given instant of time and indicates how much the phase of the carrier is changing with respect to the reference phase.

Instantaneous phase

⇒ It is the precise phase of carrier at a given instance of time

⇒ $\omega_c(t) + \theta(t)$

Instantaneous frequency deviation:

→ It is the instantaneous change in frequency of carrier and it is defined as first time derivative of instantaneous phase deviation.

→ It is expressed as $\frac{d\theta}{dt} \Rightarrow \theta'(t)$

→ The unit is radians per second [Radians/second]

$\Rightarrow \frac{\theta'(t)}{2\pi} \Rightarrow Hz$

Instantaneous frequency

→ It is the precise frequency of carrier at any instant of time and it is defined as first time derivate of instantaneous phase.

$\Rightarrow \omega_i(t) = \frac{d}{dt}[\omega_c t + \theta(t)]$

$\omega_i(t) = \omega_c + \theta'(t)$

→ unit is rad/sec (or) $\frac{\omega_c + \theta' t}{2\pi}$ Hz

Modulated output.

$V_c \cos[\omega_c t + k V_m(t)]$ → phase

$V_c \cos[\omega_c t + k_1 \int V_m(t)\, dt]$ → frequency

→ The output equations are shown for carrier signal $V_c \cos\omega_c t$ and modulated signal $V_m(t)$

→ If carrier signal is $V_c \cos\omega_c t$ and modulating signal $V_m \cos\omega_m t$, phase $\rightarrow V_c \cos[\omega_c t + k V_m \cos \omega_m t]$

frequency $\rightarrow V_c \cos[\omega_c t + k_1 \int V_m \cos \omega_m t \, dt]$

$\rightarrow V_c \cos[\omega_c t + k_1 \dfrac{V_m \sin \omega_m t}{\omega_m}$

$\rightarrow V_c \cos \left[\omega_c t + \dfrac{k V_m}{\omega_m} \sin \omega_m t\right]$

1. If the signal $v(t) = 20 \sin(6.28 \times 10^6 t + 10 \sin 6.28 \times 10^3 t)$ represents phase modulated signal determine i) carrier frequency, ii) modulating frequency iii) modulation index, iv) peak phase deviation.