Sheet [1]

Q.1

A modulating signal $m(t) = 10cos(2\pi \times 10^3 t)$ is amplitude modulated with a carrier signal $c(t) = 50cos\left(2\pi \times 10^5 t\right)$. Find the modulation index, the carrier power, and the power required for transmitting AM wave.

Sol

$$A_m = 10$$

$$f_m = 10^3$$

$$A_c = 50$$

$$f_c = 10^5$$

$$\boxed{m = \frac{A_m}{A_c} = \frac{10}{50} = 0.2}$$

$$\boxed{P_c = \frac{{A_c}^2}{2} = \frac{50^2}{2} = 1250\ W}$$

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

$$P_{Total} = \frac{{A_c}^2}{2} + \frac{(A_m/2)^2}{2} + \frac{(A_m/2)^2}{2}$$

$$\boxed{P_{Total} = \frac{{A_c}^2}{2} + \frac{{A_m}^2}{4} = \frac{50^2}{2} + \frac{10^2}{4} = 1275\ W}$$

Q.2

The equation of amplitude wave is given by:

$$s(t) = 20[1 + 0.8cos(2\pi \times 10^3 t)]cos(4\pi \times 10^5 t)$$

Find the carrier power, the total sideband power, and the band width of AM wave.

Sol

$$f_m = 10^3$$

$$A_c = 20$$

$$f_c = 2 \times 10^5$$

$$m = 0.8$$

$$m = \frac{A_m}{A_c} = \frac{A_m}{20} = 0.8$$

$$A_m = 16$$

$$\boxed{P_c = \frac{{A_c}^2}{2} = \frac{20^2}{2} = 200\ W}$$

$$P_{side\ bands} = P_{USB} + P_{LSB}$$

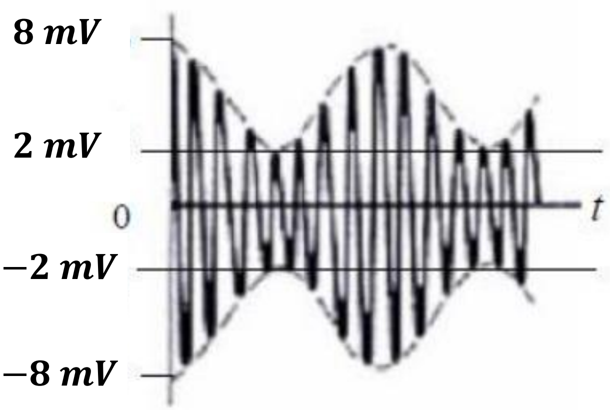
$$\boxed{P_{side\ bands} = \frac{(A_m/2)^2}{2} + \frac{(A_m/2)^2}{2} = \frac{{A_m}^2}{4} = \frac{16^2}{4} = 64}$$

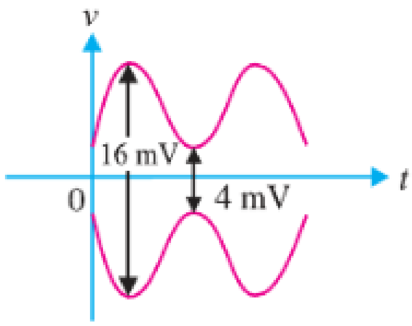
$$\boxed{B.W = 2f_m = 2\left(10^3\right) = 2\ KHz}$$

Q.3

The maximum peak-to-peak voltage of an AM wave is $16\,mV$ and the minimum peak-to-peak voltage is $4\,mV$. Calculate the modulation factor.

Sol





$$A_c = \frac{8\,mV + 2\,mV}{2} = 5\,mV$$

$$A_m = 8\,mV - A_c = 3\,mV$$

$$\boxed{m = \frac{A_m}{A_c} = \frac{3}{5} = 0.6}$$

Q.4

An AM wave is represented by the expression:

$$v = 5(1 + 0.6\cos(6280)t)\sin(211 \times 10^4)\, t\ volts$$

a) **What are the minimum and maximum amplitudes of the AM wave?**

b) **What frequency components are contained in the modulated wave and what is the amplitude of each component?**

Sol

$$f_m = \frac{6280}{2\pi} \cong 1000\ Hz$$

$$A_c = 5$$

$$f_c = \frac{211 \times 10^4}{2\pi} \cong 336\ KHz$$

$$m = 0.6$$

$$m = \frac{A_m}{A_c} = \frac{A_m}{5} = 0.6$$

$$A_m = 3$$

$$\boxed{A_{max} = A_c + A_m = 5 + 3 = 8\ V}$$

$$\boxed{A_{min} = -(A_c + A_m) = -(5 + 3) = -8\ V}$$

$$v = 5(1 + 0.6\cos(6280)t)\sin(211 \times 10^4)\, t$$

$$v = 5\sin(211 \times 10^4)\, t + 3\cos(6280t) \times \sin(211 \times 10^4 t)$$

$$v = 5\sin(211\times 10^4)\,t + \frac{3}{2}[\sin(2\pi(336\,KHz - 1\,KHz)t) + \sin(2\pi(336\,KHz + 1\,KHz)t)]$$

$$v = 5\sin(211\times 10^4)\,t + \frac{3}{2}[\sin(2\pi(335\,KHz)t) + \sin(2\pi(337\,KHz)t)]$$

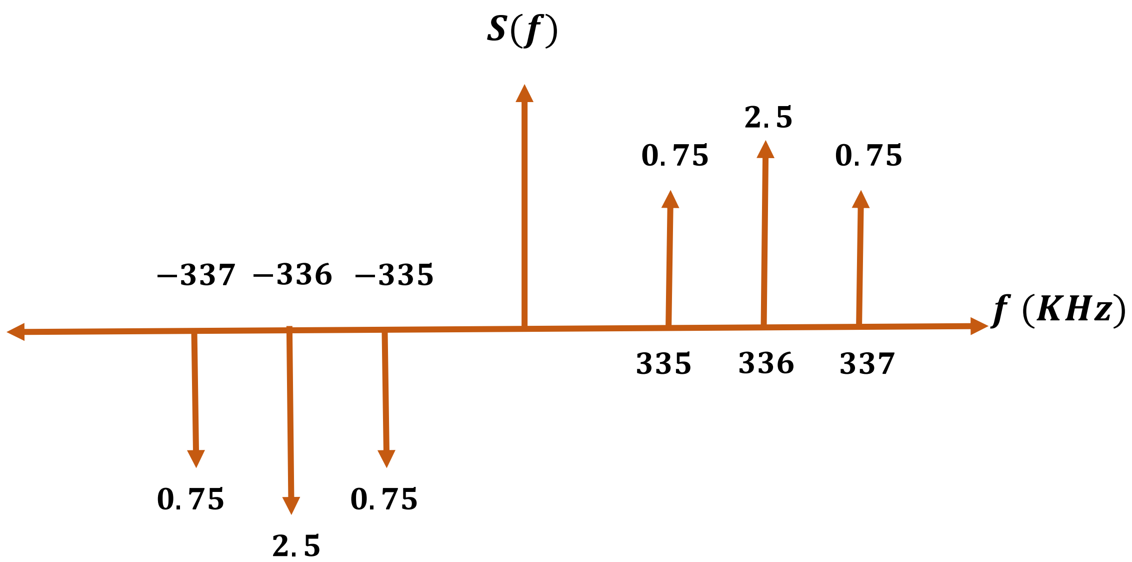
$$v = 5\sin(211\times 10^4)\,t + \frac{3}{2}\sin(2\pi(335\,KHz)t) + \frac{3}{2}\sin(2\pi(337\,KHz)t)$$

$$\boxed{Carrier \rightarrow\ 336\,KHz - 5\,V}$$

$$\boxed{LSB \rightarrow\ 335\,KHz - 1.5\,V}$$

$$\boxed{USB \rightarrow\ 337\,KHz - 1.5\,V}$$

$$V(f) = \frac{5}{2j}[\delta(f - 336\,KHz) - \delta(f + 336\,KHz)] + \frac{3}{4j}[\delta(f - 335\,KHz) - \delta(f + 335\,KHz)] + \frac{3}{4j}[\delta(f - 337\,KHz) - \delta(f + 337\,KHz)]$$



Q.5

A sinusoidal carrier voltage of frequency $1\,MHz$ and amplitude $100\,volts$ is amplitude modulated by sinusoidal voltage of frequency $5\,kHz$ producing 50% modulation. Calculate the frequency and amplitude of lower and upper sideband terms.

Sol

$$f_c = 1 \times 10^6\ Hz$$

$$A_c = 100$$

$$f_m = 5 \times 10^3\ Hz$$

$$m = 0.5$$

$$m = \frac{A_m}{A_c} = \frac{A_m}{100} = 0.5$$

$$A_m = 50$$

$$s(t) = A_c \cos(2\pi f_c t) + \frac{A_m}{2} \cos(2\pi(f_c - f_m)t) + \frac{A_m}{2} \cos(2\pi(f_c + f_m)t)$$

$$\boxed{LSB \rightarrow\ 995\ KHz - 25\ V}$$

$$\boxed{USB \rightarrow\ 1005\ KHz - 25\ V}$$

Q.6

A carrier wave of frequency $10\ MHz$ and peak value $10V$ is amplitude modulated by a $5\ kHz$ sine wave of amplitude $6V$. Determine:

a) **Modulation factor.**
b) **Sideband frequencies.**
c) **Amplitude of sideband components.**
d) **Draw the frequency spectrum.**

Sol

$$f_c = 10 \times 10^6\ Hz$$

$$A_c = 10$$

$$f_m = 5 \times 10^3\ Hz$$

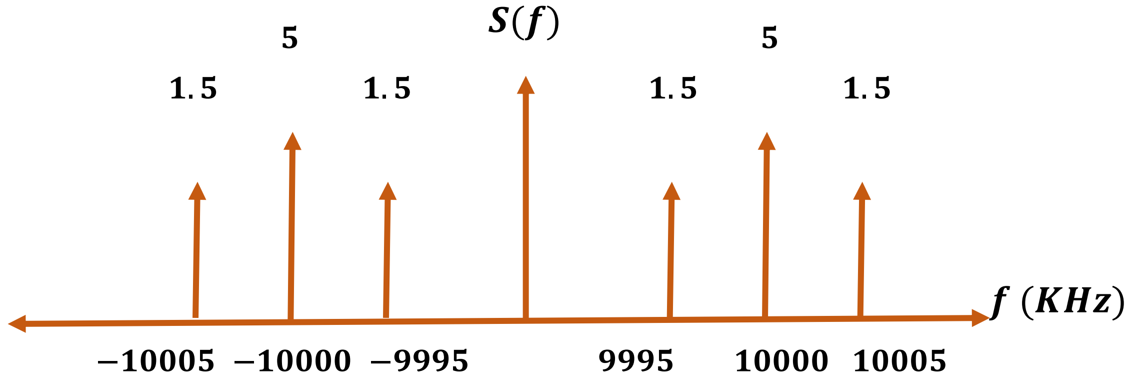
$$A_m = 6$$

$$\boxed{m = \frac{A_m}{A_c} = \frac{6}{100} = 0.6}$$

$$\boxed{LSB \rightarrow\ 9995\ KHz - 3\ V}$$

$$\boxed{USB \rightarrow\ 10005\ KHz - 3\ V}$$

Assume that m(t)is a cosine wave



Q.7

A carrier wave of $500\ watts$ is subjected to 100% amplitude modulation. Determine:

a) **power in sidebands**
b) **Power of modulated wave.**

Sol

$$P_c = 500\ W$$

$$m = 1$$

$$P_c = \frac{{A_c}^2}{2} = 500$$

$$A_c = 10\sqrt{10}$$

$$A_m = 10\sqrt{10}$$

$$\boxed{P_{side\ bands} = \frac{(A_m/2)^2}{2} + \frac{(A_m/2)^2}{2} = \frac{{A_m}^2}{4} = \frac{(10\sqrt{10})^2}{4} = 250}$$

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

$$\boxed{P_{Total} = 500 + 250 = 750\ W}$$

Q.8

A $50\ kW$ carrier is to be modulated to a level of:

a) 80% b) 10%.

What is the total sideband power in each case?

Sol

$$P_c = 50\ KW$$

$\underline{i = 0.8}$

$$P_c = \frac{{A_c}^2}{2} = 50 \times 10^3$$

$$A_c \cong 316.23$$

$$A_m \cong 253$$

$$\boxed{P_{side\ bands} = \frac{(A_m/2)^2}{2} + \frac{(A_m/2)^2}{2} = \frac{{A_m}^2}{4} = \frac{(253)^2}{4} = 16000\ \text{W}}$$

$\underline{i = 0.1}$

$$P_c = \frac{{A_c}^2}{2} = 50 \times 10^3$$

$$A_c \cong 316.23$$

$$A_m \cong 31.6$$

$$\boxed{P_{side\ bands} = \frac{(A_m/2)^2}{2} + \frac{(A_m/2)^2}{2} = \frac{{A_m}^2}{4} = \frac{(31.6)^2}{4} = 250\ \text{W}}$$

Q.9

A 40kW carrier is to be modulated to a level of 100%.

a) **What is the carrier power after modulation?**
b) **How much audio power is required if the efficiency of the modulated RF amplifier is 72%?**

Sol

$$P_c = 40\ KW$$

$$m = 1$$

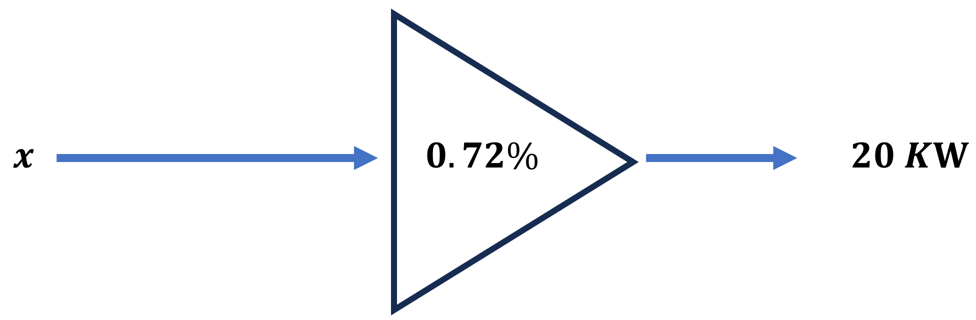
$$P_c|_{before\ modulation} = P_c|_{after\ modulation}$$

$$\boxed{P_c|_{after\ modulation} = 40\ KW}$$

$$P_c = \frac{{A_c}^2}{2} = 40 \times 10^3$$

$$A_c = A_m \cong 282.84$$

$$P_{side\ bands} = \frac{(A_m/2)^2}{2} + \frac{(A_m/2)^2}{2} = \frac{{A_m}^2}{4} = \frac{(282.84)^2}{4} = 20\ KW$$



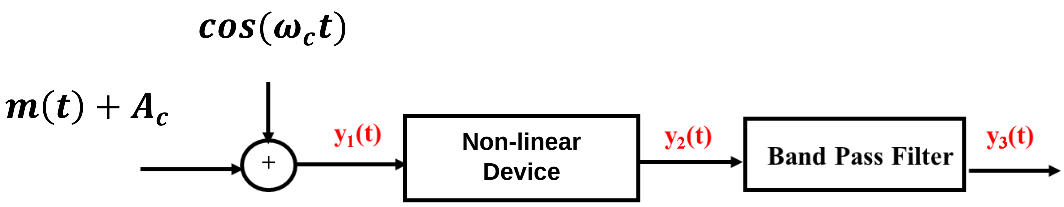
$$\frac{20\ KW}{x} = 0.72$$

$$\boxed{x \cong 27.78\ KW}$$

Q.10

Non-linear device whose $I_o = a_o v_i + a_3 {v_i}^3$, explain how such a device could be used to provide AM signal.

Sol



remember that:

$$(a+b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$$

$$cos^3(\omega_c t) = \frac{3}{4}cos(\omega_c t) + \frac{1}{4}cos(3\omega_c t)$$

$$y_1 = m(t) + A_c + cos(\omega_c t)$$

$$y_1 = x(t) + \ cos(\omega_c t)$$

$$y_2 = a_0[x(t) + \ cos(\omega_c t)] + a_3[x(t) + \ cos(\omega_c t)]^3$$

$$y_2 = a_0 x(t) + a_0 cos(\omega_c t) + a_3 x^3(t) + 3a_3 x^2(t) cos(\omega_c t) + 3a_3 x(t) cos^2(\omega_c t) + a_3 cos^3(\omega_c t)$$

$$y_2 = a_0 x(t) + a_0 cos(\omega_c t) + a_3 x^3(t) + 3a_3 (m(t) + A_c) cos(\omega_c t) + 3a_3 x(t) cos^2(\omega_c t) + a_3 cos^3(\omega_c t)$$

$$y_2 = a_0 x(t) + (a_0 + 3a_3) cos(\omega_c t) + a_3 x^3(t) + 3a_3 m(t) cos(\omega_c t) + \frac{3}{2} a_3 x(t)[1 + cos(2\omega_c t)] + a_3[\frac{3}{4}cos(\omega_c t) + \frac{1}{4}cos(3\omega_c t)]$$

$$y_2 = a_0 x(t) + (a_0 + \frac{15}{4} a_3) cos(\omega_c t) + a_3 x^3(t) + 3 a_3 m(t) cos(\omega_c t)$$
$$+ \frac{3}{2} a_3 x(t)[1 + cos(2\omega_c t)] + \frac{1}{4} a_3 cos(3\omega_c t)$$

by using a BPF centered at f_c and with a B.W of $2f_m$

we can get $y_3(t)$

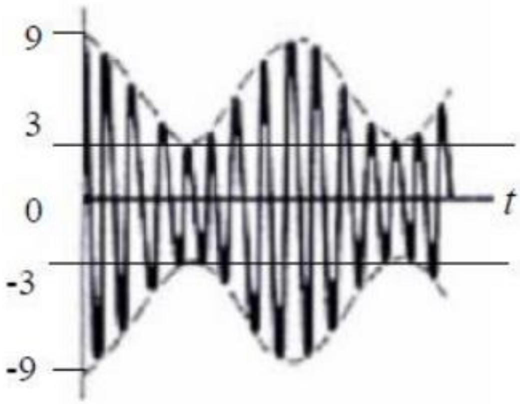
$$y_3 = (a_0 + \frac{15}{4} a_3) cos(\omega_c t) + 3 a_3 m(t) cos(\omega_c t)$$

$$A_c = (a_0 + \frac{15}{4} a_3)$$

$$A_m = 3 a_3$$

Q.11

A sinusoidally modulated ordinary AM waveform is shown



below.

(a) Determine the modulation index.
(b) Calculate the transmission efficiency.
(c) Determine the amplitude of the carrier which must be added to attain a modulation index of 0.3.

Sol

$$A_c = \frac{3+9}{2} = 6$$

$$A_m = 9 - A_c = 3$$

$$\boxed{m = \frac{A_m}{A_c} = \frac{3}{6} = 0.5}$$

$$\boxed{\eta = \frac{P|_{useful}}{P_{total}} = \frac{m^2}{m^2+2} = \frac{0.5^2}{0.5^2+2} = 11.11\%}$$

$$m = \frac{A_m}{A_c} = \frac{3}{A_c} = 0.3$$

$$\boxed{A_c = 10}$$