Problems on Modulation techniques

Quote of the day

"Any man who reads too much and uses his own brain too little falls into lazy habits of thinking."

— Albert Einstein

Important formulae to solve AM problems

$$e(t) = E_c \cos(\omega_c t) \quad \text{where } \omega_c = 2\pi f_c$$

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

$$m = \frac{E_m}{E_c}$$

$$E_{\max} = E_c + E_m$$

$$E_{\min} = E_c - E_m$$

$$\therefore m = \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}}$$

$$\text{Bandwidth} = 2 f_m$$

$$P_c = \frac{E_c^2 / 2}{R} = \frac{E_c^2}{2R} \therefore P_c = \frac{E_c^2}{2} \quad \text{for R} = 1$$

$$P_{t(total)} = \frac{E_c^2}{2}\left(1 + \frac{m^2}{2}\right) = \left(1 + \frac{m^2}{2}\right) P_c$$

$$P_{LSB} = P_{USB} = \frac{m^2 E_c^2}{8} = \frac{m^2}{4} P_c$$

$$\text{transmission efficiency} = \frac{(m^2/2) P_c}{(1 + m^2/2) P_c} = \frac{m^2}{2 + m^2}$$

For an AM, amplitude of modulating signal is 0.5 V and carrier amplitude is 1V.Find Modulation Index.

Solution: $E_c = 1\ V$ **and** $E_m = 0.5\ V$

We know that

$$\therefore m = \frac{E_m}{E_c}$$

$$\therefore m = \frac{0.5}{1}$$

$$\therefore m = 0.5$$

When the modulation percentage is 75%, an AM transmitter radiates 10KW Power. How much of this is carrier Power?

Solution: $P_t = 10\ KW$ **and** $m = 0.75$

We know that

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

$$\therefore P_c = \frac{P_{t(total)}}{\left(1 + \frac{m^2}{2}\right)}$$

$$\therefore P_c = \frac{10 \times 10^3}{\left(1 + \frac{0.75^2}{2}\right)}$$

$$\therefore P_c = 7.8 \times 10^3 W$$

$$\therefore P_c = 7.8 KW$$

An AM transmitter radiates 20KW. If the modulation Index is 0.7. Find the carrier Power.(June-July2009(2002 scheme))

Solution: $P_t = 20\ KW$ **and** $m=0.7$

We know that

$$P_{t(total)} = \left(1+\frac{m^2}{2}\right)P_c \quad \Rightarrow \quad \therefore P_c = \frac{P_{t(total)}}{\left(1+\frac{m^2}{2}\right)}$$

$$\therefore P_c = \frac{20\times10^3}{\left(1+\frac{0.7^2}{2}\right)} \quad \Rightarrow \quad \therefore P_c = 16.064\times10^3 W$$

$$\therefore P_c = 16.064 KW$$

The total Power content of an AM signal is 1000W. Determine the power being transmitted at carrier frequency and at each side bands when modulation percentage is 100%. .(Dec 2014-Jan 2015)

Solution: $P_t = 1000\ W$ **and** $m=1$

We know that

$$P_{t(total)} = \left(1+\frac{m^2}{2}\right)P_c \quad \Rightarrow \quad \therefore P_c = \frac{P_{t(total)}}{\left(1+\frac{m^2}{2}\right)}$$

$$\therefore P_c = \frac{1\times 10^3}{\left(1+\frac{1^2}{2}\right)} \quad \Rightarrow \quad \therefore P_c = 666.67W$$

$$P_{USB} = P_{LSB} = \left(\frac{m^2}{4}\right)P_c \quad \Rightarrow \quad P_{USB} = P_{LSB} = \left(\frac{1}{4}\right)\times 666.67$$

$$\therefore P_c = 166.67W$$

A500W, 100KHz carrier is modulated to a depth of 60% by modulating frequency of 1KHz. Calculate the total power transmitted. What are the sideband components of AM Wave?(Dec –Jan 2010(2006 scheme))

Solution: ***P_c = 500 W, f_c =100 KHz, m = 60% = .6*** **and** ***f_m =1 KHz***

We know that

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

$$\therefore P_{t(total)} = \left(1 + \frac{0.6^2}{2}\right) 500$$

$$\therefore P_{t(total)} = 590\,W$$

We know that

$$\therefore f_{USB} = f_c + f_m$$

$$\therefore f_{LSB} = f_c - f_m$$

$$\therefore f_{USB} = 101\ KHz$$

$$\therefore f_{LSB} = 99\ KHz$$

A400W, 1MHz carrier is amplitude-modulated with a sinusoidal signal 0f 2500Hz. The depth of modulation is 75%. Calculate the sideband frequencies, bandwidth, and power in sidebands and the total power in modulated wave. (June-July2008(2006 scheme))

Solution: ***P_c = 400 W, f_c =1 MHz, m = 75% = .75*** **and** ***f_m =2.5 KHz***

We know that

$$\therefore f_{USB} = f_c + f_m$$

$$\therefore f_{LSB} = f_c - f_m$$

$$\therefore BW = 2 f_m$$

$$\therefore f_{USB} = 1002.5\ KHz$$

$$\therefore f_{LSB} = 997.5\ KHz$$

$$\therefore BW = 2 \times 2.5 KHz = 5 KHz$$

We know that

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

$$\therefore P_{t(total)} = \left(1 + \frac{0.75^2}{2}\right) 400$$

$$\therefore P_{t(total)} = 512.5\, W$$

$$P_{USB} = P_{LSB} = \left(\frac{m^2}{4}\right) P_c$$

$$P_{USB} = P_{LSB} = \left(\frac{0.75^2}{4}\right) 400 = 56.25\, W$$

A Carrier of 750 W,1MHz is amplitude modulated by sinusoidal signal of 2 KHz to a depth of 50%. Calculate Bandwidth, Power in side band and total power transmitted.

Solution: $P_c = 750\ W, f_c = 1\ MHz, m = 50\% = .5$ **and** $f_m = 2\ KHz$

We know that

$$\therefore f_{USB} = f_c + f_m \qquad \therefore f_{LSB} = f_c - f_m$$

$$\therefore f_{USB} = 1002\ KHz \qquad \therefore f_{LSB} = 998\ KHz \qquad \therefore BW = f_{USB} - f_{LSB} = 4\ KHz$$

We know that

$$P_{t(total)} = \left(1 + \frac{m^2}{2}\right) P_c \qquad \therefore P_{t(total)} = \left(1 + \frac{0.5^2}{2}\right) 750$$

$$\therefore P_{t(total)} = 843.75\ W$$

$$P_{USB} = P_{LSB} = \left(\frac{m^2}{4}\right) P_c \qquad P_{USB} = P_{LSB} = \left(\frac{0.5^2}{4}\right) 750 = 46.875\ W$$

Calculate the percentage power saving when one side band and carrier is suppressed in an AM signal with modulation index equal to 1.(VTU Model QP-2014)

Solution: ***m = 1***

We know that

$$P_{t(total)} = \left(1 + \frac{m^2}{2}\right) P_c = \frac{3}{2} P_c$$

$$P_{\text{suppressed}} = P_c + P_{LSB}$$

$$\therefore P_{\text{suppressed}} = P_c + \left(\frac{m^2}{4}\right) P_c$$

$$\therefore P_{\text{suppressed}} = P_c + \left(\frac{1}{4}\right) P_c = \frac{5}{4} P_c$$

$$\text{Amount of power saved} = \frac{P_{\text{suppressed}}}{P_{total}}$$

$$\text{Amount of power saved} = \frac{\frac{5}{4} P_c}{\frac{3}{2} P_c} = \frac{10}{12} = 0.833 = 83.3\%$$

Calculate the percentage power saving when one side band and carrier is suppressed in an AM signal if percentage of modulation is 50%.

Solution: ***m = 0.5***

We know that

$$P_{t(total)} = \left(1 + \frac{m^2}{2}\right)P_c = \frac{9}{8}P_c$$

$$P_{\text{suppressed}} = P_c + P_{LSB}$$

$$\therefore P_{\text{suppressed}} = P_c + \left(\frac{m^2}{4}\right)P_c$$

$$\therefore P_{\text{suppressed}} = P_c + \left(\frac{1}{16}\right)P_c = \frac{17}{16}P_c$$

$$\text{Amount of power saved} = \frac{P_{\text{suppressed}}}{P_{total}}$$

$$\text{Amount of power saved} = \frac{\frac{9}{8}P_c}{\frac{17}{16}P_c} = \frac{9 \times 16}{8 \times 17} = 0.944 = 94.4\%$$

A Sinusoidal carrier frequency of 1.2MHz is amplitude modulated by a sinusoidal voltage of frequency 20KHz resulting in maximum and minimum modulated carrier amplitude of 110V & 90V respectively.

Calculate

I. frequency of lower and upper side bands

II. unmodulated carrier amplitude

III. Modulation index IV. Amplitude of each side band.

Solution: ***f_c =1.2 MHz, E_{max} = 110V, E_{min} = 90V*** **and** ***f_m =20 KHz***

We know that

$$\therefore f_{USB} = f_c + f_m \qquad \therefore f_{LSB} = f_c - f_m$$

$$\therefore f_{USB} = 1220\ KHz \qquad \therefore f_{LSB} = 1180\ KHz$$

We also know that

$$E_c = \frac{E_{max} + E_{min}}{2} \ \& \quad E_m = \frac{E_{max} - E_{min}}{2} \text{ also } m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$

$$E_c = \frac{110+90}{2} \quad \therefore E_c = 100V$$

$$\therefore E_m = \frac{110-90}{2} \quad \therefore E_m = 10V$$

$$\therefore m = \frac{110-90}{110+90} \quad \therefore m = 0.1$$

An audio frequency signal 10 sin(2π×500t) is used to amplitude modulate a carrier of 50 sin(2π×10⁵t).Calculate. **(JAN2015)**

I. frequency of side bands
II. Bandwidth
III. Modulation index
IV. Amplitude of each side band.
V. Transmission efficiency
VI. Total power delivered to a load of 600Ω.

Solution: $f_m = 500\ Hz$, $E_m = 10V$, $f_c = 100\ KHz$ and $E_c = 50V$.

We know that $\therefore f_{USB} = f_c + f_m$ $\therefore f_{LSB} = f_c - f_m$ $\therefore BW = 2f_m$

$\therefore f_{USB} = 100.5\ KHz$ $\therefore f_{LSB} = 99.5\ KHz$ $\therefore BW = 2\times 500Hz = 1KHz$

We also know that $m = \frac{E_m}{E_c}$ $\therefore m = \frac{10}{50}$ $m = 0.2 = 50\%$

$$\text{Amplitude of side band} = \frac{mE_c}{2} = \frac{0.2\times 50}{2} = 5V$$

$$\text{also carrier power } P_c = \frac{E_c^2}{2\times R} \quad P_c = \frac{2500}{2\times 600} = 2.08$$

$$\text{and total power } P_t = \left(1+\frac{m^2}{2}\right)P_c \quad \therefore P_t = 2.125$$

Transmission Efficiency

$$\text{eff.} = \frac{m^2}{2+m^2}$$

$$\text{eff.} = \frac{0.2^2}{2+0.2^2}$$

$$\text{eff.} = 0.196 = 1.96\%$$