# PCOM

## ASSIGNMENT

MODULE 03

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D10A 01

1) What is modulation, whare its advantages

→ A. message carrying signal has to get transmitted over a long distance and for it to establish a reliable communication, it neede to take help of higher frequency which should not affect the original characteristics of message signal.

Modulation is the process of changing the parameters of a carrier signals, in accordance with instantaneous values of the modulating signal

Advantages of modulation

- Antenna size gets reduced
- No signal mixing occurs
- Communication range increases
- Multiplexing of signal takes place
- Adjustments of bandwidth is allowed
- Reception quality improves

2) Derive mathematical expression of AM and FM signal

Let modulating signal be sinusoidal and be represented as

$$e_m = E_m \cos \omega_m t$$

here, $e_m$ => instantaneous amplitude

$E_m$ => Peak amplitude

Let carrier signal also be sinusoidal at a much higher frequency than that of modulating signal, the intantaneous carrier signl $e_c$ is given by

$$e_c = E_c \cos \omega_c t$$

The AM wave is expressed by the following expression

$$e_{AM} = A \cos(2\pi f_c t)$$

where $A$ => Envelope of AM wave

$$A = E_c + e_m$$
$$= E_c + E_m \cos(2\pi f_m t)$$

Hence AM wave is given by

$$e_{am} = A \cos(2\pi f_c t)$$
$$= (E_c + E_m \cos(2\pi f_m t))(\cos(2\pi f_m t))$$
$$= E_c\left[1 + \frac{E_m}{E_c}\cos(2\pi f_m t)\right] \cdot \cos(2\pi f_c t)$$

let $m = E_m/E_c \Rightarrow$ modulation index

$$\therefore e_{am} = E_c[1 + m\cos(2\pi f_m t)] \cdot \cos(2\pi f_c t)$$

ii) FM wave

Whe know that FM wave is sine wave having constant amplitude and Instantaneous. As instantaneous frequency is changing continuously, angular velocity "$\omega$" of FM wave is function of $\omega_c$ and $\omega_m$

$\therefore$ FM wave is represented by

$$e_{FM} = s(t) = E_c \sin[f(\omega_c, \omega_m)]$$
$$\therefore e_{FM} = E_c \sin \theta(t)$$
where $\theta(t) = f(\omega_c, \omega_m)$

In FM, velocity is changing continuously

$\therefore$ Angular velocity of FM is given by

$$\omega = \omega_c[1 + K_f E_m \cos \omega_m t]$$

Hence to find $\theta(t)$, we integrate $\omega$ w.r.t time

$\therefore\ \theta(t) = \int \omega\, dt = \int \omega_c [1 + K_f E_m \cos \omega_m t]\, dt$

$= \omega_c \left[ t + \frac{K_f E_m}{\omega_m} \sin \omega_m t \right]$

$= \omega_c t + \left[ \frac{K_f E_m}{\omega_m} \sin \omega_m t \right]$

$\therefore\ \theta(t) = \omega_c t + \frac{K_f E_m f_c \sin \omega_m t}{f_m}$

also, $\delta = K_f E_m f_c$

$\therefore\ \theta(t) = \omega_c t + \left[ \frac{\delta \sin \omega_m t}{f_m} \right]$

subst $\theta(t)$

$\therefore\ e_{fm} = s(t) = E_c \sin\left[ \omega_c t + \frac{\delta}{f_m} \sin \omega_m t \right]$

but $\delta / f_m = m_f \Rightarrow$ modulation index of FM

$\therefore\ e_{FM} = E_c \sin\left[ \omega_c t + \frac{\delta}{f_m} \sin \omega_m t \right]$

subst $m_f$

$\therefore\ \boxed{e_{fm} = E_c \sin [\omega_c t + m_f \sin \omega_m t]}$

3) Define related to FM

i) Modulation index

The FM modulation index is equal to ratio of the frequency deviation to the modulating frequency

$$\text{modulation index } (m) = \frac{\text{Frequency deviation}}{\text{Modulation frequency}}$$

ii) Frequency deviation

Frequency deviation in FM radio to describe the maximum difference between an FM modulated frequency and the nominal carrier frequency

iii) Deviation ratio

FM Deviation ratio is defined as the ratio of maximum carrier frequency deviation to the highest audio modulating frequency

$$\text{Deviation ratio} = \frac{\text{max carrier frequency deviation}}{\text{Highest audio modulating frequency.}}$$

4) The modulation index's effects on AM

The modulation index of an amplitude modulated signal is defined as the measure or extent of amplitude variation about an unmodulated carrier

The most widely seen example of modulation level is for a singnal that has 100 % modulation. Under these circumstances, the signal level falls to zero and rises to twice the value with no modulation. In this case the voltage rises to maximum of twice the normal level. This means that power would be four times that of quiscent value i.e $2^2$ value of the no modulation level

If less than 100% modulation is applied, then the carrier will not fall to zero, nor will it rise to twice the level, the deviation will be less than this from the quiscent level.

If the level of modulation rises above index of 1, i.e more than 100 % modulation, this causes over modulation. The carrier experiences 180° of phase shift where the carrier will try to go below zero point. These phase phase reversals gives rise to additional side bands resulting from phase modulation This can cause serious interferance to other users if not filtered.

5) Explain w.r.t AM reciever

i) Fidelity

Fidelity of a reciever is its ability to reproduce exact replical of the transmitted signal at the reciever output
For better fidelity, the amplifier must pass high bandwidth signals to amplify the frequency of outermost sidebands while for better selectivity the signal should be narrow bandwidth. Thus tradeoff is made between selectivity and fidelity

ii) Sensitivity

Sensitivity of reciever is its ability to identify and amplify weak signal at the recievers output
It is often defined in voltage that must be applite to input terminals of the reciever to produce a standard output power which is measured at output terminal.
Sensitivity is allo known as reciever threshold

iii) Selectivity

The selectivity of AM reciever is defined as its ability to accept or select the desired band of frequency and reject all other unwanted frequencies which can be interfering the signal.
The signal band width should be narrow for better selectivity

6) Explain low level and high level of modulation

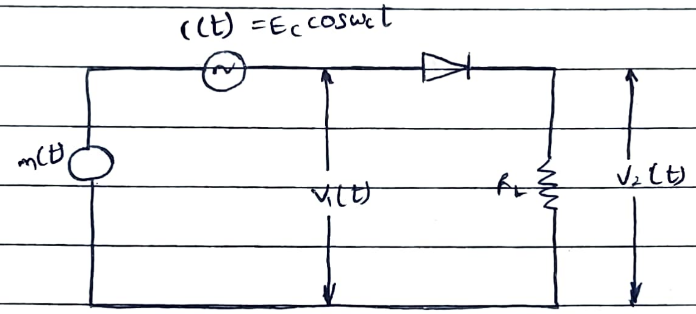
The generating circuits for AM wave are called as amplitude modulator circuit
The modulator circuits are classified into two categiries:

- Low level modulation
  The generation of AM wave takes place at lower level
  The generated AM signal is then amplified using chain of linear amplifier such as A, B or AB amplifier.
  The linear amplifier are required in order to avoid any waveform distortion. The efficiency of low level modulator is low as linear amplifier are not very efficient.

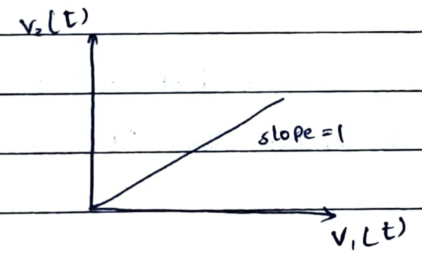
- High level modulation
  In this method, generation of AM wave takes place at high power level
  The carrier and modulating signal both are amplified first to an adequete power level and the modulation takes place in the RF amplifier stage of the transmitter
  Highly efficient class C amplifiers are used in high level modulation. Hence the efficiency of high level modulators is higher than that of low level modulation

7) Explain generation of the following

i) DSBFC using diode

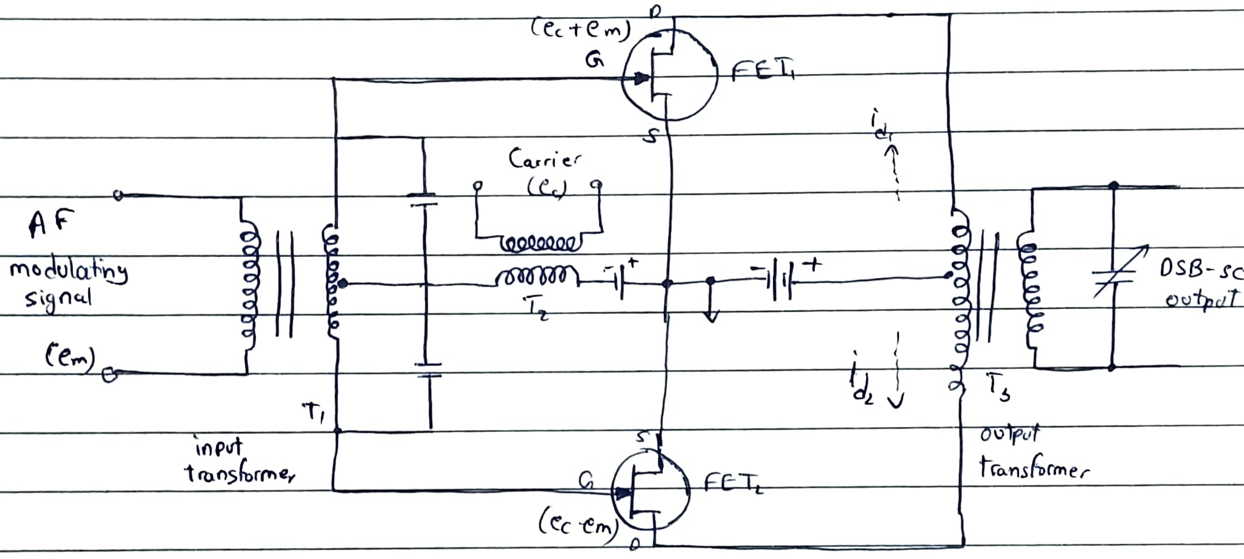



A carrier signal c(t) of large amplitude is applied to the diode.
The diode acts as a switch, ie it shows zero impedance when it is forward biased, here when $c(t) > 0$
The graph shows the transfer characteristics of the diode-load resistor combination
Since this is linear $V_1(t)$ will be sum of carrier and message signal
$\because |m(t)| << E_c \quad \therefore V_2(t) = \begin{cases} V_1(t) & c(t) > 0 \\ 0 & c(t) < 0 \end{cases}$




Thus $V_2(t)$ varies between $V_1(t)$ and zero periodically, and this variation happens at rate of carrier frequencies $f_c$. Thus we get an amplitude modulated wave according to the message signal

iii) DSBSC using balanced modulation



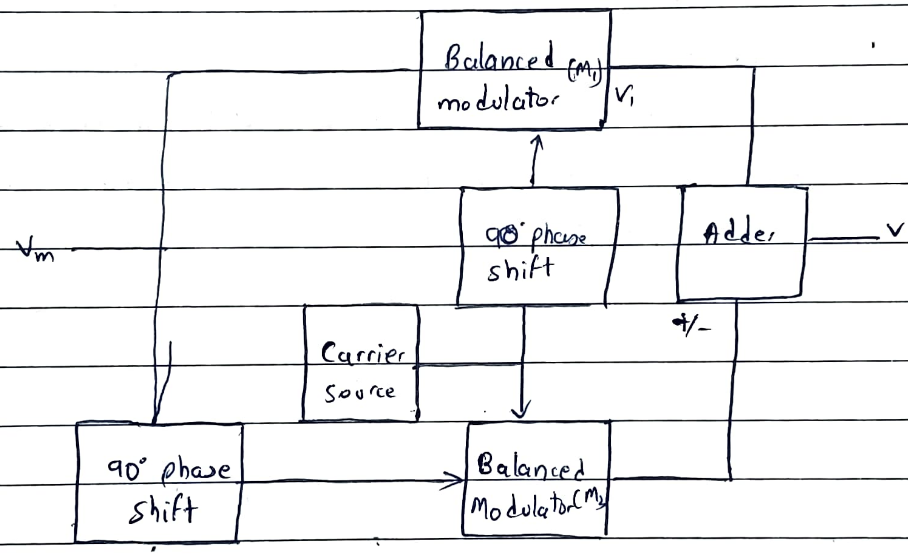

The balanced modulator using FET's is shown above. The carrier voltage is applied in phase to the two gates via transformer $T_1$ and $T_2$

However, the modulating signal appears 180° out of phase at the gates of the two FET's

This is because the input transformer $T_1$ is centre tapped form

### iii) Generation of SSBSC using phase shift method.

This method avoids filters and some of their disadvantages and instead uses two two balanced modulators and two phase shifting networks. One of the balanced modulators recieve $M_1$ 90° phase shifted message and in phase carrier signal whereas the other $M_2$ is fed 90° phase shifted message and inphase carrier signals. One of the sideband produced by these modulators will be in phase with both modulators whereas, the other will be out of phase.




Block diagram

Output balanced modulator $M_1$:

$$V_1 = V_m V_c \sin w_m t \cos w_c t = \frac{V_m V_c}{2}\left[\sin(w_c + w_m)t + \sin(w_c - w_m)t\right]$$

Output of balanced modulator $M_2$:

$$V_2 = V_m V_c \cos w_m t \sin w_c t = \frac{V_m V_c}{2}\left[\sin(w_c + w_m)t - \sin(w_c - w_m)t\right]$$

Output of adder:

$$V = V_1 \pm V_2 = V_m V_c \sin(w_c \pm w_m)t$$

8) Advantage and disadvantage of Tuned RF reciever.
Explain super heterodyne reciever with block diagram

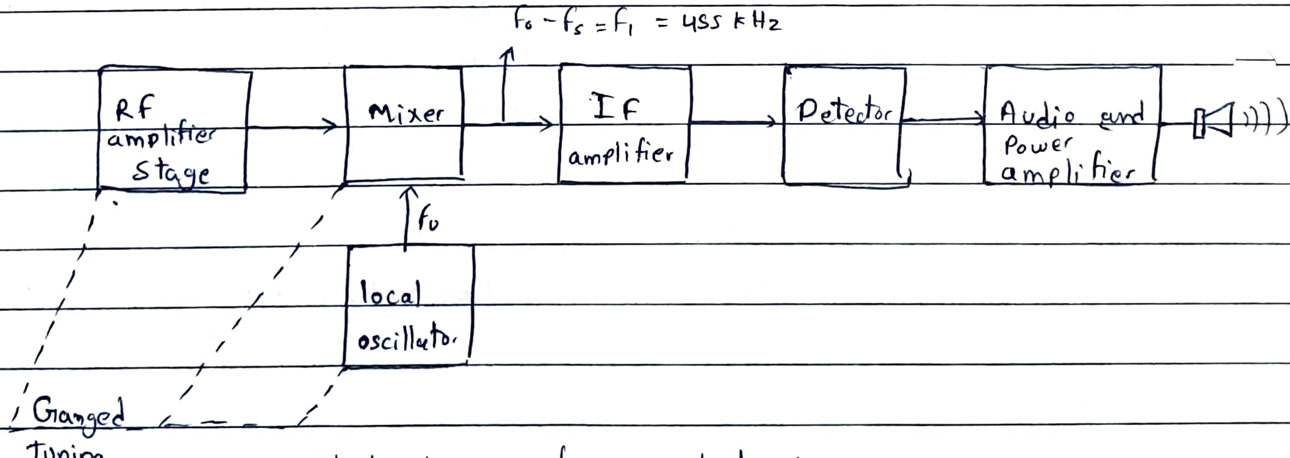
Disadvantages

1) Instability in gain :- The overall gain of RF amplifier is very high, so a very small feedback signal can initiate oscillations in RF amplifier stage, and hence the amplifier no more functions as required.

2) Badnwidth variation :- When reciever is tuned to carrier frequency, it is expected to select carrier and its sidebands of the desired range And hence reciever should have adequate bandwidth, which is inversely dependant on quality factor. At very high frequenci

3) Insufficient selectivity :- Due to increased bandwidth at higher frequency the ability of reciever to select desired signal is seriously effected This is called loss in selectivity.

Superheterodyne Recievers




Block diagram of super heterodyne

$f_s$ = station frequency
$f_i$ = intermediate frequency

i) RF amplifier : It is tuned voltage amplifier coupled through the antenna to the mixer. It selects the desired signal from the antenna and amplifies them. This stage improves sensitivity and selectivity of radio reciever

ii) Mixer and oscillator : It is a converter stage in super heterodyne reciever. The RF amplifier, mixer and local-oscillator are ganged togather to produce intermediate frequency at output of mixer which is always 455 kHz

iii) I.F Amplifier : It is a tuned voltage amplifier i.e operated in class A with fixed rheostat load in most of the reciever. The gain is provided by this

iv) Detector : The amplified signal is fed to the detector or demodulator. It recovers the message from amplitude modulated wave

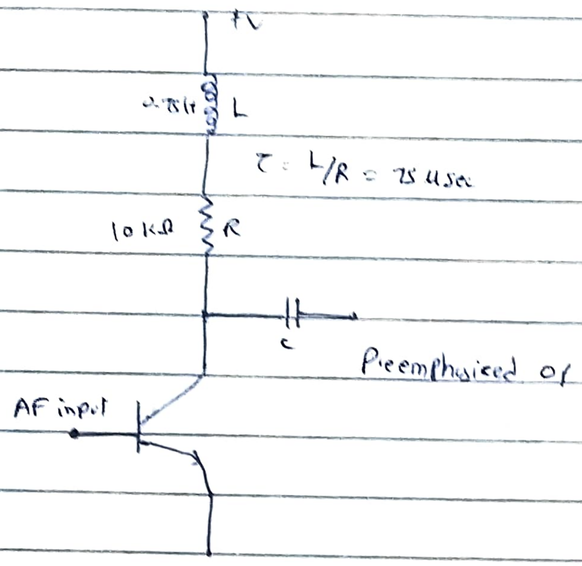
v) Audio and power amplifier : It amplifies the incoming signal as well as generates the required power to distributes the loudspeaker.

vi) Loud speaker :- It converts electrical energy to sound energy.

9) Explain pre-emphasis and de emphasis circuit used in F.M

Pre-emphasis

In the modulating voltage, high frequency components have small amplitude and hence they produce frequency devation for less than max permitted value of 75 kHz. Consequently the signal strength of these waves is very low. To improve S/N ratio, at this high modulating frequency, preemphasis circuit is used to emphasize circuit is used to emphasize the higher frequency components prior to modulation. In this process a high pass filter is used. The figure below shows circuit diagram for active preemphasis curve




Pre emphasis network provides a constant increase in the amplitude signal with an increase in frequency. The network shown above uses 75 μsec time constant. Therefore the break frequency approximately equals to $f = \frac{1}{2\pi 4R}$

$\therefore f = 2.12$ kHz

Deemphasis

To return the frequency response to its normal level a de emphasis circuit is used at the reciever. This is simple low pass filter, with time constant of 75 μsec. It feature cut off frequency of 2.12 KHz, according to signal above this frequency to be attenuated at rate of 6dB/octave. As a result, of preemphasis at the transmitter is exactly offset by the deemphasis circuit in the reciever providing normal frequency response. The combined effect of preemphasis and de-emphasis is to increase the high frequency components during transmission so that they will be stronger and not masked by noise. This improves fidelity and intelligibility.

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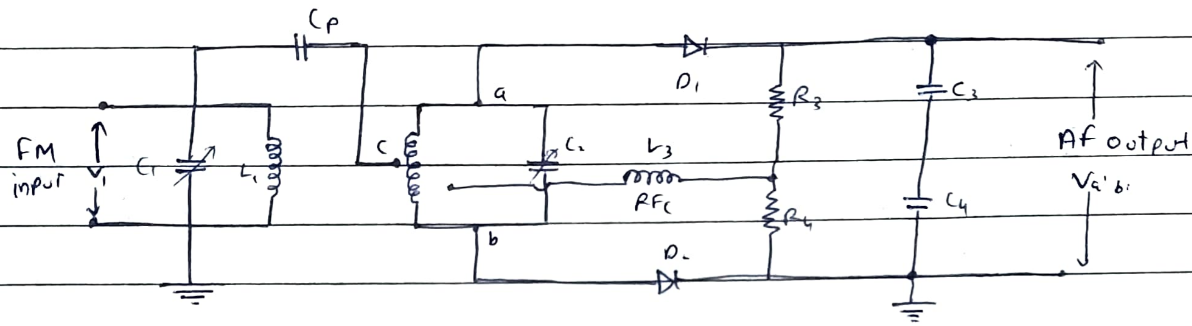
10) Compare AM and FM

| Amplitude Modulation | Frequency modulation |
|---|---|
| 1) In AM, The amplitude of carrier is changed with instaneous value of the modulating signal. frequency of phase remains constant. | 1) In FM, the frequency of carrier is changed with the instantaneous value of the modulating signal. Amplitude and phase remains constant. |
| 2) AM operates in medium and high frequency bands | 2) FM operates at high and ultra high frequency |
| 3) Requires smaller BW than FM | 3) Requires 7-15 larger B.W than AM |
| 4) Modulation index is always less than 1 | 4) Modulation index is always greater than 1 |
| 5) In AM, noise is affected on reception | 5) In FM, noise is eliminated using limiter circuit in reciever |
| 6) Only one side band pair is produced | 6) Infinite side band pairs are produced |
| 7) AM cover large area | 7) FM covers smaller area |

11) Explain FM demodulators with neat circuit diagram




Circuit diagram

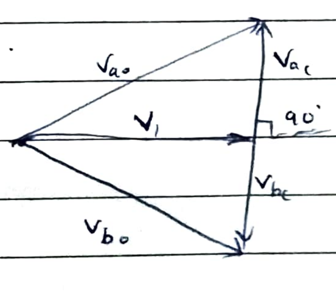
The phase descrimination is shown above in the figure. Here primary and secondary winding both are tuned to the same centered frequency 'fc' of the incoming signal, but the voltages applied to two diodes D1 and D2 are not constant. They vary depending on the prequency of the input signal, due to the change in phase shift between the primary and secondary winding depending on the imput frequency the capacitor Cp is coupling capacitor which passes all the frequency at the input to the centre tap of the transformer C4 by passes ressistance R4 and so voltage accross the upper and lower half. Thus input to each diode is equal to the vector sum of primary voltage $V_1$ and half the secondary voltage

Output voltage of the phase descriminator is equal to the difference between the outputs of two diodes rectifiers :- $V_o = V_{a'b'} = V_{a'o} - V_{b'o}$

Although diode drops are not knowns, it is sure that the poutput is proportional to input voltages of $D_1$ and $D_2$ . $V_o \propto V_{ao} - V_{bo}$

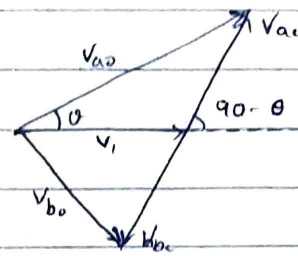
i) $f_{in} = f_c$ :

When frequency is equal to center frequency. The phaseshift between primary and secondary voltages is exactly 90°



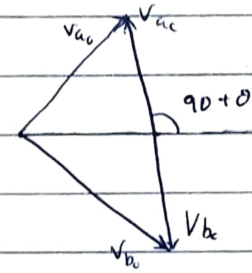
ii) $f_{in} > f_c$

At input frequecnies above centre frequency, secondary voltage $V_{ab}$ leads the primary voltage by less than 90°

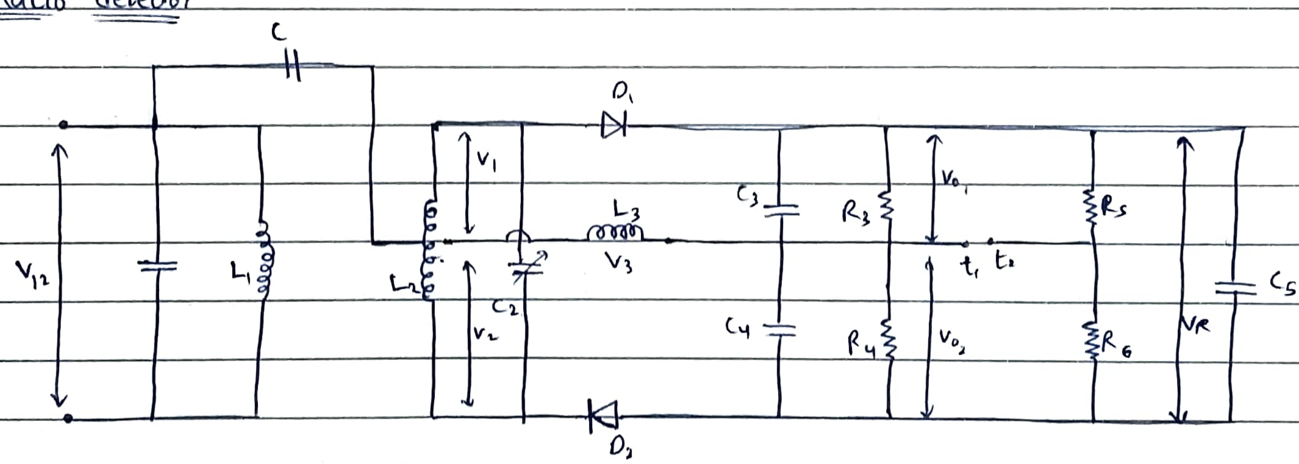



iii) $f_{in} < f_c$

At input frequency less than centre frequency, the secondary voltage $V_{ab}$ leads the primary voltage by more than 90°




## Ratio detector




Circuit diagram

Ratio detetor is an improvement over the discriminator and is widely used. It doesn't respond through amplitude variation, a limiter is not required. The circuit is similar to that of phase discriminator except

a) Polarity of diode $D_2$ is reversed

b) The output voltage is taken from the tapped of ressistor R that shonts the load of two diodes. The output voltage varies with the input signal, but its magnitude is reduced to half

Amplitude limiting by Ratio detector

If input voltage has been constant for sometime, $C_s$ is able to change upto the voltage a and b. This is the DC voltage. There will be no current either following in to change the capacitor or following out to change it. Since instantaneous change in voltage across capacitor is not possible voltage across $t_1, t_2$ remains constant. Similarly when input voltage falls, diode current falls, but voltage across $C_s$ doesn't change

12) Explain concept of Image frequency and double spotting and also explain how to reject image frequency.

Image frequency: In a broadcast AM recievers, the local oscillator's frequency is made higher than the incoming signal frequency. It is made equal at all time to the signal frequency plus the intermediate frequency

$$f_o = f_s + f_i$$

If the frequency $f_{si}$ reaches the mixer such that,

$$f_{si} = f_o + f_i$$

$$\therefore f_{si} = f_s + 2f_i$$

The term $f_{si}$ is called image frequency and is defined as the signal frequency plus twice the intermediate frequency i.e $f_{si} = f_s + 2f_i$

Image frequency Rejection

To avoid interference due to an object at it is necessary that these signals do not reach the mixer. This can be achieved by increasing their selectivity towards image frequency signals

Double spotting

Double spotting means the same station gets picked up at two different nearby points on the reciever dial. It happens due to poor front end selectivity i.e inadequate image frequency rejection. It is especially harmful because a weak station may be masked by the reception of strong station at the same point on the dial

13) AM radio reiever the loaded Q is 100. If intermediate frequency is 455 kHz calculate image frequency and its rejection at 1MHz

→ $Q = 100, \quad f_i = 455\ kHz,$

$f_s = 1MHz = 1000\ kHz$

$f_{si} = f_s + 2f_i$

$= 1000 + 2(455)$

$\therefore f_{si} = 1910\ kHz$

rejection ratio $\alpha = \sqrt{1 + Q^2 \times \rho^2}$

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{1910}{1000} - \frac{1000}{1910} = 1.3864$

$\therefore \alpha = \sqrt{1 + (100^2 \times 1.3864^2)}$

$\therefore \alpha = \sqrt{19221.0496}$

$\therefore \alpha = 138.64$

14) If AM wave $x_c(t) = 10(1 + 0.6\cos 200\pi t + 0.4\cos 400\pi t) . \cos 20\pi t$, do the foll.

ii) Find total power iii) Find side band power, iv) modulation index

i) Sketch the ~~modulating index~~ amplitude spectrum, ii)

→ $x_c(t) = 10 . (1 + 0.6\cos 200\pi t + 0.4\cos 400\pi t) . \cos(200\pi t)$

Comparing with

$e = E_c[1 + m_1\cos \omega_{m_1} t + m_2 \cos \omega_{m_2} t] . \cos \omega_c t$

$\therefore m_1 = 0.6, \quad m_2 = 0.4$

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

$\therefore m = \sqrt{0.36 + 0.16}$

$\therefore m = 0.721$

$\omega_c = 200\pi \quad \therefore f_c = \dfrac{2000\pi}{2\pi} = 1\ kHz$

$\omega_{m_1} = 200\pi \quad \therefore f_{m_1} = \dfrac{200\pi}{2\pi} = 0.1\ kHz$

$\omega_{m_2} = 400\pi \quad \therefore f_{m_2} = \dfrac{400\pi}{2\pi} = 0.2\ KHz$

Upper sideband $USB_1 = f_c + f_{m_1} = 1.1\ kHz$

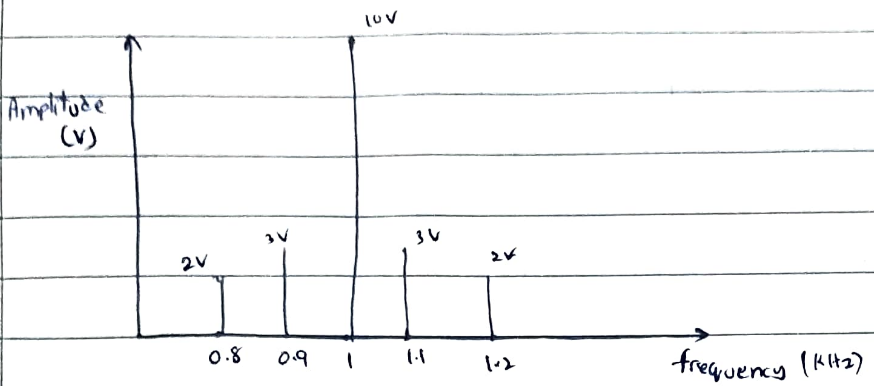
Upper sideband $USB_2 = f_c + f_{m_2} = 1.2\ KHz$

Lower sideband $LSB_1 = f_c - f_{m_1} = 0.9\ kHz$

Lower sideband $LSB_2 = f_c - f_{m_2} = 0.8\ kHz$

Amplitude of $USB_1 = \dfrac{m_1 E_c}{2} = 3\ V$

Amplitude of $USB_2 = \dfrac{m_2 E_c}{2} \quad 2V$




Carrier power $P_c = \frac{E_c^2}{R \times 2} = \frac{100}{2(50)} = 1W$

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

$= 1\left[1 + \frac{0.721^2}{2}\right]$

$\underline{\underline{P_t = 1.2599\,W}}$

Side band power $P_{SB} = \frac{m^2}{2} \cdot P_c$

$= \frac{0.721^2}{2} \times 1$

$\therefore \underline{\underline{P_{SB} = 0.2599\,W}}$

15) A sinusoidal carrier has an amplitude of 10V and frequency of 100 kHz. It is AM by sinusoidal voltage of amplitude 3V and 500Hz. Resistance is 75 $\Omega$

$E_c = 10V$, $f_c = 100kH$, $E_m = 3V$, $f_m = 500 kHz$, $R = 75\Omega$

Modulation index $m = \frac{E_m}{E_c} = \frac{3}{10} = 0.3$

Equation of modulated wave

$e_{AM} = E_c(1 + m\cos\omega_m t)\cos\omega_c t$

$= 10(1 + 0.3\cos(2\pi \cdot 500t)) \cdot \cos(2\pi \cdot 100 \cdot 10^3 t)$

$\therefore e_{AM} = 10(1 + 0.3\cos 1000\pi t) \cdot \cos(2\times10^5 \pi t)$

Frequencies

$f_c = 100$ kHz, $f_m = 500$ Hz $= 0.5$ kHz

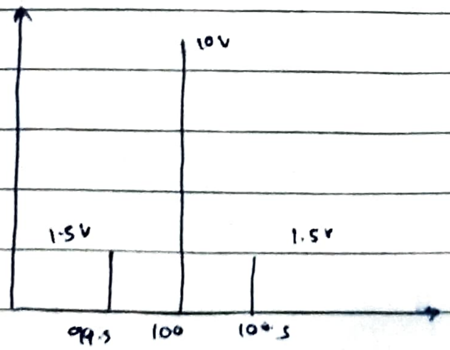
USB $= f_c + f_m = 100 + 0.5 = 100.5$ kHz

LSB $= f_c - f_m = 100 - 0.5$ 99.5 kHz

Amplitude

$E_c = 10V$

LSB and USB $= \frac{mE_c}{2} = \frac{0.3\times10}{2} = 1.5V$



Power carried by carriers

$$P_c = \frac{E_c^2}{2R} = \frac{100}{2(75)} = \underline{0.6667\ w}$$

Total power

$$P_T = P_c\left[1 + \frac{m^2}{2}\right] = 0.6667\left[1 + \frac{0.09}{2}\right] = 0.6667\left(\frac{2.09}{2}\right)$$

$$\therefore P_T = \underline{0.6967\ w}$$

Total sideband power

$$P_{SB} = \frac{m^2}{2} \times P_c = \frac{0.9 \times 0.6667}{2}$$

$$P_{SB} = \underline{0.03\ w}$$

(6) A sinusoidal carrier has frequency of 200kHz, It is amplitude modulated by a sinusoidal voltage of amplitude 6V and frequency 1kHz. $R = 8\,0\,\Omega$

• Modulation idex: m

$$m = \frac{E_m}{E_c} = \frac{6}{20} = 0.3$$

• Modulated wave equation : $e_{AM}$

$$e_{AM} = E_c\left(1 + m\cos w_m t\right)\cos w_c t$$

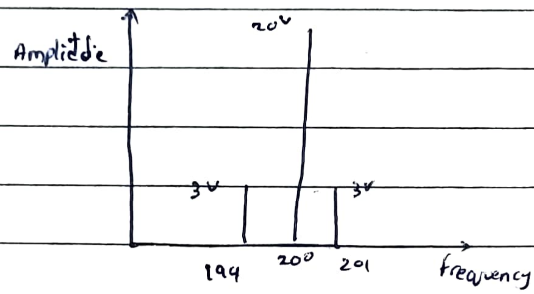
$$\therefore e_{AM} = 20\left(1 + 0.3\cos\left(2\pi \times 10^3 t\,(1)\right)\right\} \cdot \cos\left(2\pi \times 10^3 t\,(200)\right))$$

$$\therefore e_{AM} = 20\left(1 + 0.3\cos(2\pi \times 10^3 t) \cdot \cos(4\pi \times 10^5 t)\right)$$

iii) USB = $f_c + f_m = 200 + 1 = 201$ kHz

LSB = $f_c - f_m = 200 - 1 = 199$ kHz

Amplitude of LSB and USB = $\frac{m E_c}{2} = 0.3 \times 20 = \underline{\underline{3V}}$




Total power $P_t$

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

$$= \frac{E_c^2}{2R}\left[1 + \frac{m^2}{2}\right] = \frac{20^2}{2 \times 80}\left[1 + \frac{0.3^2}{2}\right] = \frac{5}{2}\left[\frac{2.09}{2}\right]$$

$\therefore \underline{P_t = 2.6125 \text{ W}}$

1) A sinusoidal carrier has an amplitude of 20V and frequency of 30 kHz. It is amplitude modulated by 3V and frequency 2 kHz, R = 50 Ω

- modulation idex m:

$$m = \frac{E_m}{E_c} = \frac{3}{20} = 0.15$$

· Equation of modulated wave

$$e_{AM} = E_c [1 + m \cos \omega_m t] . \cos \omega_c t$$

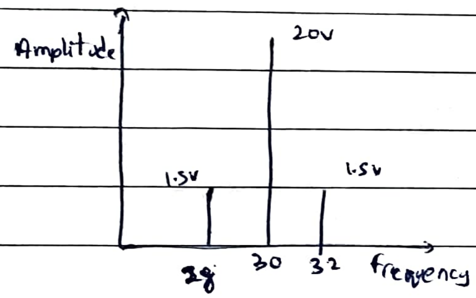
$$= 20 . [1 + 0.15 \cos (2\pi \times 2 \times 10^3 t)] . \cos (2\pi \times 30 \times 10^3 t)$$

$$\therefore e_{AM} = 20 [1 + 0.15 \cos (4\pi \times 10^3 t)] . \cos (6\pi \times 10^4 t)$$

· USB = $f_c + f_m$ = 30 + 2 = 32 kHz

· LSB = $f_c - f_m$ = 30 − 2 = 28 kHz

Amplitude for each sideband $= \frac{m E_c}{2} = \frac{0.15 \times 20}{2} = 1.5 V$



18) A single tone FM signal is given by $v_{FM} = 10\sin(16\pi \times 10^8 t + 20\sin 2\pi \times 10^3 t)$
find a) Max frequency deviation, b) B.W of FM

→ Comparing equation with

$$e_{FM} = E_c \cdot \sin[\omega_c t + m_f \sin\omega_m t]$$

$m_f = 20$

$\omega_m = 2\pi \times 10^3 t$

$\therefore f_m = \frac{2\pi \times 10^3}{2\pi} = 10^3\ Hz = 1\ kHz$

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

$\therefore \Delta f = f_m \times m_f = 20 \times 1 = \underline{\underline{20\ kHz}}$

By carsons rule

$BW = 2[\Delta f + f_{m_{max}}]$

$= 2[20+1]$

$\therefore \underline{\underline{BW = \cancel{22}\ 42\ kHz}}$