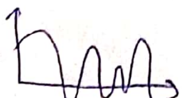
22 - Mar - 2021

Analog Communication

Communication:

Exchanging of info.

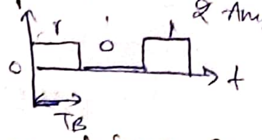


CTS : continous in time only.

Analog: Continuous in time, Amplitude, (or) infinite Amplitudes w.r.t time

Digital: ~~Discrete~~ in time, only Amplitude, (or) & Amplitude

not same Discrete: Discretre in time only.



→ Exchange info b/w two Analog machines is Analog communication.

→ The info. of low freq. that is baseband signal.

Voice - 300Hz , Video - 0 to 4.5 MHz

Audio - 20 Hz to 20,000 Hz

At Transmitter:

→ Modulators convert base band to band pass. signals

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It Modulation
Amplication
Filter

(or)

Modifies the signal to pass through the channel without any disturbances.

Channel: → wireless - air.
→ wired - copper wire, wave guides.

Receiver:

Receive the modified version and processes it to recreate the original.

→ Signal: physical quantity which varies w.r.t time

(or)

It is electrical waveform which carries info.

Ex: $m(t) = A\cos(\omega t + \phi)$

ω → freq = rad/sec

ϕ → phase angle (rad)

A → Amplitude (v)

t → time

Baseband Signals:

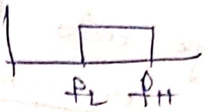
Zero freq or near to zero freq.

Ex: Voice, Audio, video, Bio-medical signals

Band pass signal:

If A signal contains band of frequencies far away from base or zero

Ex: AM, FM
↓
Ampli-modify



Message:

It is sequence of symbols

Ex: Happy New Year 2020

Information:

The content in the message is called information $\boxed{\text{Info} = \frac{1}{\text{Prob}}}$

Avg inform^n^ conveyed is entropy.

Units:- bits, decits, nats
bits → base 2, decits → base 10, nats → base e

* Limitations and Resources of communication system:

1) Bandwidth & Noise:
→ Effect of noise be reduced by providing more Bandwidth to stations but due to this less no of stations can only be accommodated.

$$\underbrace{C}_{\text{capacity}} = \overbrace{B}^{\text{Bw.}} \log_2\left(1 + \frac{\text{Signal }(S)}{\text{Noise }(N)}\right)$$

$S/N > 1$ for more signal strength

2) Signal to Noise Ratio (SNR):

→ Noise should be low, but unavoidable in commun^n^ system.

→ Two primary resources are average transmitte power and channel bandwidth

Generally, Communication channels

- Power limited channels
  - Satellites – In Space
- Band limitted channels
  - Radio's, TV's, etc
  - FCC → gives freq bands
    - Fedraul communication commission

Modulation:- → changes freq

★ It is the process of varying the characteristics parameters of (Amp, freq, phase) high frequency carrier in accordance with instantaneous values (→ Amplitude) of modulating or message or baseband signal.

↳ Audio frequency / Voice signal / video signal

(or)

It is a freq. translation technique which converts baseband or low freq. signal to band pass or high freq. signal.

Types of Modulation.

- continuous wave modulation
  - Amplitude modulation (AM)
  - Angle modulation (Amp, t ... and υ)
    - Freq modulation (FM)
    - Phase modulation (PM)
- Pulse Modulation
  - ASK, FSK, PSK, DMT
  - Pulse Analog Modulation
    - PAM → Amp
    - PWM → width
    - PPM → position
  - Pulse Digital Modulation
    - Pulse code modulation → DPCM
    - Delta Modulation → $\boxed{ADM}$

$\theta = \omega_c t$

Amp

Amplitude Modulation

Freq. Modulⁿ

Phase Modulation

* Benefits or Need of Modulation:

1) To reduce the length or height of antenna.
∵ $\lambda/4$ (Quarter wavelength).

$$\lambda = \frac{c}{f} \quad c = 3\times10^8 \text{ m/s} \quad f = \text{Hz}$$

if $f = 10\text{kHz}$

$$\lambda = \frac{3\times10^8}{10\times10^3} = \frac{3\times10^4}{4} = 7.5 \text{ km}$$

if $f = 1\text{MHz}$

$$\lambda = \frac{3\times10^8}{100} = 3\times10^2 = \frac{300}{4} = 75 \text{ m}.$$

∴ Antenna height = 75 m

2) For multiplexing. (combine all i/ps to a channel after separating acc to freq)

B = 20 to 20 k — Audio

f_c: 100 k, 120 k

carrier freq = 100. k

3) For narrow banding or freq. translation

4) To reduce noise effect.

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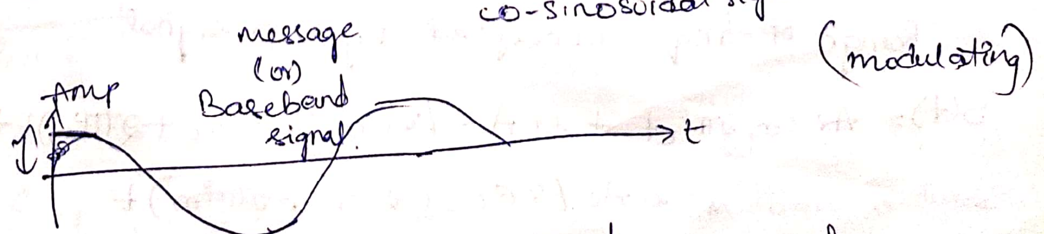
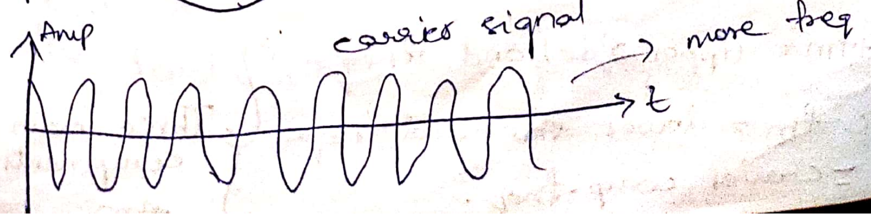
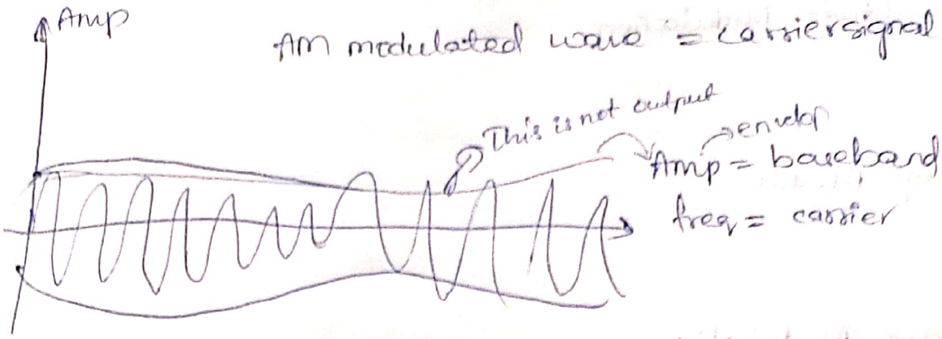
Amplitude Modulation:







AM modulated wave = carrier signal +

→ when carrier signal is varied acc to Amp of message signal.

low + high = high freq but shape is low

The carrier signal is given by

$$\boxed{c(t) = A_c \cos \omega_c t}$$

A_c = max Amp

$\omega_c = 2\pi f_c$ = carrier freq.

$$m(t) = \boxed{x(t) = A_m \cos \omega_m t}$$

A_m of msg signal → freq of msg signal

★ Standard modulated signal

$$\boxed{s(t) = \underbrace{A_c \cos 2\pi f_c t}_{c(t)} \, [1 + k_a(\underbrace{A_m \cos 2\pi f_m t}_{m(t)})]}$$

Compulsory in the exam ★ $\boxed{\mu = k_a A_m = \frac{A_m}{A_c}}$ = Modulation Index / depth of Modulation / % modulation

k_a = Amp sensitivity

(or)

$$\boxed{s(t) = A_c(1 + k_a(m(t))) \cos 2\pi f_c t}$$

* Time Domain representation of Am:

Range of freq occupied by Am signal.

$$s(t) = A_c \cos 2\pi f_c t + \mu A_c/2 \cos(2\pi f_c + 2\pi f_m)t + \mu A_c/2 \cos(2\pi f_c - 2\pi f_m)t$$

✓ $f_c + f_m$ = upper sideband freq

✓ $f_c - f_m$ = lower sideband freq.

✓ f_c = carrier comp. freq.

} Three main components in Am

Scanned with CamScanner

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* Freq. Domain representation of AM:

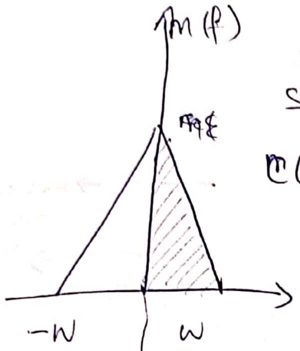
$\because s(t) = A_c \cos 2\pi f_c t \,[1 + k_a m(t)]$

Time domain → Fourier transform → Freq. domain.

Taking F.T of b.s

cos $\xrightarrow{FT}$ Impulse

$$S(f) = \frac{A_c}{2}[\delta(f-f_c)+\delta(f+f_c)] + \frac{A_c k_a}{2}[M(f-f_c)+M(f+f_c)]$$



$s(t) \rightarrow S(f)$

$x(t)\cos 2\pi f_c t \xrightarrow{FT}$ signal with impulse freq.

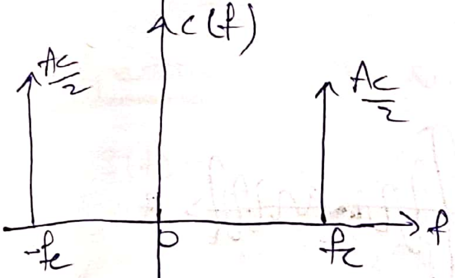
signal + impulse

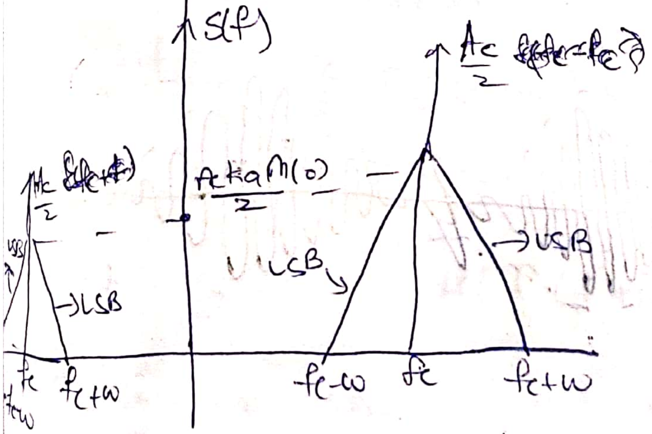
$C(f) = \frac{A_c}{2}[\delta(f-f_c)+\delta(f+f_c)]$

$M(f) = \frac{A_c k_a}{2}[M(f-f_c)+M(f+f_c)]$

Band limited. to W Hz

↳ $W - 0 = W$





↳ $\cancel{f_c}+W - \cancel{f_c}+W = 2W$.

B.W req. for transmition of AM wave is twice the band width of message signal.

Modulation Index:

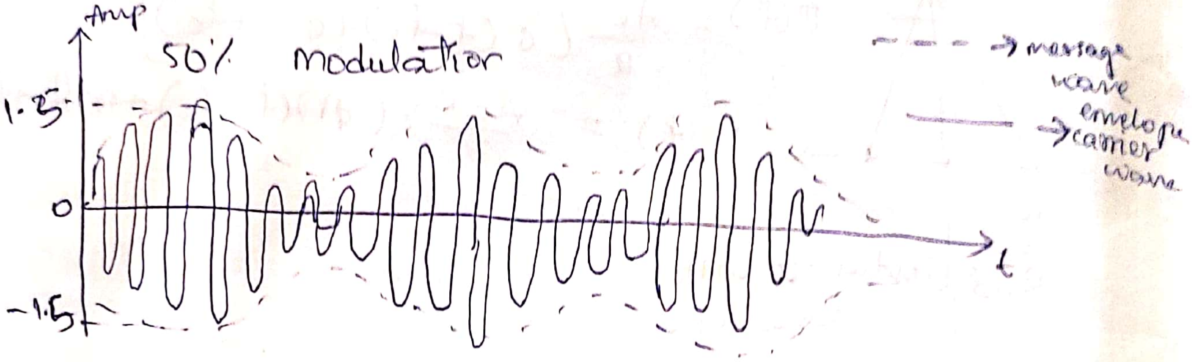
Extent of amplitude variation about an un-modulated carrier

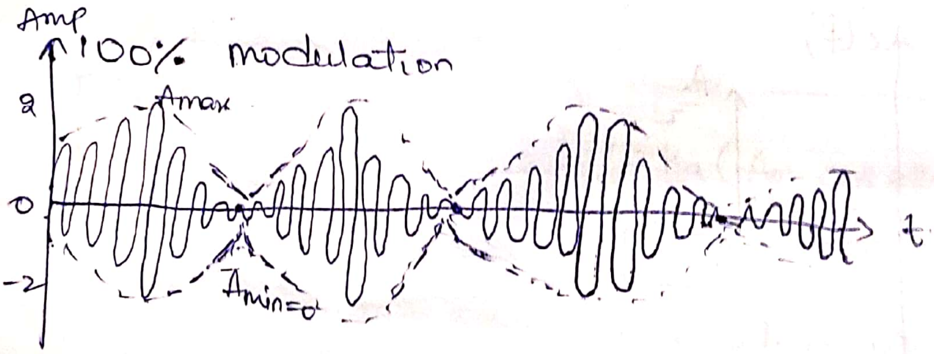
$$\boxed{\mu = [A_{max} - A_{min} / A_{max} + A_{min}] = \frac{A_m}{A_c}}$$

$$\% \mu = \frac{A_m}{A_c} \times 100$$

Types of Modulation

1) Under Modulation ($\mu < 1$) ✓
2) Critical modulation ($\mu = 1$) ✓
3) Over Modulation ($\mu > 1$) ✗





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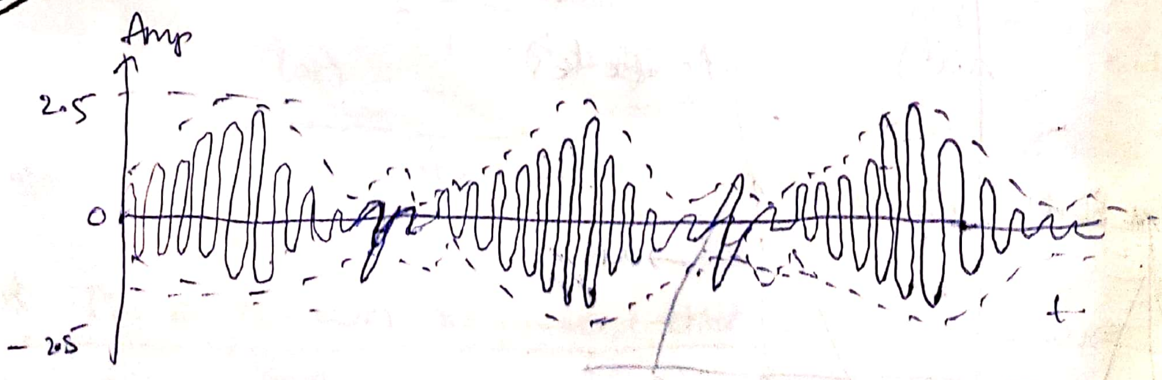


* Single tone modulation of Amplitude modulation

$$s(t) = A_c[1 + K_a m(t)] \cos 2\pi f_c t$$

$$m(t) = A_m \cos 2\pi \underbrace{f_m}_{\text{single freq.}} t$$

$s(t) = A$

$$s(t) = A_c\underbrace{[1 + \mu \cos 2\pi f_m t]}_{\text{Amplitude of modulated signal}} \cos 2\pi f_c t$$

where $\mu = K_a A_m$

$A_{max} = (1+\mu)A_c$, where $\cos 2\pi f_m t = 1$

$A_{min} = (1-\mu)A_c$, where $\cos 2\pi f_m t = -1$

$$\frac{A_{max}}{A_{min}} = \frac{A_c(1+\mu)}{A_c(1-\mu)}$$

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

Spectrum for single tone modulation:

$$s(t) = A_c \cos 2\pi f_c t + A_c K_a A_m \cos 2\pi f_m t \cos 2\pi f_c t$$

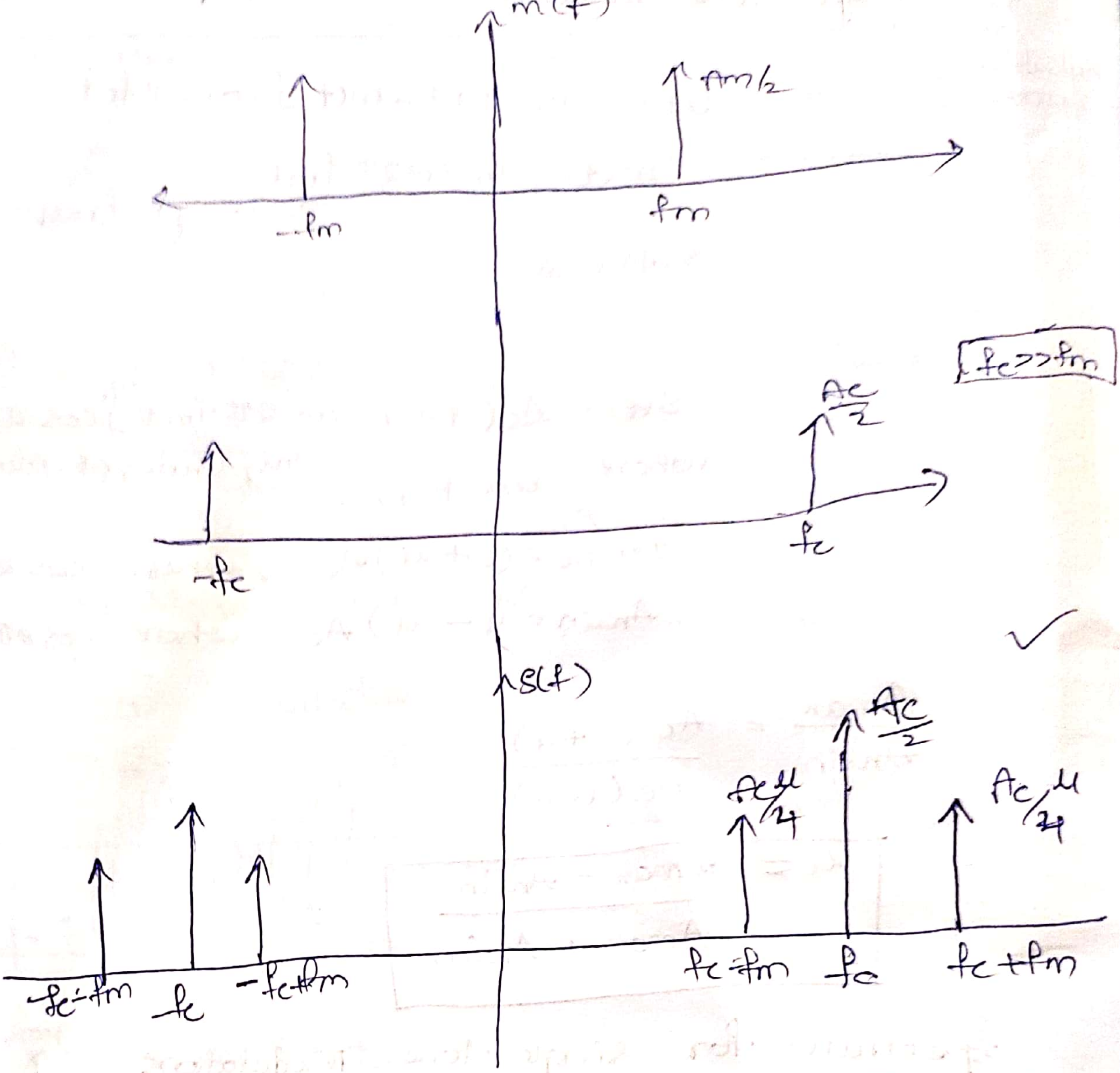
$$= \underbrace{A_c \cos 2\pi f_c t}_{\text{carrier freq.}} + \frac{A_c \mu}{2}[\cos 2\pi \underbrace{(f_c - f_m)}_{\text{Lower freq}} t + \cos 2\pi \underbrace{(f_c + f_m)}_{\text{Upper freq}} t]$$

$$s(t) \xrightarrow{F.T} S(f)$$

$$S(f) = \frac{A_c}{2}[\delta(f+f_c) + \delta(f-f_c)] + \frac{A_c}{4}\mu[\delta(f+f_c+f_m) + \delta(f-f_c-f_m)] + \frac{A_c}{4}\mu[\delta(f+f_c+f_m) + \delta(f-f_c+f_m)].$$

($\Rightarrow$ carrier freq. doesn't contain any information.)

$\because \cos f \xrightarrow{F.T} [\delta(f+f_c) + \delta(f-f_c)]$



$$B.W = UF - LF$$
$$= \cancel{f_c} + f_m - \cancel{-f_c} + f_m$$
$$\boxed{\therefore B.W = 2f_m}$$

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Power calculations of AM signal:- (single tone modulation)

Power required for ~~transmission~~ of amp modulated signal $(P_t) = P_c\left(1+\frac{\mu^2}{2}\right)$

from single tone modulation

$$s(t) = A_c \cos 2\pi f_c t + \frac{A_c}{2}\mu\left[\underbrace{\cos 2\pi(f_c+f_m)t}_{USB} + \underbrace{\cos 2\pi(f_c-f_m)t}_{LSB}\right]$$

$$\boxed{P_t = P_c + P_{SB}}$$

★ Derivation + problems

P_t = total power

P_c = carrier power

P_{SB} = side band power (USB, LSB)

$\because P = \frac{V^2}{R} = I^2 R$

$\because R = 1\Omega,\ P = V^2 = I^2$

Max value $= A_c$ rms $= \frac{A_c}{\sqrt{2}}$

$$\boxed{\therefore P_{c_{avg}} = P_c = \frac{A_c^2}{2}}$$

$P_{SB} = P_{LSB} + P_{USB}$

we have max value $= \frac{A_c\mu}{2}$ $\boxed{rms = \frac{A_c\mu}{2\sqrt{2}}}$

$$P_{SB} = \frac{A_c^2\mu^2}{8} + \frac{A_c^2\mu^2}{8}$$

$$\boxed{\therefore P_{SB} = \frac{A_c^2\mu^2}{4}}$$

$$\therefore P_t = \frac{A_c^2}{2} + \frac{A_c^2\mu^2}{4}$$

$$= \frac{A_c^2}{2}\left[1+\frac{\mu^2}{2}\right]$$

$$★\ \boxed{P_t = P_c\left[1+\frac{\mu^2}{2}\right]}$$

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

* Efficiency calculations of AM signal:- (single tone modulation)

Efficiency $= \frac{P_{SB}}{P_t}$ ($\because P_c$ doesnot contain any info).

$$= \frac{A_c^2\mu^2 \times \cancel{2}}{4\times \cancel{A_c^2}\left(1+\frac{\mu^2}{2}\right)} \quad (\mu \le 1)$$

$$\boxed{\eta = \frac{\mu^2}{2+\mu^2}}$$

$$\boxed{\text{Redundancy} = 1 - \eta}$$

not necessary signal

$$\% \eta = \frac{\mu^2}{2+\mu^2} \times 100 \quad (\because \mu = 1) \text{ critical modulation}$$

$$= \frac{1}{3} \times 100$$

$$= 33.33\%$$

Only 33% is untilized by the side bands where as rest of the power is utilized by carrier

→ The remaining 66% is wasted.

Q A 400 watts carrier is modulated to a depth of 75%. calculate the total power in the modulated wave. Assume the modulated signal to be sinusoidal.

Sol:

$P_c = 400$ W

$\% \mu = 75\% = 0.75$

w.k.t $P_t = P_c \left(1 + \frac{\mu^2}{2}\right)$

$$= \frac{\cancel{400}^{200}}{} \left(\frac{2 + (0.75)^2}{\cancel{2}}\right)$$

$$= 200(2.56)$$

$$= 512.5 \text{ W}$$

2) A broad cast radio transmitter radiates 5k watt of power when the modul^n index % = 60%. what is the carrier power

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

$P_t = 5K$

$\mu = 0.6$

$$5000 = P_c(1 + 0.18)$$

$$P_c = \frac{5000}{1.18} = 4237.2 \text{ W}$$

* Multitone Modulation of amplitude modulation.

$$m(t) = A_{m_1}\cos 2\pi f_{m_1}t + A_{m_2}\cos 2\pi f_{m_2}t + \dots$$

$$s(t) = A_c[1 + k_a m(t)]\cos 2\pi f_c t$$

$$s(t) = A_c[1 + k_a\{A_{m_1}\cos 2\pi f_{m_1}t + A_{m_2}\cos 2\pi f_{m_2}t + \dots\}]\cos 2\pi f_c t$$

$$s(t) = A_c\cos 2\pi f_c t + [A_c\mu_1\cos 2\pi f_{m_1}t + A_c\mu_2\cos 2\pi f_{m_2}t + \dots]\cos 2\pi f_c t$$

$$\Rightarrow A_c\cos 2\pi f_c t + \frac{A_c\mu_1}{2}[\cos 2\pi(f_c + f_{m_1})t + \cos 2\pi(f_c - f_{m_1})t]$$

$$+\frac{A_c\mu_2}{2}[\cos 2\pi(f_c + f_{m_2})t + \cos 2\pi(f_c - f_{m_2})t] + \dots (f_c + f_{m_3})(f_c - f_{m_3})$$

$$\boxed{P_t = P_c + P_{SB}} \qquad P_c = \frac{A_c^2}{2}$$

$$P_{SB} = \frac{A_c^2\mu_1^2}{4} + \frac{A_c^2\mu_2^2}{4} + \frac{A_c^2\mu_3^2}{4} + \dots$$

$$P_{SB} = \frac{A_c^2}{4}[\mu_1^2 + \mu_2^2 + \mu_3^2 + \dots]$$

$$P_t = \frac{A_c^2}{2}\left[1 + \frac{1}{2}(\mu_1^2 + \mu_2^2 + \dots)\right]$$

$$\boxed{P_t = P_c\left[1 + \frac{\mu_t^2}{2}\right]}$$

where μ_t is effective modulation index

$$\mu_t^2 = \mu_1^2 + \mu_2^2 + \dots$$

$$\mu_t = \sqrt{\mu_1^2 + \mu_2^2 + \mu_3^2 + \dots}$$

$$\boxed{\text{i.e., } \mu_t \le 1}$$

* Current calculations:

$$\frac{P_t}{P_c} = \frac{I_t^2 R}{I_c^2 R}$$

we have $R = 1\Omega$

$$\Rightarrow \frac{\cancel{P_c}\left[1+\frac{\mu^2}{2}\right]}{\cancel{P_c}}$$

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

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

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

Q: A 300 watts carrier is simultaneously modulated by 2 audio waves with modulation % of +50 and +60 respectively. what is the total side band power radiated.

Sol:

Given $P_c = 300$ watts.

$$\boxed{\therefore P_{SB} = \frac{A_c^2 \mu_t^2}{4} = \frac{P_c \mu_t^2}{2}}$$

$$\mu_t^2 = \mu_1^2 + \mu_2^2 = (0.5)^2 + (0.6)^2$$

$$= 0.25 + 0.36 = 0.61$$

$$\therefore P_{SB} = \frac{(\cancel{300}^{150})(0.61)}{\cancel{2}} = 91.5\ W$$

Q: The antenna current of an AM transmitter is 8A when only carrier is sent. But it increases to 8.96 A when the carrier is modulated by a single-tone sinusoidal. Find the % μ and also the antenna current when depth of modulation changes to 0.8

i)
$$I_t = I_c\left[1+\frac{\mu^2}{2}\right]^{1/2}$$

$$\cancel{8.96}\ 1.12 = 8\left[1+\frac{\mu^2}{2}\right]^{1/2}$$

$$1.25 = \left[1+\frac{\mu^2}{2}\right]$$

$$2.5 = [2+\mu^2]$$

$$0.5 = \mu^2$$

$$\mu = 0.7$$

ii) $\mu = 0.8$, $I_c = 8.96A$, $I_t = ?$

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

$$= 8\left(1+\frac{(0.7)^2}{2}\right)^{1/2}$$

$$= 8\left(2+0.24\right)^{1/2}$$

$$= 8(1.98)$$

$$= 9.19\ A$$

Q: A transmitter radiates 10 K watts with carrier un modulated and 12 K W when carrier is sinusoidally modulated. Calculate the μ if another sinewave corresponding to 50% modulation is transmitted simultaneously. Determine the total modulation power

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

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

$12k = 10k\left(1+\frac{\mu^2}{2}\right)$

$1.2\,\cancel{k} = \left(1+\frac{\mu^2}{2}\right)$

$2.4\,\cancel{k} = 2+\mu^2$

$2.4\cancel{00} - 2 = \mu^2$

$\cancel{2898 = \mu^2}$

$0.4 = \mu^2$

$\therefore \mu = 0.6$

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

$\mu_t^2 = \mu_1^2 + \mu_2^2$

$= (0.6)^2 + (0.5)^2$

$= 0.61$

$P_t = P_c\left(1+\frac{0.61}{2}\right)$

$\cancel{P_t k} = 10k\left(1+0.3\right)$

$P_t = 13050\ w.$