

POSTAL Book Package

2023

Electrical Engineering

Conventional Practice Sets

Communication Systems

Contents

Sl.	Topic	Page No.
1.	Amplitude Modulation	2
2.	Frequency Modulation	25
3.	Transmitters and Receivers	42
4.	Digital Communication	49
5.	Noise	67



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Amplitude Modulation

Q1 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,

$$\begin{aligned}\phi_{AM}(t) &= 10 \left[1 + \frac{5}{10} \cos(2\pi \times 10^3 t) + \frac{4}{10} \cos(4\pi \times 10^3 t) \right] \cos(2\pi \times 10^6 t) \\ &= 10 \left[1 + 0.5 \cos(2\pi \times 10^3 t) + 0.4 \cos(4\pi \times 10^3 t) \right] \cos(2\pi \times 10^6 t) \\ m_1 &= 0.5 \text{ and } m_2 = 0.4 \\ \phi_{AM}(t) &= 10 \cos 2\pi \times 10^6 t + 5 \cos(2\pi \times 10^3 t) \cos(2\pi \times 10^6 t) + 4 \cos(4\pi \times 10^3 t) \cos(2\pi \times 10^6 t) \\ &= 10 \cos(2\pi \times 10^6 t) + \frac{5}{2} \cos[2\pi \times (10^6 + 10^3)t] + \frac{5}{2} \cos[2\pi \times (10^6 - 10^3)t] \\ &\quad + 2 \cos[2\pi \times (10^6 + 2 \times 10^3)t] + 2 \cos[2\pi \times (10^6 - 2 \times 10^3)t]\end{aligned}$$

Upper sidebands,

$\Rightarrow$

$$F_C + F_1 = 10^6 + 10^3 = 1.001 \text{ MHz}$$

$\Rightarrow$

$$F_C + F_2 = 10^6 + 2 \times 10^3 = 1.002 \text{ MHz}$$

Now, Lower sidebands,

$\Rightarrow$

$$F_C - F_1 = 10^6 - 10^3 = 0.999 \text{ MHz}$$

$\Rightarrow$

$$F_C - F_2 = 10^6 - 2 \times 10^3 = 0.998 \text{ MHz}$$

Each sidedband W_1 ,

$$\frac{m_1 E_c}{2} = \frac{0.5 \times 10}{2} = 2.5 \text{ V}$$

Each sideband W_2 ,

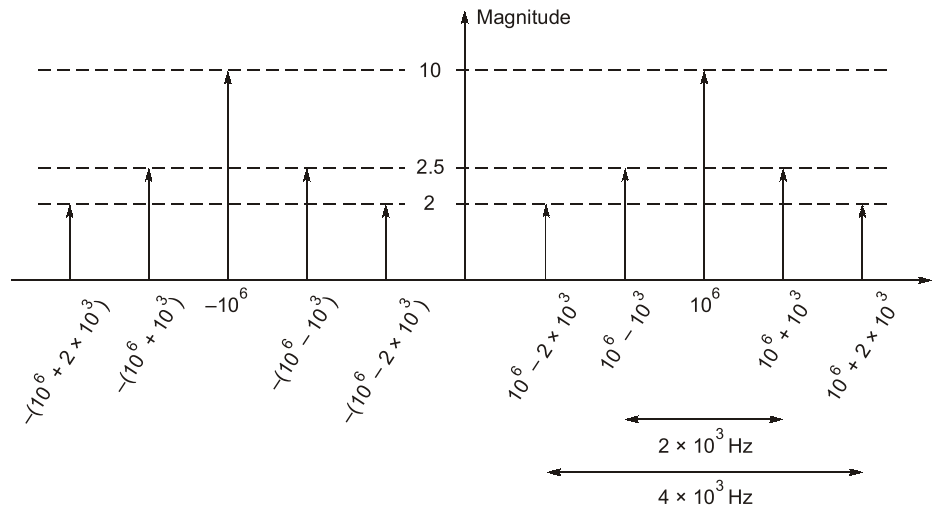
$$\frac{m_2 E_c}{2} = \frac{0.4 \times 10}{2} = 2 \text{ V}$$

Total bandwidth = $2 \times$ Bandwidth of message signal m_2

$$W_m = 2 \text{ kHz}$$

Total bandwidth = $2 \times 2 = 4 \text{ kHz}$

So, the frequency present are:



Q2 An AM modulator has output

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

Determine the modulation index and efficiency.

Solution:

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

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:

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

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

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

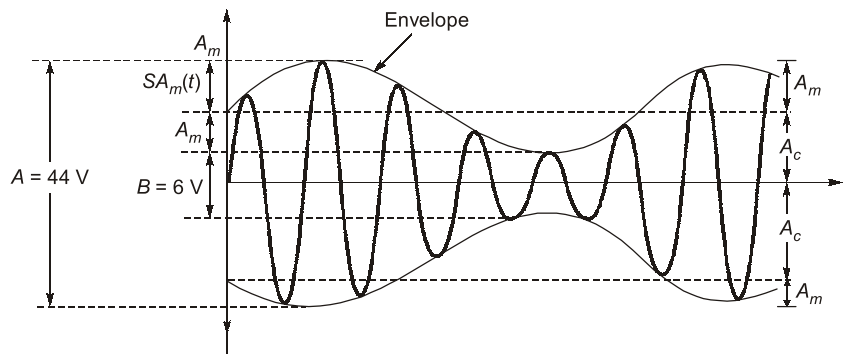
$$= \frac{A_c^2}{2} + \frac{A_c^2}{8} + \frac{A_c^2}{8} = \frac{3A_c^2}{4}$$

So,

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

Q4 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,

$$A = 2(A_c + A_m) \quad \dots(i)$$

$$B = 2(A_c - A_m) \quad \dots(ii)$$

Solving equation (i) and (ii),

$$A_c = \frac{A + B}{4}$$

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

Hence,

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

$$\text{Percentage modulation} = \mu \times 100 = 76\%$$

Peak to peak unmodulated carrier voltage

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

Q5 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_a) 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,
$$I_t^2 R = I_c^2 R \left(1 + \frac{\mu^2}{2} \right)$$

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

$\Rightarrow I_t = I_c \sqrt{1 + \frac{\mu^2}{2}}$ Ampere

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

$\Rightarrow I_c = 10.96$ 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.

$$I_t = I_c \sqrt{1 + \frac{\mu^2}{2}}$$

$$12.5 = 10.96 \sqrt{1 + \frac{\mu^2}{2}}$$

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

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

$\Rightarrow \mu = 0.775$

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%.

- Q6** (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.