Final

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## Basics of Modulation :

Q: what is Modulation?

⇒ Modulation is a process which are used for changing signal properties.

⇒ Modulation is the process of changing the characteristics of a carrier signal with respect to a message / modulating signal.

$$\underset{\text{Amplitude}}{A} \cos\,(\underset{\text{angular frequency}}{\omega} t + \underset{\text{Phase}}{\Phi})$$

Signal properties

[যেকোন signal এ এই properties থাকে]

(i) Amplitute

(ii) Frequency

(iii) Phase

☆ Signals involved in the process of Modulation.

1. Message / Modulating signal:

It is an audio / video signal containing the necessary data or information to be transmitted.

⇒ It is a low frequency signal (20 Hz - 20 kHz)

(II) Carrier signal:

It is a high frequency signal with frequency range from 10KHz to 30,000 MHz whose characteristics such as amplitude, frequency or phase is altered with respect to the message/ modulating signal.

* Basically, Message signal rides over carrier signal by the process of modulation.

## Types of Modulation:

3 types:

(I) Amplitude Modulation

(II) Frequency Modulation

(III) Phase Modulation

Q: Why we need Modulation?

⇒ There are 4 reasons:

1. Frequency range and energy
2. Antenna length
3. Wireless communication
4. Interference

(i) Frequency range and energy: [Energy directly Frequency এর সমানুপাতিক]

⇒ We know,

$$\text{Energy} \propto \text{Frequency}$$

For message signal,

the frequency is low. Since, we have low frequency, then we will get low energy content. It is not able to transmit the message signal in long distance.

(ii) Antenna length:

* Antenna হলো metalic conductor. [Electric signal কে Electromagnetic wave এ convert করে]

For effective radiation of energy into space.

The length of the antenna should be equal to the wavelength of the wave.

$c$ → আলোর বেগ $3\times10^{8}\ ms^{-1}$

$$c = f\lambda$$

$$\lambda = \frac{c}{f}$$

$f_{min} = 20H$

$f_{max} = 20KHz$

যদি $f_{min}$ এর value দেই thn $\lambda = 15000\ km$

যদি $f_{max}$ " " " thn $\lambda = 15\ km$

বাস্তবিক ভাবে এইরকম antenna তৈরি করা সম্ভব না তাই আমরা modulation use করি।

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* Reasons of modulation:

3. Wireless communication

4. Effects of Interference

3. Wireless communication:

* Audio frequency signals or message signals need material medium for transmission. For this reason their transmission range is low.

[material medium example: twisted cable
copper cable]

* carrier signal or radio frequency signal donot need any material medium for transmission. since carrier signal has high frequency, so they have high energy components. As a result their transmission range is vast.

4. Effects of interference:

Noise
distortion

→ expectation → should be low

* From electromagnetic wave theory, we can say that - mutual interference is higher when the frequency of a signal is low and mutual interference (MI) is lower, when the frequency of a signal is higher.

message signal

solution → Modulation
↳ carrier signal
↳ frequency → high
↳ It will give us low interference
↳ That should be our goal

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~~$y(t) = A_c \sin \omega_c t$~~

~~$\frac{A_c \mu}{2} (\cos(\omega_c - \omega_m)t$ → lower side band~~

* Sideband Amplitude = ~~$\frac{A_c \mu}{2}$~~ $= \frac{A_m}{2}$

$y(t)$

$$= A_c \sin \omega_c t + \frac{A_c \mu}{2} \cos \underbrace{(\omega_c - \omega_m) t}_{\text{Lower side band (LSB)}} - \frac{A_c \mu}{2} \cos \underbrace{(\omega_c + \omega_m)}_{\text{upper side band (USB)}}$$

*

$$\text{Sideband Amplitude} = \frac{A_c \mu}{2} = \frac{A_m}{2}$$

USB = LSB

Upper side band angular frequency

$(\omega_c + \omega_m) t$

$\downarrow \quad \downarrow$

$(2\pi f_c + 2\pi f_m) t$

$f_c + f_m \rightarrow$ USB frequency

$f_c - f_m \rightarrow$ LSB frequency

Modulating index / depth of wave / modulation

$$m / \mu = \frac{A_m}{A_c} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$ → [voltage দেয়া থাকলে এই রূপ

Modulating signal,

$m(t) = A_m \overset{\to \sin}{\cos}\, \omega_m t$ [cos ও হতে পারে sin ও হতে পারে]

Carrier signal

$c(t) = A_c \overset{\to \sin}{\cos}\, \omega_c t$

$\therefore$ $\boxed{f_c \gg f_m}$ $\boxed{A_c \gg A_m}$

$P_c \rightarrow$ Power of carrier signal
$P_T \rightarrow$ Power of transmission
$I_T \rightarrow$ Current transmission
$I_c \rightarrow$ modulating current
এখানে signal থেকে আসছে।

$\mu = 2\left(\frac{P_T}{P_c} - 1\right)$ [Power এর জন্য]

$\mu = \cancel{\sqrt{2\left(\frac{P_T}{P_c} - 1\right)}}\ \sqrt{2\left(\frac{I_T}{I_c}\right)^2 - 1}$ [current এর জন্য]

Total transmission power,

1. $$\boxed{P_T = P_c + \underbrace{P_{USB}}_{\text{upper side band}} + \underbrace{P_{LSB}}_{\text{lower side Band}}}$$

$P_c = \frac{A_c^2}{2R}$ [$\because$ R = circuit এর resistance (হবে)]

$P_{USB} = P_{LSB} = \frac{\mu^2 A_c^2}{8R}$

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

$\cancel{\mu = 1}$

$\mu = 1$ হলে

$\boxed{P_T = 1.5 P_c}$ [এই rules apply]

$\therefore$ Transmission efficiency,

$$\eta\% = \frac{\mu^2}{2 + \mu^2} \times 100$$

$$\eta = \frac{P_{LSB} + P_{USB}}{P_T} \times 100$$

Bandwidth,

$$Bw = 2 \times f_m$$

Total transmitted current,

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

Problem: 1

A 500 watt carrier is modulated to ~~th~~ a depth of 75 Percent, calculate the total power in the modulated wave?

$P_c = 500\,watt$

$\mu = 75\% = 0.75$

$P_T = ?$

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

$$= 500 \left(1 + \frac{(0.75)^2}{2}\right)$$

$$= 640.625W$$

Prob: 2

A modulating signal $\underbrace{30\sin(2\pi\times10^3)t}^{M(t)}$ is used to modulate a carrier signal $\underbrace{40\sin(2\pi\times10^4)t}_{C(t)}$

(i) Modulating Index $\rightarrow \mu$

(ii) Percentage of modulation

(iii) frequencies $\rightarrow f_m, f_c, f_{USB}, f_{LSB}$

(iv) Bandwidth $\rightarrow BW$

(v) draw the spectrum of the AM wave (Amplitude modulation)

(vi) transmission efficiency $\rightarrow \eta$

(i) $m(t) = A_m \sin W_m t \rightarrow A_m = 30$

$c(t) = A_c \sin W_c t$

$W_m = 2\pi f_m$

$2\pi\times10^3 = 2\pi f_m$

$\therefore f_m = 10^3$

$\mu = \frac{A_m}{A_c}$

$= \frac{30}{40}$

$= 0.75$

$\rightarrow A_c = 40$

$f_c = 10^4$

(ii) percentage of modulation $= 0.75\times100 = 75\%$

(iii) $m(t) = A_m \sin W_c t \longrightarrow A_m = 30$

$c(t) = A_c \sin W_c t$

$W_m = 2\pi f_m$

$f_m = \frac{W_m}{2\pi}$

$= 10^3$

$\rightarrow A_c = 40$

$W_c = 2\pi f_c$

$f_c = \frac{W_c}{2\pi}$

$10^4$

$f_{USB} = f_c + f_m = 11000 = 11 KHZ$

$f_{LSB} = f_c - f_m = 9000 = 9 KHZ$

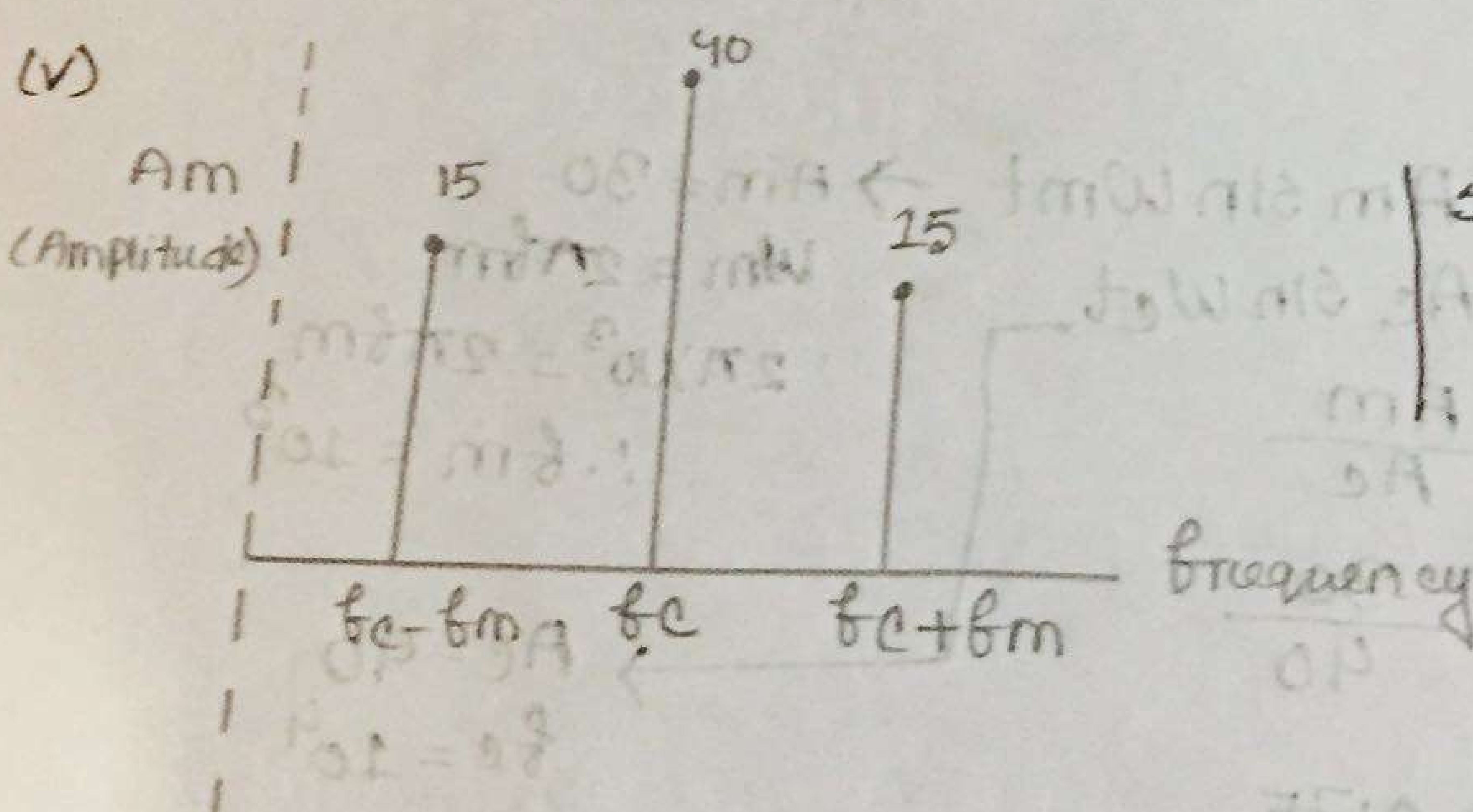
(iv) Bandwidth

$BW = 2 \times f_m$

$= 2 \times 10^3$

$= 2000$

(v)




Side band Amplitude,

$\frac{A_m}{2} \Big/ \frac{A_c \mu}{2}$

$\frac{30}{2} = 15$

(vi) Transmission efficiency $\eta = \frac{\mu^2}{2+\mu^2} \times 100$

$= 52.94\%$

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Problems:

1. A modulating signal of $3\cos 5000t$ is amplitude modulated over a carrier signal of $6\cos 20000t$. Derive the total transmitted power and transmission efficiency.

2. The amplitude modulated wave is with maximum amplitude 12V and the minimum amplitude 8V. Find the modulation index.

3. For the amplitude modulated wave $s(t) = \underbrace{100}_{A_c}(1 + \underbrace{0.6}_{\mu}\sin 6280t)$ → AM
$\sin(2\pi * 10^6 t)$. Determine

(i) frequency of message signal & carrier signal
(ii) Modulation index
(iii) frequency of upper sid lands and lower side bands.
$f_c + f_m$ ↓ $f_c - f_m$

1. $m(t) = 3\cos 5000t$ $\quad A_m = 3$
$= A_m \cos \omega_m t$ $\quad \omega_m = 2\pi f_m$
$f_m = \frac{\omega_m}{2\pi}$

1. $m(t) = A_m \cos \omega_m t \Rightarrow A_m = 3 \rightarrow \omega_m = 2\pi f_m \Rightarrow f_m = \frac{\omega_m}{2\pi}$

$= 795.7$

$c(t) = A_c \cos \omega_c t \Rightarrow A_c = 6 \Rightarrow \omega_c = 2\pi f_c \Rightarrow f_c = \frac{\omega_c}{2\pi}$

$= 3183.09$

$f_{USB} = f_c + f_m$

$= 3.97 \text{ KHZ}$

$f_{LSB} = f_c - f_m$

$= 2.38 \text{ KHZ}$

(ii) maximum aplitude, $A_c + A_m = 12V$

minimum ", $A_c - A_m = 8V$

$2A_c = 20V$

$\Rightarrow A_c = 10$

$\Rightarrow A_m = 2V$

$\mu = \frac{A_m}{A_c}$

$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$

[voltage দিলের না Amplitude দিলের তাই A]

3. $m(t) = A_m \sin W_m t$

$c(t) = A_c \sin W_c t$

$A_c + A_m$
কারেন্ট high
পাওয়া যাবে।

$s(t) = A_c\,(1 + \mu\, m(t).c(t))$

$= A_c\,(1 + \mu \cdot \sin W_m t) \sin W_c t$

$A_c = 100$

$\mu = 0.6$

$W_m = 6280$

$W_c = 2\pi \times 10^6$

$\therefore$ frequency of message signal,

$W_m = 2\pi f_m$

$f_m = \dfrac{W_m}{2\pi}$

$= 999.49$

$= 1 KHZ$

and carrier signal $W_c = 2\pi f_c$

$f_c = \dfrac{W_c}{2\pi}$

$= \dfrac{\cancel{2\pi} \times 10^6}{\cancel{2\pi}}$

$= 10^6$

$= 1 MHZ$

$f_c - f_m$

(iii) $f_c + f_m$

(ii)

(i) $m(t) = 3\cos 5000t$
$c(t) = 6\cos 20000t$

$A_m = 3$
$\omega_m = 5000$
$A_c = 6$
$\omega_c = 20000$

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

$\eta = ? \rightarrow \frac{P_{SB}}{P_T} \times 100$

$$P_c = \frac{A_c^2}{2R}$$

$$= \frac{36}{2R}$$

$$= \frac{18}{R}$$

$$\mu = \frac{3}{6} = 0.5$$

$$P_T = \frac{18}{R}\left(1 + \frac{(0.5)^2}{2}\right)$$

$$= \frac{81}{4R}$$

$$P_{LSB} = P_{USB} = \frac{\mu^2 A_c^2}{8R}$$

$$P_{SB} = 2 \times P_{USB}$$

$$\eta = \frac{2 \times P_{USB}}{P_T} \times 100\%$$

$$= 11.1\%$$