# Principles of Communication

# ASSIGNMENT No. 3


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CLASS : D10A

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# PCOM Assignment 3

## Question 1.

What is modulation and what are its advantages ?

**Answer:**

Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted. In amplitude modulation the amplitude of the carrier signal is varied in accordance with the modulating signal.

**Advantages of Modulation :-**

(i) Reduces height of antenna :

For efficient transmission and reception the height of antennas should be equal to quarter wavelength of the signal ( $\lambda/4$ ). Thus, for a signal of frequency 10 kHz (say) the required height of antenna is about 7.5 Km which is practically impossible. Now, consider a modulated signal of frequency 1 MHz, the antenna height would be only 75 m.

ii) Avoids mixing of signals

If the baseband sound signals are transmitted from different sources, then all the transmitted signals will be in the same frequency band i.e. 0 to 20 kHz, and hence they will get mixed together. By modulation of the message signal, the carrier signal of each station can be different and can occupy different frequency bands.

iii) Multiplexing

Modulation helps in shifting the given message signal frequencies to a very high frequency range where it can occupy only negligible percentage of the spectrum. This means that more number of message signals can be accomodated at higher frequencies.

iv) Increases range of communication

Low frequency signals like that of audio get attenuated very quickely. Attenuation reduces with frequency of the signal. Modulation process increases the frequency of the signal and hence, the signal can travel quite long distances.

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Question 2.

Derive the mathematical expression of AM and FM signal.

Answer:

Mathematical expression of amplitude modulated signal :-

Let the carrier voltage and modulating voltage be Vm and Vc and it is represented by :

$$v_m = V_m \sin \omega_m t$$

$$v_c = V_c \sin \omega_c t$$

where $v_m$ and $v_c$ are instantaneous value of modulating and carrier signals, respectively, and $V_m$ and $V_c$ is the max value of the modulating and carrier signals respectively, and $\omega$ is the angular velocity.

Modulation index is defined as the ratio of maximum amplitudes of modulating signal to that of the carrier signal.

$$\therefore \text{Modulation index} \quad m = \frac{V_m}{V_c}$$

The final amplitude of the modulated signal voltage will be

$$A = V_c + v_m$$
$$= V_c + V_m \sin(\omega_m t)$$
$$= V_c + m V_c \sin(\omega_m t) \quad \left[\because m = \frac{V_m}{V_c}\right]$$

Thus, the instantaneous voltage of the resulting amplitude modulated signal is

$$v = A \cdot \sin(\omega_c t)$$
$$\therefore v = (V_c + m V_c \sin(\omega_m t)) \sin(\omega_c t)$$
$$= V_c \sin \omega_c t + m V_c \sin \omega_m t \cdot \sin \omega_c t$$
$$= V_c \sin \omega_c t + \frac{m V_c}{2} [\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t]$$

$$\therefore v = V_c \sin \omega_c t + \frac{m V_c}{2} \cos(\omega_c - \omega_m)t - \frac{m V_c}{2} \cos(\omega_c + \omega_m)t$$

This is the required expression for AM wave in terms of sin wave.

Mathematical expression of frequency modulated signal :-

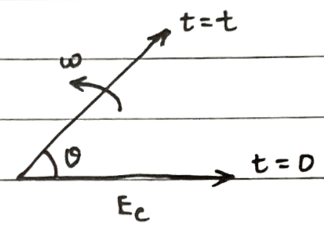
Frequency modulated wave is a signal having constant amplitude and a variable instantaneous frequency. As the instantaneous frequency is changing continuously, the angular velocity $\omega$ of an FM wave is the function of $\omega_c$ and $\omega_m$.

Therefore the FM wave is represented by

$$e_{FM} = E_c \sin[F(\omega_c, \omega_m)]$$
$$= E_c \sin \theta(t)$$

where $\theta(t) = F(\omega_c, \omega_m)$

As shown alongside, $E_c \sin \theta(t)$ is a rotating vector. In FM "$E_c$" is rotating at a variable velocity.




The angular velocity of FM wave is given as :

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

where $K_f$ = frequency deviation constant.

$$\therefore \theta(t) = \int \omega \, dt = \int \omega_c (1 + K_f E_m \cos \omega_m t) \, dt$$
$$= \omega_c \int (1 + K_f E_m \cos \omega_m t) \, dt$$
$$= \omega_c \left[ t + \frac{K_f E_m \sin \omega_m t}{\omega_m} \right]$$

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

As per definition, frequency deviation $\delta = K_f E_m f_c$

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

$$\therefore \; e_{FM} = s(t) = E_c \sin\left[ w_c t + \frac{\delta}{f_m} \sin w_m t \right]$$

But $\frac{\delta}{f_m} = m_f$ i.e. the modulation index of FM wave

Hence the final required equation of FM wave is :

$$e_{FM} = E_c \sin\left[ w_c t + m_f \sin w_m t \right]$$

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Question 3.

Define related to FM (i) modulation index (ii) frequency deviation (iii) deviation ratio

Answer :

i) Modulation index

The modulation index of an FM wave is defined as the ratio of frequency deviation to the maximum modulating frequency.

$$m_f = \frac{\delta}{f_m}$$

ii) Frequency deviation

Frequency deviation $\delta$ is defined as the maximum departure of the instantaneous frequency $f_i(t)$ of the FM wave from the carrier frequency $f_c$. Since, $\delta = k_f E_m$, the frequency deviation is proportional to the amplitude of modulating voltage $E_m$ and is independent of modulating frequency $f_m$.

iii) Deviation ratio

Deviation ratio is defined as the modulation index corresponding to the maximum deviation and maximum modulating frequency.

$$\text{Deviation ratio} = \frac{\text{Maximum deviation}}{\text{Maximum modulating frequency}}$$

Question 4.

What is the effect of modulation index on AM ?

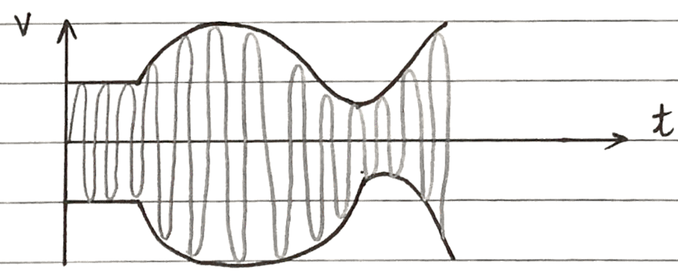
Answer:

i) When modulation index is less than 1

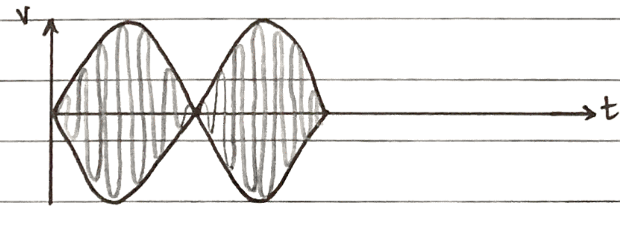
$$m_a < 1$$

$$\therefore V_m < V_c$$

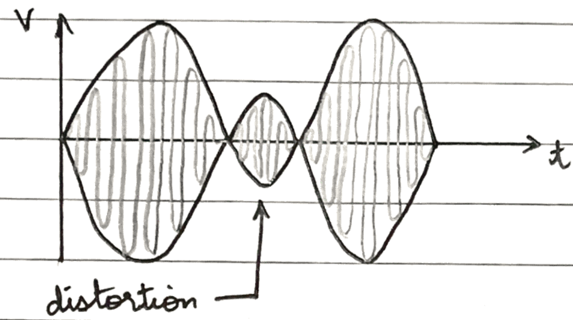
This type of modulation is known as Under Modulation.




ii) When modulation index is equal to unity i.e. $m_a = 1$ it is known as fully modulated signal.



iii) When modulation index is greater than 1, i.e. $m_a > 1$
$\Rightarrow V_m > V_c$, it is known as Over Modulation.




Question 5.
Explain (i) Fidelity (ii) Sensitivity (iii) Selectivity with respect to AM receivers.

Answer :

i) Fidelity

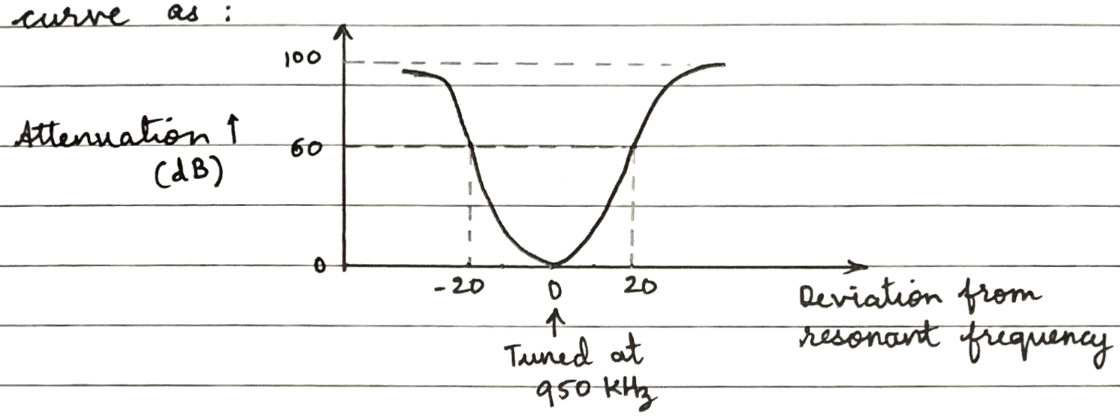
Fidelity is the ability of a receiver to reproduce all the modulating frequencies equally. It basically depends on the frequency response of the amplifier. High fidelity is essential in order to reproduce a good quality sound, without introducing any distortion.

ii) Sensitivity

Sensitivity is defined as the ability of a radio receiver to amplify weak signals. Mathematically the sensitivity of a radio receiver is defined as a carrier voltage which must be applied to the receiver's input terminal. Sensitivity is expressed in microvolts and millivolts or in dB below 1V.

iii) Selectivity

Selectivity of a receiver is defined as its ability to reject unwanted signals. It is expressed in terms of the given curve as :




It shows that the receiver offers minimum rejection at 950 Hz i.e. the frequency at which the receiver is tuned, but the rejection / attenuation increases as the input signal deviates on both sides of 950 Hz. Selectivity of a receiver depends on the IF amplifier.

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Question 6.

Explain high level and low level AM Modulation.

Answer :

i) High level modulation

Here, stabilised crystal oscillator generates carrier frequency and first we amplify this carrier frequency and modulating frequency to an adequate level using class C and class B power amplifiers respectively.

If we want 100% modulation then modulating signal must be

33% of total power.

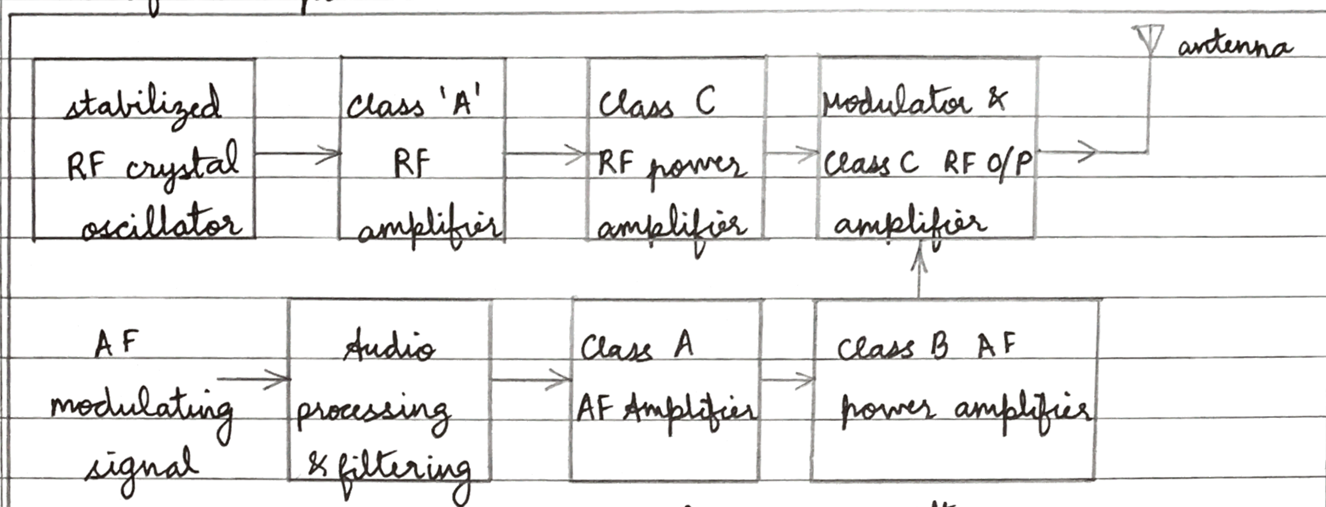



Diagram of high level AM transmitter

Modulation takes place in last class 'C' RF amplifier. At output of this modulator we are getting AM wave. Here we use collector modulated transistorized circuit or plate modulated vacuum tube as modulator. Efficiency is high because of class 'C' amplifier and power level is also high.

ii) <u>Low level modulation</u>

RF oscillator produces stabilized carrier signal in order to maintain carrier frequency deviation within prescribed limit carrier frequency is same as transmitting frequency. Amplified modulating signal is applied to modulator along with carrier. At the output we get AM wave. This AM wave is amplified using chain of linear amplifier to increase its power level. It can be of class A, B or AB. Linear amplifiers are used in order to avoid waveform distortion in AM wave. This AM signal is then transmitted using $Tx^g$ antenna.
Its designing is simple but efficiency is low.

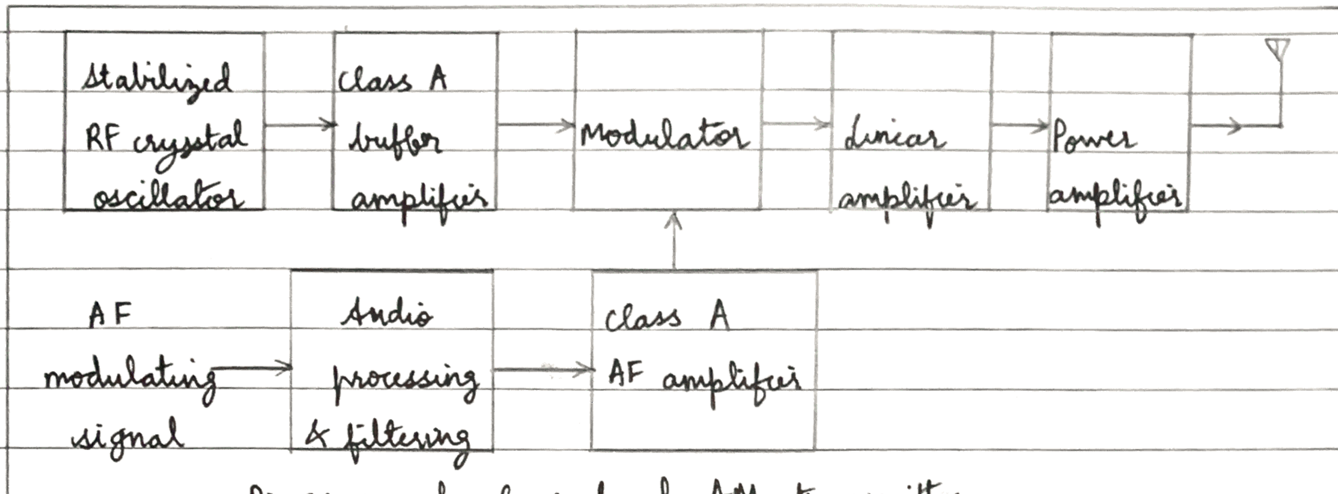


Diagram of low level AM transmitter

**Question 7.**

Explain generation of the following with neat diagram:

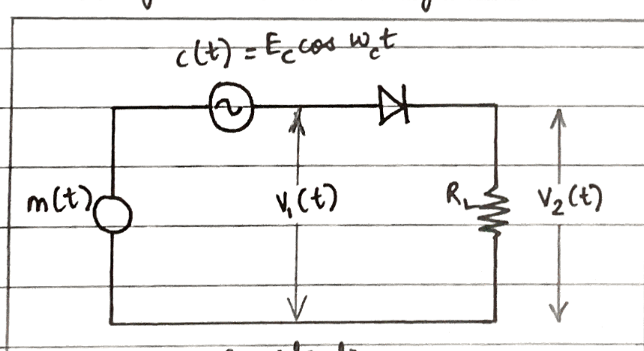
(i) DSBFC using diode

(ii) DSBFC using balance modulator

(iii) SSBSC using phase shift method

**Answer:**

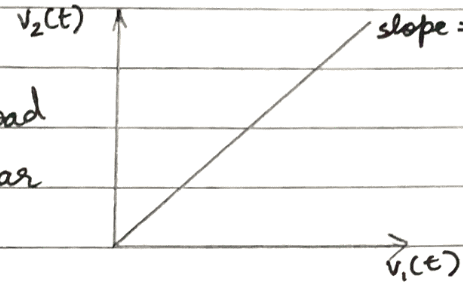
i) generation of DSBFC using diode



circuit diagram

A carrier signal c(t) of large amplitude is applied to the diode. The diode acts as a switch i.e. it shows zero impedance when it is forward biased, here when $c(t) > 0$.

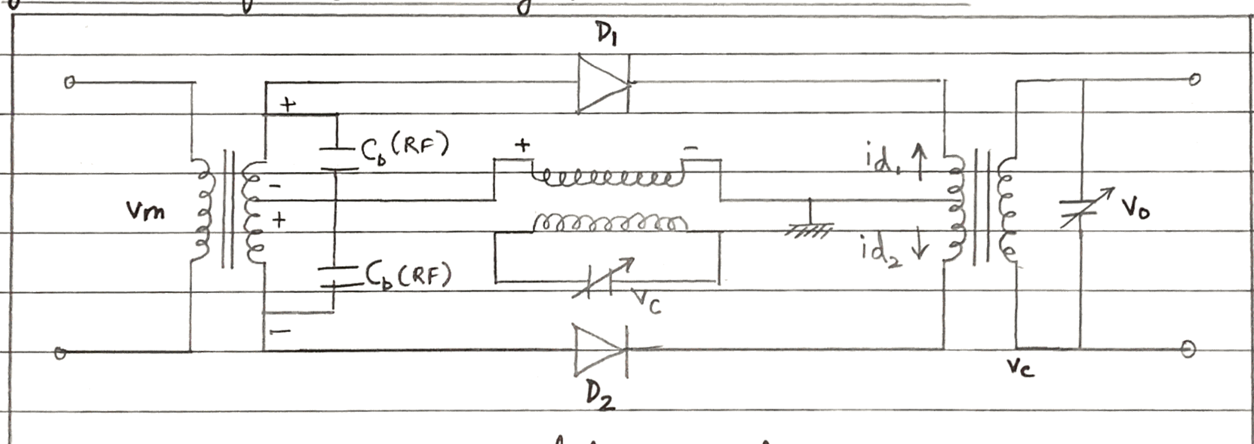
The graph alongside shows the transfer characteristic of the diode-load resistor combination. Since this is linear $v_1(t)$ will be the sum of carrier and message signals.




$\because |m(t)| << E_c \quad \therefore \quad v_2(t) = \begin{cases} v_1(t) & c(t) > 0 \\ 0 & c(t) < 0 \end{cases}$

Thus $v_2(t)$ varies between $v_1(t)$ and zero periodically, and this variation happens at the rate of carrier frequency $f_c$. Thus we get an amplitude modulated wave according to the message signal.

ii) Generation of DSBSC using balanced modulator



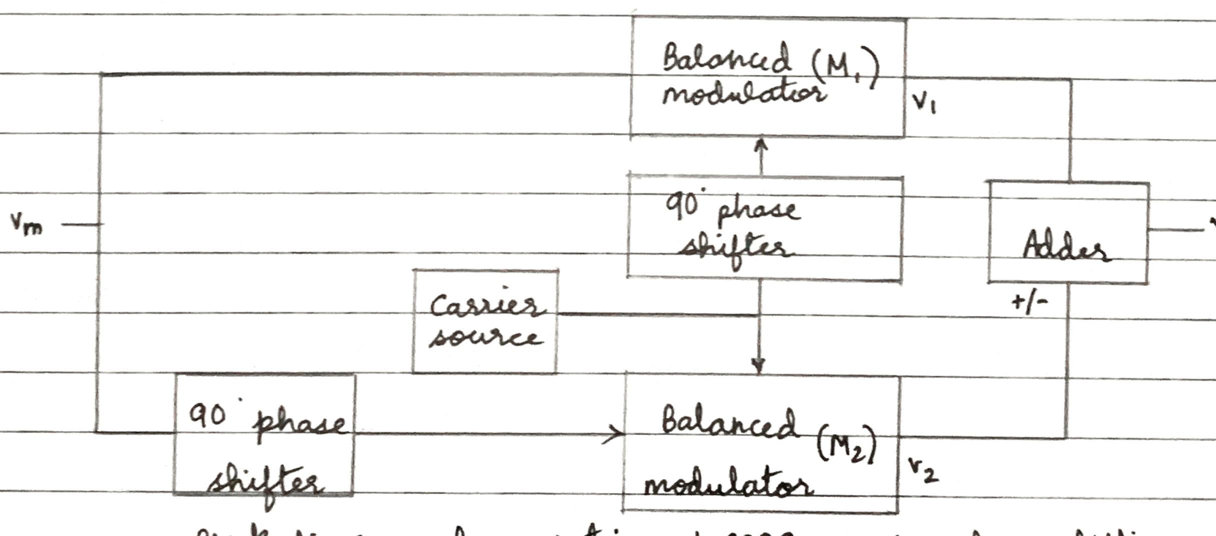

Circuit diagram of a balanced modulator

A balanced modulator is a circuit with two inputs namely modulating signal and carrier signal and produces two sidebands and suppresses the carrier completely.

The principle of operation of a balanced modulator is based on the non-linear resistance property of the diodes. Both the diodes receive the carrier voltage in phase whereas the modulating signal appears 180° out of phase at the input of diodes. The currents which is modulated of the two diodes are combined in the center-primary of the output transformer. If this system is made perfectly symmetrical the carrier frequency is completely cancelled.

iii) Generation of SSBSC using phase shift method

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




Block diagram of generation of SSBSC using phase shifting

Output of balanced modulator $M_1$ is given by:

$$v_1 = V_m V_c \sin \omega_m t \cos \omega_c t = \frac{V_m V_c}{2}\left[\sin(\omega_c+\omega_m)t + \sin(\omega_c-\omega_m)t\right]$$

Output of balanced modulator $M_2$ is given by:

$$v_2 = V_m V_c \cos \omega_m t \sin \omega_c t = \frac{V_m V_c}{2}\left[\sin(\omega_c+\omega_m)t - \sin(\omega_c-\omega_m)t\right]$$

Output of the adder is:

$$v = v_1 \pm v_2$$

$$= \begin{cases} V_m V_c \sin(\omega_c+\omega_m)t & \text{OR} \\ V_m V_c \sin(\omega_c-\omega_m)t \end{cases}$$

Thus resulting in the generation of SSB signal.

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**Question 8.**

What are the disadvantages of Tuned RF receivers? And explain super-heterodyne receiver with block diagram.

**Answer:**

**Disadvantages of Tuned RF receivers:**

i) **Instability in gain**

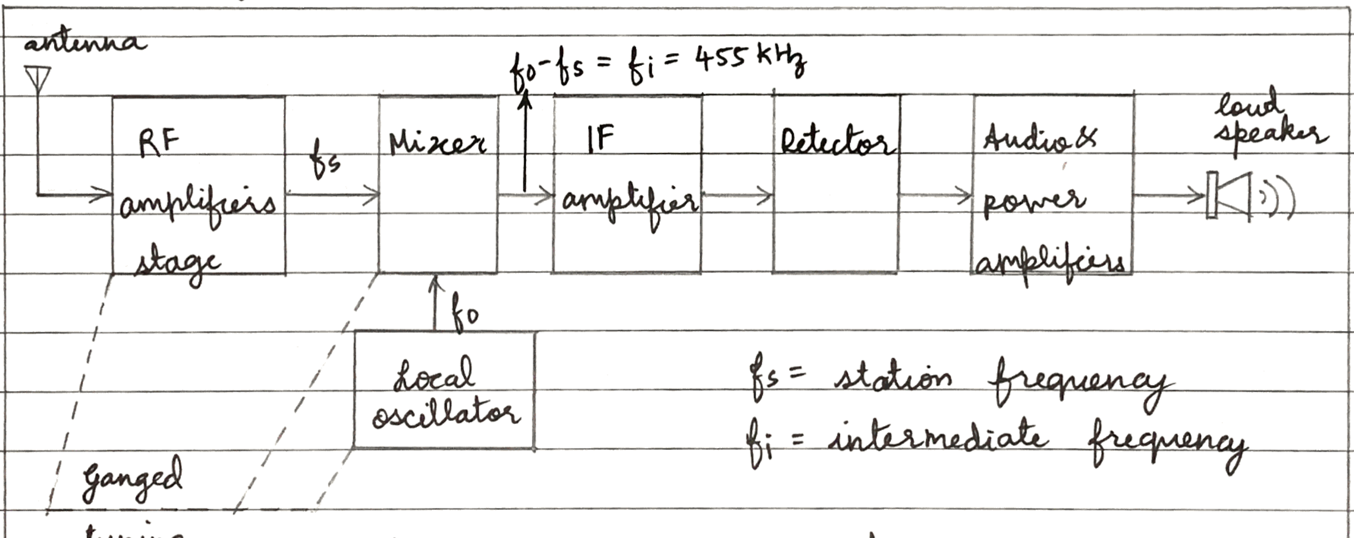
The overall gain of RF amplifiers is very high. So a very small feedback signal can initiate oscillations in the RF amplifier stage, and hence the amplifiers no more work as amplifiers. This feedback depends on stray capacitances which decreases at higher frequency. Thus instability increases with increase in frequency.

ii) **Bandwidth variation**

When receiver is tuned to the carrier frequency, it is expected to select carrier and its sidebands of the desired signal. And hence receiver should have adequate bandwidth, which is inversely dependent on quality factor. At very high frequencies the sufficient bandwidth cannot be attained due to sufficient losses in the quality factor, and so the bandwidth value changes.

iii) Insufficient selectivity:
Due to increased bandwidth at higher frequencies the ability of the receiver to select desired signal is seriously affected. This is called loss in selectivity.

Superheterodyne Receivers:



Block diagram of a superheterodyne receiver

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 the radio receiver.

ii) Mixer and local oscillator : It is a convertor stage in a superheterodyne receiver. The RF amplifier, mixer and local-oscillator are ganged together to produce intermediate frequency at the output of mixer which is always = 455 kHz.

iii) IF amplifier : It is a tuned voltage amplifier i.e. operated in class A with fixed rheostat load in most of the receiver. The gain is provided by IF amplifier.

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

v) Audio and power amplifier : It amplifies the incoming signal as well as generates the required power to distribute the loud speaker.

v) Loudspeaker : It converts electrical energy to sound energy.

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Question 9.

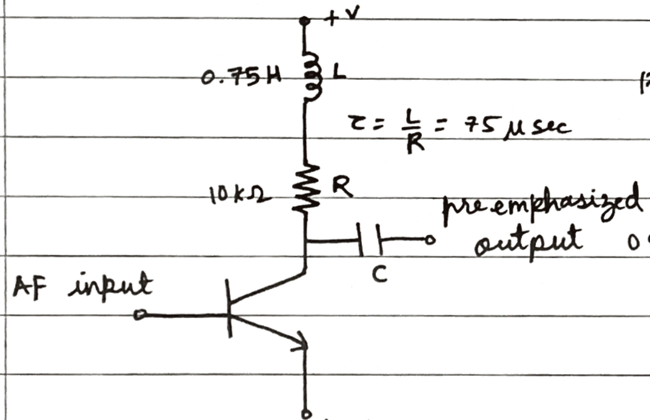
Explain pre-emphasis and de-emphasis circuit used in FM.

Answer :

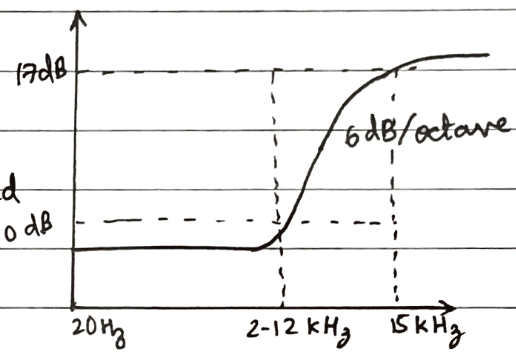
Pre-emphasis :

In the modulating voltage, high frequency components have small amplitudes and hence they produce frequency deviation for less than maximum permitted value of 75 KHz. Consequently the signal strength of these waves is very low. To improve the S/N ratio at this high modulating frequency, pre-emphasis circuit is used to emphasize the high frequency components prior to modulation.

In pre-emphasis process a high pass filter is used. The figure below shows circuit diagram for active pre-emphasis network and their corresponding frequency response curves:




circuit diagram

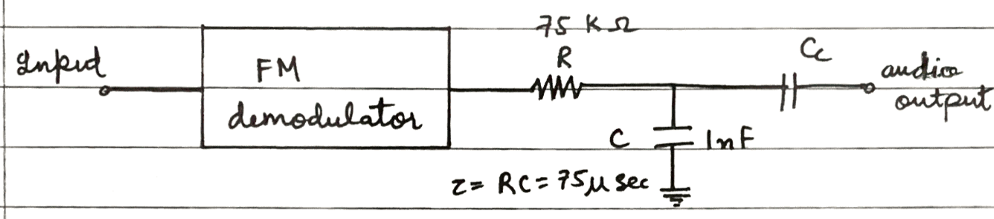


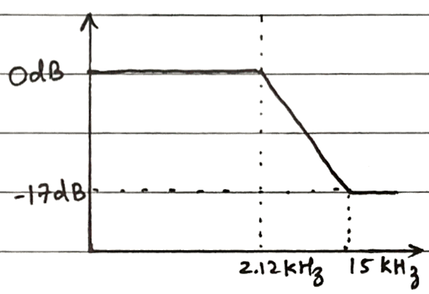

Pre emphasis network provides a constant increase in the amplitude of the modulating signal with an increase in the frequency. The network shown above uses 75 $\mu$ sec time constant. Therefore the break frequency approximately equates to $F = \frac{1}{2\pi\, L/R}$

$\therefore \; F = 2.12\ KHz$

**De-emphasis:**

To return the frequency response to its normal level a de--emphasis circuit is used at the receiver. This is a simple low pass filter with time constant of 75 $\mu$ sec. It features cutoff frequency of 2.12 kHz, accusing the signal above this frequency to be attenuated at the rate of 6 dB/octave. As a result of pre-emphasis at the transmitter is exactly offset by the de-emphasis circuit in the receiver providing normal frequency response. The combined effect of the pre-emphasis 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 fedality and intelligibility.




Question 10.

Compare AM and FM.

Answer:

| Amplitude Modulation | Frequency Modulation |
| --- | --- |
| i) In AM, the amplitude of carrier is changed with instantaneous value of the | i) In FM, the frequency of carrier is changed with the instantaneous value of modulating signal. |

| | |
|---|---|
| modulating signal. Frequency and phase remains constant. | Amplitude and phase remains constant. |
| ii) AM operates in medium & high frequency bands. | ii) FM operates in very high frequency (VHF) and ultra high frequency (UHF) bands. |
| iii) It requires smaller band width than FM. $B.W. = 2 \times F_{m(max)}$ | iii) It requires 7 to 15 times large band width than AM. $B.W. = 2 \times (\delta_{max} + f_{m(max)})$ |
| iv) Modulation index is always less than unity. $m_a = \frac{V_m}{V_c}$ | iv) Modulation index is greater than unity $m_f = \frac{\delta}{f_m}$ |
| v) In AM, noise is affected on reception. | v) In FM noise is eliminated using limiter circuit in receiver. |
| vi) Only one side band pair is produced. | vi) Infinite side band pair are produced. |
| vii) AM covers large area | vii) FM covers smaller area. |

Question 11.

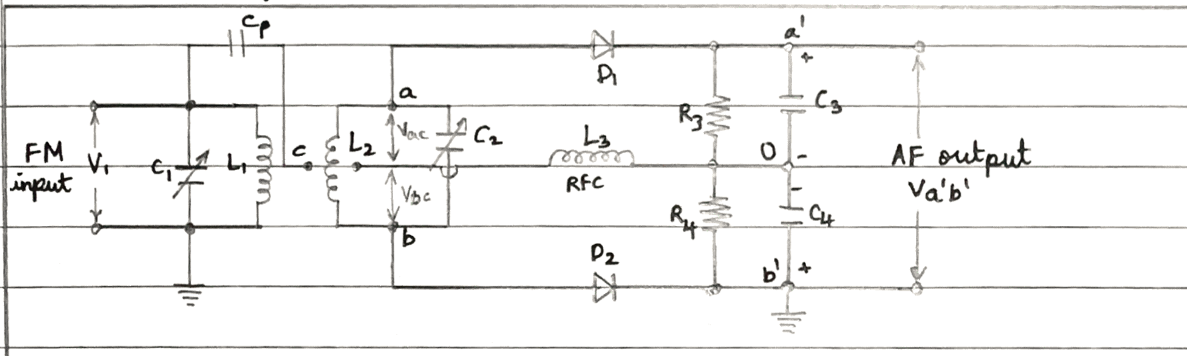
Explain FM demodulators with neat circuit diagram :-

i) Foster seeley demodulator

ii) Ratio detector

Answer:

i) Foster Seeley Demodulator (Phase discriminator)



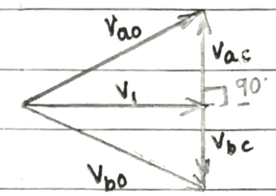

circuit diagram of Phase discriminator

The phase discriminator or Foster Seeley Discriminator is as shown above in the figure. Here the primary and the secondary windings both are tuned to the same center frequency '$f_c$' of the incoming signal, but the voltages applied to the two diodes $D_1$ and $D_2$ are not constant. They vary depending on the frequency of the input signal, due to the change in phase shift between the primary and secondary windings depending on the input frequency. The capacitor $C_p$ is a coupling capacitor which passes all the frequencies at the input to the center tap of the transformer secondary. $C_4$ bypasses resistance $R_4$ and so voltage across RFC will be equal to the input voltage $V_1$. The secondary voltage $V_{ab}$ gets devided equally across the upper and lower halves. Thus input to each diode is equal to the vector sum of the primary voltage $V_1$ and half the secondary voltage.

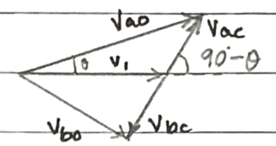
Output voltage of the phase discriminator is equal to the difference between the outputs of the two diode rectifiers :- $V_0 = V_{a'b'} = V_{a'0} - V_{b'0}$

Although diode drops are not known, it is sure that the output is proportional to the input voltages of $D_1$ & $D_2$. $V_0 \propto V_{a0} - V_{b0}$

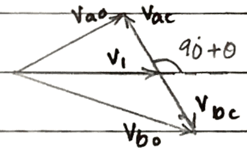
i) $f_{in} = f_c$ : When the input frequency is equal to the center frequency, the phase shift between the primary and secondary voltages is exactly 90°.



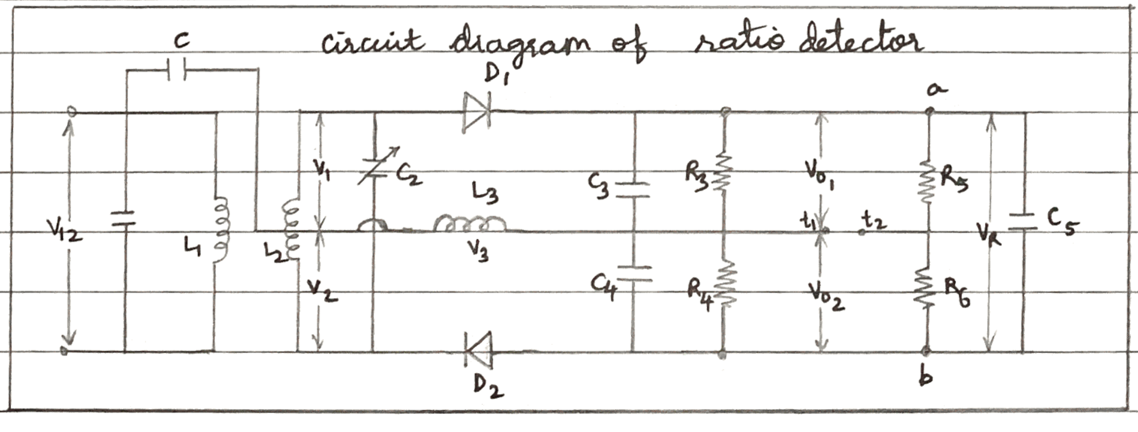

ii) $f_{in} > f_c$ : At input frequencies above the center frequency, secondary voltage $V_{ab}$ leads the primary voltage by less than 90°.




iii) $f_{in} < f_c$ : For input frequencies below the center frequency, the secondary voltage $V_{ab}$ leads the primary voltage by more than 90°.




ii) <u>Ratio detector</u>



Ratio detector is an improvement over the foster seeley discriminator and is widely used. It does not respond through amplitude variation, a limiter is not required. The circuit is similar to that of phase discriminator except for the following:

i) The polarity of diode $D_2$ has been reversed.

ii) The output voltage is taken from the center tapped of resistor R that shunts the load impedance of two diodes. The output voltage, like in Foster Seeley, varies with the input signal, but its magnitude is reduced to half.

Amplitude limiting by Ratio Detector : If input voltage has been constant for some time, $C_5$ is able to change up to the voltage between a and b. This is the DC voltage, there will be no current either flowing in to change the capacitor or flowing out to change it, i.e. impedance of input of $C_5$ is infinite.

If input voltage tries to rise, extra current flows into the capacitor $C_5$ changing 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 $C_5$ does not change.

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Question 12.

Explain the concept of Image frequency and Double spotting and also explain how to reject image frequency.

Answer :

Image Frequency : In a broadcast AM receivers the local oscillator frequency is made higher than the incoming signal frequency. It is made equal at all times to the signal frequency plus the intermediate frequency.

$$f_o = f_s + f_i$$

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

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

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

where $f_{si}$ = image frequency

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 image frequency signal it is necessary that these signals do not reach the mixer. This can be achieved by increasing the number of tuned circuits between the antenna and mixer and secondly by increasing their selectivity against image frequency signals.

## Double spotting :

Double spotting means the same station gets picked up at two different nearby points on the receiver 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 a strong station at the same point on the dial. It can be be reduced by increasing the front end selectivity of the receiver. Inclusion of the RF amplifier stage will help in avoiding double spotting.

Question 13.

In an AM radio receiver the loaded Q of the antenna circuit at the input to the mixer is 100. If the intermediate frequency is 455 kHz, calculate the image frequency and its rejection at 1 MHz.

Answer:

Loaded $Q = 100$

Intermediate frequency $f_i = 455\text{ kHz}$

Signal frequency $f_s = 1\text{ MHz} = 1000\text{ kHz}$

Image frequency $f_{si} = ?$

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

$$= 1000 + 2 \times 455$$

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

Image frequency rejection ratio $\alpha = ?$

$$\because \alpha = \sqrt{1 + Q^2 \rho^2}$$

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

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

$$\therefore \alpha = 138.64$$

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Question 14.

If an amplitude modulated wave $X_c(t) = 10(1 + 0.6\cos 200\pi t + 0.4\cos 400\pi t)\cos 2000\pi t$. (1) Sketch the amplitude spectrum of $X_c(t)$ (2) Find total power (3) Find side band power (4) What is $m_a$?

Answer :

$x_c(t) = 10\left[1 + 0.6\cos 200\pi t + 0.4 \cos 400\pi t\right] \cos 2000\pi t$

Comparing it with

$e = E_c\left[1 + m_1 \cos w_{m_1} t + m_2 \cos w_{m_2} t\right] \cos w_c t$

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

iv) $\therefore$ Modulation index $m = \sqrt{m_1^2 + m_2^2}$

$= \sqrt{0.6^2 + 0.4^2}$

$= 0.721$

$\therefore w_c = 2000\pi \qquad \therefore f_c = \frac{\cancel{2000}^{1000} \cancel{\pi}}{\cancel{2\pi}} = 1\ kHz$

$\therefore w_{m1} = 200\pi \qquad \therefore f_{m_1} = \frac{\cancel{200}^{100} \cancel{\pi}}{\cancel{2\pi}} = 0.1\ kHz$

$\therefore w_{m2} = 400\pi \qquad \therefore f_{m_2} = \frac{\cancel{400}^{200} \cancel{\pi}}{\cancel{2\pi}} = 0.2\ kHz$

i) $\therefore$ Upper side band $USB_1 = f_c + f_{m_1} = 1.1\ kHz$

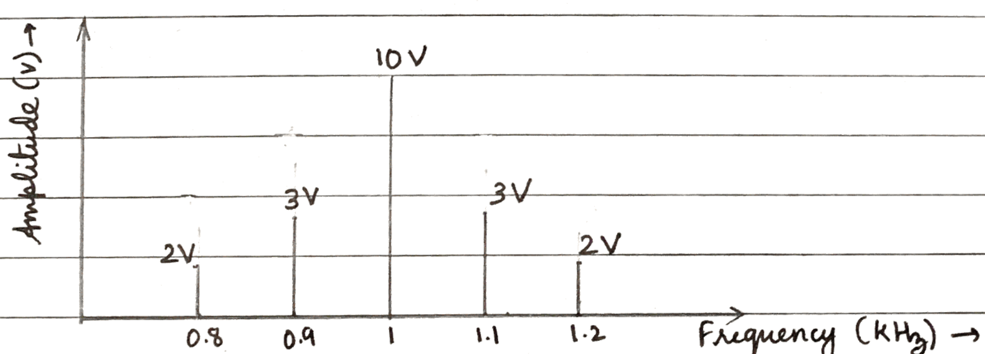
Upper side band $USB_2 = f_c + f_{m_2} = 1.2\ kHz$

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

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

$\therefore$ Amplitude of $USB_1 = mE_c/2 = 3\ V$ & of $USB_2 = 2\ V$

$\therefore$ Amplitude spectrum of $x_c(t)$ :-



Carrier power $P_c = \frac{E_c^2}{2R} = \frac{100}{2 \times 50} = 1$ W $[\because R = 50\,\Omega]$

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

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

$= 1.2599$

$\approx 1.26$ W

iii) Sideband power $P_{SB} = \frac{m^2}{2} P_c$

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

$= 0.2599$

$\approx 0.26$ W

Question 15.

A sinusoidal carrier has an amplitude of 10 V and a frequency of 100 KHz. It is amplitude modulated by a sinusoidal voltage of amplitude 3V and frequency 500 Hz. Modulated voltage is developed across 75 Ω resistance:

i) Show the equation of modulated wave

ii) Determine modulation index

iii) Draw spectrum of modulated wave

iv) Calculate total average power.

v) Calculate the power carried by sidebands

Answer :

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

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

i) Equation of modulated wave :

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

$$= 10\left(1 + 0.3\cos\left(2\pi \times 500\,t\right)\right)\cos\left(2\pi \times 100 \times 10^3 t\right)$$

$$\therefore e_{AM} = 10\left(1 + 0.3\cos 1000\pi t\right)\cos\left(2 \times 10^5 \pi t\right) \text{ //}$$

iii) Frequencies :-

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

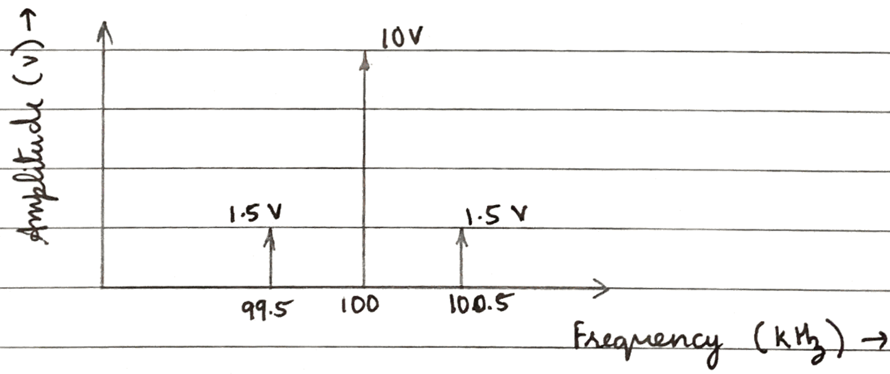
USB $= f_c + f_m = 100 + 0.5 = 100.5$ kHz

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

Amplitudes :-

$E_c = 10V$

LSB and USB $= \frac{mE_c}{2} = \frac{0.3 \times 10}{2} = 1.5$ V




iv) Power carried by carrier $P_c = \frac{E_c^2}{2R} = \frac{100}{2 \times 75} = 0.6667$ W

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

$$= 0.6667 \times \left(1 + \frac{0.3^2}{2}\right)$$

$$\therefore P_t = 0.6967 \text{ W}$$

Total sideband power $P_{SB} = \frac{m^2}{2} \times P_c = \frac{(0.3)^2}{2} \times \frac{2}{3}$

$$\therefore P_{SB} = 0.03 \text{ W}$$

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Question 16.

A sinusoidal carrier has an amplitude of 20V and a frequency of 200 KHz. It is amplitude modulated by a sinusoidal voltage of amplitude 6 V and frequency of 1KHz. Modulated voltage is developed across 80 Ω resistance :

i) Write the equation of modulated wave

ii) Determine modulation index

iii) Draw spectrum of modulated wave

iv) calculate the total average power

Answer :

$E_c = 20V$, $f_c = 200 \text{ kHz}$, $E_m = 6V$, $f_m = 1 \text{ kHz}$, $R_L = 80 \Omega$

ii) Modulation index $m = \frac{E_m}{E_c} = \frac{6}{20} = 0.3$

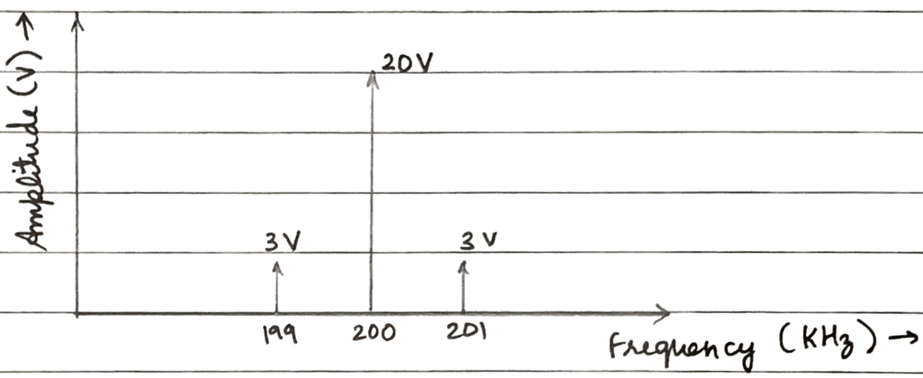
i) Equation of modulated wave :

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

$$\therefore e_{AM} = 20\left(1 + 0.3\cos\left(2\pi \times 1 \times 10^3 t\right)\right)\cos\left(2\pi \times 200 \times 10^3 t\right)$$
$$= 20\left[1 + 0.3\cos\left(2\pi \times 10^3 t\right)\right]\cos\left(4\pi \times 10^5 t\right)$$

iii) $USB = f_c + f_m = 200 + 1 = 201\ kH_z$
$LSB = f_c - f_m = 200 - 1 = 199\ kH_z$

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




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

$$= \frac{E_c^2}{2R}\left(1 + \frac{m^2}{2}\right) \quad \left[\because P_c = \frac{E_c^2}{2R}\right]$$

$$= \frac{20^2}{2 \times 80}\left(1 + \frac{0.3^2}{2}\right)$$

$$= 2.6125\ W$$

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Question 17.

A sinusoidal carrier has an amplitude of 20V and a frequency of 30kHz. It is amplitude modulated by a sinusoidal voltage of amplitude 3V and frequency 2kHz. Modulated voltage is developed across $50\,\Omega$ resistance :

i) Write the equation of modulated wave

ii) Calculate modulation index

iii) Draw spectrum of modulated wave.

**Answer:**

$E_c = 20V$, $E_m = 3V$, $f_c = 30\,kHz$, $f_m = 2\,kHz$, $R = 50\,\Omega$

ii) Modulation index $m = \frac{E_m}{E_c} = \frac{3}{20} = 0.15$

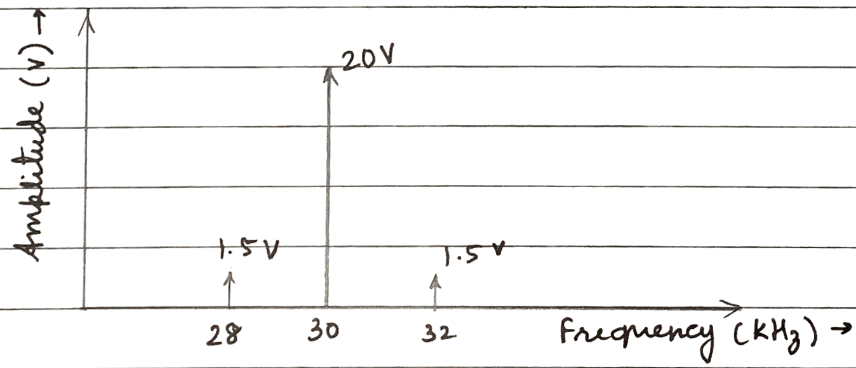
i) Equation of modulated wave :

$$e_{AM} = E_c[1 + m \cos w_m t] \cos w_c t$$
$$= 20[1 + 0.15 \cos(2\pi \times 2 \times 10^3 t)] \cos(2\pi \times 30 \times 10^3 t)$$
$$= 20[1 + 0.15 \cos(4\pi \times 10^3 t)] \cos(6\pi \times 10^4 t)$$

iii) $USB = f_c + f_m = 30 + 2 = 32\,kHz$

$LSB = f_c - f_m = 30 - 2 = 28\,kHz$

Amplitude of each sideband $= \frac{mE_c}{2} = \frac{0.15 \times 20}{2} = 1.5V$




Question 18.

A single tone FM signal is given by $V_{FM} = 10 \sin (16\pi \times 10^8 t + 20 \sin 2\pi \times 10^3 t)$. Calculate:

i) Maximum frequency deviation

ii) BW of FM by using Carson's Rule

Answer:

Comparing the equation with

$$e_{FM} = E_c \sin [w_c t + m_f \sin w_m t]$$

$\therefore$ Modulation index $m_f = 20$

$w_m = 2\pi \times 10^3$

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

i) We know that, $m_f = \dfrac{\Delta f}{f_m}$

$\therefore$ Maximum frequency deviation $\Delta f = f_m \times m_f$

$= 20 \times 1 kHz$

$= 20 \ kHz$

ii) By Carson's rule,

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

$$= 2 [20 + 1]$$

$\therefore$ BW $= 42 \ kHz$