Modulation

Modulation is the process by which an audio frequency waves are superimposed on radio frequency wave.

The radio-frequency wave is called the carrier wave, the audio frequency wave is called the modulating (signal) wave and the resultant wave is called the modulated wave.

There are three types of modulation

1. Amplitude modulation → The amplitude of sinusoidal carrier wave is varied in accordance with the modulating signal keeping the frequency and phase of the carrier wave const is called amplitude modulation.
2. Frequency modulation → The frequency of the carrier wave is varied in accordance with the modulating signal keeping the frequency and amplitude of carrier wave const is called frequency modulation
3. Phase modulation → In phase modulation the phase of the carrier wave is varied in accordance with the phase of modulating signal keeping the frequency and amplitude of carrier wave constant.

Amplitude modulation → let the carrier wave

$$e_c = E_c \cos\omega_c t$$

the signal (modulating signal) voltage

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

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$E(t) = (E_c + K_a E_m \cos\omega_m t)$

where K_a = constant of proportionality so the maximum variation in the amplitude of the modulated wave for the given value of signal voltage

$e = E(t) \cos\omega_c t$

$= (E_c + K_a E_m \cos\omega_m t) \cos\omega_c t$

$m_a = \frac{K_a E_m}{E_c}$ modulation factor

$= E_c \cos\omega_c t + \frac{K_a E_m}{E_c} \cos\omega_m t \cos\omega_c t$

$= E_c (\cos\omega_c t + m_a \cos\omega_m t \cos\omega_c t)$

$\cos A \cdot \cos B = \cos\frac{A+B}{2} + \cos\frac{A-B}{2}$

$= E_c \cos\omega_c t + \frac{m_a E_c}{2} (\cos(\omega_c + \omega_m) t) + \frac{m_a E_c}{2} \cos(\omega_c - \omega_m) t$

(i) (ii) (iii)

The amplitude-modulated wave thus contains three term

(i) Unmodulated wave. Thus the process of amplitude modulation does not change the original wave.

(ii) A component of amplitude $\frac{m_a E_c}{2}$ and frequency $\frac{\omega_c - \omega_m}{2}$

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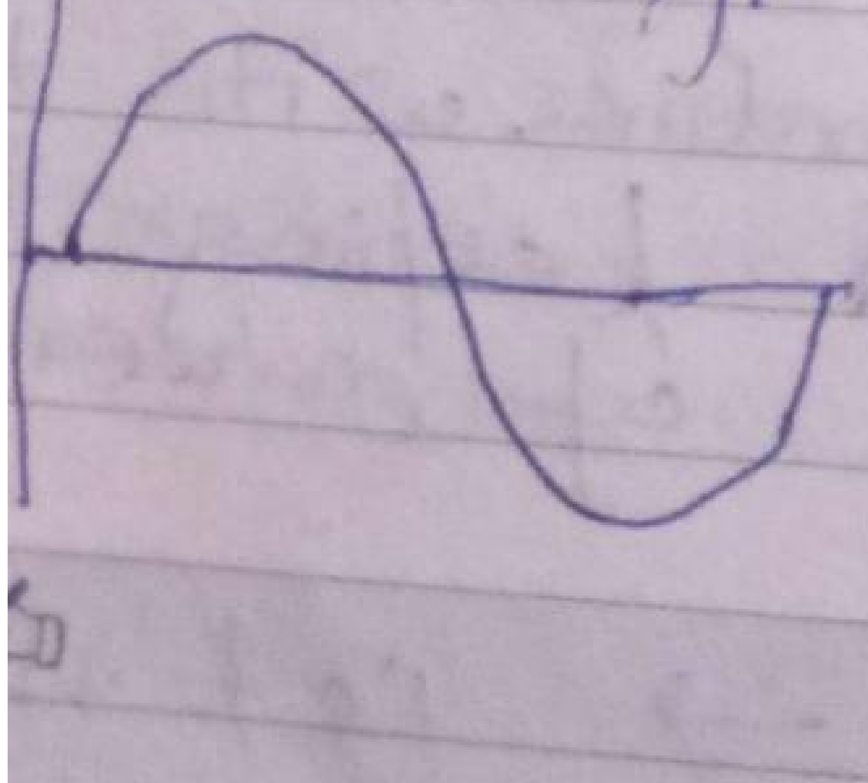
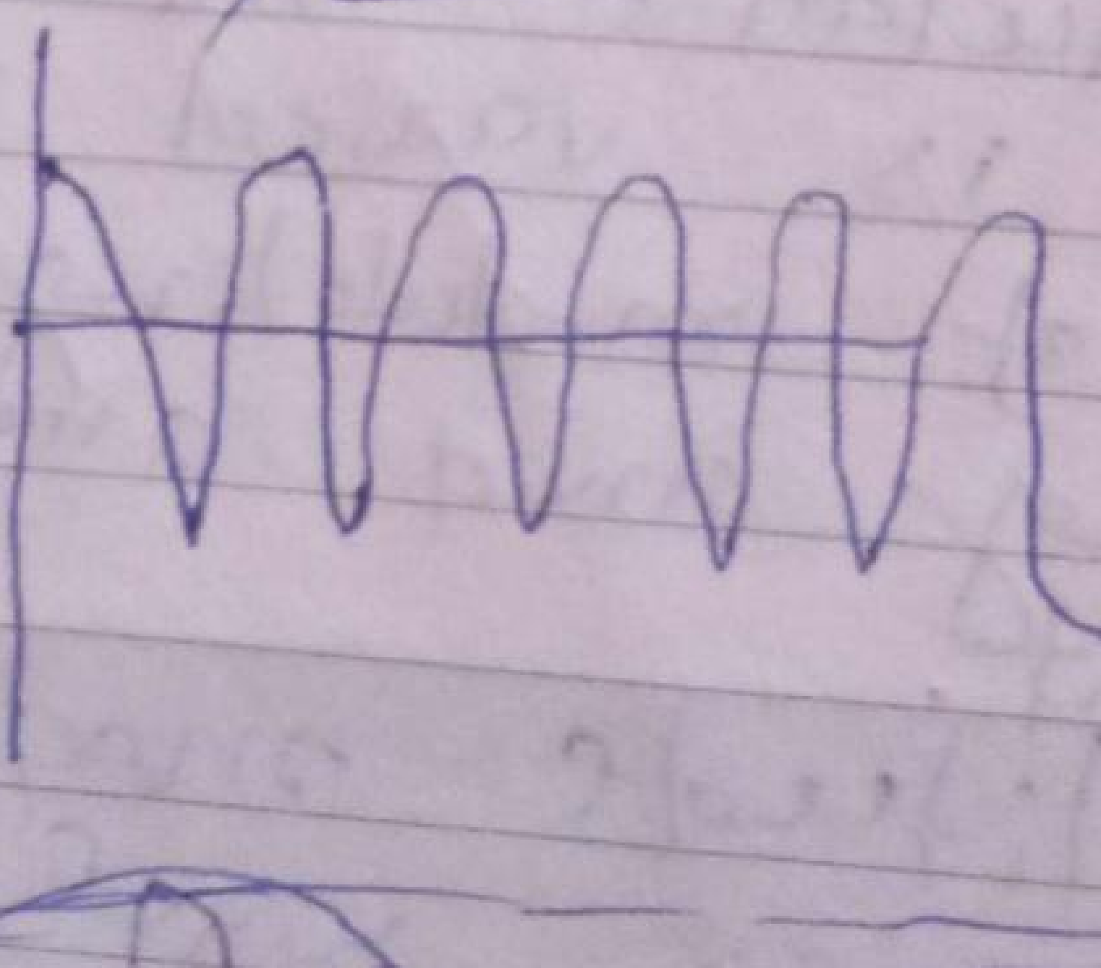
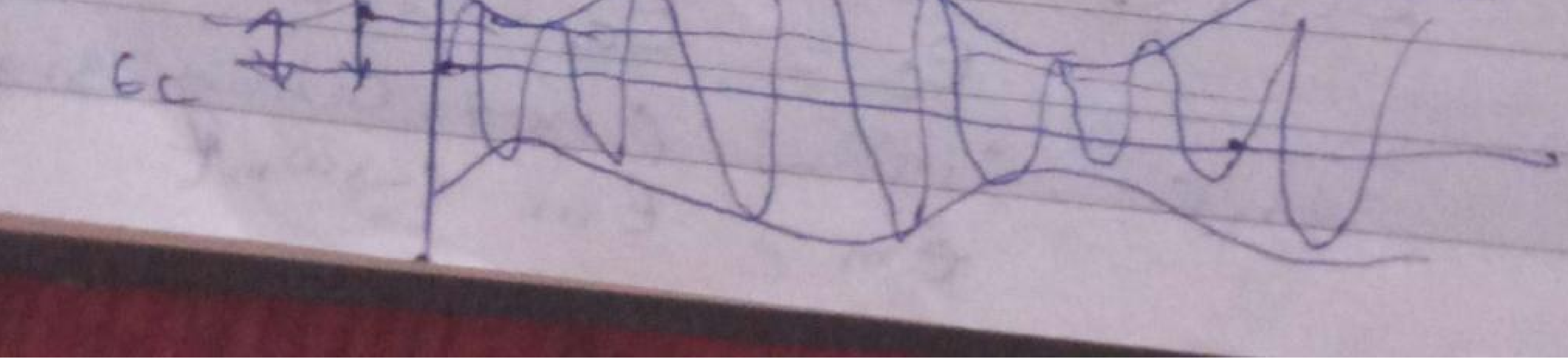
(iii) A component of amplitude $\frac{m_a E_c}{2}$ frequency $\omega_c + \omega_m/2$







Power in AM wave → The power carried by a voltage wave is proportional to the square of its amplitude.

$$P_T \propto \left(\frac{E_c}{\sqrt{2}}\right)^2 + \left(\frac{mE_c}{2\sqrt{2}}\right)^2 + \left(\frac{mE_c}{2\sqrt{2}}\right)^2$$

$$\propto \frac{E_c^2}{2}\left(1 + \frac{m^2}{4} + \frac{m^2}{4}\right) = \frac{E_c^2}{2}\left(1+\frac{m^2}{2}\right)$$

power P_s carried by the sidebands

$$P_s \propto \left(\frac{mE_c}{2\sqrt{2}}\right)^2 + \left(\frac{mE_c}{2\sqrt{2}}\right)^2$$

$$= \frac{E_c^2}{2}\left(m^2/2\right)$$

∴ Fraction of total power carried by side bands

$$P = \frac{P_s}{P_T} = \frac{m^2/2}{1+m^2/2} = \left(\frac{m^2}{2+m^2}\right)$$

(i) when $m = 0$ $P = 0$

(ii) when $m = 0.5$ $P = 11.1\%$

(iii) when $m = 1$ $P = 33.3\%$

Limitations →

(i) Noisy reception (ii) low efficiency, (iii) small operating range.