UNIT-5, Communication System

FORMULAS

Amplitude Modulation :- (AM)

① Expression of AM Wave / Expression for the envelope of AM wave :-

$$\boxed{v_{AM} = V_c \sin\omega_c t + \frac{mV_c}{2}\left[\cos(\omega_c-\omega_m)t - \cos(\omega_c+\omega_m)t\right]}$$

Where $V_c \rightarrow$ Amplitude of Carrier Wave

$m \rightarrow$ modulation Index

$\omega_c \rightarrow 2\pi f_c \rightarrow$ Carrier Freq.

$\omega_m = 2\pi f_m \rightarrow$ Modulating Freq.

② Modulation Index $\boxed{m = \frac{V_m}{V_c}}$

$V_m \rightarrow$ Amplitude of modulating Signal

$V_c \rightarrow$ Amplitude of Carrier Signal.

③ $\boxed{\text{Bandwidth of AM} = 2f_m}$

$f_m \rightarrow$ Maximum Modulating Freq.

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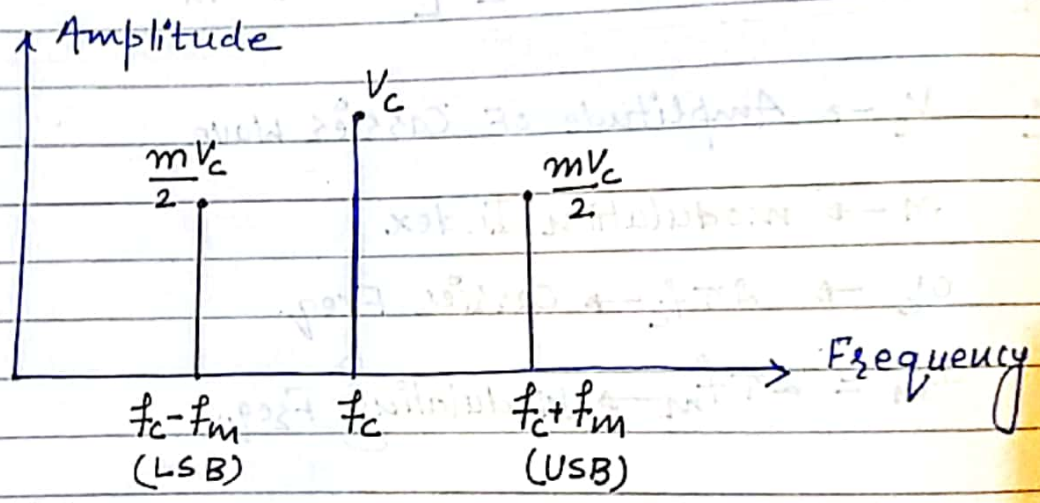
④ $\boxed{\text{Upper side Band (USB)} = f_c + f_m}$

⑤ $\boxed{\text{Lower side Band (LSB)} = f_c - f_m}$

f_c → Carrier Freq.

f_m → modulating Freq.

⑥ Spectrum OF AM Wave :-



⑦ Modulation Index OF AM Wave Should be :-

(a) $\boxed{m \leq 1}$ Called As Linear modulating Wave

(b) $\boxed{m > 1}$ causes distortion, called as over modulation

(8) $$\boxed{V_m = \frac{V_{max} - V_{min}}{2}}$$

$$\boxed{V_c = \frac{V_{max} + V_{min}}{2}}$$

(9) Power of AM Wave :-

$$\boxed{P_T \text{ or } P_{AM} = \frac{V_c^2}{2R} + \frac{m^2 V_c^2}{8R} + \frac{m^2 V_c^2}{8R}}$$

(10) Where $\boxed{\frac{V_c^2}{2R} = \text{Power due to Carrier Signal}}$

(11) $\boxed{\text{Power due to LSB} = \text{USB} = \frac{m^2 V_c^2}{8R}}$

(12) Relation Between modulation Index (m) & power of AM:-

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

↳ Total power.

13) Transmission Efficiency :-

$$\boxed{\eta = \frac{P_{USB} + P_{LSB}}{P_T}} \quad \text{or} \quad \boxed{\eta = \frac{m^2}{2+m^2}}$$

(14) $$\boxed{I_T = I_c \sqrt{1+\frac{m^2}{2}}}$$

I_c → unmodulated Carrier Current

I_T → Total Current (modulated)

Note :- If written in numerical, Another sine wave or several sine waves then 'm' will be replaced by 'm_t' where $\boxed{m_t = \sqrt{m_1^2+m_2^2}}$

(15) $$\boxed{f_c = \frac{1}{2\pi\sqrt{LC}}}$$

f_c → Carrier freq.

L = Value of Inductor
C = Value of Capacitor

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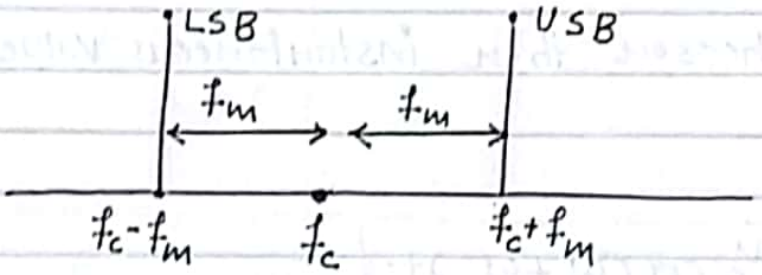
Double Side band Suppresed Carrier (DSBSC) :-

(16) $\boxed{\text{Bandwidth of DSBSC} = 2f_m}$

(17) Freq. spectrum of DSBSC :-



(18) $$\boxed{P_{DSBSC} = P_c\left(\frac{m^2}{2}\right)}$$

(19) $$\boxed{P_{LSB} = P_{USB} = \frac{m^2 V_c^2}{8R}}$$

Single Side Band :- (SSB)

(20) $\boxed{\text{Bandwidth of SSB} = f_m}$

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NUMERICALS Communication

QNO1) The tuned CKT oF the oscillator in AM transmitter employs 50 µH coil and a 1 nF Capacitor. IF the oscillator o/p is modulated by audio Frequencies upto 10 KHZ, What is the Freq. range occupied by sidebands.

Sol^n:- Given $L = 50\,\mu H$

$C = 1\,nF$

$f_m = 10\,KHZ$

$$f_c = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{50\times10^{-6}\times1\times10^{-9}}}$$

$$\boxed{f_c = 712\ KHZ}$$

Range occupied by sidebands $= f_c + f_m$ and $f_c - f_m$

$f_c + f_m = 712 + 10 = 722\,KHZ$

$f_c - f_m = 712 - 10 = 702\ KHZ$

Range Extending from 722 to 702 KHZ Ans

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Q NO 2> A modulating signal of $10 \sin(2\pi 10^3 t)$ is used to modulate a carrier signal of $20 \sin(2\pi \times 10^4 t)$. Find –

① Amplitude of modulating signal i.e. V_m
(2) Amplitude of carrier signal i.e. V_c
(3) modulation Index
(4) Bandwidth
(5) Amplitude of sideband components
(6) side band components Frequencies
(7) Freq. spectrum of AM wave

⑧ What is the Total power delivered to a load of 600Ω.
⑨ Find its Transmission Efficiency also.
⑩ Power of sideband components.

Sol^n:- Given $v_m = 10 \sin(2\pi \times 10^3 t) \longrightarrow ①$

but $v_m = V_m \sin \omega_m t$

$v_m = V_m \sin(2\pi f_m t) \longrightarrow ②$

Compare Eq^n ① & ②:-

① $\boxed{V_m = 10V}$

$\boxed{f_m = 10^3 \text{ Hz}}$ or $\boxed{f_m = 1 \text{ KHz}}$

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Similarly $v_c = 20 \sin(2\pi \times 10^4 t) \longrightarrow (3)$

but $v_c = V_c \sin \omega_c t$

$v_c = V_c \sin(2\pi f_c t) \longrightarrow (4)$

Compare Equations (3) & (4)

(2) $\boxed{V_c = 20V}$, $f_c = 10^4$ Hz

$\boxed{f_c = 10 \text{ kHz}}$

(3) Modulation Index $m = \frac{V_m}{V_c} = \frac{10}{20}$

$\boxed{m = .5}$

(4) Bandwidth $= 2f_m = 2 \times 1$ kHz

$\boxed{\text{B.width} = 2 \text{ kHz}}$

(5) Amplitude of sideband Components (LSB and USB) $= \frac{mV_c}{2}$

$= \frac{.5 \times 20}{2}$

$= \underline{\underline{5V}}$

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(6) Frequency of side band component LSB $= f_c - f_m$

$= 10\,KHZ - 1\,KHZ$

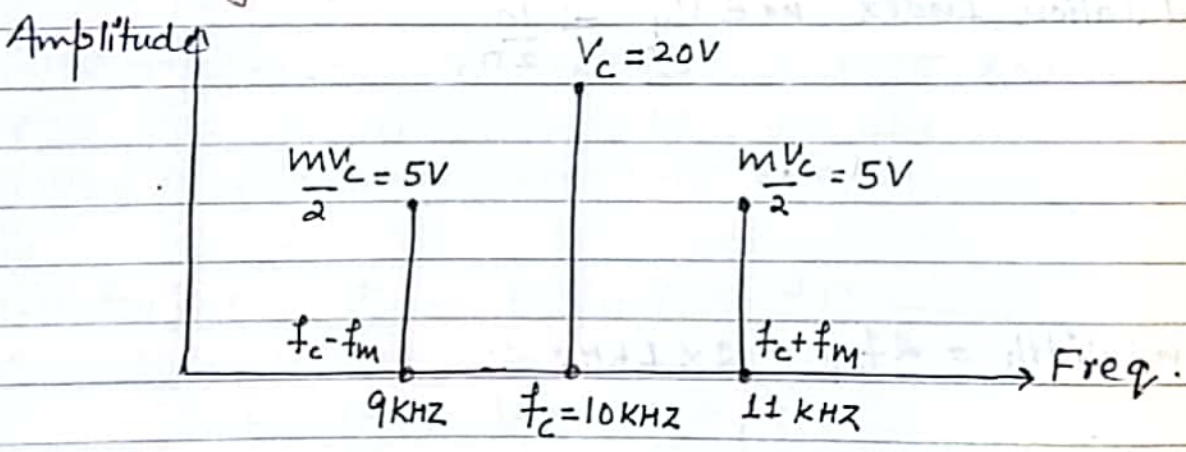
$= 9\,KHZ$

Frequency of U.S.B component $= f_c + f_m$

$= 10\,KHZ + 1\,KHZ$

$= 11\,KHZ$

(7) Frequency spectrum of AM :-



(8) Total power delivered $\boxed{P_T = P_c\left[1 + \frac{m^2}{2}\right]}$

Where

$$P_c = \frac{V_c^2}{2R} = \frac{20 \times 20}{2 \times 600}$$

$$\boxed{P_c = .33\ Watt}$$

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$$\therefore \quad P_T = .33\left[1 + \frac{(.5)^2}{2}\right]$$

$$= .33\left[1 + \frac{.25}{2}\right]$$

$$\boxed{P_T = .371 \text{ watts}}$$

⑨ Transmission Efficiency $\eta = \dfrac{m^2}{2+m^2} = \dfrac{(.5)^2}{2+(.5)^2}$

$$\boxed{\eta = .11}$$

$$\boxed{\% \, \eta = 11\%}$$

⑩ Power of Sideband Components :-

Power of LSB = Power of USB $= \dfrac{m^2 V_c^2}{8R} = \dfrac{(.5)^2 \times (20)^2}{8 \times 600}$

$= .02$ Watts. Ans

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QNo3 The Anteena Current of an AM transmitter is 8 Amperes when only the Carrier is sent. It increases to 8.93 amp. when the Carrier is modulated by a single sine wave. Find–

(1) % modulation

(2) Also determine anteena current when % modulation changes to 0.8.

Solⁿ:-

$$\boxed{I_t = I_c\sqrt{1+\frac{m^2}{2}}}$$

Given $I_c = 8$ Amp.

$I_t = 8.93$ Ampere

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

$$\left(\frac{8.93}{8}\right)^2 - 1 = \frac{m^2}{2} \Rightarrow \boxed{m = .701}$$

(1) $\boxed{\% m = 70.1\%}$

(2) For $\boxed{m = 0.8}$

$$I_t = I_c\sqrt{1+\frac{m^2}{2}}$$

$$= 8\sqrt{1+\frac{(.8)^2}{2}}$$

$$\boxed{I_t = 9.19 \text{ Ampere}}$$ Ans

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QNO4) A Certain transmitter modulates 9 KW with the carrier unmodulated and 10.125 KW when the carrier is sinusoidally modulated. Calculate the modulation Index.

If another sinewave is transmitted with modulation Index of 0.4, determine total Radiated power.

Sol^n :- Given $P_T = 10.125$ KW

$P_c = 9$ KW

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

$$\frac{P_T}{P_c} - 1 = \frac{m^2}{2} \Rightarrow \frac{10.125}{9} - 1 = \frac{m^2}{2}$$

① $\boxed{m = 0.5}$

② Note:- Here written another sinewave, therefore 'm' will be replaced by 'm_t'.

$$m_t = \sqrt{m_1^2 + m_2^2} \qquad \text{Given } m_2 = 0.4.$$

$$= \sqrt{(.5)^2 + (0.4)^2}$$

$$\boxed{m_t = 0.64.}$$

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Total Power radiated $\boxed{P_T = P_c\left[1+\frac{m_t^2}{2}\right]}$

$$P_T = 9\,KW\left[1+\frac{(.64)^2}{2}\right]$$

$\boxed{P_T = 10.8\ KW}$ Ans

QNO57 The anteena Current OF an AM broadcast transmitter modulated to a depth OF 40% by an audio sinewave is 11 Amp. It increases to 12 ampere as a result OF simultaneous modulation by another sinewave. What is the modulation Index due to this second wave.

Solⁿ:- Given $\%\,m = 40\%$

$\longrightarrow$ $m_1 = 0.4$.

$\longrightarrow$ $I_t = 11$ amp.

We know

$$\boxed{I_t = I_c\sqrt{1+\frac{m_1^2}{2}}}$$

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$$\left(\cancel{\frac{I_t}{I_c}}\right)^2 \quad \cancel{1+\frac{m^2}{2}}$$

$$\Rightarrow \quad I_c = \frac{I_t}{\sqrt{1+\frac{m_1^2}{2}}} = \frac{11}{\sqrt{1+\frac{(.4)^2}{2}}}$$

$$\boxed{I_c = 10.58 \text{ Amp.}}$$

<u>Now</u> I_t becomes $= 12$ amp.

$$\therefore \quad I_t = I_c\sqrt{1+\frac{m_t^2}{2}}$$

$$12 = 10.58\sqrt{1+\frac{m_t^2}{2}}$$

$$\boxed{m_t = 0.757}$$

<u>We know</u> $m_t = \sqrt{m_1^2+m_2^2}$

$$(m_t)^2 = m_1^2+m_2^2$$

$$m_2^2 = m_t^2 - m_1^2$$

$$= (.757)^2 - (0.4)^2$$

$$\boxed{m_2 = 0.643}$$ <u>Ans</u>

QNO6) A 400 watt carrier is modulated to a depth of 75%. Calculate total power in the modulated wave.

Sol^n:- Given $P_c = 400$ watt

$m = .75$

$P_T = ?$

We know

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

$$P_T = 400\left(1 + \frac{(.75)^2}{2}\right)$$

$$\boxed{P_T = 512.5 \text{ watt}}$$ Ans

QNO7) A broadcast radio transmitter radiates 10 kW when the modulation percentage is 60. How much of this is carrier power.

Sol^n:. Given $P_T = 10\text{kW}$

$m = .60$

$P_c = ?$

We know $P_T = P_c\left[1 + \frac{m^2}{2}\right]$

$$P_c = \frac{P_T}{1 + \frac{m^2}{2}} = \frac{10}{1 + \frac{(.6)^2}{2}} \Rightarrow \boxed{P_c = 8.47 \text{kW}}$$ Ans

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QNO8) A 400W carrier is amplitude modulated to a depth of 100%. Calculate the total power in case of AM and DSBSC techniques.

How much power saving (in Watt) is acheived for DSBSC.

If the depth of modulation is changed to 75%, then how much power (in W) is required for transmitting the DSBSC wave.

Compare the powers required for DSBSC in both the cases and comment on reason for change in power levels.

Soln:- Given $P_c = 400W$

$m = 1$

① Total power in AM, $P_{AM} = P_c\left(1+\frac{m^2}{2}\right)$

$= 400\left(1+\frac{1}{2}\right)$

$$\boxed{P_{AM} = 600W}$$

Total power in DSBSC, $P_{DSBSC} = P_c\left(\frac{m^2}{2}\right)$

$= 400 \times \frac{1}{2}$

$$\boxed{P_{DSBSC} = 200W}$$

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(2) Power saving (in W) $= P_{AM} - P_{DSBSC}$

$= 600 - 200$

$$\boxed{\text{Power saving} = 400\,W}$$

Thus we require only 200W in case of DSBSC which is $1/3^{rd}$ of total AM power. This is the gain we acheive using DSBSC.

(3) When $P_c = 400W$ and $m = .75$

Total power in DSBSC, $P_{DSBSC} = P_c\left(\frac{m^2}{2}\right)$

$= 400\left[\frac{(.75)^2}{2}\right]$

$$\boxed{P_{DSBSC} = 112.5\,W}$$

(4) The power required in this case is lower than $\boxed{m=1}$ case. This infers that the total power in DSBSC also depends on the depth of modulation. It will be maximum ie $1/3^{rd}$ of total AM power when $\boxed{m=1}$ & less for $\boxed{m<1}$ Ans

QNo9> A DSBSC transmitter radiates 1 KW when the modulation percentage is 60%. How much of carrier power in (KW) is required if we want to transmit the same message by an AM transmitter.

Sol:- Given $P_{DSBSC} = 1\,KW$

$m = 0.6$

We know $P_{DSBSC} = P_c \left(\frac{m^2}{2}\right)$

$\therefore P_c = P_{DSBSC} \frac{2}{m^2}$

$= 1 \times \frac{2}{(.6)^2}$

$\boxed{P_c = 5.56\,KW}$ Ans

QNo10> A SSB transmitter radiates 0.5 KW when modulation percentage is 60%. How much of carrier power (in KW) is required if we want to transmit the same message by an AM transmitter?

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Sol^n :- Given $P_{SSB} = 0.5\,KW$

$m = 0.6$

We know $P_{SSB} = P_c\left(\frac{m^2}{4}\right)$

$\therefore P_c = P_{SSB} \times \frac{4}{m^2}$

$= .5 \times \frac{4}{(.6)^2}$

$\boxed{P_c = 5.56\,kW}$

→ We require 5.56 kW to transmit Carrier Component along with the existing 0.5KW For one side band and 0.5 KW more for another sideband when m=0.6.

So In total 6.56 kW is required by AM transmitter.

Ans

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Q.No.11) Calculate percentage power saving when the carrier and one of the sidebands are suppressed in an AM wave modulated to a depth of (a) 100%
(b) 50%

Sol^n:- (a) When $m = 100\%$

$\therefore \boxed{m = 1}$

$\rightarrow P_{AM} = P_c\left(1 + \frac{m^2}{2}\right)$

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

$\boxed{P_{AM} = 1.5 P_c}$

$\rightarrow P_{SSB} = P_c\left(\frac{m^2}{4}\right)$

$= P_c \times \frac{1}{4}$

$\boxed{P_{SSB} = .25 P_c}$

$\rightarrow$ Power Saving $= \frac{1.5 - .25}{1.5} = .833$

(1) $\boxed{\% \text{ saving} = 83.3\%}$

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(b) When $m = 50\%$

$$m = 0.5$$

$\rightarrow$ $P_{AM} = P_c\left(1 + \frac{m^2}{2}\right) = P_c\left[1 + \frac{(.5)^2}{2}\right]$

$$\boxed{P_{AM} = 1.125\,P_c}$$

$\rightarrow$ $P_{SSB} = P_c\left(\frac{m^2}{4}\right) = P_c\left[\frac{(.5)^2}{4}\right]$

$$\boxed{P_{SSB} = .0625\,P_c}$$

$\rightarrow$ % power saving $= \frac{1.125 - .0625}{1.125} \times 100$

$$\boxed{\%\ \text{saving} = 94.4\ \%}$$

Ans

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QNO12) A 400W Carrier is amplitude modulated to a depth OF 100 %. Calculate the total power in case OF SSB technique.

How much power saving in (W) is acheived For SSB Compared to AM & DSBSC.

IF the depth OF modulation is changed to 75 % then how much power (in W) is required For transmitting the SSB wave.

Compare the powers required For SSB in both the cases and Comment on the reason For change in power levels.

Sol^n:- Case 1:- Given $P_c = 400W$

$m = 1$ (100%)

(1)

→ Total power in SSB, $P_{SSB} = P_c\left(\frac{m^2}{4}\right)$

$= 400 \times \frac{1}{4}$

$$\boxed{P_{SSB} = 100 \text{ Watt}}$$

→ $P_{AM} = P_c\left[1 + \frac{m^2}{2}\right] = 400\left[1 + \frac{1}{2}\right]$

$$\boxed{P_{AM} = 600 \text{ Watt}}$$

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→ Total power in DSBSC, $P_{DSBSC} = P_c\left(\frac{m^2}{2}\right)$

$= 400 \times \frac{1}{2}$

$$\boxed{P_{DSBSC} = 200W}$$

(2) Power saving (in W) compared to AM $= P_{AM} - P_{SSB}$

$= 600 - 100$

$= 500$ watt

Power saving compared to DSBSC $= P_{DSBSC} - P_{SSB}$

$= 200 - 100$

$= 100$ watt

(3) Case 2:- $P_c = 400W$,

$m = .75$

→ Total power in SSB, $P_{SSB} = P_c\left(\frac{m^2}{4}\right) = 400 \times \frac{(.75)^2}{4}$

$$\boxed{P_{SSB} = 56.25W}$$

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(4) The power required in this case is lower than $\boxed{m=1}$ case. This indicates that the total power in SSB also depends on the depth of modulation. It will be maximum ie $1/6^{th}$ of total AM power when $\boxed{m=1}$ and less for $\boxed{m<1}$

Ans

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