POSTAL BOOK PACKAGE 2024

MADE EASY PUBLICATIONS

ELECTRICAL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

COMMUNICATION SYSTEMS

1 CHAPTER Amplitude Modulation

Q.1 A two-tone modulating signal $e_m(t)$ = 5 cos $2\pi \times 10^3$ (t) + 4 cos $4\pi \times 10^3 t$ modulates a carrier voltage $e_c(t)$ = 10 cos $2\pi \times 10^6 t$. Find various frequency components present and corresponding modulation indices. Also obtain the amplitude of the signals present in each sidebands and the bandwidths.

Solution:

The expression of AM is given by,

$$\phi_{AM}(t) = 10\left[1+\frac{5}{10}\cos(2\pi\times 10^3 t)+\frac{4}{10}\cos(4\pi\times 10^3 t)\right]\cos(2\pi\times 10^6 t)$$

$$= 10\left[1+0.5\cos(2\pi\times 10^3 t)+0.4\cos 4\pi\times 10^3 t\right]\cos(2\pi\cdot 10^6 t)$$

$$m_1 = 0.5 \text{ and } m_2 = 0.4$$

$$\phi_{AM}(t) = 10\cos 2\pi\, 10^6 + 5\cos(2\pi\times 10^3 t)\cos(2\pi\times 10^6 t) + 4\cos(4\pi\times 10^3 t)\cos(2\pi\times 10^6 t)$$

$$= 10\cos(2\pi\times 10^6)+\frac{5}{2}\cos\left[2\pi\times(10^6+10^3)t\right]+\frac{5}{2}\cos\left[2\pi\times(10^6-10^3)t\right]$$
$$+2\cos\left[2\pi\times(10^6+2\times 10^3)t\right]+2\cos\left[2\pi\times(10^6-2\times 10^3)t\right]$$

Upper sidebands,

$\Rightarrow$ $F_C + F_1 = 10^6 + 10^3 = 1.001$ MHz

$\Rightarrow$ $F_C + F_2 = 10^6 + 2 \times 10^3 = 1.002$ MHz

Now, Lower sidebands,

$\Rightarrow$ $F_C - F_1 = 10^6 - 10^3 = 0.999$ MHz

$\Rightarrow$ $F_C - F_2 = 10^6 - 2 \times 10^3 = 0.998$ MHz

Each sidedband W_1, $\dfrac{m_1 E_c}{2} = \dfrac{0.5\times 10}{2} = 2.5$ V

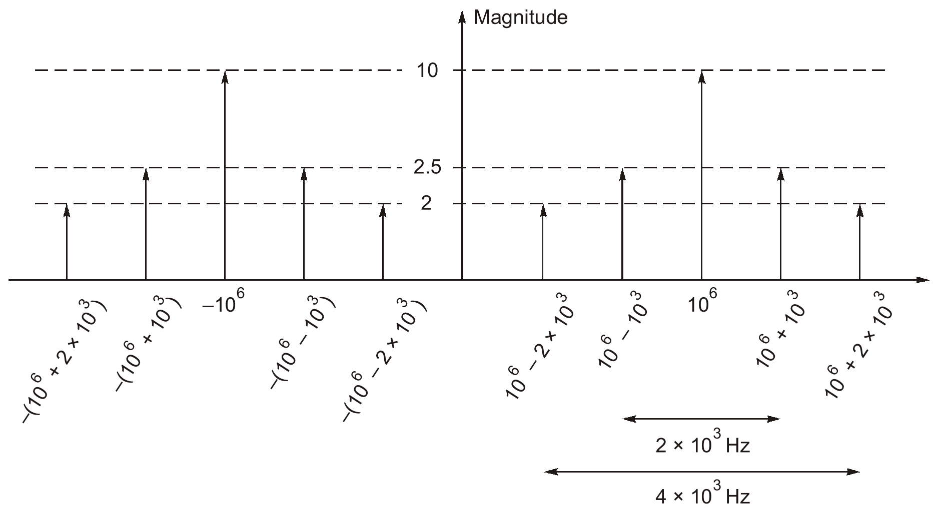
Each sideband W_2, $\dfrac{m_1 E_c}{2} = \dfrac{0.4\times 10}{2} = 2$ V

Total bandwidth = 2 × Bandwidth of message signal m_2

W_m = 2 kHz

Total bandwidth = 2 × 2 = 4 kHz

So, the frequency present are:



Q2 An AM modulator has output

$$x(t) = 30 \cos 2\pi(200t) + 6 \cos 2\pi(180t) + 6 \cos 2\pi(220)t$$

Determine the modulation index and efficiency.

Solution:

$$\begin{aligned} x(t) &= 30 \cos 2\pi(200t) + 6 \cos 2\pi(180t) + 6 \cos 2\pi(220)t \\ &= 30 \cos 2\pi(200t) + 12 \cos 2\pi(200t) \times \cos (2\pi\,(10t) \\ &= 3 \cos 2\pi(200t)\,[10 + 4 \cos(2\pi \times 10t)] \\ &= 3[10 + 4 \cos 2\pi(10t)] \cos 2\pi(200t) \\ &= 30[1 + 0.4 \cos 2\pi(10t)] \cos 2\pi(200t) \end{aligned}$$

So, modulation index $= \mu = 0.4$

$$\text{Efficiency} = \frac{\mu^2}{2+\mu^2} = \frac{0.16}{2.16} = 0.074 = 7.4\%$$

Q3 Show that power contained in one sideband is 1/6 to the total power of amplitude modulated signal at 100% modulation index.

Solution:

$$\begin{aligned} S_{AM}(t) &= A_c\,(1 + \mu \cos 2\pi f_m t) \cos 2\pi f_c t \\ &= A_c\,[1 + \cos 2\pi f_m t] \cos 2\pi f_c t \qquad [\mu = 1] \\ &= A_c \cos 2\pi f_c t + A_c \cos 2\pi f_m t \cos 2\pi f_c t \\ &= A_c \cos 2\pi f_c t + \frac{A_c}{2}\left[\cos 2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t\right] \\ &= A_c \cos 2\pi f_c t + \frac{A_c}{2}\cos 2\pi(f_c + f_m)t + \frac{A_c}{2}\cos 2\pi(f_c - f_m)t \end{aligned}$$

$$\text{Power in one sideband} = \frac{A_c^2}{4 \times 2} = \frac{A_c^2}{8}$$

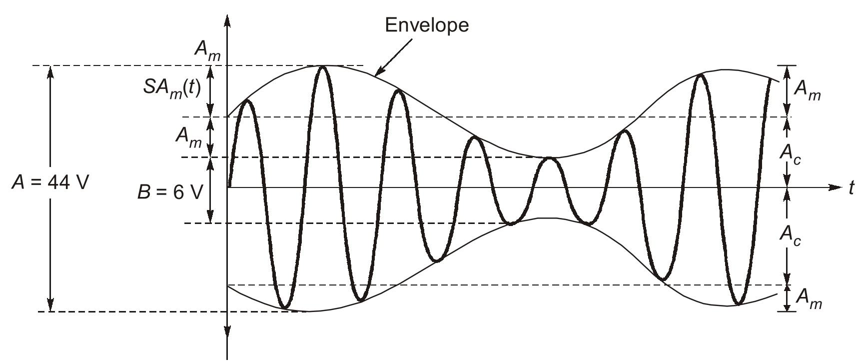
$$\text{Total power} = \frac{A_c^2}{2} + \left(\frac{A_c}{2}\right)^2 \times \frac{1}{2} + \left(\frac{A_c}{2}\right)^2 \times \frac{1}{2}$$

$$= \frac{A_c^2}{2} + \frac{A_c^2}{8} + \frac{A_c^2}{8} = \frac{3A_c^2}{4}$$

So, $$\text{Ratio} = \frac{\frac{A_c^2}{8}}{\frac{3A_c^2}{4}} = \frac{1}{6}$$

Q.4 An amplitude modulated signal, viewed on an oscilloscope, has a crest voltage of 44 V peak-to-peak. The bottom (or trough) point of the wave measures 6 V peak-to-peak. Find the modulation factor, percentage modulation and peak-to-peak unmodulated carrier voltage.

Solution:



Modulation factor, $$m = \frac{A_m}{A_c}$$

From figure, $$A = 2(A_c + A_m) \quad ...(i)$$
$$B = 2(A_c - A_m) \quad ...(ii)$$

Solving equation (i) and (ii), $$A_c = \frac{A+B}{4}$$

$$A_m = \frac{A-B}{4}$$

Hence, $$\mu = \frac{A-B}{A+B} = \frac{44-6}{44+6} = \frac{38}{50} = 0.76$$

Percentage modulation $= \mu \times 100 = 76\%$

Peak to peak unmodulated carrier voltage

$$= 2A_c = \frac{A+B}{2} = \frac{44+6}{2} = 25 \text{ V}$$

Q.5 The antenna current of a transmitter is 11.5 amperes, when it is modulated to a depth of 45% by an audio wave. The current enhances to 12.5 amperes on account of simultaneous modulation by another audio sine wave. Find the modulation index of the second audio wave.

Solution:

Given, antenna current (I_t) of a transmitter is 11.5 amperes when modulation index (μ_1) is 0.45.

Total power in amplitude modulated signal is given as,

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

where, $P_t = I_t^2 R$ and $P_c = I_c^2 R$

R = Resistance and I_C = Carrier current

So, $$I_t^2 R = I_c^2 R\left(1+\frac{\mu^2}{2}\right)$$

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

$\Rightarrow$ $$I_t = I_c\sqrt{\left(1+\frac{\mu^2}{2}\right)} \text{ Ampere}$$

As per question, $$11.5 = I_c\sqrt{\left(1+\frac{(0.45)^2}{2}\right)}$$

$\Rightarrow$ $$I_c = 10.96 \text{ Amperes}$$

On account of simultaneous modulation by another audio wave (modulation index, μ_2); the total modulation index is given by μ.

So, I_t become 12.5 Amperes.

$$I_t = I_c\sqrt{\left(1+\frac{\mu^2}{2}\right)}$$

$$12.5 = 10.96\sqrt{\left(1+\frac{\mu^2}{2}\right)}$$

$\Rightarrow$ $$1+\frac{\mu^2}{2} = 1.3$$

$$\frac{\mu^2}{2} = 1.3 - 1 = 0.3$$

$\Rightarrow$ $$\mu = 0.775$$

The total modulation is due to simultaneous modulation of two audio waves. So,

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

$$(0.775)^2 = (0.45)^2 + \mu_2^2$$

$$0.6 - 0.2025 = \mu_2^2$$

$\Rightarrow$ $$\mu_2 = 0.63$$

Hence, the modulation index of the second audio wave is 0.63 or 63%.

Q.6 (i) The antenna current of an AM broadcast transmitter, modulated to a depth of 40 percent by an audio sine wave, is 11 amperes. It increases to 12 amperes as a result of simultaneous modulation by another audio sine wave. What is the modulation index due to this second wave?

(ii) A certain transmitter radiates 9 kW with the carrier unmodulated and 10.125 kW when the carrier is simultaneously modulated. Estimate the modulation index. If another sine wave, corresponding to 40% modulation, is transmitted simultaneously, find out the total radiated power.

Solution:

(i) Given that: Depth of modulation, μ_1 = 40% = 0.4; Antenna current, I_t = 11 A

$$I_t^2 = I_c^2\left(1+\frac{\mu_1^2}{2}\right)$$

$$I_c = I_t\sqrt{\frac{1}{1+\frac{\mu_1^2}{2}}} = 11\sqrt{\frac{1}{1+\frac{(0.4)^2}{2}}} = 10.58 \text{ A}$$

Now, given that

antenna current I_t = 12 A

Let the second modulated wave be of modulation index μ_2

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

$$(12)^2 = (10.58)^2\left(1+\frac{(0.4)^2}{2}+\frac{\mu_2^2}{2}\right)$$

From here, μ_2 = 0.64

(ii) Given that, Carrier power, P_c = 9 kW

Total power, P_t = 10.125 kW

Let modulation depth is μ_1

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

$$10.125 = 9\left(1+\frac{\mu_1^2}{2}\right)$$

From here $\mu_1 = \frac{1}{2}$ or 50%

Simultaneous modulated with μ_2 = 40%

$$P_t = P_c\left(1+\frac{\mu_1^2}{2}+\frac{\mu_2^2}{2}\right) = 9\left(1+\frac{(0.5)^2}{2}+\frac{(0.4)^2}{2}\right)\text{kW} = 10.845 \text{ kW}$$

Q.7 A given AM broadcast station transmits a total power of 50 kW, when the carrier is modulated by a sinusoidal signal with a modulation index of 0.707. Calculate

(a) The carrier power.

(b) The transmission efficiency.

(c) The peak amplitude of the carrier after modulation assuming the antenna to be represented by a (50 + *j*0)Ω load.

Solution:

(a) Total power transmitted by the AM broadcast station is given by,

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

$$\Rightarrow \quad 50 = P_C\left(1+\frac{(0.707)^2}{2}\right)$$