Module-1 :-

Amplitude Modulation

(Numerical problems) V.T.U Q. Papers

List of Formulae :-

1. Amplitude Modulation Index (or) Depth of Modulation :

$\mu = K_a A_m$, where A_m = Amplitude of message signal in Volts.

K_a = Amplitude sensitivity parameter

(or) $\boxed{\mu = K_a A_m}$

Note : • The Maximum Value of Modulation index is "1"

- When, $\mu < 1 \Rightarrow$ Results in under Modulation
- When, $\mu = 1 \Rightarrow$ Results in critical Modulation
- when, $\mu > 1 \Rightarrow$ Results in over Modulation.

2. AM wave equation :

↳ Single-tone AM : (considering single message signal)

- $s(t) = A_c\left[1 + \mu \cos(2\pi f_m t)\right] \cos(2\pi f_c t)$

↳ Multitone AM : (considering multiple message signals)

- $s(t) = A_c\left[1 + \mu_1 \cos(2\pi f_{m_1} t) + \mu_2 \cos(2\pi f_{m_2} t) + \dots\right] \cos(2\pi f_c t)$

where, $\mu_1 = K_a A_{m_1}$; $\mu_2 = K_a A_{m_2}$

3. Net Modulation Index :-

For Multitone Modulation, Net Modulation Index μ_t is

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

4. The Maximum and Minimum amplitudes of AM :-

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

→ A_{max} & A_{min} are required to sketch resulting AM signal for any given Modulation index 'μ'.

5. Total power in AM-wave :-

↳ In terms of carrier power 'P_c' and 'μ'

$$P_t = P_c\left(1+\frac{\mu^2}{2}\right) \; ; \; P_c = \frac{A_c^2}{2R} \; : \; R = \text{Load Resistance}$$

↳ power in sidebands : $P_{LSB} = P_{USB} = P_c \frac{\mu^2}{4}$ Watts

↳ Total power in side bands : $P_{SB} = P_{LSB} + P_{USB} = P_c \frac{\mu^2}{2}$

$$P_t = P_c + P_{LSB} + P_{USB} = P_c + P_{SB} \implies P_{SB} = P_t - P_c$$

↳ In terms of Antenna RMS currents : $P_t = I_t^2 R$ and $P_c = I_c^2 R$

Note :- When $\mu = 1$: $P_t\Big|_{max} = P_c\left(1+\frac{\mu^2}{2}\right)\Big|_{\mu=1} = \frac{3}{2} P_c = 1.5 P_c$.

∴ The Max. transmitted power is 1.5 times Carrier power

6. Efficiency of AM :-

$$\eta = \frac{P_{LSB} + P_{USB}}{P_t} = \frac{\mu^2}{2+\mu^2}$$

Note : Max. efficiency of AM is $\eta_{max} = \frac{\mu^2}{2+\mu^2}\Big|_{\mu=1} = \frac{1}{3} = 0.3333$

7. Total transmission Band Width of AM :-

$$BW_T = 2W = f_{USB} - f_{LSB}$$

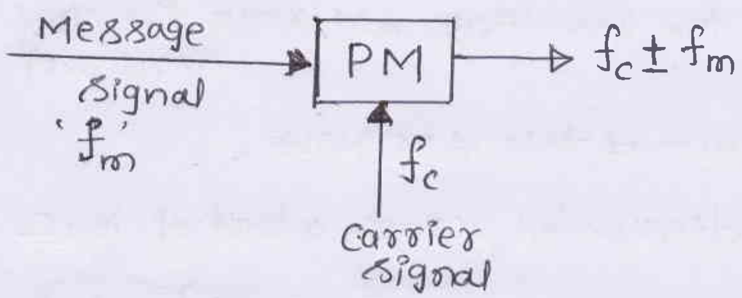
where $W = \text{Maximum}(f_{m_1}, f_{m_2}, \ldots, f_{m_n})$; for Multitone AM.

$W = f_m$, for single-tone AM

f_{USB} = Frequency of upper side Band $= f_c + f_m$

f_{LSB} = Frequency of Lower side Band $= f_c - f_m$

8. Product Modulator :- <DSBSC - Generator>



↳ product Modulator produces two output frequencies
(i) $f_c + f_m = f_{USB}$
(ii) $f_c - f_m = f_{LSB}$

9. Band pass Filter :- It is used to select any one side band frequency.

- $f_c \pm f_m \longrightarrow \boxed{BPF} \longrightarrow f_c + f_m$: if Center frequency of BPF is $(f_c + f_m)$
- $f_c \pm f_m \longrightarrow \boxed{BPF} \longrightarrow f_c - f_m$: if Center frequency of BPF is '$f_c - f_m$'

10. Amplitude of each side band in AM $= \mu \frac{A_c}{2}$

11. General formulas :-

↳ $\cos A \cdot \cos B = \frac{1}{2}\{\cos(A-B) + \cos(A+B)\}$.

↳ $\cos(2\pi f_0 t) \overset{F.T}{\rightleftharpoons} \frac{1}{2}\left[\delta(f-f_0) + \delta(f+f_0)\right]$

↳ $A_c\, m(t) \cdot \cos(2\pi f_c t) \overset{F.T}{\rightleftharpoons} \frac{A_c}{2}\left[M(f-f_0) + M(f+f_0)\right]$

Where, • $\delta(f-f_c) = \begin{cases} 1 & : \text{only at } f = f_c \\ 0 & : ew \end{cases}$ ⇐ Impulse signal (or) Delta function

• $\delta(f+f_c) = \begin{cases} 1 & : \text{only at } f = -f_c \\ 0 & : ew \end{cases}$

• $M(f)$ is spectrum of $m(t)$..

12. Band width of SSBSC is : $BW_{SSB} = W = f_m$

1. Consider a message signal $m(t) = 20\cos(2\pi t)$ Volts and a carrier signal $c(t) = 50\cos(100\pi t)$ Volts.
   (i) Find and sketch the resulting AM wave for 75% modulation. (VTU Q.P)
   (ii) Sketch the spectrum of this AM wave.
   (iii) Find the power dissipated across a load of $100\,\Omega$.

↳ Given data : $m(t) = 20\cos(2\pi t)$ ∴ $A_m = 20$; $f_m = 1$ Hz

$c(t) = 50\cos(100\pi t)$ ∴ $A_c = 50$; $f_c = 50$ Hz

(i) Resulting AM wave for 75% Modulation :- (i.e., for $\mu = 0.75$)

W.K.T. for single Tone AM,

$$S(t) = A_c\left[1 + \mu\cos(2\pi f_m t)\right]\cos(2\pi f_c t)$$

∴ The Resulting AM wave for $\mu = 0.75$; $A_c = 50$V ; $f_m = 1$ and $f_c = 50$ is

$$\boxed{S(t) = 50\left[1 + 0.75\cos(2\pi t)\right]\cos(100\pi t)}$$

- To Sketch AM signal :- • $A_{max} = A_c(1+\mu) = 50(1+0.75) = 87.5$V
  • $A_{min} = A_c(1-\mu) = 50(1-0.75) = 12.5$V

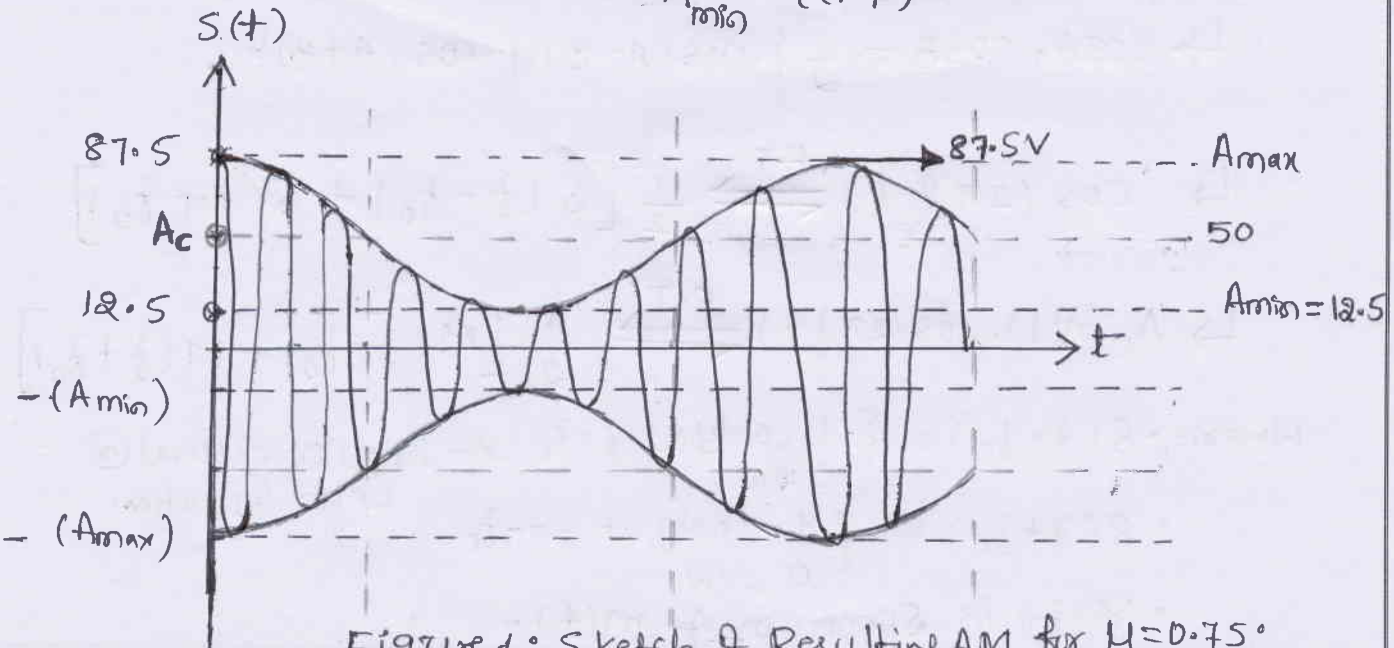


Figure 1: Sketch of Resulting AM for $\mu = 0.75$.

(ii) Spectrum of AM wave :-

W.K.T the resulting AM wave is.

$$s(t) = A_c\left[1+\mu\cos(2\pi f_m t)\right]\cos(2\pi f_c t)$$

$$s(t) = 50\left[1+0.75\cos(2\pi(1)t)\right]\cos(2\pi(50)t)$$

$$\therefore\ s(t) = 50\cos 2\pi(50)t + 37.5\cdot\cos 2\pi(50)t\cdot\cos 2\pi(1)t$$

W.K.T $\cos A\cdot\cos B = \frac{1}{2}\left(\cos(A-B)+\cos(A+B)\right)$

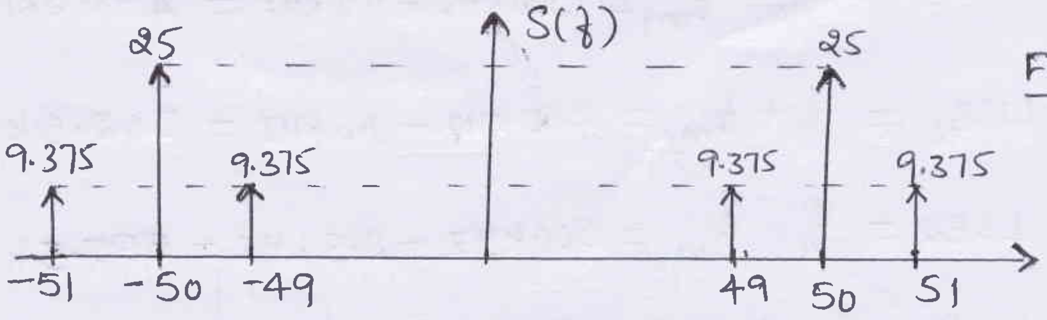
$$\therefore\ s(t) = 50\cos 2\pi(50)t + \frac{37.5}{2}\left[\cos 2\pi(50-1)t + \cos 2\pi(50+1)t\right]$$

$$\boxed{s(t) = 50\cos 2\pi(50)t + 18.75\cos 2\pi(49)t + 18.75\cos 2\pi(51)t} \quad \text{— ①}$$

Taking Fourier Transform of Equation ① we get

$$S(f) = \frac{50}{2}\left[\delta(f-50)+\delta(f+50)\right] + \frac{18.75}{2}\left[\delta(f-49)+\delta(f+49)\right] + \frac{18.75}{2}\left[\delta(f+51)+\delta(f-51)\right]$$

$$\boxed{\therefore\ S(f) = 25\left[\delta(f-50)+\delta(f+50)\right] + 9.375\left[\delta(f-49)+\delta(f+49)\right] + 9.375\left[\delta(f+51)+\delta(f-51)\right]}$$



frequency (f) HZ

Fig.2:- Spectrum of S(t)

(iii) Power dissipated across R=100Ω :-

W.K.T. $P_t = P_c\left(1+\frac{\mu^2}{2}\right)$; $P_c = \frac{A_c^2}{2R} = \frac{(50)^2}{2\times 100} = 12.5\,W$

$$\therefore\ P_t = 12.5\left(1+\frac{(0.75)^2}{2}\right) \simeq \underline{16.016\,W}$$

2. A carrier wave $4\sin(2\pi \times 500 \times 10^3 t)$ Volts is amplitude modulated by an audio wave $[0.2\sin 3(2\pi \times 500t) + 0.1\sin 5(2\pi \times 500t)]$ Volts. Determine the upper and lower sidebands and sketch the complete spectrum of the modulated wave. Estimate the total power in the side band. (VTU Q.P)

↳ Given: $c(t) = 4\sin(2\pi \times 500 \times 10^3 t)$.

$\therefore A_c = 4V$ & $f_c = 500 \times 10^3 = 500KHz$.

The Message signal (Audio wave),

$$m(t) = 0.2\sin 2\pi \times 1500 \times t + 0.1\sin 2\pi \times 2500t$$

$\therefore A_{m_1} = 0.2$; $f_{m_1} = 1500 = 1.5KHz$

$A_{m_2} = 0.1$; $f_{m_2} = 2500 = 2.5kHz$.

$\therefore \mu_1 = \frac{A_{m1}}{A_c} = \frac{0.2}{4} = 0.05$; and $\mu_2 = \frac{A_{m2}}{A_c} = \frac{0.1}{4} = 0.025$.

Net Modulation index : $\mu_t = \sqrt{\mu_1^2 + \mu_2^2} = \sqrt{0.05^2 + 0.025^2} = 0.056$

(*) Upper and lower side bands (USB and LSB):-

i) $USB1 = f_c + f_{m_1} = 500KHz + 1.5KHz = 501.5KHz$

$LSB1 = f_c - f_{m_1} = 500kHz - 1.5kHz = 498.5kHz$.

ii) $USB_2 = f_c + f_{m_2} = 500kHz - 2.5KHz = 502.5KHz$

$LSB2 = f_c - f_{m_2} = 500KHz - 2.5kHz = 497.5KHz$

• To Sketch the Complete Spectrum of the modulated wave:-

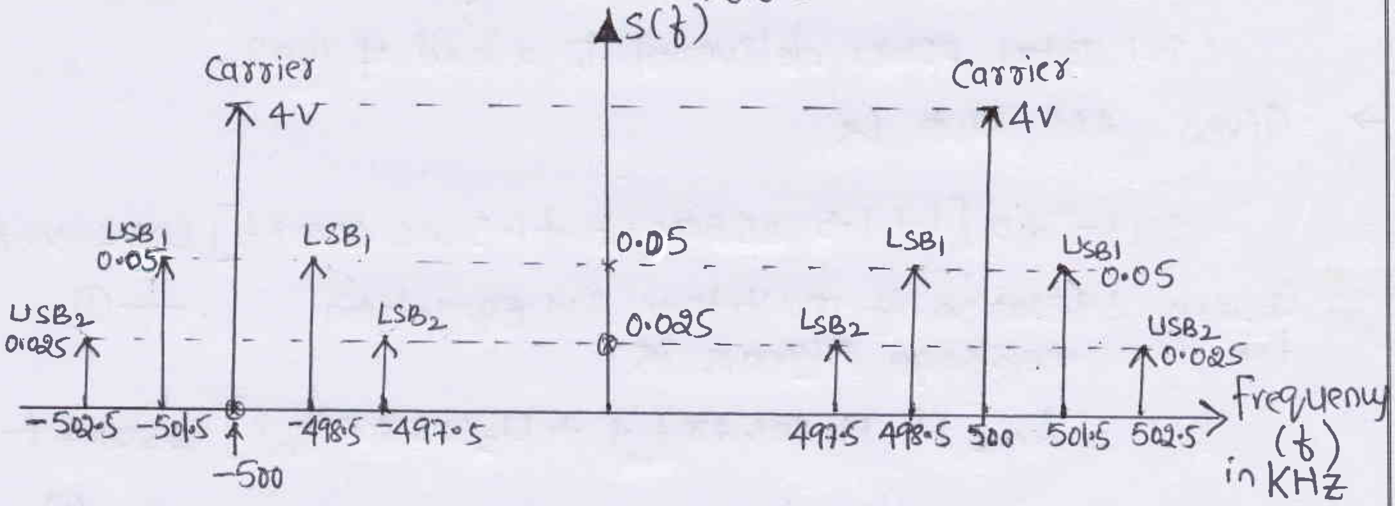
Amplitudes of upper side band and Lower side band for frequency spectrum is $\frac{\mu A_c}{4}$ & that of carrier is $\frac{A_c}{2}$.

i) Amplitude of Carrier frequency 'f_c' : $\frac{A_c}{2} = \frac{4}{2} = 2V$.

ii) Amplitudes of USB1 and LSB1 is : $\frac{\mu_1 A_c}{4} = \frac{0.05 \times 4}{4} = 0.05$

iii) Amplitudes of USB2 & LSB2 is : $\frac{\mu_2 A_c}{4} = \frac{0.025 \times 4}{4} = 0.025$

∴ Complete Spectrum of AM signal is



* Total power in side bands:-

$$P_{SB} = P_{LSB} + P_{USB} = P_c \frac{\mu_t^2}{2}$$

$$\mu_t = \sqrt{\mu_1^2 + \mu_2^2} = 0.056$$

$$\therefore P_{SB} = P_c \times \frac{0.056^2}{2} \quad ; \quad P_c = \frac{A_c^2}{2R} = \frac{4^2}{2R} = \frac{8}{R} \text{ Watts}$$

$$P_{SB} = \frac{8}{R} \times 0.0125$$

$$\boxed{P_{SB} = \frac{0.0125}{R}}$$ Watts ; where R = load resistance

if $\boxed{R = 1\Omega}$

$$\boxed{P_{SB} = 0.0125 \text{ Watts}}$$

<3> An AM wave has the form,

$$s(t) = 20\left[1 + 1.5\cos 2000\pi t + 1.5\cos 4000\pi t\right]\cos 40000\pi t$$

Determine,

(i) Net Modulation Index

(ii) The carrier power and side band power

(iii) S(f) and Draw its frequency spectrum.

(iv) Total power delivered to a load of 100Ω.

↳ Given AM wave is

$$s(t) = 20\left[1 + 1.5\cos 2000\pi t + 1.5\cos 4000\pi t\right]\cos 40000\pi t \quad \text{--- (1)}$$

General equation of multitone AM equation for two message signals is

$$s(t) = A_c\left[1 + \mu_1 \cos 2\pi f_{m_1} t + \mu_2 \cos 2\pi f_{m_2} t\right]\cos 2\pi f_c t \quad \text{--- (2)}$$

∴ By comparing equations (1) & (2) we get —

$A_c = 20V$; $\mu_1 = 1.5 = \mu_2$; $f_{m_1} = 1kHz$; $f_{m_2} = 2kHz$; $f_c = 20kHz$
and Load resistance $R = 100\Omega$

(i) Net Modulation index :-

$$\mu_t = \sqrt{\mu_1^2 + \mu_2^2} = \sqrt{1.5^2 + 1.5^2} = 2.12$$

(Note: s(t) is over Modulated) $\because \mu_t > 1$

(ii) carrier power & side band power :-

↳ carrier power : $P_c = \frac{A_c^2}{2R} = \frac{20^2}{2 \times 100} = 2$ Watts.

↳ Side band power : $P_{SB} = P_c \frac{\mu_t^2}{2}$

$$P_{SB} = \frac{2 \times 2.12^2}{2} = 4.4944 \text{ Watts.}$$

where, P_{SB} = Total power in all side bands.

(iii) S(f) and Frequency spectrum :-

from given data

$$S(t) = 20\left[1 + 1.5\cos 2000\pi t + 1.5\cos 4000\pi t\right]\cos 40{,}000\pi t$$

i.e.. $S(t) = \underset{A_c}{20}\left[1 + \underset{\mu_1}{1.5}\cos(2\pi \times \underset{\substack{f_{m1}\\1\times10^3}}{1000} \times t) + \underset{\mu_2}{1.5}\cos 2\times \underset{\substack{f_{m2}\\2\times10^3}}{2000}\pi t\right]\cos 2\pi \times \underset{\substack{f_c\\20\times10^3}}{20{,}000}t$

$$\therefore S(t) = 20\cos 2\pi\times20\times10^3 t + 30\underbrace{\cos 2\pi\times20\times10^3 t \cdot \cos 2\pi\times1\times10^3 t}$$

$$+ 30\underbrace{\cos 2\pi\times20\times10^3 t \cdot \cos 2\times2\times10^3 t}.$$

W.K.T $\cos A\cdot\cos B = \frac{1}{2}\left[\cos(A-B) + \cos(A+B)\right]$

$$\therefore S(t) = 20\cos 2\pi\times20\times10^3 t + \frac{30}{2}\left[\cos 2\pi\times(20-1)\times10^3 t + \cos 2\pi\times(20+1)\times10^3 t\right]$$

$$+ \frac{30}{2}\left[\cos 2\pi\times(20-2)\times10^3 t + \cos 2\pi(20+2)\times10^3 t\right]$$

$$S(t) = 20\cos 2\pi\times20\times10^3 t + 15\left[\cos 2\pi\times19\times10^3 t + \cos 2\pi\times21\times10^3 t\right]$$

$$+15\left[\cos 2\pi\times18\times10^3 t + \cos 2\pi\times22\times10^3 t\right]$$

Take Fourier Transformation for Equation ① ——— ①

$$S(f) = \frac{20}{2}\left[\delta(f-20K) + \delta(f+20K)\right] + \frac{15}{2}\left[\delta(f+19K) + \delta(f-19K)\right]$$

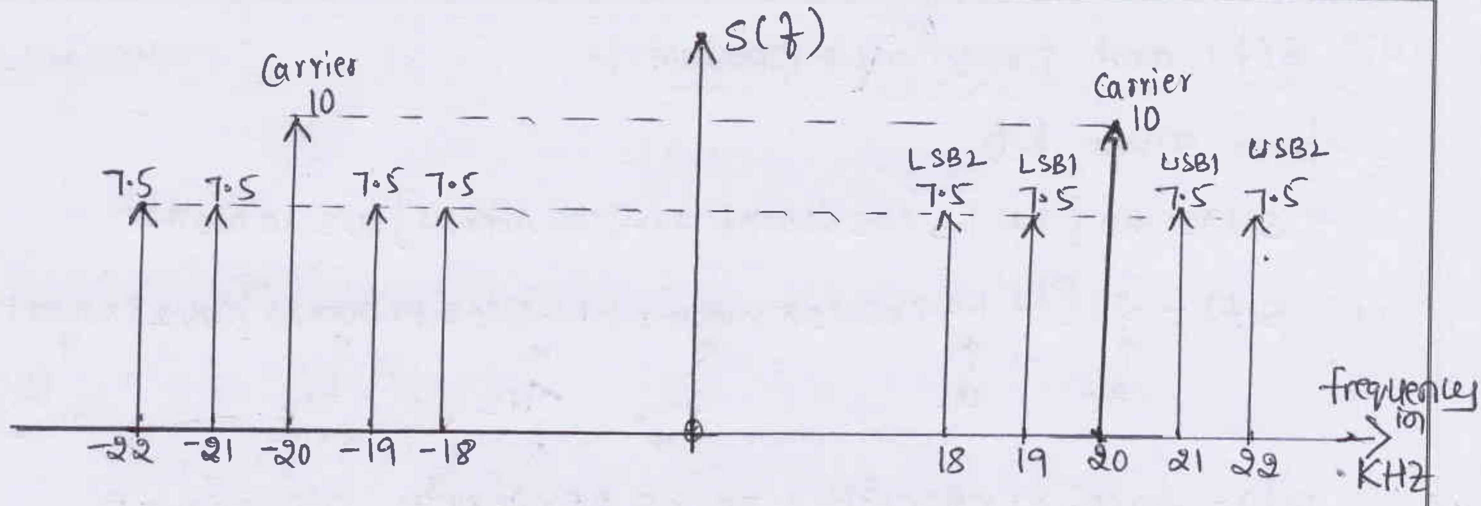
$$+\frac{15}{2}\left[\delta(f-21K) + \delta(f+21K)\right] + \frac{15}{2}\left[\delta(f+18K) + \delta(f-18K)\right]$$

$$+\frac{15}{2}\left[\delta(f-22K) + \delta(f+22K)\right]$$

$$\boxed{\begin{aligned}\therefore S(f) = {} & 10\left[\delta(f-20K) + \delta(f+20K)\right] + 7.5\left[\delta(f+19K) + \delta(f-19K)\right. \\ & + \delta(f-21K) + \delta(f+21K) + \delta(f-22K) + \delta(f+22K) \\ & \left. + \delta(f+18K) + \delta(f-18K)\right]\end{aligned}}$$

Equation ② gives the equation of S(f) with ——— ②

$\boxed{f_c = 20KHZ \text{ Amplitude } 10V}$; $f_{LSB1} = 19KHZ$, $f_{USB1} = 21KHZ$; $f_{LSB2} = 18KHZ$, $f_{USB2} = 22KHZ$ } Amplitude 7.5V



-: complete spectrum of s(t) :- (Plot of S(f))

(iv) Total power delivered to a load of 100Ω :-

Method 1:

W.K.T.

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

$$P_c = 2W \; ; \; \mu_t = 2.12$$

$$\therefore P_t = 2\left[1+\frac{2.12^2}{2}\right]$$

$$\boxed{P_t = 6.4944\,\text{Watts}}$$

Method 2 :-

Since we already Calculated P_c & Total side bands power P_{SB}.

Total power is

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

$$P_t = 2 + 4.4944$$

$$\boxed{P_t = 6.4944}\ \text{Watts}$$

(4) An AM-Broadcasting transmitter radiates 50KW of carrier power. What will be the radiated power at 85% Modulation?

↳ Given data : carrier power, $P_c = 50\,KW$; $\mu = 0.85$

$\therefore$ radiated power, $P_t = P_c\left[1+\frac{\mu^2}{2}\right] = 50\times10^3\left[1+\frac{0.85^2}{2}\right]$

$$\boxed{P_t = 68.0625\,KW}$$

⟨5⟩ An audio frequency signal $10 \sin 2\pi(500)t$ is used to amplitude modulate a carrier of $50 \sin 2\pi(10^5)t$. Assume modulation index = 0.2. Determine.

i) side band frequencies

ii) Amplitude of each side band.

iii) Bandwidth required.

iv) Efficiency of AM Wave.

↳ Given: $m(t) = 10 \sin 2\pi(500)t \Rightarrow A_m = 10V$; $f_m = 500\text{ Hz}$

$f_m = 0.5\text{ KHZ}$

$c(t) = 50 \sin 2\pi(10^5)t \Rightarrow A_c = 50V$; $f_c = 10^5\text{ Hz}$

and $\mu = 0.2$ (given) $f_c = 100\text{ KHZ}$

i) Side band frequencies:-

- $f_{USB} = f_c + f_m = 100k + 0.5k = \underline{100.5\text{ KHZ}}$.
- $f_{LSB} = f_c - f_m = 100k - 0.5k = \underline{99.5\text{ KHZ}}$.

ii) Amplitude of Each side band $= \dfrac{\mu A_c}{2} = \dfrac{0.2 \times 50}{2} = \underline{5V}$

iii) Bandwidth required: $BW = 2f_m = 2(0.5\text{ KHz})$

$$\boxed{BW = 1\text{ KHZ}}$$

iv) Efficiency of AM Wave:-

$$\%\eta = \frac{\mu^2}{2+\mu^2} \times 100 = \frac{0.2^2}{2+0.2^2} \times 100$$

$$\boxed{\%\eta = 1.96}$$

<V.T.U> <6> An Amplitude modulated signal is given by

$$s(t) = [10\cos 2\pi\times10^6 t + 5\cos 2\pi\times10^6 t \cdot \cos 2\pi\times10^3 t + 2\cos 2\pi\times10^6 t \cdot \cos 4\pi\times10^3 t].$$ Determine.

i) Net Modulation index

ii) side band power

iii) Total modulated power. Assume $R = 100\,\Omega$

↳ Given AM signal is

$$s(t) = [10\cos 2\pi\times10^6 t + 5\cos 2\pi\times10^6 t \cdot \cos 2\pi\times10^3 t + 2\cos 2\pi\times10^6 t \cdot \cos 4\pi\times10^3 t]$$

$$s(t) = 10\cos 2\pi\times10^6 t\left[1 + \frac{5}{10}\cos 2\pi\times10^3 t + \frac{2}{10}\cos 4\pi\times10^3 t\right]$$

$$s(t) = 10[1 + 0.5\cos 2\pi\times10^3 t + 0.2\cos 4\pi\times10^3 t]\cos 2\pi\times10^6 t \quad \text{—— (1)}$$

The standard AM equation for two message signals is

$$s(t) = A_c[1 + \mu_1\cos 2\pi f_{m_1} t + \mu_2\cos 2\pi f_{m_2} t]\cos 2\pi f_c t \quad \text{—— (2)}$$

$\therefore A_c = 10V$; $\mu_1 = 0.5$; $\mu_2 = 0.2$; $f_{m_1} = 1\times10^3 = 1KHZ$; $f_{m_2} = 2\times10^3 = 2KHZ$; $f_c = 10^6$ HZ, $f_c = 1000KHZ$

<i> Net Modulation Index : $\mu_t = \sqrt{\mu_1^2 + \mu_2^2} = \sqrt{0.5^2 + 0.2^2} = 0.538$

<ii> Sideband power :- $P_{SB} = P_{LSB} + P_{USB} = P_c \cdot \frac{\mu_t^2}{2}$

$$P_c = \frac{A_c^2}{2R} = \frac{10^2}{2\times100} = 0.5W.$$

$$\therefore P_{SB} = 0.5 \times \frac{0.538^2}{2} = 0.072\,W$$

<iii> Total modulated power :- $P_t = P_c\left[1 + \frac{\mu_t^2}{2}\right] = P_c + P_{SB} = 0.572\,W.$

7) An AM signal has the form,

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$$S(t) = \cos(2000\pi t) + 4\cos(2400\pi t) + \cos(2800\pi t).$$

Determine the ratio of power in message signal to that of power in unmodulated carrier signal.

↳ Given AM-equation is

$$S(t) = \cos(2000\pi t) + 4\cos(2400\pi t) + \cos(2800\pi t)$$

$$\therefore S(t) = \cos(\underset{\uparrow f_{LSB}}{2\pi \times 1000 \times t}) + 4\cos(\underset{\uparrow f_c}{2\pi \times 1200 t}) + \cos(\underset{\uparrow f_{USB}}{2\pi \times 1400 t}) \quad \text{— (1)}$$

It has 3-components, carrier signal, Lower side band (LSB) and upper side band (USB).

$\therefore$ the ~~Amplitude~~ of Carrier, $A_c = 4V$.

~~Amplitude~~ of LSB & USB is $\frac{\mu A_c}{2} = 1 \Rightarrow \boxed{\mu = \frac{2}{A_c} = \frac{2}{4} = \frac{1}{2}}$

$\therefore$ ~~Amplitude~~ of message signal, $A_m = A_c \times \mu = 4 \times \frac{1}{2} = 2V \quad (\because \mu = \frac{A_m}{A_c})$

$\therefore$ The Ratio of power in Message signal to that of carrier power $\Big\} = \dfrac{\left(\frac{A_m^2}{2R}\right) \leftarrow \text{Power in message signal}}{\left(\frac{A_c^2}{2R}\right) \leftarrow \text{power in Carrier signal}}$

$$\frac{P_m}{P_c} = \frac{A_m^2}{A_c^2} = \left(\frac{A_m}{A_c}\right)^2$$

$$\frac{P_m}{P_c} = \left(\frac{2}{4}\right)^2 = (0.5)^2$$

$$\boxed{\frac{P_m}{P_c} = 0.25}$$

*Note:- In General for Any AM signal the Ratio of power present in Message signal to that of Carrier signal is equal to "μ^2"

- For problem 10, $\boxed{\frac{P_m}{P_c} = \mu^2 = (0.5)^2 = 0.25}$

8) Consider a 2-stage SSB-Modulator as shown in figure.1. the input signal consists of a voice signal in a frequency range of 300HZ to 3.4KHZ. The two oscillators frequencies have values f_{c_1} = 100KHZ and f_{c_2} = 10MHZ. Determine

(i) sidebands of DSBSC modulated waves appearing at the outputs of the product modulators.

(ii) sidebands of SSB modulated wave appearing at two BPF's output.

(iii) passband and Guard band of two BPF's.

(iv) Sketch the spectrum at each stage of the ..

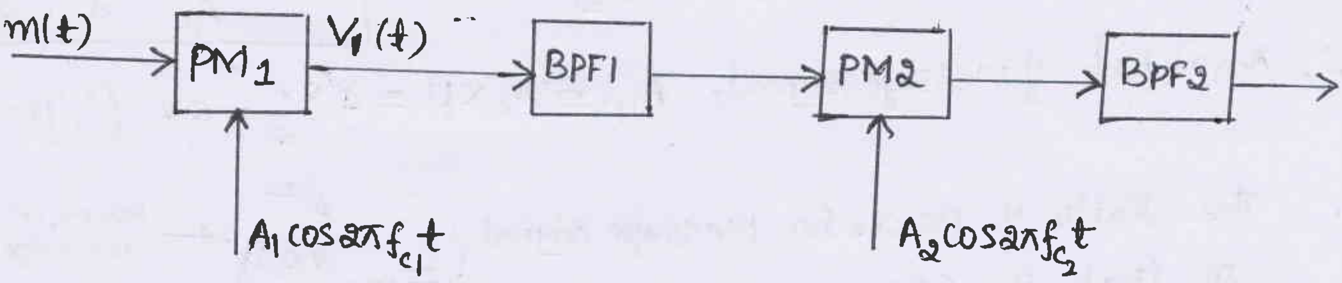


Figure1: Two Stage SSB Modulator

↳ Given :- Frequency of m(t) : f_m = 300HZ to 3.4KHZ

f_m = 0.3KHZ to 3.4KHZ

Frequency of Carrier1 : f_{c_1} = 100KHZ
used for PM1

Frequency of Carrier 2 : f_{c_2} = 10MHZ
used for PM2

i) The PM1 output $V_1(t)$ consists of two side bands as follows : LSB = $f_{c_1} - f_m$ = 100KHZ − (0.3KHZ to 3.4KHZ)

$$\boxed{\text{LSB} = 99.7\text{KHZ to } 96.6\text{KHZ}}$$

and, $USB = f_{c_1} + f_m$

$USB = 100KHZ + (0.3KHZ \text{ to } 3.4KHZ)$

$$\boxed{USB = 100.3KHZ \text{ to } 103.4 \ KHZ}$$

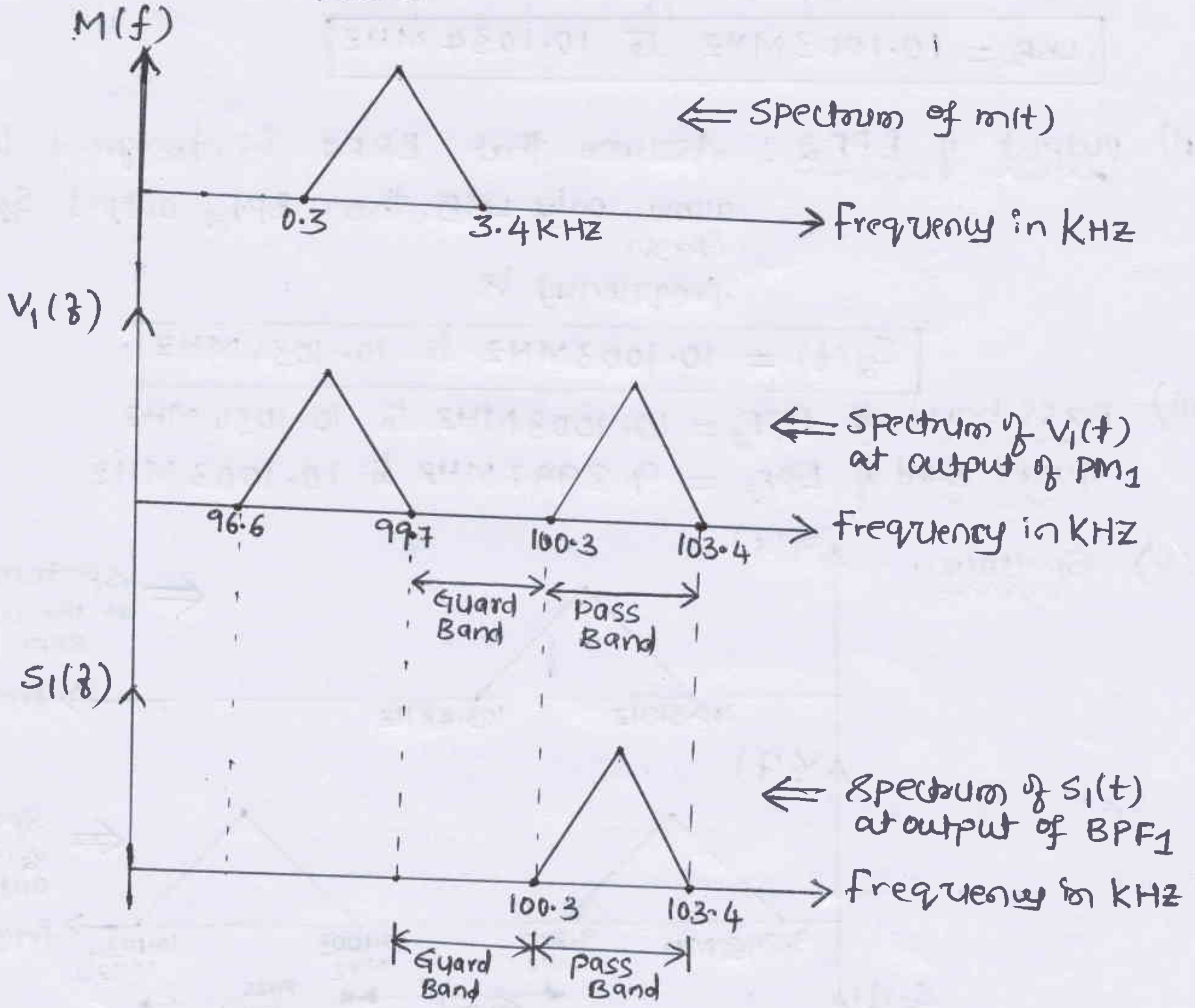
ii) output of BPF1 : Assume that BPF1 is designed to (pass) allow only USB. Then, BPF1 output $S_1(t)$ frequency is.

$$\boxed{S_1(t) = 100.3KHZ \text{ to } 103.4KHZ}$$

iii) ∴ Pass Band of BPF1 = 100.3 KHz to 103.4 KHZ. } shown in Spectrum

Guard Band of BPF_1 = 99.7 KHz to 100.3 KHZ

iv)



∴ Spectrum at each stage :-

* Similarly, the PM2 output consists of two side bands as follows. (Its input is $S_1(t)$ as message signal with frequency $f_m = f_{USB} = \underbrace{100.3\,KHz \text{ to } 103.4\,KHz}_{m(t)\text{ frequency Range for PM2}}$ & carrier frequency $f_{c_2} = 10\,MHz$)

(i) $LSB = f_{c_2} - f_m$

$= 10\,MHz - (100.3\,KHz \text{ to } 103.4\,KHz)$

$\boxed{LSB = 9.8997\,MHz \text{ to } 9.8966\,MHz}$ and

$USB = f_{c_2} + f_m$

$= 10\,MHz + (100.3\,KHz \text{ to } 103.4\,KHz)$

$\boxed{USB = 10.1003\,MHz \text{ to } 10.1034\,MHz}$

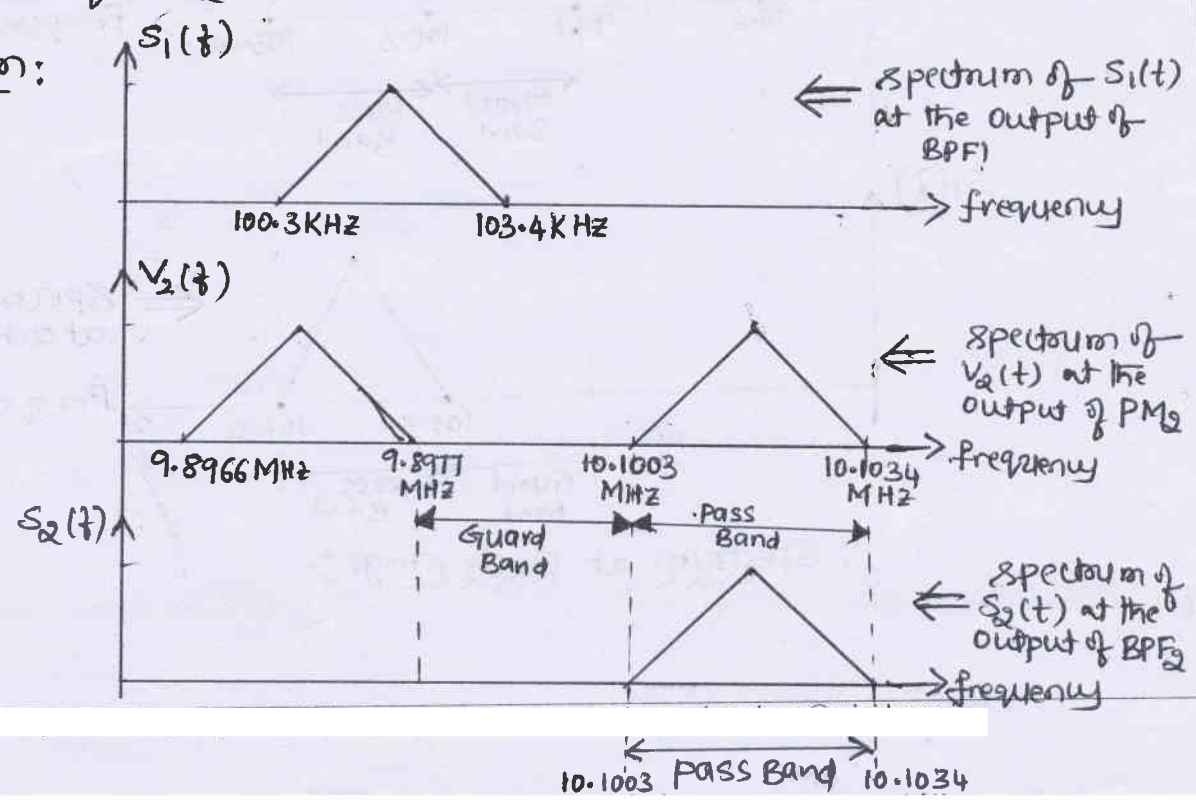
ii) output of BPF2: Assume that BPF2 is designed to allow only USB. then BPF_2 output $S_2(t)$ (pass) frequency is

$\boxed{S_2(t) = 10.1003\,MHz \text{ to } 10.1034\,MHz}$.

iii) pass band of BPF_2 = 10.1003 MHz to 10.1034 MHz

Guard Band of BPF_2 = 9.8997 MHz to 10.1003 MHz.

iv) Spectrum:



9) A 250W carrier of 1000KHZ is simultaneously modulated by sinusoidal signals of 2KHZ, 6KHZ and 8KHZ with modulation indices of 35%, 55% and 75% respectively. What are the frequencies present in the modulated wave and what is the radiated power.

June/July 2016

5 Marks

↳ Given Data:- $P_c = 250W$; $f_c = 1000\,KHZ$

$f_{m1} = 2KHZ$; $f_{m2} = 6KHZ$; $f_{m3} = 8KHZ$

$\mu_1 = 0.35$; $\mu_2 = 0.55$; $\mu_3 = 0.75$

i) Frequencies present in the Modulated Wave:-

↳ carrier $f_c = 1000\,KHZ$

↳ $LSB1 = f_c - f_{m1} = 1000K - 2K = 998\,KHZ$

↳ $USB_1 = f_c + f_{m2} = 1000K + 2K = 1002\,KHZ$

↳ $LSB_2 = f_c - f_{m2} = 1000K - 6K = 994\,KHZ$

↳ $USB_2 = f_c + f_{m2} = 1000K + 6K = 1006\,KHZ$

↳ $LSB3 = f_c - f_{m3} = 1000K - 8K = 992\,KHZ$

↳ $USB_3 = f_c + f_{m3} = 1000K + 8K = 1008\,KHZ$

ii) Radiated power:-

W.K.T $P_t = P_c\left(1 + \frac{\mu_t^2}{2}\right)$

$P_c = 250W$

$\mu_t = \sqrt{\mu_1^2 + \mu_2^2 + \mu_3^2} = \sqrt{0.35^2 + 0.55^2 + 0.75^2}$

$\mu_t = 0.9937$

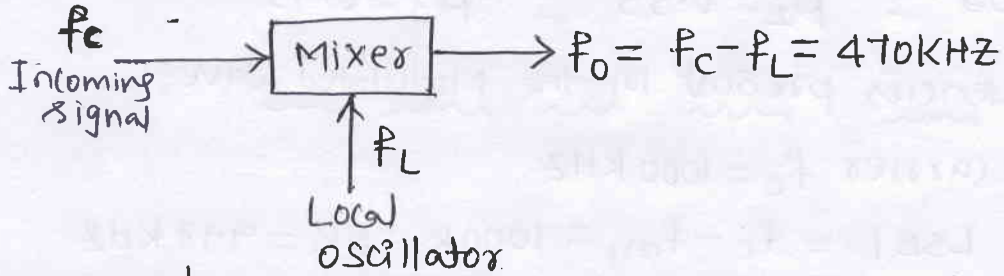
∴ Radiated power, $P_t = 250\left(1 + \frac{0.9937^2}{2}\right)$

$\boxed{P_t = 373.4}$ Watts

10) The Incoming signal has a midband frequency that may lie in the range 530KHZ to 1650KHZ. The associated bandwidth is 10KHZ. This signal is to be translated to a fixed frequency band Centered at 470KHZ. Determine the tuning range that must be provided by the local oscillator.

Given : $f_c = 530KHZ$ to $1650KHZ$; $BW = 10KHZ$

$f_0 = 470KHZ$; $f_L = ?$ ∴ It is down frequency Translator (or) Mixer.



From given data Translator (mixer) output $f_0 = 470KHZ = f_c - f_L$

∴ Local oscillator frequency, f_L is given by;

$$f_L = f_c - f_0$$

When, $f_c = 530KHZ$; $f_L = 530K - 470K = 60KHZ$

$f_c = 1650KHZ$; $f_L = 1650K - 470K = 1180KHZ$

$\boxed{\text{∴ Tuning range of Local oscillator frequency } f_L \text{ is } 60KHZ \text{ to } 1180KHZ.}$

11) Determine the Bandwidth of FDM-system which uses SSB modulation at the transmitter for 24 Voice signals having a Bandwidth of 4KHZ each.

↳ Given $N = 24$, Voice signals with SSB Modulation.

$W = f_m = 4KHZ$

∴ Total Bandwidth of FDM system is

$$BW = N \times f_m = 24 \times 4KHZ$$

$$\boxed{BW = 96KHZ}$$

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