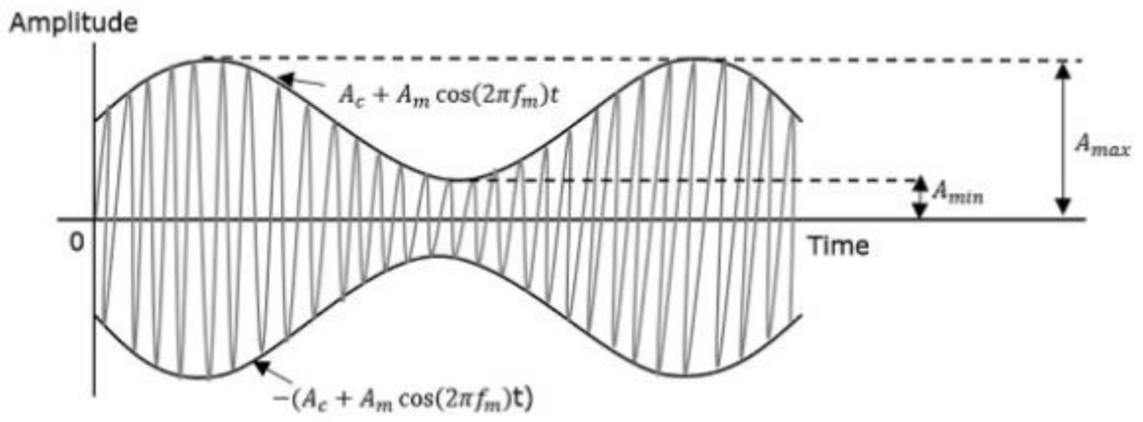
MODULATION INDEX & POWER IN AM SYSTEMS

EEN 462 – ANALOGUE COMMUNICATION

Monday, June 9, 2025

WHAT IS MODULATION INDEX?

1. **Modulation index (also called modulation depth /factor)** is a measure of how much the amplitude of the carrier wave is varied by the modulating signal.
2. **Modulation Index is defined as the ratio of the amplitude of the modulating signal (or message) to the amplitude of the carrier signal**.



Modulation Index, $m_a = \dfrac{A_{max} - A_{min}}{A_{max} + A_{min}}$

POWER CONTAINED IN AM SYSTEM

1. If the modulating signal and carrier signal are respectively

$$x_m(t) = A_m sin\omega_m t \text{ and } x_c(t) = A_c sin\omega_c t$$

2. Then the modulated signal can be written as

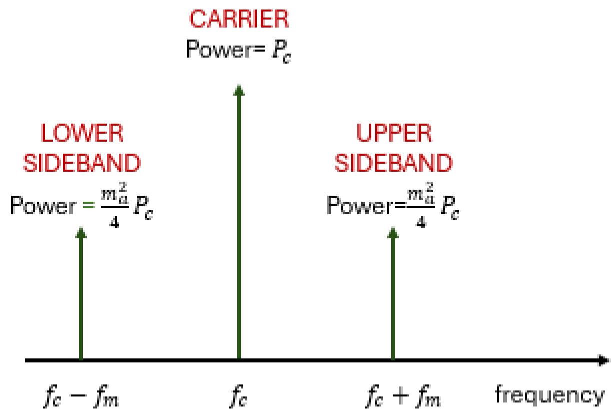
$$x(t) = A_c sin\omega_c t + \frac{m_a A_c}{2}[\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t]$$

3. From the equation, we get the following

- Power in the carrier, $P_c = A_c^2$
- Power in the Lower Side-Band(LSB) = $(\frac{m_a A_c}{2})^2 = \frac{m_a^2}{4} A_c^2 = \frac{m_a^2}{4} P_c$
- Power in the Upper Side-Band(USB) = $(\frac{m_a A_c}{2})^2 = \frac{m_a^2}{4} A_c^2 = \frac{m_a^2}{4} P_c$
- Total power, $P_t = Power\ in\ Carrier + Power\ in\ LSB + Power\ in\ USB$

$$= P_c + \frac{m_a^2}{4} P_c + \frac{m_a^2}{4} P_c$$

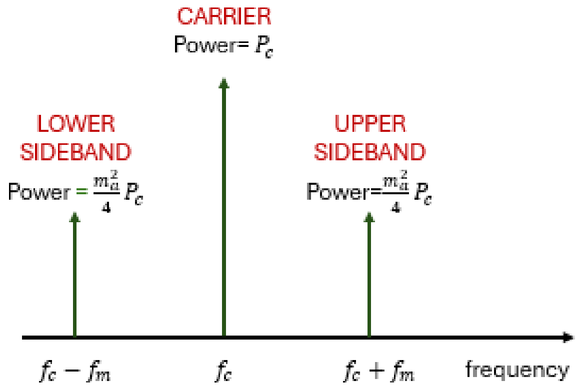
$$= P_c\left(1 + \frac{m_a^2}{2}\right)$$



POWER SAVING IN DIFFERENT AM SYSTEMS /01

1. **We have power expression in AM system given by**

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



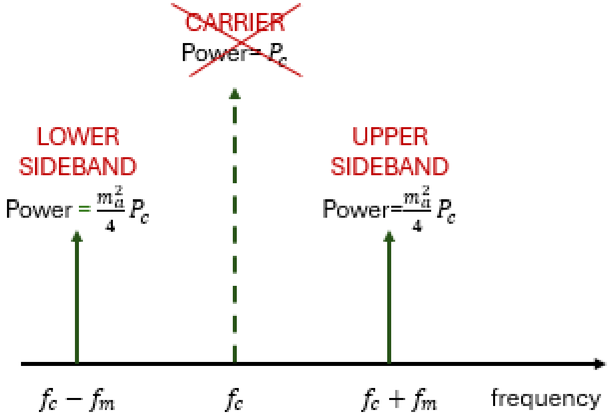
2. **CASE 1:** AM DOUBLE SIDEBAND WITHOUT SUPPRESSION

If $m_a = 1$ then $P_t = \frac{3P_c}{2}$

3. **CASE 2:** AM DOUBLE SIDEBAND SUPPRESSED CARRIER (DSB-SC)

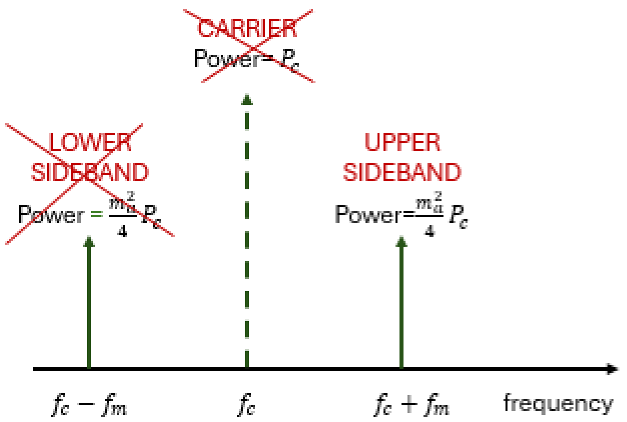
- If $m_a = 1$ then $P_t = \frac{P_c}{2}$
- Power saving is P_c since the carrier is suppressed
- Power saving compared with case without suppression is therefore:

$$Saving = \frac{Power\ saved}{Power\ without\ suppression} = \frac{P_c \times 100}{3P_c/2} = 67\%$$



POWER SAVING IN DIFFERENT AM SYSTEMS /03

3. **CASE 3:** AM SINGLE SIDEBAND SUPPRESSED CARRIER (DSB-SC)



- If $m_a = 1$ then $P_t = \frac{P_c}{4}$
- Power saving is $P_c + \frac{P_c}{4} = \frac{5P_c}{4}$ since the carrier is suppressed
- Power saving compared with case without suppression is therefore:

$$Saving = \frac{Power\ saved}{Power\ without\ suppression} = \frac{\frac{5P_c}{4}\times 100}{3P_c/2} = 83\%$$

WORKED EXAMPLE

A modulating signal $\mathrm{m(t)} = 10\sin(2\pi \times 10^3 t)$ is used to modulate a carrier $c(t) = 20\sin(2\pi \times 10^4 t)$. Determine the following:

(a) Modulation index

(b) Percentage modulation

(c) Frequencies of LSB and USB

(d) Amplitudes of LSB and USB

(e) Bandwidth of modulated signal

WORKED EXAMPLE SOLUTION

1. We can write the modulating signal, $\mathrm{m(t)} = 10\sin(2\pi \times 10^3 t)$ as $v_m \sin(2\pi \times f_m t)$
2. Similarly, we can write the carrier signal $c(t) = 20\sin(2\pi \times 10^4 t)$ as $c(t) = A_c \sin(2\pi \times f_c t)$
3. Using the above variables, we can infer the following:

   (a) Modulation index $m_a = \frac{v_m}{A_c} = \frac{10}{20} = 0.5$

   (b) percentage modulation = $100 \times m_a$ = 50%

   (c) frequencies of LSB and USB are $10^4 \pm 10^3$ i.e 9KHz and 11 KHz

   (d) Amplitudes of LSB and USB are given by $\frac{m_a A_c}{2} = \frac{0.5 \times 20}{2}$ = 5 Volts

   (e) Bandwidth of modulated signal = $2 \times f_m = 2 \times 1000$ = 2000 Hz