Amplitude Modulation

❖ **Define modulation? Explain different types of modulation.**

Modulation is the process of changing some characteristics (amplitude, frequency & phase) of a carrier wave in accordance with the instantaneous value of the modulating signal.

There are 3 types of modulations:

i) Amplitude modulation
ii) Frequency modulation and
iii) phase Modulation.

i) Amplitude modulation :-

Amplitude modulation is defined as the modulation in which the amplitude of the carrier wave is varied in accordance with the instantaneous amplitude of the modulating signal, keeping its (carrier) frequency & phase constant.

ii) Frequency modulation :-

Frequency modulation is defined as the modulation in which the frequency of the carrier wave is varied in accordance with the instantaneous amplitude of the modulating signal, keeping its (carrier) amplitude & phase constant.

iii) phase modulation :-

Phase modulation is defined as the modulation in which the phase of the carrier wave is varied in accordance with the instantaneous amplitude of the modulating Signal, Keeping its (carrier) amplitude and frequency constant.

❖ **Explain the NEED for modulation?**

❖ **Explain the advantages of modulation?**

The advantages of modulation are

1) Reduces the height of antenna:-

Height of antenna is a function of Wavelength 'λ'. The minimum height of antenna is given by $\lambda/4$.

i.e. height of antenna $= \frac{\lambda}{4} = \frac{c}{4f}$ $\qquad \boxed{\because \lambda = \frac{c}{f}}$

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

$c = 3\times10^8$, velocity of light

f = Transmitting frequency.

ex:- i) $f = 15\,KHz$,

height of antenna $= \frac{\lambda}{4} = \frac{c}{4f} = \frac{3\times10^8}{4\times15\times10^3} = 5000$ meters

ii) $f = 1\,MHz$,

height of antenna $= \frac{\lambda}{4} = \frac{c}{4f} = \frac{3\times10^8}{4\times1\times10^6} = 7$ meters.

From above two examples it is clear that as the transmitting frequency is increased, height of the antenna is decreased.

2) Avoids mixing of Signals:-

All audio (message) Signals ranges from 20 Hz to 20 KHz.

The transmission of message signals from various sources causes the mixing of signals and then it is difficult to separate these signals at the receiver end.

3) Increases the range of communication:-

* Low frequency signals have poor radiation and they get highly attenuated. Therefore baseband signals cannot be transmitted directly over long distances.
* Modulation increases the frequency of the signal and thus they can be transmitted over long distances.

4) Allows multiplexing of signals:-

* Modulation allows the multiplexing to be used. Multiplexing means transmission of two or more signals simultaneously over the same communication channel.

eg:-

1) Number of TV channels operating simultaneously.

2) Number of radio stations broadcasting the signals in MW & SW band simultaneously.

5) Allows adjustments in the bandwidth:-

Bandwidth of a modulated signal may be made smaller or larger.

6) Improves quality of reception:-

Modulation techniques like frequency modulation, pulse

Code modulation reduces the effect of noise to great extent. Reduction of noise improves quality of reception.

❖ **Define standard form of amplitude modulation and explain the time and frequency domain expression of AM wave**

July 09- 6M Jan 05 - 4M

❖ **Define amplitude modulation. Derive the expression on AM by both time domain and frequency domain representation with necessary waveforms.**

July-08,12M

· Amplitude modulation is defined as the modulation in which the amplitude of the carrier wave is varied in accordance with the instantaneous amplitude of the modulating Signal Keeping its (carrier) Frequency & phase Constant.

Time-Domain Description :-

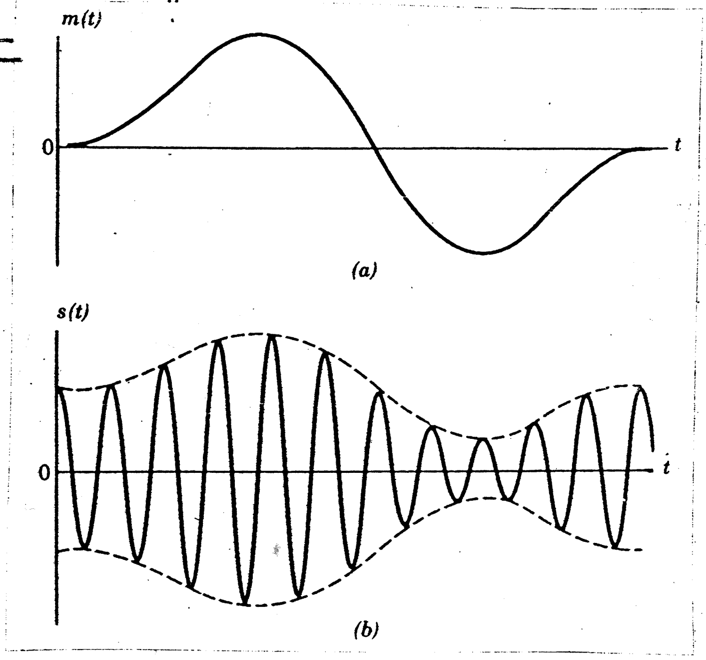


Fig ⓐ Message Signal, ⓑ AM wave S(t).

* The Instantaneous value of modulating Signal is given by

$$\boxed{m(t) = A_m \cos(2\pi f_m t)} \longrightarrow ①$$

Where, $A_m \rightarrow$ maximum amplitude of the modulating Signal

$f_m \rightarrow$ Frequency of modulating Signal.

* The Instantaneous value of carrier Signal is given by

$$\boxed{c(t) = A_c \cos(2\pi f_c t)} \longrightarrow (2)$$

Where,

$A_c \rightarrow$ Maximum amplitude of the carrier Signal.

$f_c \rightarrow$ Frequency of carrier Signal.

The Standard equation for AM wave is given by

$$\boxed{S(t) = A_c[1 + K_a m(t)]\cos(2\pi f_c t)} \longrightarrow (3)$$

Where,

K_a is a constant called the amplitude Sensitivity of the modulator.

Substituting eq (1) in eq (3), we get

$$S(t) = A_c[1 + K_a A_m \cos(2\pi f_m t)]\cos(2\pi f_c t)$$

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

Where, $\boxed{\mu = K_a A_m}$ is called the modulation Index or modulation factor.

$$S(t) = A_c \cos(2\pi f_c t) + \mu A_c \cos(2\pi f_c t) \cdot \cos(2\pi f_m t) \longrightarrow (4)$$

equation (4) can be further expanded, by means of the trigonometric-al relation:

$$\boxed{\cos a \cdot \cos b = \frac{1}{2}\cos(a-b) + \frac{1}{2}\cos(a+b)}$$

$$S(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2}\cos[2\pi f_c - 2\pi f_m]t + \frac{\mu A_c}{2}\cos[2\pi f_c + 2\pi f_m]t \rightarrow (5)$$

equation (5) is the amplitude modulated Signal, consist of three frequency Component

1) The first term is the carrier itself. It has a frequency 'f_c' and amplitude 'A_c'.

2) The 2nd Component is $\frac{\mu A_c}{2} \cos 2\pi(f_c - f_m)t$. It has frequency $(f_c - f_m)$ Called Lower Sideband (F_{LSB}) and having amplitude $\frac{\mu A_c}{2}$

3) Similarly 3rd Component is $\frac{\mu A_c}{2} \cos 2\pi (f_c + f_m)t$. It has frequency $(f_c + f_m)$ called upper Sideband (F_{USB}) and having - amplitude $\frac{\mu A_c}{2}$.

Frequency - Domain Description :-

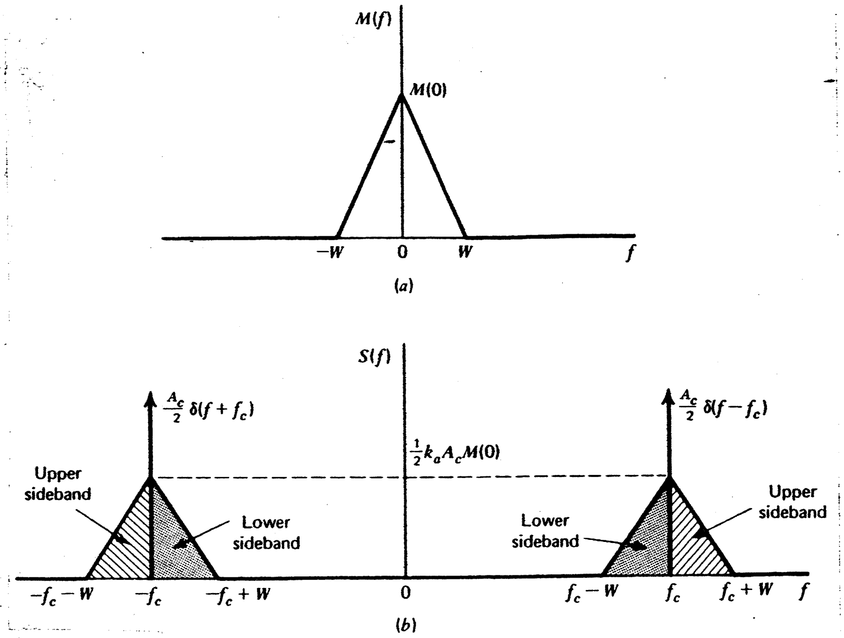
The time domain description of a conventional AM wave is given below:

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

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

Taking fourier transforms on both the Sides of eq(1), we get

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



(a) Spectrum of baseband signal. (b) Spectrum of AM wave.

* The amplitude spectrum of the AM wave has 2 Sidebands on either Sides of $\pm f_c$.
* For +ve frequencies, the highest frequency component of the AM wave equals $f_c + W$, called UPPER Sideband f_{USB} and the lowest frequency Component equals $f_c - W$, called LOWER Sideband f_{LSB}.

Transmission Bandwidth (B_T):-

The difference between upper Sideband and lower Sideband frequencies defines the transmission bandwidth 'B_T'.

$$B_T = f_{USB} - f_{LSB}$$
$$= (f_c + f_m) - (f_c - f_m)$$
$$= \cancel{f_c} + f_m - \cancel{f_c} + f_m$$
$$\boxed{B_T = 2f_m}$$

∴ Bandwidth required for transmission of an AM wave is twice the modulating Signal frequency i.e. $2f_m$.

❖ Define modulation index and percentage modulation index.

The ratio of change in amplitude of modulating signal to the amplitude of carrier wave is known as modulation index or modulation factor or modulation co-efficient or depth of modulation or degree of modulation 'μ'.

$$\boxed{\mu = \frac{A_m}{A_c}} \quad \text{or} \quad \boxed{\mu = K_a A_m}$$

percentage modulation index

$$\boxed{\% \mu = \left(\frac{A_m}{A_c}\right) \times 100}$$

NOTE :-

* If A_m is greater than A_c then distortion is introduced into the system.
* The modulating signal voltage 'A_m' must be less than carrier signal voltage 'A_c' for proper amplitude modulation.

❖ Explain transmission efficiency of an AM wave.

Transmission efficiency is defined as the ratio of the power carried by the sidebands to the total transmitted power is called transmission efficiency 'η' and is given by

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

WKT

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

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

$$\eta = \frac{\frac{\mu^2 A_c^2}{8R} + \frac{\mu^2 A_c^2}{8R}}{P_c(1+\mu^2/2)}$$

$$= \frac{\frac{\cancel{2}\,\mu^2 A_c^2}{4\,\cancel{8}R}}{P_c\left[\frac{2+\mu^2}{2}\right]} = \frac{\frac{\mu^2}{2}\left[\frac{A_c^2}{2R}\right]}{P_c\left[\frac{2+\mu^2}{2}\right]}$$

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

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

❖ **Obtain the expression for total transmitted power of AM wave.**

W.K.T

$$S(t) = A_c \cos 2\pi f_c t + \frac{\mu A_c}{2}\cos 2\pi[f_c - f_m]t + \frac{\mu A_c}{2}\cos 2\pi[f_c+f_m]t$$

The AM wave has three components: unmodulated carrier, Lower Sideband and upper Sideband.

∴ The total power of AM wave is the sum of the carrier power 'P_c' and powers in the two sidebands i.e. P_{USB} & P_{LSB}

$$P_T = P_c + P_{USB} + P_{LSB}$$

* The average carrier power

$$P_c = \frac{(A_c/\sqrt{2})^2}{R}$$

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

W.K.T.

RMS value $V_{rms} = \frac{V_m}{\sqrt{2}}$

IIly $A_{c_{rms}} = \frac{A_c}{\sqrt{2}}$

W.K.T

Power 'p' $= \frac{V_{rms}^2}{R}$

$$P_c = \frac{A_{c_{rms}}^2}{R}$$

$$P_c = \frac{(A_c/\sqrt{2})^2}{R}$$

* The average Sideband power:

$$P_{USB} = P_{LSB} = \frac{\left(\mu A_c/2\sqrt{2}\right)^2}{R}$$

$$= \frac{\frac{\mu^2 A_c^2}{4\times 2}}{R}$$

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

$$P_{USB} = P_{LSB} = \frac{\left(\frac{\mu A_c}{2\sqrt{2}}\right)^2}{R}$$

$$= \frac{\frac{\mu^2 A_c^2}{4\times 2}}{R}$$

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

∴ The average total power,

$$P_T = P_c + P_{USB} + P_{LSB}$$

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

$$= \frac{A_c^2}{2R}\left[1 + \frac{\mu^2}{4} + \frac{\mu^2}{4}\right]$$

$$\boxed{\frac{\mu^2}{4} + \frac{\mu^2}{4} = \frac{\mu^2}{2}}$$

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

For 100% modulation $\mu = 1$, we have

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

$$P_T = P_C\left[\frac{2+1}{2}\right]$$

$$= P_C\left[\frac{3}{2}\right]$$

$$\boxed{P_T = 1.5\,P_C}$$

NOTE:-

$$P_T = 1.5\,P_C$$

$$P_C = \frac{1}{1.5}\,P_T$$

$$\boxed{P_C = 0.666\,P_T}$$

In Amplitude modulated wave, the 66.66% of the transmitted power is used by the carrier signal and remaining 33.33% of the power is used by the sidebands (P_{USB} & P_{LSB}).

- **Derive the followings:**
  - **i. Modulation index interms of P_T and P_C.**
  - **ii. Current relation of AM wave.**
  - **iii. Modulating index interms of I_T and I_C.**
  - **iv. Voltage relation of AM wave.**
  - **v. Modulation index interms of V_T and V_C.**

i) Modulation Index interms of P_T & P_C :-

W.K.T $$P_T = P_C\left[1+\frac{\mu^2}{2}\right]$$

$$\frac{P_T}{P_C} = 1+\frac{\mu^2}{2}$$

$$\frac{\mu^2}{2} = \frac{P_T}{P_C} - 1$$

$$\mu^2 = 2\left[\frac{P_T}{P_c} - 1\right]$$

$$\boxed{\mu = \sqrt{2\left[\frac{P_T}{P_c} - 1\right]}}$$

ii) Current relation of AM Wave :-

Let $I_T \rightarrow$ Total Current

$I_c \rightarrow$ Carrier Current

W.K.T $\quad P = I^2 R$

$|||^{ly}$ $\quad P_T = I_T^2 R$ and

$P_c = I_c^2 R.$

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

$$I_T^2 \cancel{R} = I_c^2 \cancel{R}\left[1 + \frac{\mu^2}{2}\right]$$

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

$$I_T = \sqrt{I_c^2\left[1 + \frac{\mu^2}{2}\right]}$$

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

iii) Modulation Index interms of I_T & I_c :-

W.K.T

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

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

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

$$\frac{\mu^2}{2} = \left(\frac{I_T}{I_c}\right)^2 - 1$$

$$\mu^2 = 2\left(\frac{I_T}{I_c}\right)^2 - 1$$

$$\boxed{\mu^2 = \sqrt{2\left(\frac{I_T}{I_c}\right)^2 - 1}}$$

iv) Voltage relation of AM Wave :-

Let $A_T = V_T$ = Total voltage &

$A_c = V_c$ = Carrier voltage.

$\boxed{V = A}$

$A_T = V_T$

$A_c = V_c$

W.K.T $\quad P = \frac{V^2}{R}$

$\parallel^{ly}$ $\quad P_T = \frac{A_T^2}{R}$ &

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

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

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

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

$$\boxed{A_T = A_c\sqrt{1+\left[\mu^2/2\right]}}$$

v) Modulation Index interms of A_T & A_c.

W.K.T $\quad A_T = \sqrt{A_c^2\left[1+\mu^2/2\right]}$

$$A_T^2 = A_c^2\left[1+\mu^2/2\right]$$

$$1+\frac{\mu^2}{2} = \left(\frac{A_T}{A_c}\right)^2$$

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

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

$$\boxed{\mu = \sqrt{2\left[A_T/A_c\right]^2 - 1}}$$

❖ **Derive modulation index using AM wave.**

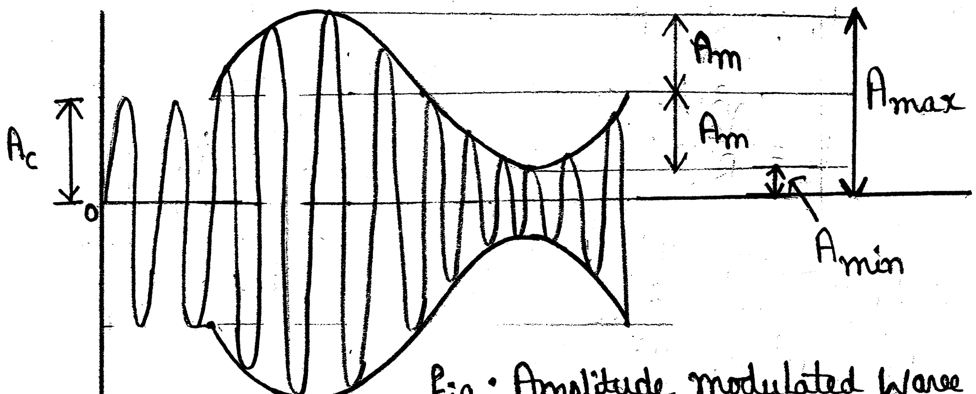


Fig : Amplitude modulated Wave

We can calculate the modulation Index from the amplitude modulate wave.

W.K.T $\boxed{\mu = \frac{A_m}{A_c}}$

From figure,

$$\boxed{A_m = \frac{A_{max} - A_{min}}{2}} \rightarrow (1)$$

$$A_c = A_{max} - A_m \rightarrow (2)$$

Substituting equation (1) in equation (2)

$$A_c = A_{max} - \left[\frac{A_{max} - A_{min}}{2}\right]$$

$$A_c = \frac{2A_{max} - A_{max} + A_{min}}{2}$$

$$\boxed{A_c = \frac{A_{max} + A_{min}}{2}}$$

$$\therefore \mu = \frac{A_m}{A_c} = \frac{A_{max} - A_{min}/\cancel{2}}{A_{max} + A_{min}/\cancel{2}}$$

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

❖ **Explain amplitude modulation for single tone information.**

A Single-tone modulating Signal $m(t)$ has a Single (tone) Frequency Component 'f_m' and is defined as follows:

$$\boxed{m(t) = A_m \cos(2\pi f_m t)} \rightarrow (1)$$

Where A_m is the amplitude of the modulating wave and f_m is the frequency of the modulating wave.

Let $$\boxed{c(t) = A_c \cos(2\pi f_c t)} \rightarrow (2)$$

Where A_c is the amplitude of the carrier wave and f_c is the frequency of the carrier wave.

* The time-domain expression for the Standard AM wave is

$$\boxed{S(t) = A_c[1 + K_a m(t)] \cos 2\pi f_c t} \rightarrow (3)$$

Substituting eq (1) in eq (3), we get

$$S(t) = A_c[1 + K_a A_m \cos 2\pi f_m t] \cos 2\pi f_c t$$

Since, the modulation Index $\boxed{\mu = K_a A_m}$

We get

$$S(t) = A_c[1 + \mu \cos 2\pi f_m t] \cos 2\pi f_c t. \rightarrow (4)$$

equation (4) Can be further expanded, by means of the trigonometric-al relation

$$\boxed{\cos a . \cos b = \frac{1}{2} \cos(a-b) + \frac{1}{2} \cos(a+b)}$$

$$S(t) = A_c \cos(2\pi f_c t) + \mu A_c \underbrace{\cos(2\pi f_c t)}_{\cos a} \cdot \underbrace{\cos(2\pi f_m t)}_{\cos b}$$

$$S(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2} \cos[2\pi f_c - 2\pi f_m]t + \frac{\mu A_c}{2} \cos[2\pi f_c + 2\pi f_m]t \rightarrow (5)$$

Taking Fourier transform on both sides of eq (5), we get

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

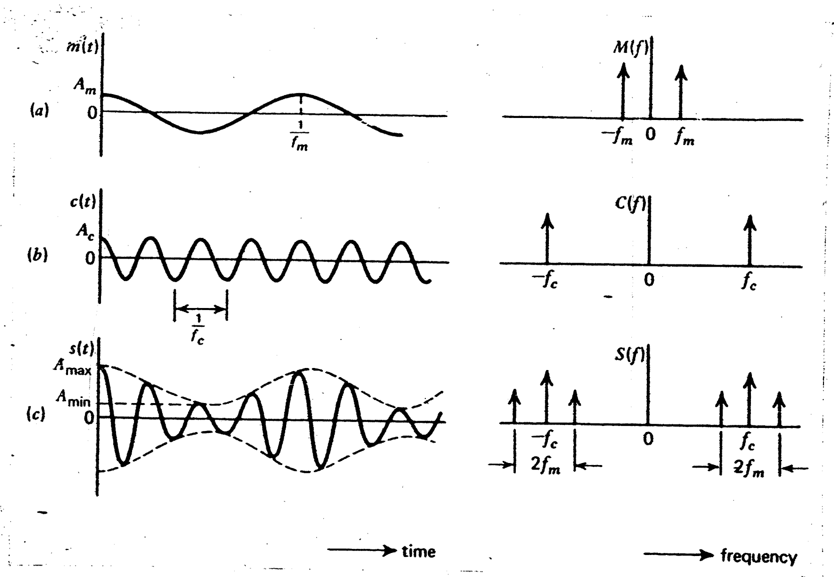


fig (1) Illustrating the time-domain (on the left) and frequency domain (on the right) characteristics of a standard amplitude modulation produced by a single tone.
(a) Modulating wave (b) Carrier wave (c) AM wave.

* In practice, the AM wave $s(t)$ is a voltage or current wave. The average power delivered by an AM wave to a 1-ohm resistor is calculated as follows:

Average carrier power 'P_c' $= \frac{A_c^2}{2}$

'P_{USB}', Upper Side-frequency power $= \frac{\mu^2 A_c^2}{8}$

'P_{LSB}', Lower Side-frequency power $= \frac{\mu^2 A_c^2}{8}$

The transmission efficiency 'η' is the ratio of the total Sideband power to the total power in the modulated wave

$$\eta = \frac{\text{Power in Sidebands}}{\text{Total power } (P_T)} = \frac{P_{USB} + P_{LSB}}{P_c\left[1+\frac{\mu^2}{2}\right]}$$

$$= \frac{\frac{\mu^2 A_c^2}{8} + \frac{\mu A_c^2}{8}}{P_c\left[1+\mu^2/2\right]} = \frac{\frac{\cancel{2}\,\mu^2 A_c^2}{4\,\cancel{8}}}{P_c\left[\frac{2+\mu^2}{2}\right]}$$

$$= \frac{\frac{\mu^2 A_c^2}{4}}{P_c\left[\frac{2+\mu^2}{2}\right]} = \frac{\frac{\mu^2}{2}\left[\frac{A_c^2}{2}\right]}{P_c\left[\frac{2+\mu^2}{2}\right]}$$

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

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

If $\mu=1$, that is, 100 percent modulation is used, the total power in the two side frequencies of the resulting AM wave is only $1/3^{rd}$ of the total power in the modulated wave as shown in fig ②.

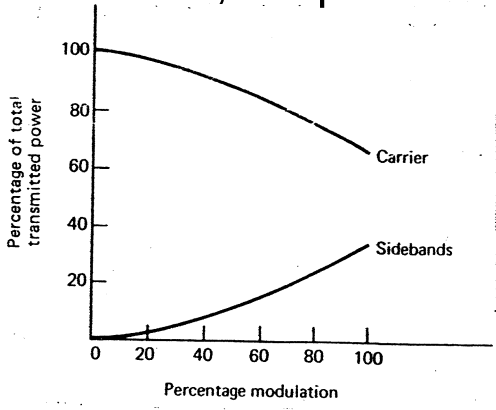


Fig (2) variations of carrier power and total sideband power with percentage modulation.

❖ **A multitone modulating signal has the following time-domain form:**

$m(t)=E_1\cos 2\pi f_1 t + E_2\cos 2\pi f_2 t + E_3\cos 2\pi f_3 t$ volts **where $E_1 > E_2 > E_3$**

$f_3 > f_2 > f_1$

i. **Give the time – domain expression for the conventional AM wave.**

ii. **Draw the amplitude spectrum for the AM wave obtained in part i. Also find the minimum transmission bandwidth.**

Sol:-

(a) The time-domain expression for the conventional AM wave is

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

Substituting the value of m(t) in eq (1), we get

$$S(t) = A_c[1+\underline{K_a E_1}\cos 2\pi f_1 t + \underline{K_a E_2}\cos 2\pi f_2 t + \underline{K_a E_3}\cos 2\pi f_3 t] \times \cos 2\pi f_c t$$

W.K.T, $\mu_1 = K_a E_1$, $\mu_2 = K_a E_2$ & $\mu_3 = K_a E_3$

$$S(t) = A_c[1+\mu_1\cos 2\pi f_1 t + \mu_2\cos 2\pi f_2 t + \mu_3\cos 2\pi f_3 t]\cos 2\pi f_c t.$$

$$S(t) = A_c\cos 2\pi f_c t + \mu_1 A_c\cos 2\pi f_c t.\cos 2\pi f_1 t + \mu_2 A_c\cos 2\pi f_c t.\cos 2\pi f_2 t + \mu_3 A_c\cos 2\pi f_c t.\cos 2\pi f_3 t$$

W.K.T

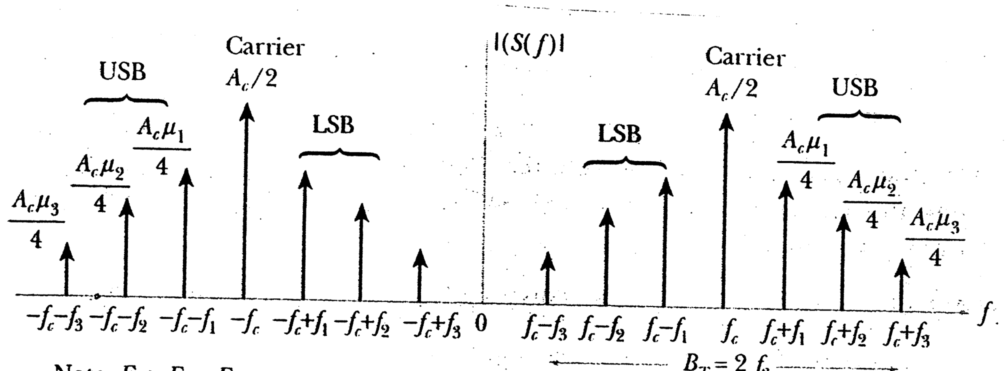
$$\boxed{\cos A.\cos B = \frac{1}{2}\cos(A+B) + \frac{1}{2}\cos(A-B)}$$

$$s(t) = A_c \cos 2\pi f_c t + \frac{\mu_1 A_c}{2}\cos 2\pi(f_c - f_1)t + \frac{\mu_1 A_c}{2}\cos 2\pi(f_c+f_1)t$$
$$+ \frac{\mu_2 A_c}{2}\cos 2\pi(f_c - f_2)t + \frac{\mu_2 A_c}{2}\cos 2\pi(f_c+f_2)t$$
$$+ \frac{\mu_3 A_c}{2}\cos 2\pi(f_c - f_3)t + \frac{\mu_3 A_c}{2}\cos 2\pi(f_c+f_3)t \rightarrow (2)$$

b) Taking Fourier transform on both sides of equation (2), we get

$$S(f) = \frac{A_c}{2}\left[\delta(f-f_c)+\delta(f+f_c)\right] + \frac{\mu_1 A_c}{4}\left\{\delta[f-(f_c-f_1)]+\delta[f+(f_c-f_1)]\right\}$$
$$+ \frac{\mu_1 A_c}{4}\left\{\delta[f-(f_c+f_1)]+\delta[f+(f_c+f_1)]\right\} + \frac{\mu_2 A_c}{4}\left\{\delta[f-(f_c-f_2)]+\delta[f+(f_c-f_2)]\right\}$$
$$+ \frac{\mu_2 A_c}{4}\left\{\delta[f-(f_c+f_2)]+\delta[f+(f_c+f_2)]\right\} + \frac{\mu_3 A_c}{4}\left\{\delta[f-(f_c-f_3)]+\delta[f+(f_c-f_3)]\right\}$$
$$+ \frac{\mu_3 A_c}{4}\left\{\delta[f-(f_c+f_3)]+\delta[f+(f_c+f_3)]\right\}$$

The amplitude spectrum is shown below



Note: $E_1 > E_2 > E_3 \Longrightarrow \mu_1 > \mu_2 > \mu_3$

The maximum frequency is f_3.

$\therefore$ The transmission bandwidth $\boxed{B_T = 2f_3}$

❖ **Derive an expression for multitone amplitude modulation, total transmitted power and total modulation index.**

W.K.T an amplitude modulated wave is expressed as:

$$S(t) = A_c\left[1+K_a m(t)\right]\cos 2\pi f_c t.$$

For simplicity consider two modulating signal:

$$m_1(t) = A_{m1}\cos 2\pi f_{m1} t$$

$$m_2(t) = A_{m2}\cos 2\pi f_{m2} t.$$

$$\therefore\; S(t) = A_c\left[1+K_a\left(m_1(t)+m_2(t)\right)\right]\cos 2\pi f_c t.$$

$$= A_c\left[1+K_a\left(A_{m1}\cos 2\pi f_{m1}t + A_{m2}\cos 2\pi f_{m2} t\right)\right]\cos 2\pi f_c t.$$

$$= A_c\left[1+\underbrace{K_a A_{m1}}_{\mu_1}\cos 2\pi f_{m1} t + \underbrace{K_a A_{m2}}_{\mu_2}\cos 2\pi f_{m2} t\right]\cos 2\pi f_c t.$$

$$S(t) = A_c\left[1+\mu_1\cos 2\pi f_{m1} t + \mu_2\cos 2\pi f_{m2} t\right]\cos 2\pi f_c t.$$

$$S(t) = A_c\cos 2\pi f_c t + \mu_1 A_c\cos 2\pi f_c t\cdot\cos 2\pi f_{m1} t + \mu_2 A_c\cos 2\pi f_c t\cdot\cos 2\pi f_{m2} t$$

W.K.T

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

$$S(t) = A_c\cos 2\pi f_c t + \frac{\mu_1 A_c}{2}\cos 2\pi\left[f_c - f_{m1}\right]t + \frac{\mu_1 A_c}{2}\cos 2\pi\left[f_c+f_{m1}\right]t$$
$$+ \frac{\mu_2 A_c}{2}\cos 2\pi\left[f_c - f_{m2}\right]t + \frac{\mu_2 A_c}{2}\cos 2\pi\left[f_c+f_{m2}\right]t \rightarrow (5)$$

From equation (5) it is clear that, when we have two modulating frequencies, we get four additional frequencies, two upper-sidebands (USB) f_c+f_{m1}, f_c+f_{m2} and two lower sidebands 'LSB' f_c-f_{m1}, f_c-f_{m2}.

Total transmitted power:-

The total power in the amplitude modulated wave is calculated as follows:

$$P_T = P_c + P_{USB1} + P_{USB2} + P_{LSB1} + P_{LSB2}$$

$$= \frac{(A_c/\sqrt{2})^2}{R} + \frac{\mu_1 A_c^2}{8R} + \frac{\mu_1^2 A_c^2}{8R} + \frac{\mu_2^2 A_c^2}{8R} + \frac{\mu_2^2 A_c^2}{8R}$$

$$= \frac{A_c^2}{2R} + \cancel{2}\cdot\frac{\mu_1 A_c^2}{4\cancel{8}R} + \cancel{2}\cdot\frac{\mu_2^2 A_c}{4\cancel{8}R}$$

$$= \frac{A_c^2}{2R} + \frac{\mu_1^2 A_c^2}{4R} + \frac{\mu_2^2 A_c}{4R}$$

$$= \frac{A_c^2}{2R}\left[1 + \frac{\mu_1^2}{2} + \frac{\mu_2^2}{2}\right]$$

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

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

Where, $\frac{\mu_t^2}{\cancel{2}} = \frac{\mu_1^2}{\cancel{2}} + \frac{\mu_2^2}{\cancel{2}}$

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

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

In general, Total modulation index is given by

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

Generation of AM wave:-

There are two important methods of AM generation for low power applications:

1. Square Law Modulator
2. Switching Modulator.

❖ **Explain generation of AM wave using SQUARE- LAW modulator helps to produce AM wave. Derive the related equations and draw the waveforms** **July-05,8M**

❖ **Explain the generation of AM wave using SQUARE- LAW modulator along with relevant diagram & analysis.** **July-08,10M**

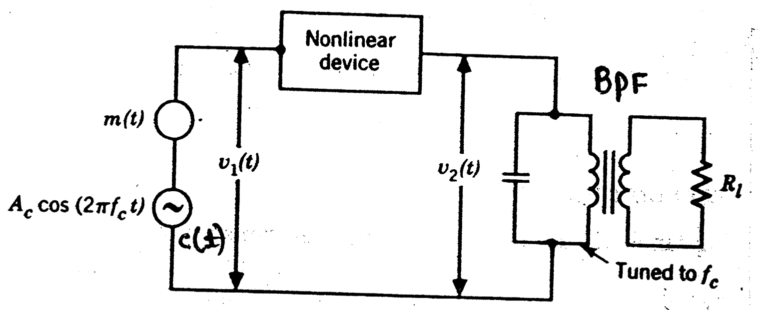


Fig ①: Square-law modulator.

The Square-law modulator consists of three elements:

1) Summer: It adds the carrier and modulating signal.

2) Non-linear device: A device with non-linear I/p-o/p relation.

3) Band pass filter (BPF): It extract desired signal (term) from modulator product.

* The semiconductor diodes or transistor can be used as non-linear element and single or double tuned circuit can be

used as the filter.

* When a non-linear element such as diode is suitably biased and the signal applied is relatively weak, it is possible to approximate the transfer characteristics as:

$$\boxed{V_2(t) = a_1 V_1(t) + a_2 V_1^2(t)} \longrightarrow ①$$

Where a_1 and a_2 are constants.

* The I/p voltage '$V_1(t)$' is the sum of carrier signal and modulating signal.

i.e. $$\boxed{V_1(t) = A_c \cos 2\pi f_c t + m(t)} \longrightarrow ②$$

Substituting equation ② in equation ①

$$V_2(t) = a_1\left[A_c \cos 2\pi f_c t + m(t)\right] + a_2\left[A_c \cos 2\pi f_c t + m(t)\right]^2$$

W.K.T $$\boxed{(a+b)^2 = a^2 + b^2 + 2ab}$$

$$V_2(t) = a_1 A_c \cos 2\pi f_c t + a_1 m(t) + a_2\left[A_c^2 \cos^2 2\pi f_c t + m^2(t) + 2m(t).A_c \cos 2\pi f_c t\right]$$

$$V_2(t) = \underline{a_1 A_c \cos 2\pi f_c t} + a_1 m(t) + a_2 A_c^2 \cos^2 2\pi f_c t + a_2 m^2(t) + \underline{2a_2 m(t).A_c \cos 2\pi f_c t}.$$

$$V_2(t) = a_1 A_c \cos 2\pi f_c t + 2a_2 m(t) A_c \cos 2\pi f_c t + a_1 m(t) + a_2 A_c^2 \cos^2 2\pi f_c t + a_2 m^2(t).$$

$$= \underbrace{a_1 A_c\left[1 + \frac{2a_2}{a_1} m(t)\right] \cos 2\pi f_c t}_{\text{AM Wave}} + \underbrace{a_1 m(t) + a_2 A_c^2 \cos^2 2\pi f_c t + a_2 m^2(t)}_{\text{unwanted terms}} \to ③$$

* The first term of equation (3) is the desired AM wave with $K_a = \frac{2a_2}{a_1}$, amplitude sensitivity of the AM wave.

* The remaining three terms are unwanted and are removed by appropriate filtering.

$$\therefore \; S(t) = a_1 A_c [1 + K_a m(t)] \cos 2\pi f_c t.$$

❖ **With a neat block diagram, relevant waveforms and expressions explain generation of AM wave using SWITCHING MODULATOR**

Jan-08,10M

❖ **Explain the generation of AM wave using SWITCHING MODULATOR with relevant equations waveforms and spectrum before and after filtering process.** **Jan-07,10M Jan-05,6M July-07,10M July-08,6M July-09,8M Jan-10,10M June-107M July-09,8M**

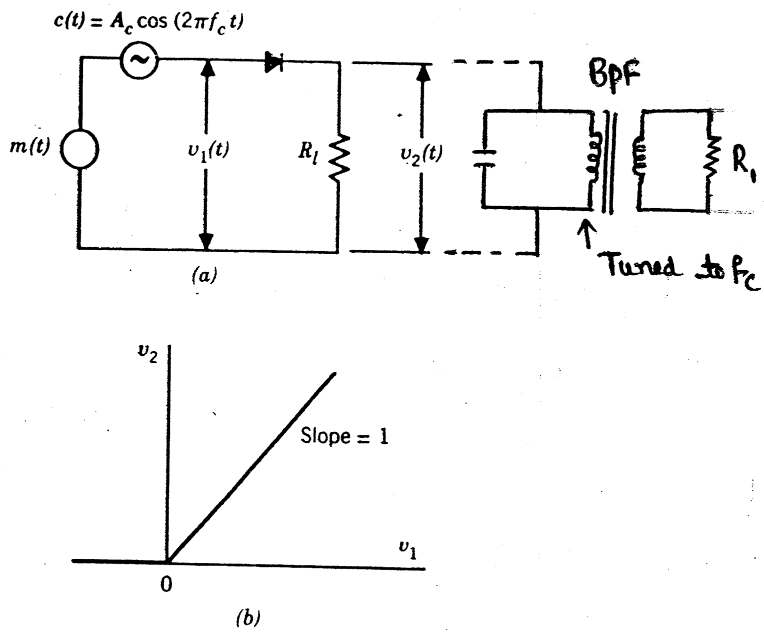


fig (1)

Switching modulator. (a) Circuit diagram. (b) Idealized input–output relation.

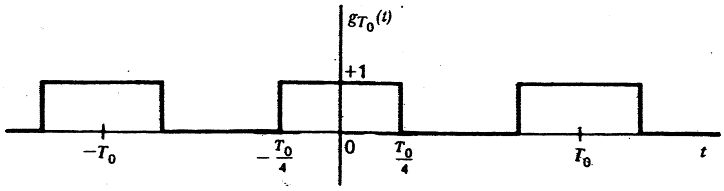


fig (2) Periodic pulse train.

* Consider a Semiconductor diode used as an ideal Switch to which a carrier wave $c(t)$ and an message Signal $m(t)$ are Simultaneously applied as Shown in fig (1).

* It is assumed that the carrier wave $c(t)$ applied to the diode is large in amplitude.

  The total I/p '$V_1(t)$' to the diode is given by

$$V_1(t) = m(t) + c(t)$$

$$\boxed{V_1(t) = m(t) + A_c \cos 2\pi f_c t} \longrightarrow (1)$$

Where $|m(t)| \ll A_c$.

* The o/p of the diode is

$$V_2(t) = \begin{cases} V_1(t), & c(t) > 0 \\ 0, & c(t) < 0 \end{cases}$$

i.e. the o/p of the diode varies between 0 & V_1 at a rate equal to carrier frequency $T_0 = \frac{1}{f_c}$.

* The non-linear behavior of the diode can be replaced by assuming the weak modulating Signal compared with the carrier wave. Thus the o/p of the diode is approximately equivalent to linear-time varying operation.

Mathematically, the o/p of the diode can be written as:

$$V_2(t) = V_1(t) \cdot g_p(t) \rightarrow (2)$$

$$V_2(t) = [m(t) + A_c \cos 2\pi f_c t]\, g_p(t) \rightarrow (3)$$

Where $g_p(t)$ (fig 2) is a rectangular pulse train with a period equal to $T_0 = 1/f_c$.

Representing $g_p(t)$ by its Fourier Series, we have

$$g_p(t) = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos[2\pi f_c (2n-1) t]$$

$$g_p(t) = \frac{1}{2} + \underbrace{\frac{2}{\pi} \cos 2\pi f_c t}_{n=1} + \text{odd harmonic components} \rightarrow (4)$$

Substituting equation (4) in equation (3)

$$V_2(t) = [m(t) + A_c \cos 2\pi f_c t]\left[\frac{1}{2} + \frac{2}{\pi} \cos 2\pi f_c t + \ldots\right]$$

$$V_2(t) = \frac{1}{2} m(t) + \frac{2m(t)}{\pi} \cos 2\pi f_c t + \frac{A_c}{2} \cos 2\pi f_c t + \frac{2A_c}{\pi} \underline{\cos^2 2\pi f_c t} + \ldots$$

W.K.T

$$\boxed{\cos^2\theta = \frac{1}{2} + \frac{\cos 2\theta}{2}}$$

$$V_2(t) = \frac{m(t)}{2} + \frac{2m(t)}{\pi} \cos 2\pi f_c t + \frac{A_c}{2} \cos 2\pi f_c t + \frac{2A_c}{\pi}\left[\frac{1}{2} + \frac{\cos 2[2\pi f_c t]}{2}\right]$$

$$V_2(t) = \frac{m(t)}{2} + \frac{2m(t)}{\pi} \cos 2\pi f_c t + \frac{A_c}{2} \cos 2\pi f_c t + \frac{\cancel{2}A_c}{\cancel{2}\pi} + \frac{\cancel{2}A_c \cos 4\pi f_c t}{\cancel{2}}$$

$$V_2(t) = \frac{m(t)}{2} + \frac{2m(t)}{\pi} \cos 2\pi f_c t + \frac{A_c}{2} \cos 2\pi f_c t + \frac{A_c}{\pi} + A_c \cos 4\pi f_c t + \ldots \rightarrow (5)$$

* The required AM wave centred at f_c is obtained by passing '$V_2(t)$' through an ideal 'BPF' having a centre frequency 'f_c' and bandwidth $B_T = 2W$ Hz.

* The o/p of the BPF is

$$V_2'(t) = \frac{2}{\pi} m(t) \cos 2\pi f_c t + \underline{\frac{A_c}{2} \cos 2\pi f_c t}.$$

$$V_2'(t) = \frac{A_c}{2} \cos 2\pi f_c t \left[1 + \frac{2 \cdot 2}{\pi A_c} m(t) \right]$$

$$= \frac{A_c}{2} \cos 2\pi f_c t \left[1 + \frac{4}{\pi A_c} m(t) \right]$$

Where $K_a = \frac{4}{\pi A_c}$ amplitude Sensitivity

$$\boxed{V_2'(t) = \frac{A_c}{2} \cos 2\pi f_c t \left[1 + K_a m(t) \right]}$$

Define Demodulation ? Mention different types of AM demodulation (OR Detection)

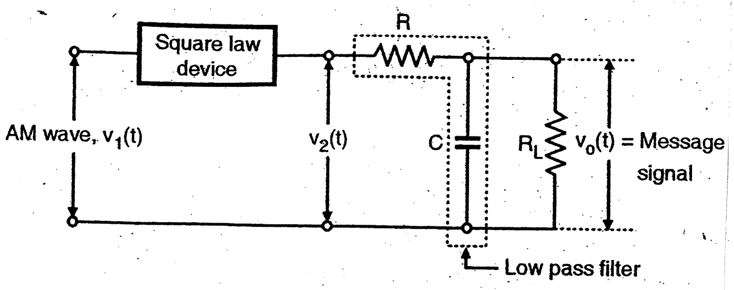
Demodulation or detection is the process of recovering the original message signal from the modulated wave at the receiver. Demodulation is the inverse of the modulation process.

There are two types of detectors :

1) Square-law demodulator
2) Envelope detector.

❖ **Show that a SQUARE LAW device can be used for the detection of an AM wave.** **Jan-07,6M**

❖ **Show that a SQUARE LAW can be used for the detection of an AM wave.** **June-10,6M**



A square law detector

* A Square-law detector is essentially obtained by using a square-law modulator for the purpose of detection.

* An AM Signal can be demodulated by Squaring it and then passing the squared signal through a Low pass filter (LPF)

The transfer characteristics of a non-linear device is given by:

$$\boxed{V_2(t) = a_1 V_1(t) + a_2 V_1^2(t)} \longrightarrow ①$$

Where,

$V_1(t) \rightarrow$ I/p voltage

$V_2(t) \rightarrow$ O/p voltage

a_1 and $a_2 \rightarrow$ are Constants.

* The I/p voltage of the AM wave is given by

$$\boxed{V_1(t) = A_c[1 + K_a m(t)] \cos 2\pi f_c t} \longrightarrow ②$$

Substituting equation ② in equation ①, we get

$$V_2(t) = a_1\{A_c[1+K_a m(t)]\cos 2\pi f_c t\} + a_2\{A_c[1+K_a m(t)]\cos 2\pi f_c t\}^2$$

$$V_2(t) = a_1 A_c[1+K_a m(t)]\cos 2\pi f_c t + a_2\{A_c^2[1+K_a m(t)]^2\cos^2 2\pi f_c t\}$$

W.K.T

$$\boxed{(a+b)^2 = a^2+b^2+2ab} \quad \text{and} \quad \boxed{\cos^2\theta = \frac{1+\cos 2\theta}{2}}$$

$$V_2(t) = a_1 A_c[1+K_a m(t)]\cos 2\pi f_c t + a_2 A_c^2 \cos^2 2\pi f_c t\,[1^2+K_a^2 m^2(t)+2K_a m(t)]$$

$$V_2(t) = a_1 A_c[1+K_a m(t)]\cos 2\pi f_c t + a_2 A_c^2\left[\frac{1+\cos 2(2\pi f_c t)}{2}\right][1+K_a^2 m^2(t) + 2K_a m(t)]$$

$$V_2(t) = a_1 A_c[1+K_a m(t)]\cos 2\pi f_c t + \frac{a_2 A_c^2}{2}[1+K_a^2 m^2(t)+2K_a m(t)](1+\cos 4\pi f_c t) \rightarrow ③$$

* In eq ③ $\frac{a_2 A_c^2}{\cancel{2}}\cancel{2}K_a m(t)$ is the desired term which is due to the $a_2 V_1^2$ term. Hence the name of this detector is - Square law detector.

* The desired term is extracted by using a LPF (fig). Thus the o/p of LPF is $\boxed{V_0(t) = a_2 A_c^2 K_a m(t)}$

Thus the message signal m(t) is recovered at the o/p of the message signal.

Distortion in the detector o/p :-

* The other term which passes through the LPF to the load resistance R_L is as follows : $\frac{1}{2}a_2 A_c^2 K_a^2 m^2(t)$.

* This is an unwanted signal & gives rise to a signal distortion.

The ratio of desired signal to the undesired one is given by:

$$D = \frac{\cancel{a_2} \cancel{A_c^2} \cancel{K_a} \cancel{m(t)}}{\frac{1}{2} \cancel{a_2} \cancel{A_c^2} K_a^{\cancel{2}} m^{\cancel{2}}(t)} = \frac{1}{\frac{1}{2} K_a m(t)} = \frac{2}{K_a m(t)}$$

{

We should maximize this ratio in order to minimize the distortion. To achieve this we should choose $|K_a m(t)|$ small as compared to unity for all values of t. If K_a is small then the AM wave is weak.

}

Envelope Detector:

❖ **How a modulating signal can be detected using a AM detector? Use a envelope detector and explain.** **July-05,8M**

❖ **Explain the detection of message signal from amplitude modulated signal using an envelope detector & bring out the significance of RC time constant**

July-09,6M	**July-07,5M**	**June-09,6M**	**July-06,5M**

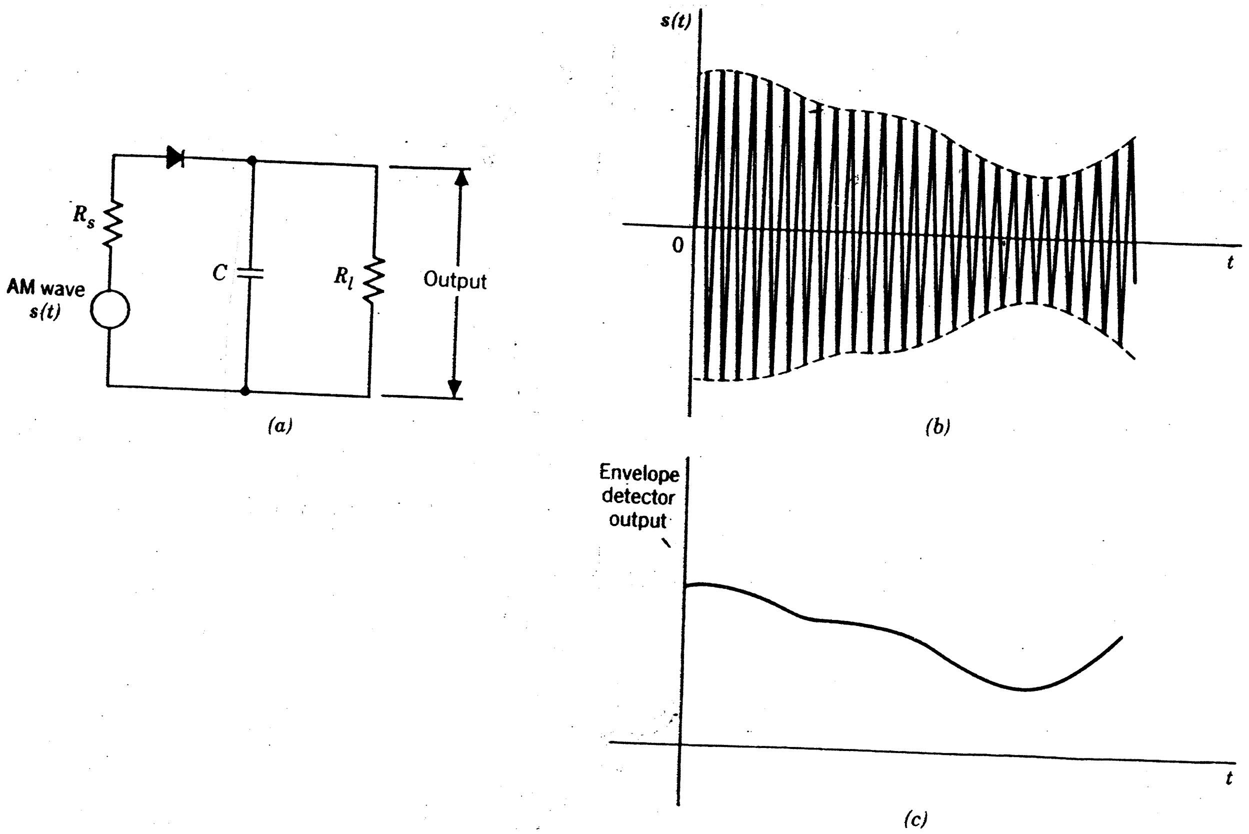


Figure
Envelope detector. (a) Circuit diagram. (b) AM wave input. (c) Envelope detector output.

* Envelope detector is a simple and highly effective device used to demodulate AM wave. It consists of a diode and a resistor capacitor (RC) filter.

operation :-

During positive half cycle of the I/p Signal, diode is forward-biased and the capacitor 'C' charges upto the peak-value of the I/p Signal. When the I/p voltage falls below this value the diode becomes reverse biased and capacitor 'C' discharges slowly through the load resistor R_L. As a result only positive half cycle of AM wave appears across R_L.

The discharging process continues until the next positive half cycle. When the I/p Signal becomes greater than the voltage across the capacitor, the diode conducts again and the process is repeated.

Selection of the RC time Constant :-

* The capacitor charges through 'D' & R_S when the diode is 'ON' & it discharges through 'R_L' when diode is OFF.
* The charging time constant R_SC should be short as compared to the carrier period $1/f_c$ $\therefore$ $\boxed{R_SC \ll \frac{1}{f_c}}$ So capacitor 'C' charges rapidly.
* on the other hand the discharging time constant R_LC should be long enough to ensure that the capacitor discharges slowly through the load resistance 'R_L' b/w +ve peak of the carrier wave

i.e. $\boxed{\frac{1}{f_c} \ll R_LC \ll \frac{1}{W}}$, Where W = Maximum modulating frequency.

Result is that the capacitor voltage or detector o/p is very nearly the same as the envelope of AM wave. The detector o/p usually has a small ripple at the carrier frequency. This ripple is easily removed by Low pass filter.

Advantages of AM:-

1) AM Txer's are less complex
2) AM receivers are simple, detection is easy.
3) AM receivers are cost efficient.
4) AM waves can travel a longer bandwidth.
5) Low bandwidth.

* Mention the disadvantages of AM wave.

OR

* Mention the Limitation of DSB-FC Wave (AM)

The disadvantages of AM waves are:

1) power is wasted in the transmitted signal.
2) AM needs larger bandwidth
3) AM waves gets affected due to noise.

* Applications of AM:-

1) Radio broadcasting
2) Picture transmission in a TV system.

Explain the disadvantages & limitation of AM Wave (DSB-FC)

Amplitude modulation has several disadvantages:

1) Power is wasted in the transmitted signal

* Most of the transmitted power is in the carrier, which does not carry any information.
* For 100% modulation i.e. $\mu = 1$, only 33.33% ($1/3^{rd}$) of the total power will be in sidebands which carries information and 66.67% ($2/3^{rd}$) of the total power will be in the carrier, which does not contain any information.

2) The DSB-FC system is bandwidth inefficient system.
The transmitted signal requires twice the bandwidth of the message signal i.e. $B_T = 2f_m$. This is due to the transmission of both the sidebands, out of which only one sideband is sufficient to convey all the information. Thus the bandwidth of DSB-FC is double than actually required.

3) AM wave gets affected due to noise:-

When the AM wave travels from the transmitter to receiver over a communication channel, noise gets added to it. The noise will change the amplitude of the envelope of AM in a random manner. As the information is contained in the amplitude variations of the AM wave, the noise will contaminate the information contents in the AM. Hence the performance of AM is very poor in presence of noise.

Power Wastage in AM (DSB-FC)

* power wastage due to DSB-FC (AM) transmission.

W.K.T, the total power transmitted by an AM wave is given by

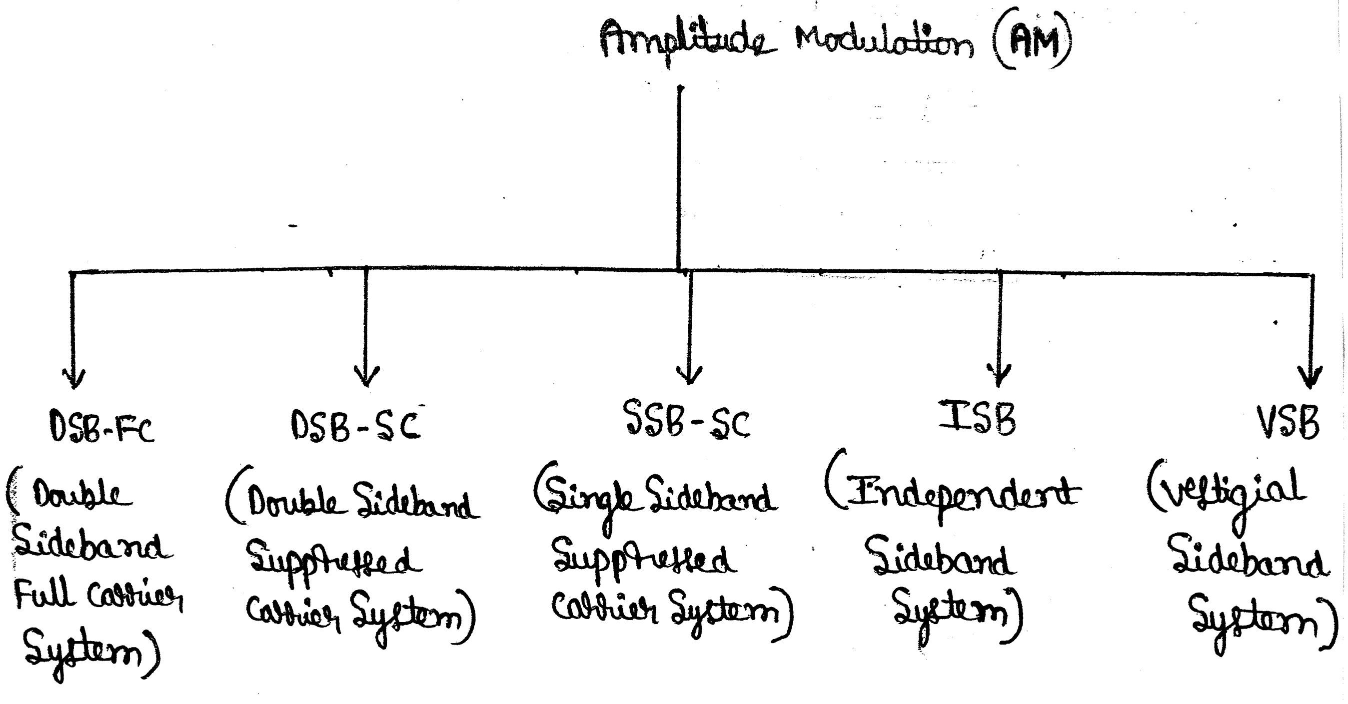
$$P_T = P_c + P_{USB} + P_{LSB} \rightarrow ①$$

$$P_T = P_c + \frac{\mu^2}{4} P_c + \frac{\mu^2}{4} P_c \rightarrow ②$$

In equation ②, Carrier Component doesnot Contain any information & one Sideband is redundant. So out of the total power, $P_T = P_c\left[1+\frac{\mu^2}{2}\right]$, the wasted power is given by:

$$\text{Power wastage} = P_c + \frac{\mu^2}{4} P_c$$

other types of Amplitude Modulation :-



❖What is DSB-SC modulation? Explain the time and frequency domain expression of DSB-SC wave.

To overcome the drawback of power wastage in AM wave (DSB-FC) an DSB-SC method is used.

* DSB-SC is a method of transmission where only the TWO Sidebands are transmitted without the Carrier (Suppressing Carrier)

OR

The Conventional AM wave in which the carrier is Suppressed is called DSB-SC modulation.

Time domain representation of DSB-SC Wave:-

* Let m(t) be the message Signal having a bandwidth equal to 'W' Hz and

$c(t) = A_c \cos 2\pi f_c t$ represents the carrier, then the time-domain expression for DSB-SC wave is

$$S(t) = m(t)\, c(t)$$

$$\boxed{S(t) = A_c \cos(2\pi f_c t)\, m(t)} \rightarrow (1)$$

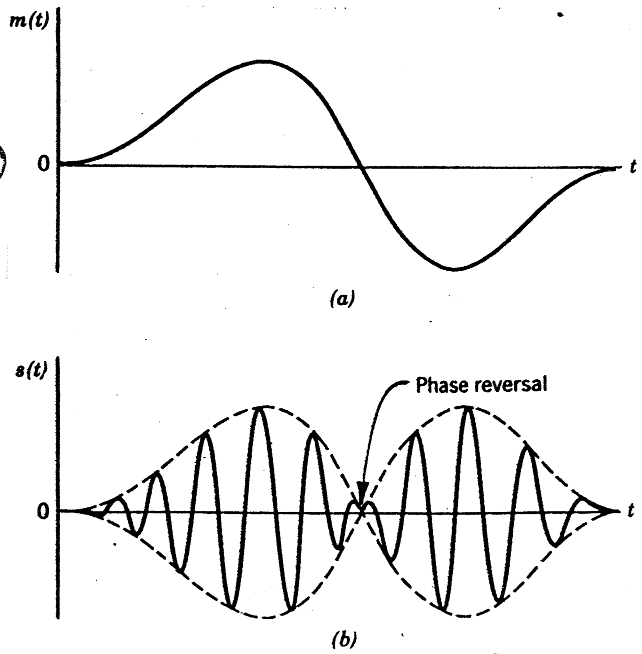


Figure
(a) Message signal. (b) DSBSC-modulated wave s(t).

* The S(t) Signal undergoes a phase reversal whenever the message Signal crosses Zero.

Frequency-Domain Description :-

Taking Fourier transform on both Sides of equation ②, we get

$$\boxed{S(f) = \frac{A_c}{2}\left[M(f-f_c) + M(f+f_c)\right]} \longrightarrow (3)$$

Where S(f) is the Fourier transform of the modulated wave S(t)

M(f) is the Fourier transform of the message Signal m(t).

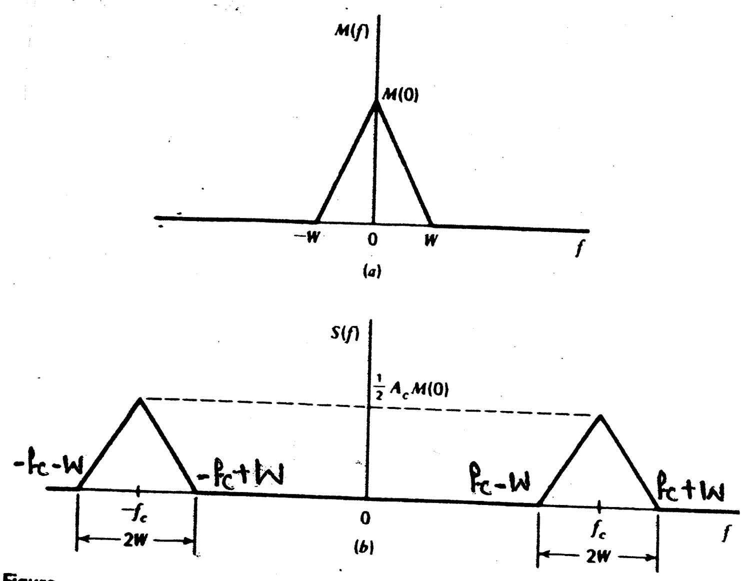


Figure
(a) Spectrum of message signal. (b) Spectrum of DSBSC modulated wave.

The amplitude Spectrum drawn above exhibits the following facts

i) on either Sides of $\pm f_c$, we have two Sidebands designated as Lower and upper Sidebands.

ii) The Impulse are absent at $\pm f_c$ in the amplitude Spectrum, Signifying the fact that the carrier term is Suppressed in the transmitted Wave.

iii) The minimum transmission bandwidth required is $2W$ i.e. twice the message bandwidth.

NOTE :- A DSB-SC Signal can be generated by a multiplier. A carrier Signal can be Suppressed by adding a carrier Signal opposite in phase but equal in magnitude to the amplitude modulated Wave, So the Carrier get Cancelled Finally double Sidebands are available in the DSB-SC Wave.

❖ **Explain DSB-SC modulation for single tone information.**

* Let $m(t) = A_m \cos 2\pi f_m t$ be the Single tone modulating Signal and

$$\boxed{c(t) = A_c \cos 2\pi f_c t}$$

be the Carrier Signal.

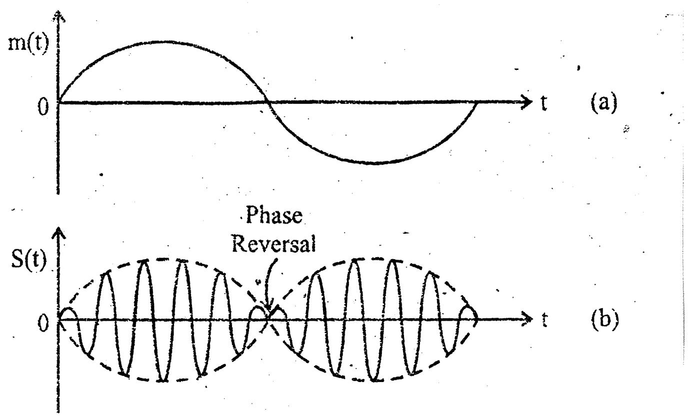


Fig. : (a) Modulating signal m(t); (b) DSBSC modulated wave s(t)

Then the time domain expression for the DSB-SC Wave is

$$S(t) = m(t) . c(t)$$

$$S(t) = A_m \cos 2\pi f_m t \cdot A_c \cos 2\pi f_c t$$

W.K.T.

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

$$\boxed{S(t) = \frac{A_m A_c}{2}\cos 2\pi(f_c - f_m)t + \frac{A_m A_c}{2}\cos 2\pi(f_c + f_m)t} \rightarrow (1)$$

Taking Fourier transform on both sides of the equation (1)

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

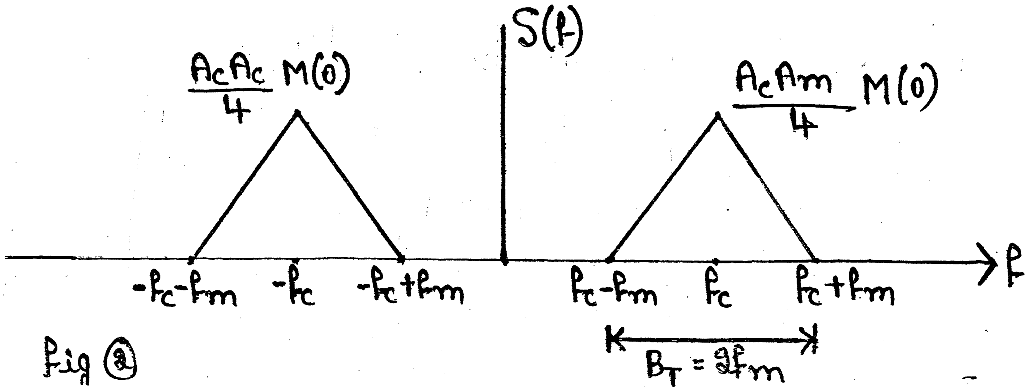
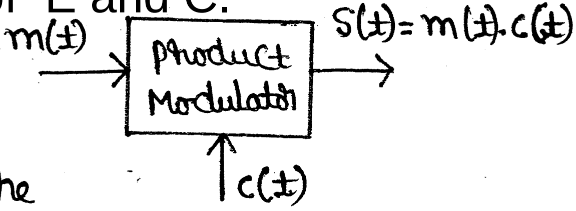


fig (2)

fig (2) shows amplitude spectrum of a DSB-SC signal. We observe that either side of $\pm f_c$, we have lower and upper sideband also the carrier term is suppressed in the spectrum as there are no impulses at $\pm f_c$.

* The minimum transmission bandwidth in DSB-SC is '$2f_m$'.

Generation of DSB-SC Wave:



* A DSB-SC wave simply consists of the product of the modulating signal and the carrier signal.

* The devices used to generate DSB-SC waves are known as the product modulators.

There are two types of modulators:

1) Balanced Modulator

2) Ring Modulator.

Balanced Modulator:

❖ **With a neat block diagram, explain the balanced modulator method of generating DSB-SC wave.** **June-10,6M**

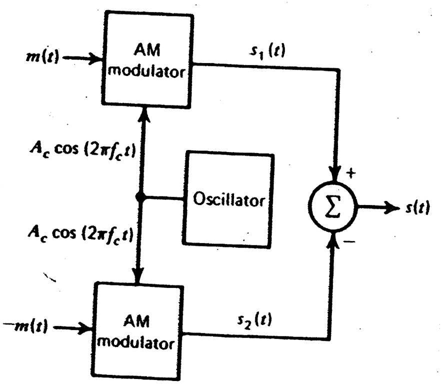


Figure
Balanced modulator.

Fig ① shows the block diagram of a balanced modulator used for generating a DSB-SC signal.

* It Consist of two amplitude modulators that are interconnected in such a way as to suppress the carrier.

* one I/p to the amplitude modulator is from an oscillator that generates a carrier wave. The second I/p to the amplitude modulator in the top path is the modulating signal $m(t)$ while in the bottom path is $-m(t)$.

. The o/p of the two AM modulator are as follows:

$$S_1(t) = A_c[1+K_a m(t)]\cos 2\pi f_c t \quad \text{and}$$

$$S_2(t) = A_c[1-K_a m(t)]\cos 2\pi f_c t.$$

The o/p of the summer is

$$S(t) = S_1(t) - S_2(t)$$

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

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

$$= \cancel{A_c\cos 2\pi f_c t} + A_c K_a m(t)\cos 2\pi f_c t - \cancel{A_c\cos 2\pi f_c t} + A_c K_a m(t)\cos 2\pi f_c t.$$

$$\boxed{S(t) = 2A_c K_a m(t)\cos 2\pi f_c t} \rightarrow (1)$$

* The balanced modulator o/p is equal to the product of the modulating signal $m(t)$ & carrier $c(t)$ except the scaling factor $2K_a$.

Taking Fourier Transform on both side of equation (1), we get

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

$$\boxed{S(f) = A_c K_a[M(f-f_c) + M(f+f_c)]}$$

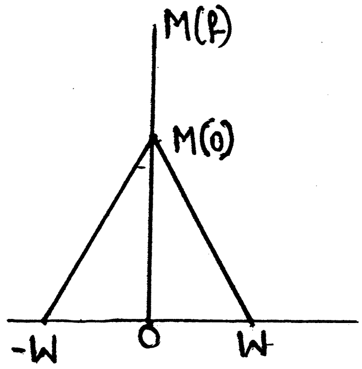


Fig ⓐ: Message Spectrum

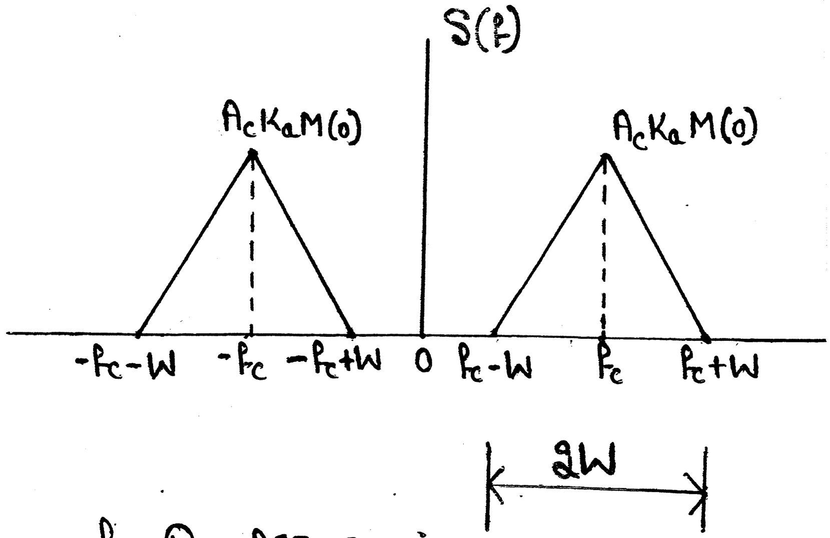


Fig ⓑ : DSB-SC Spectrum

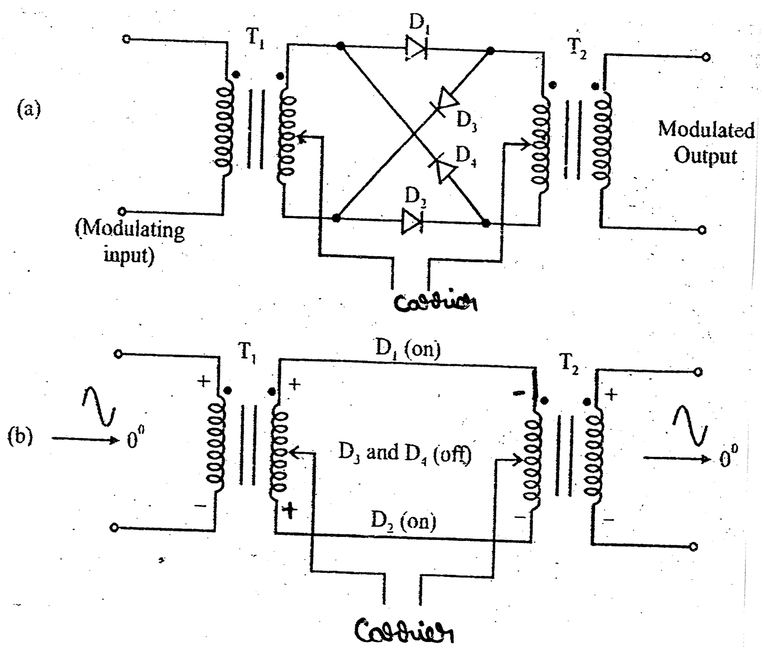
Since the carrier component is eliminated, the o/p is called DSB-SC Signal.

❖ **Explain how RING modulator can be used to generate DSB-SC modulation**

Jan-05,9M

❖ **Briefly explain generation of DSB-SC modulated wave using RING modulator. Give relevant mathematical expressions and waveforms.**

Jan-08,10M Jan-07,8M Jan-09,6M July-09,10M June-10,10m



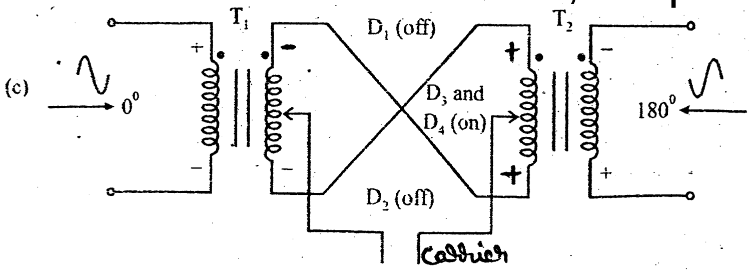


Fig. : (a) Balanced Ring Modulator
(b) Equivalent Circuit when square wave carrier positive
(c) Equivalence circuit when square wave carrier negative

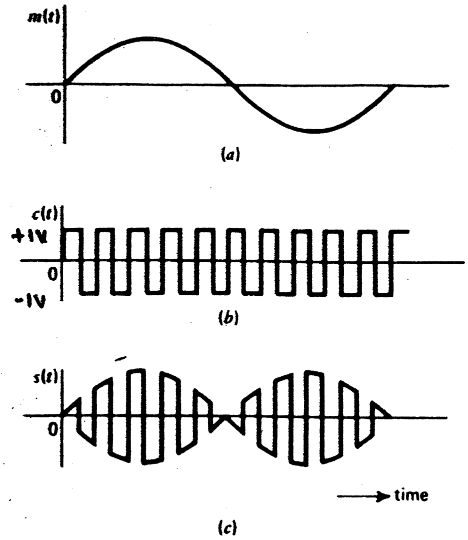


Figure
Waveforms illustrating the operation of the ring modulator for a sinusoidal modulating wave. (a) Modulating wave. (b) Square-wave carrier. (c) Modulated wave.

Ring modulator is a product modulator used for generating DSB-SC modulated wave. The ring modulator consists of :-

1) I/p transformer 'T_1'
2) o/p transformer 'T_2'
3) Four diodes connected in a bridge circuit (Ring)

The carrier amplitude 'A_c' is greater than the modulating signal amplitude 'A_m' i.e. $A_c > A_m$ and carrier frequency 'f_c' is greater than modulating signal 'f_m' $= W$ i.e. $f_c > W$. These conditions ensures that the diode operation is controlled by $c(t)$ only.

* The diodes are controlled by a square wave carrier $c(t)$

of frequency 'f_c' which is applied by means of two center-tapped transformer.

* The modulating signal $m(t)$ is applied to the I/p transformer 'T_1'. The o/p appears across the secondary of the transformer 'T_2'.

Operation :-

i) When the carrier is +ve, the diodes D_1 & D_2 are forward-biased and diodes D_3 & D_4 are reverse biased. Hence the modulator multiplies the message signal $m(t)$ by +1 i.e.

$V_0(t) = m(t)$.

ii) When the carrier is -ve, the diodes D_3 & D_4 are forward biased whereas D_1 & D_2 are reverse biased. Thus the modulator multiplies the message signal $m(t)$ by -1 i.e. $V_0(t) = -m(t)$.

* The square wave carrier $c(t)$ can be represented by a Fourier series as:

$$c(t) = \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos\left[2\pi f_c t (2n-1)\right]$$

$$c(t) = \frac{4}{\pi}\Big[\underbrace{\cos 2\pi f_c t}_{n=1} - \underbrace{\frac{1}{3}\cos 6\pi f_c t}_{n=2} + \cdots\cdots\Big] \rightarrow (1)$$

The ring modulator o/p is

$$s(t) = c(t) \cdot m(t) \rightarrow (2)$$

Substituting equation (1) in equation (2), we get

$$s(t) = \left[\frac{4}{\pi}\cos 2\pi f_c t - \frac{4}{3\pi}\cos 6\pi f_c t + \cdots\cdots\right] m(t)$$

$$s(t) = \frac{4}{\pi} m(t) \cos 2\pi f_c t - \frac{4}{3\pi} m(t) \cos 6\pi f_c t + \cdots\cdots\Big] \rightarrow (3)$$

Taking Fourier transform on both Sides of equation ③, we get

$$S(f) = \frac{2\cancel{4}}{\cancel{2}\pi}\left[M(f-f_c)+M(f+f_c)\right] - \frac{2\cancel{4}}{\cancel{2}\times 3\pi}\left[M(f-3f_c)+M(f+3f_c)\right]$$

$$\boxed{S(f) = \frac{2}{\pi}\left[M(f-f_c)+M(f+f_c)\right] - \frac{2}{3\pi}\left[M(f-3f_c)+M(f+3f_c)\right]}$$

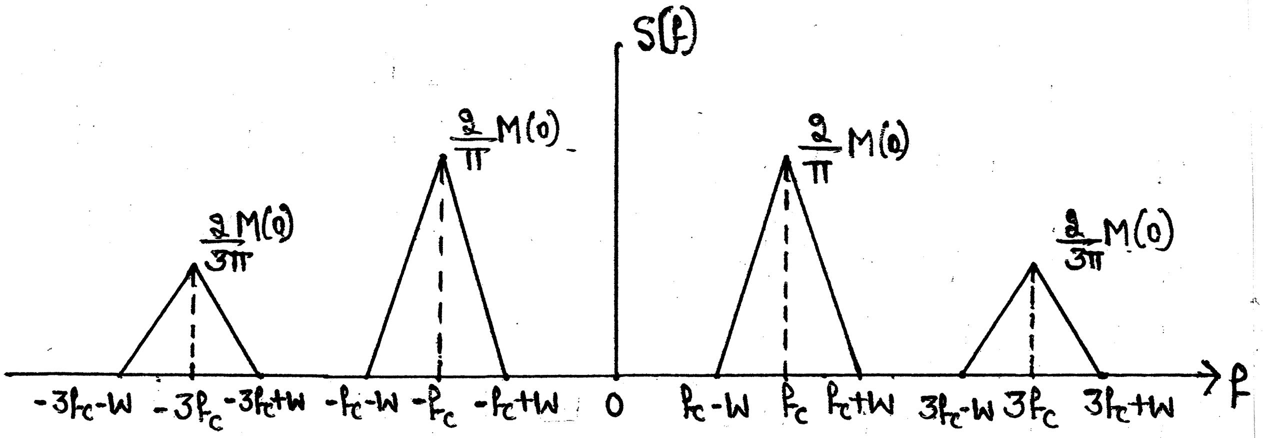


Fig : Amplitude Spectrum of S(f).

* The DSB - SC Wave is extracted from S(t) by passing equation ③ (S(t)) through an Ideal BPF having centre frequency 'f_c' and bandwidth equal to 2WHz.

The o/p of the BPF is

$$\boxed{S(t) = \frac{4}{\pi} m(t) \cos 2\pi f_c t}$$

COHERENT Detection of DSB-SC wave:-

❖ **With block diagram and related equations explain coherent detection of a DSB-SC wave. What are its disadvantages? Explain the synchronous receiving system(COSTAS Loop)** **June-10,8M July-08,10M**

❖ **Write a note on how coherent detection is used in DSB-SC receiver** **July-06,7M**

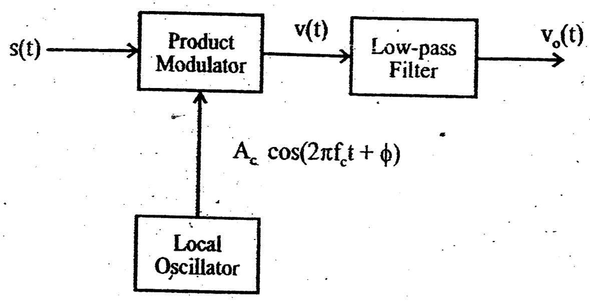


Fig. : Coherent detective for DSBSC

* The modulating signal $m(t)$ is recovered from a DSB-SC wave $S(t)$ by first multiplying $S(t)$ with a locally generated carrier wave and then low pass filtering the product as shown in fig ①.

* For faithful recovery of modulating signal $m(t)$, the local oscillator o/p should be exactly coherent or synchronized in both frequency and phase with the carrier wave $c(t)$ used in the product modulator to generate $V_0(t)$ with the local oscillator o/p equal to $\cos(2\pi f_c t + \phi)$.

The product modulator o/p can be given as:

$$V(t) = S(t) \cdot \cos(2\pi f_c t + \phi) \longrightarrow ①$$

W.K.T $\quad S(t) = A_c \cos 2\pi f_c t \cdot m(t) \longrightarrow ②$

Substituting equation ② in equation ①, we get

$$V(t) = A_c \cos(2\pi f_c t + \phi) \cos(2\pi f_c t) \cdot m(t)$$

W.K.T

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

$$V(t) = \frac{A_c m(t)}{2}\left[\cos(\cancel{2\pi f_c t} + \phi - \cancel{2\pi f_c t})\right] + \frac{A_c m(t)}{2}\left[\cos(2\pi f_c t + \phi + 2\pi f_c t)\right]$$

$$V(t) = \frac{A_c m(t)}{2}\cos\phi + \frac{A_c m(t)}{2}\cos(4\pi f_c t + \phi) \longrightarrow (2)$$

{ Taking Fourier transform on both sides of equation (2), we get

$$V(f) = \frac{A_c}{2} M(f)\cos\phi + \frac{A_c}{4}\left[M(f-2f_c) + M(f+2f_c)\right]$$

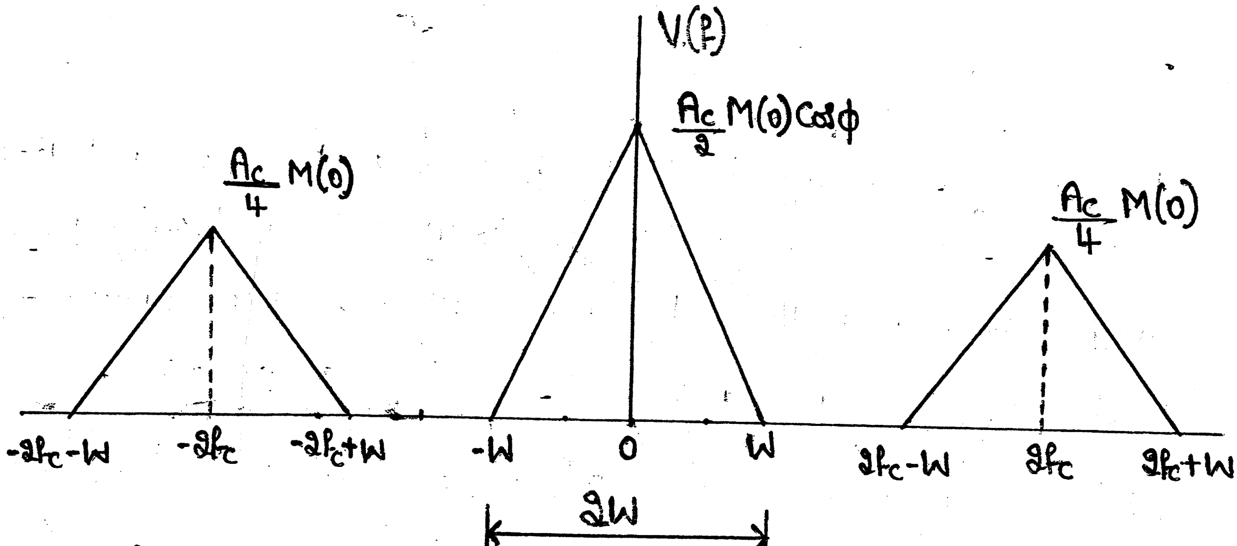


Fig (2) Amplitude Spectrum of v(f).
}

* The desired message signal is obtained by passing V(t) through a LPF having the bandwidth greater than 'W' Hz but less than '$2f_c - W$' Hz.

* The o/p of the LPF is

$$\boxed{V_o(t) = \frac{A_c}{2}\cos\phi \, m(t)}$$

The demodulated signal $V_o(t)$ is therefore proportional to m(t).
Where, $\phi \rightarrow$ phase error.

When ϕ = Constant, $V_0(t)$ is proportional to $m(t)$

When $\phi = 0$, Amplitude of $V_0(t)$ is maximum.

When $\phi = \pm\pi/2$, Amplitude of $V_0(t)$ is minimum (represents the quadrature Null effect of the Coherent detector)

COSTAS LOOP:-

- **Explain the method of obtaining a practical synchronous receiving system with DSB-SC modulated waves using COSTAS loop** **June-10,8M July-08,10M**
- **With a neat block diagram explain the synchronous receiving system for receiving DSB-SC modulated waves.** **July-07,6M**
- **With neat block diagram of DSB-SC, the detection using COSTAS receiver.** **Jan-09,6M July-09, 5M**

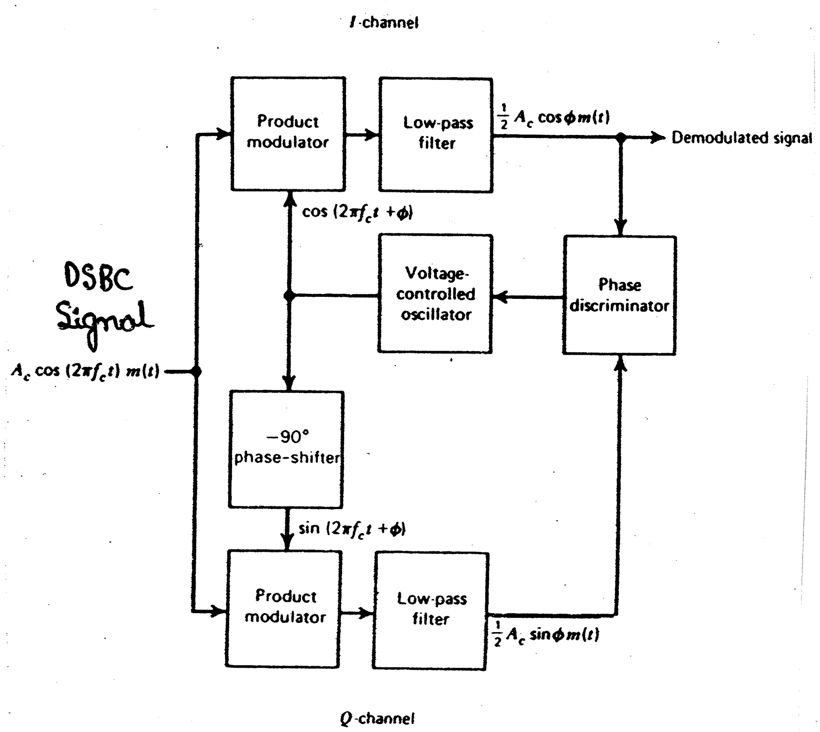


Fig : Costas loop

* The Costas loop is a method of obtaining a practical synchronous receiver system, suitable for demodulating DSB-SC waves.

* The receiver consists of two coherent detectors supplied with the same I/p signal (DSB-SC wave) $A_c \cos(2\pi f_c t) m(t)$, but with individual local oscillator signals that are in-phase quadrature with respect to each other. (i.e. the local oscillator signal supplied to the product modulators are 90° out of phase).

* The frequency of the local oscillator is adjusted to be the same as the carrier frequency 'f_c'.

* The detector in the upper path is referred to as the In-phase coherent detector or I-Channel and that in the lower path is referred to as the Quadrature-phase coherent detector or Q-Channel.

* These two detectors are coupled together to form a negative feedback system designed in such a way as to maintain the local oscillator synchronous with the carrier wave.

operation:-

i) When local oscillator signal is of the same phase as the carrier wave $A_c \cos(2\pi f_c t)$ used to generate the incoming DSB-SC wave under these conditions, the I-Channel o/p contains the desired demodulated signal $m(t)$, where as Q-Channel o/p is zero.

$$V_{OI} = \frac{1}{2} A_c m(t) \cos\phi$$

i.e. Whenever the Carrier is Synchronized

$\phi = 0$ and $\cos\phi = \cos(0) = 1$

$$\boxed{V_{OI} = \frac{1}{2} A_c m(t)}$$ and

$\sin\phi = \sin(0) = 0$

$$\boxed{V_{OQ} = 0}$$

ii) When local oscillator phase changes by a small angle 'ϕ' radians, the I-Channel o/p will remain unchanged, but Q-Channel produces some o/p which is proportion to $\sin\phi$.

The o/p of I and Q-Channels are Combined in phase-discriminator (which Consists of a multiplier followed by a LPF), a dc Control Signal is obtained that automatically corrects for local phase errors in the voltage Controlled-oscillator (VCO).

Disadvantages of DSB-SC Coherent detection :-

Amplitude of the demodulated Signal is maximum when $\phi = 0$ & minimum when $\phi = \pm\pi/2$ So, perfect Synchronization has to be achieved for detection which inturn increases the Cost of the receiver.

Quadrature Carrier Multiplexing or Quadrature Amplitude Modulation:-

- **Explain the principle of QAM and with a functional block diagram describe the salient features of QAM transmitter and receiver.** **Jan-06,8M**

- **What is Quadrature null effect? How it can be eliminated?** **Jan-07,8M**

- **With neat block diagram, explain the operation of Quadrature carrier multiplexing.** **July-09,5M Jan-10,6M July-09,8M July-07,5M**

* QAM is a technique in which we can transmit more number of signals (DSB-SC wave) within the same channel bandwidth.

∴ QAM is a bandwidth-conservation scheme.

Principle of QAM Scheme:-

The QAM enables two DSB-SC modulated waves to occupy the same transmission channel bandwidth and allows the separation of the two message signals at the receiver o/p.

∴ QAM is called Bandwidth-Conservation Scheme.

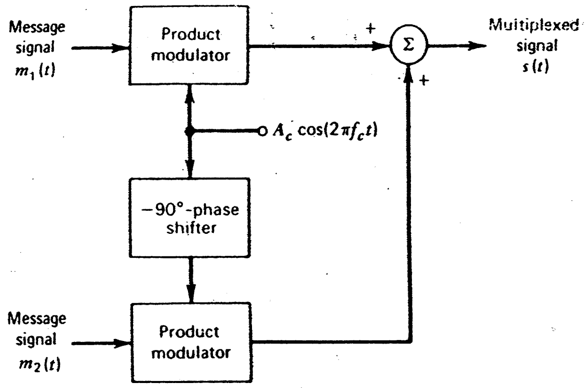


Fig a: QAM Transmitter

Fig ⓐ Shows QAM transmitter. It consist of two product modulators that are supplied with two carrier waves of the same frequency but differing in phase by -90°.

* The o/p of the two product modulators are summed to produce multiplexed signal $S(t)$.

i.e.

$$\boxed{S(t) = A_c m_1(t)\cos 2\pi f_c t + A_c m_2(t)\sin 2\pi f_c t}$$

Where $m_1(t)$ and $m_2(t)$ denotes the two different message signals applied to the product modulators.

* Thus $S(t)$ occupies a channel bandwidth of '$2W$' centered at the carrier frequency 'f_c', where 'W' is the message bandwidth of $m_1(t)$ & $m_2(t)$.

QAM Receiver:

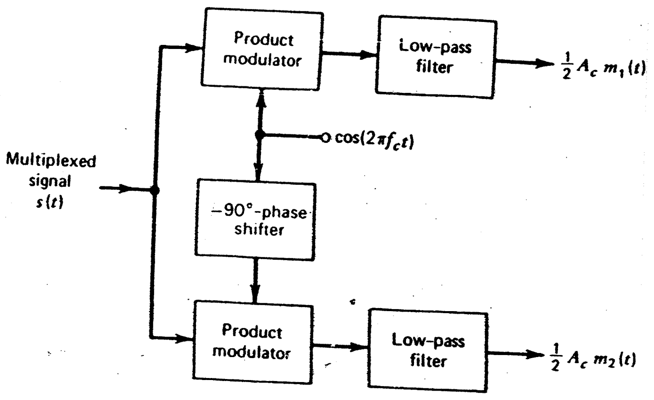


Fig ⓑ QAM receiver

* Fig ⓑ Shows the QAM receiver, which consists of two coherent detectors which are fed by locally generated carrier signals having same frequency but out of phase by 90°.

The received multiplexed Signal $S(t)$ is applied to the two product modulators. The o/p of the Top product modulator is given by

$$\boxed{S_1(t) = S(t) \cos 2\pi f_c t}$$

The top LPF removes the high frequency term and allows only $\frac{A_c m_1(t)}{2}$.

$$\therefore \boxed{S_1(t) = \frac{A_c}{2} m_1(t)}$$

* The o/p of the bottom product modulator is given by

$$S_2(t) = S(t) . \sin 2\pi f_c t.$$

* The bottom LPF removes the high frequency term & allows only $\frac{A_c m_2(t)}{2}$, Thus the o/p of LPF is

$$\boxed{S_2(t) = \frac{A_c}{2} m_2(t)}$$

* For correct operation of the Quadrature carrier multiplexing-System it is necessary to maintain the correct phase and frequency relationship between the local oscillators used in transmitter and receiver of the System.

Salient features of QAM:-

1) We can transmit more number of DSB-SC wave within the same channel bandwidth.

2) QAM is a bandwidth-conservation Scheme.

3) QAM finds application in Colour Television (CTV)

NOTE :

* The o/p of the top product modulator is given by :

$$\boxed{S_1(t) = S(t)\cos 2\pi f_c t}$$

$$S_1(t) = \left[A_c m_1(t)\cos 2\pi f_c t + A_c m_2(t)\sin 2\pi f_c t\right]\cos 2\pi f_c t.$$

$$S_1(t) = A_c m_1(t)\underline{\cos} 2\pi f_c t . \underline{\cos} 2\pi f_c t + A_c m_2(t)\sin 2\pi f_c t . \cos 2\pi f_c t.$$

$$S_1(t) = A_c m_1(t)\cos^2 2\pi f_c t + A_c m_2(t)\sin 2\pi f_c t . \cos 2\pi f_c t.$$

W.K.T

$$\boxed{\cos^2\theta = \frac{1}{2} + \frac{\cos 2\theta}{2}} \quad \text{and} \quad \boxed{\sin A \cos B = \frac{1}{2}\sin(A-B) + \sin(A+B)}$$

$$S_1(t) = A_c m_1(t)\left[\frac{1}{2} + \frac{\cos 2(2\pi f_c t)}{2}\right] + \frac{A_c m_2(t)}{2}\sin\left[\overset{0}{\cancel{2\pi f_c t - 2\pi f_c t}}\right] + \frac{A_c m_2(t)}{2}\sin\left[2\pi f_c t + 2\pi f_c t\right]$$

$$\boxed{S_1(t) = \frac{A_c m_1(t)}{2} + \frac{A_c m_1(t)\cos 4\pi f_c t}{2} + \frac{A_c m_2(t)}{2}\sin\left[4\pi f_c t\right]}$$

* The top LPF removes the high frequency term & allows only $\frac{A_c m_1(t)}{2}$

$$\therefore \quad \boxed{S_1(t) = \frac{A_c}{2} m_1(t)}$$

* The o/p of the bottom product modulator is given by :

$$S_2(t) = S(t)\sin 2\pi f_c t$$

$$S_2(t) = \left[A_c m_1(t)\cos 2\pi f_c t + A_c m_2(t)\sin 2\pi f_c t\right]\sin 2\pi f_c t$$

$$S_2(t) = A_c m_1(t)\sin 2\pi f_c t . \cos 2\pi f_c t + A_c m_2(t) . \sin^2 2\pi f_c t.$$

W.K.T

$$\boxed{\sin^2\theta = \left[\frac{1}{2} - \frac{\cos 2\theta}{2}\right]} \quad \& \quad \boxed{\sin A . \cos B = \frac{1}{2}\sin(A-B) + \frac{1}{2}\sin(A+B)}$$

$$S_2(t) = \frac{A_c m_1(t)}{2}\sin\left[2\pi f_c t - 2\pi f_c t\right] + \frac{A_c m_1(t)}{2}\sin\left[2\pi f_c t + 2\pi f_c t\right] + \frac{A_c m_2(t)}{2} - \frac{A_c m_2(t)}{2}\cos 4\pi f_c t.$$

* The bottom LPF removes the high frequency term & allows only $\frac{A_c}{2} m_2(t)$.

Thus the o/p of LPF is

$$\boxed{s_2(t) = \frac{A_c}{2} m_2(t)}$$

Distortion in Envelope detector:-

❖ **Discuss the drawbacks of envelope detector** **Jan-10,4m**

There are two types of distortions which can occur in the detector output. They are:

1. **Diagonal Clipping and**
2. **Negative peak clipping.**

Diagonal Clipping:

This type of distortion occurs when the **RC time constant** of the load current is **too long**. Due to this the RC circuit cannot follow the fast change in the modulating envelope and is as shown in fig1.

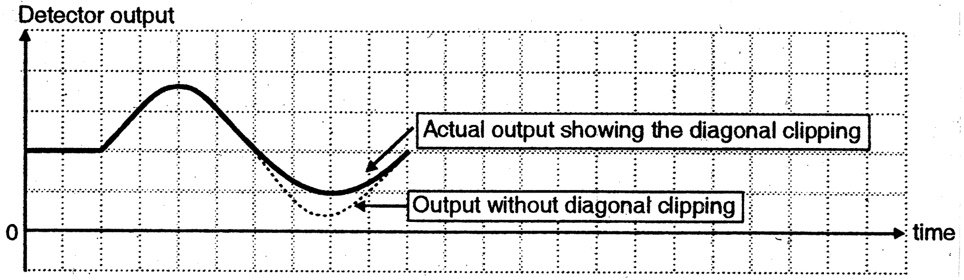


Fig. 1 : Diagonal clipping

Negative Peak Clipping:

This distortion occurs due to a fact that the modulation index on the output side of the detector is higher than that on its input side. So at higher depths of modulation of the transmitted signal, the **over modulation** may take place at the output of the detector. As a result negative peak clipping take place as shown in fig2.

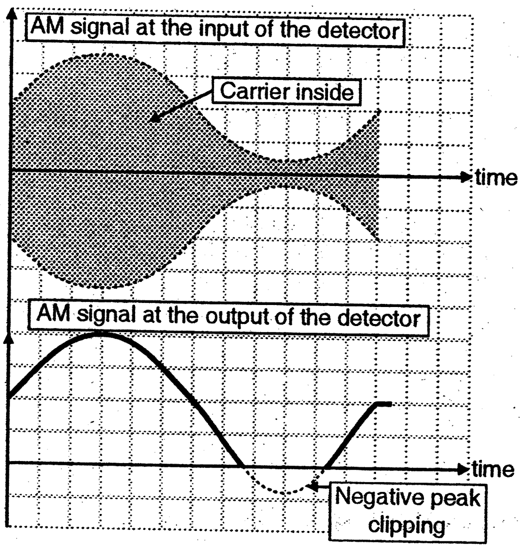


Fig. 2 : Negative peak clipping

Remedy: The distortions in detector output is reduced or eliminated by **properly choosing RC time constant.**

❖ **What is DSB-SC modulation? What are the advantages and limitations of DSB-SC as compared to standard AM?** June-09,6M Jan-05,5M

Advantages:

1. Low Power consumption or power saving.
2. The modulation system is simple.
3. Efficiency is more than AM
4. Carrier wave is suppressed
5. Linear modulation type is required
6. It can be used for point to point communication

Disadvantages:

1. Design of receiver is complex
2. Bandwidth required is same as that of AM

Application:

1. Analogue TV systems to transmit color information.

Latha H N, Dept of E and C.
ARUNKUMAR G M.Tech
Lecturer in E&CE Department
S.T.J.I.T., Ranebennur

FORMULAE

1. **Equation for AM wave** : $s(t)=A_c(1+\mu\cos 2\pi f_m t)\cos 2\pi f_c t$
2. **Modulation Index** : $\mu = Am/Ac$
3. **Amplitude of each sideband** : $\mu Ac/2$
4. **Upper Sideband Freq.** : $f_{USB} = (f_c+f_m)$
5. **Lower Sideband Freq.** : $f_{LSB} = (f_c-f_m)$
6. **Bandwidth of AM** : $BW= 2f_m$
7. **Total Txed Power** : $P_t=P_c+P_{USB}+P_{LSB}$

   $P_t= P_c\,(1+ \mu^2/2)$

   $P_t=I_t^2R$
8. **Power in each sideband** : $P_{USB} = P_{LSB} = P_c\,(\mu/4)$
9. **Total Sideband power** P_{SB} : $P_{USB} + P_{LSB} = P_c\,(\mu^2/2)$

   $P_{SB} = P_T - P_c$
10. **Power Wastage** : $P_c + P_c\,(\mu^2/4)$
11. **Transmission efficiency** : $\eta = \mu^2/(2+ \mu^2)$
12. **Carrier Power** : $P_c=A_c^2/2R$

    $P_c=I_c^2/R$
13. **Maximum Freq. in AM wave** : $f_{max} = f_c+f_m$
14. **Minimum Freq. in AM wave** : $f_{min} = f_c-f_m$
15. **Modulation index from AM Wave :**

$$\mu = (A_{max}-A_{min})/A_{max}+A_{min})$$

Modulation by Several sinewaves

16. **AM Wave with two Modulating signals :**

$$s(t)=A_c(1+\mu_1\cos 2\pi f_{m1}t+\mu_2\cos 2\pi f_{m2}t)\cos 2\pi f_c t$$

17. **Transmitted power** : $P_t=P_c(1+\mu^2_1/2+\mu^2_2/2)$

18. **Total Modulation index or Effective modulation index**

$$\mu=\sqrt{\mu_1^2+\mu_2^2}$$

19. **Total Power** : $P_t=P_c(1+\mu^2_t/2)$

20. **Amplitudes of AM Wave** : $A_{max}=A_c(1+\mu^2)$

$A_{min}=A_c(1-\mu^2)$

21. **Peak Amplitude of carrier** : $A_c=(A_{max}+A_{min})/2$

22. **Peak Amplitude of message signal :** $A_c=(A_{max}-A_{min})/2$

23. **Modulation index from AM wave** :

$$\mu=(A_{max}+A_{min})/(A_{max}-A_{min})$$

An amplitude modulated signal is given by

$s(t)=[10\cos(2\pi x10^6t) + 5\cos(2\pi x10^3t) + 2\cos(2\pi x10^6t) + \cos(4\pi x10^3t)]$ volts.

Find i) total modulated power ii) Sideband power and iii) net modulation index.

Jan-10,6M

Sol :-

WKT

$$\boxed{S(t) = A_c\left[1 + \mu_1 \cos 2\pi f_1 t + \mu_2 \cos 2\pi f_2 t\right] \cos 2\pi f_c t} \longrightarrow (1)$$

Given

$$S(t) = \left[10\cos(2\pi \times 10^6 t) + 5\cos(2\pi \times 10^6 t)\cos(2\pi \times 10^3 t) + 2\cos(2\pi \times 10^6 t)\cos(4\pi \times 10^3 t)\right]$$

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

$$\boxed{S(t) = 10\cos(2\pi \times 10^6 t)\left[1 + 0.5\cos(2\pi \times 10^3 t) + 0.2\cos(4\pi \times 10^3)t\right]} \rightarrow (2)$$

Comparing eq (1) & (2), we get

$A_c = 10V$, $\mu_1 = 0.5$, $\mu_2 = 0.2$, $f_1 = 1\times10^3 Hz$, $f_2 = 2\times10^3 Hz$, $f_c = 1\times10^6 Hz$

* Net modulation index $\mu_t = \sqrt{\mu_1^2 + \mu_2^2} = \sqrt{(0.5)^2 + (0.2)^2}$

$$\boxed{\mu_t = 0.538} \longrightarrow \boxed{\text{2 Marks}}$$

$R = 1\Omega$

* Carrier power $P_c = \frac{A_c^2}{2R} = \frac{(10)^2}{2\times1}$

$$\boxed{P_c = 50W}$$

* Sideband power $P_{SB} = P_{USB} + P_{LSB} = \frac{\mu_t^2}{2} P_c = \frac{(0.538)^2}{2} 50$

$$\boxed{P_{SB} = 7.25W} \longrightarrow \boxed{\text{2Marks}}$$

* Total modulated power

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

$$= 50\left[1+\frac{0.538^2}{2}\right]$$

$$\boxed{P_T = 57.25\,W} \longrightarrow \boxed{2\text{ Marks}}$$

OR

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

$$= 50W + 7.25W$$

$$\boxed{P_T = 57.25\,W}$$

NOTE :-

* Sideband power $P_{SB} = P_T - P_c = 57.25W - 50W$

$$\boxed{P_{SB} = 7.25\,W}$$

Consider a message signal m(t)=20cos(2πt)volts and a carrier signal c(t)=50cos(100πt)volts.

i. **Sketch to scale resulting AM wave for 75% modulation.**

ii. **Find the power delivered across a load of 100Ω due to this AM wave.** June-10,6M

Given :- $A_m = 20V$, $f_m = 1Hz$, $A_c = 50V$, $f_c = 50Hz$, $\mu = 0.75$ & $R = 100\Omega$

WKT AM wave is given by

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

$$\therefore \boxed{s(t) = 50\left[1+0.75\cos 2\pi(1)t\right]\cos 2\pi(50)t} \longrightarrow \boxed{2\text{ Marks}}$$

i) $A_{max} = A_c(1+\mu) = 50(1+0.75) = \underline{87.5V}$

$A_{min} = A_c(1-\mu) = 50(1-0.75) = \underline{12.5V}$

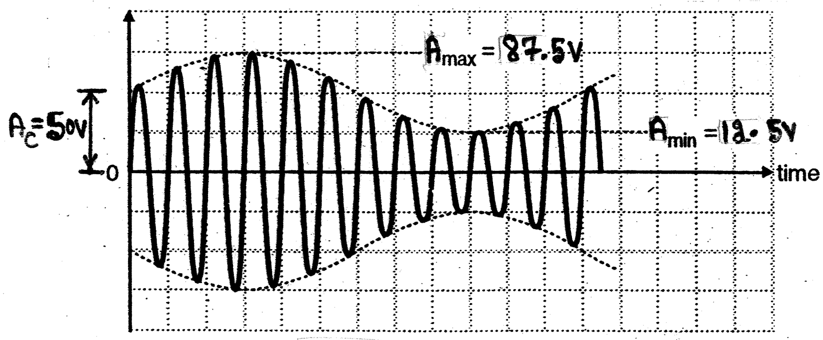


Fig. : AM wave for m = 0.75

→ 2Marks

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

$* \; P_c = \frac{A_c^2}{2R} = \frac{50^2}{2\times100} = \underline{12.5\,W}$ → 1 Mark

$P_T = 12.5\left[1+\frac{0.75^2}{2}\right]$

$\boxed{P_T = 16.015\,W}$ → 1 Mark

A carrier wave with amplitude 12V and frequency 10 MHz is amplitude modulated to 50% level with a modulated frequency of 1 KHz. Write down the equation for the above wave and sketch the modulated signal in frequency domain. June-10,7M

Given : $A_c = 12V$, $f_c = 10MHz$, $\mu = 0.5$, $f_m = 1KHz$

Sol :-

WKT AM wave is given by :

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

$\boxed{S(t) = 12[1+0.5\cos 2\pi(1\times10^3)t]\cos 2\pi(10\times10^6)t}$ → 3 Marks

WKT for Single tone modulation is given by

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

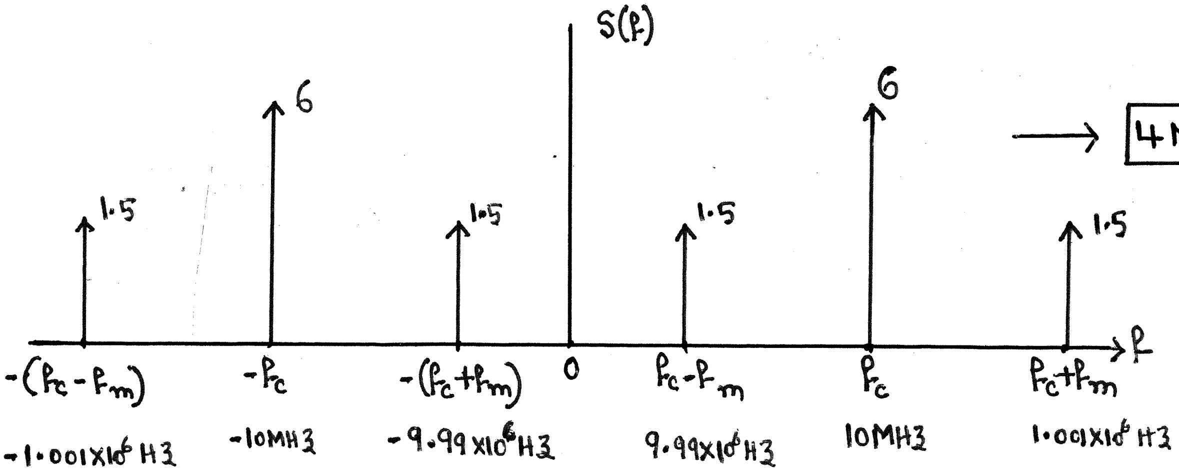
$$s(t) = 12 \cos 2\pi (10\times10^6 t) + \frac{0.5 \times 12}{2} \cos 2\pi \left(10\times10^6 + 1\times10^3\right) t$$

$$+ \frac{0.5\times12}{2} \cos 2\pi \left(10\times10^6 - 1\times10^3\right) t$$

$$s(t) = 12 \cos 2\pi (10\times10^6 t) + 3 \cos 2\pi (1.001\times10^6 t) + 3 \cos 2\pi (9.99\times10^6 t) \longrightarrow (1)$$

Taking FT on both Side of eq (1), we get

$$S(f) = \frac{12}{2}\left[\delta(f - 10\times10^6) + \delta(f + 10\times10^6)\right] + \frac{3}{2}\left[\delta(f - 1.001\times10^6) + \delta(f + 1.001\times10^6)\right] + \frac{3}{2}\left[\delta(f - 9.99\times10^6) + \delta(f + 9.99\times10^6)\right]$$



$\longrightarrow$ $\boxed{\text{4 Marks}}$

Consider a message signal m(t)=20cos(2πt)volts and a carrier signal c(t)=50cos(100πt)volts.

i. The resulting AM wave for 75% modulation.

ii. Sketch the Spectrum of this AM wave

iii. Find the power developed across the load of 100Ω. Jan-08, 10M June-10,10M

Given : $m(t) = 20 \cos 2\pi t\, V$, $c(t) = 50 \cos 100\pi t$ & $\mu = 0.75$

$\omega_m = 2\pi$ $\cancel{2\pi} f_m = \cancel{2\pi}$ $f_m = 1Hz$	$\omega_c = 100\pi$ $\cancel{2\pi} f_c = \cancel{100\pi}\ 50$ $f_c = 50Hz$

i) WKT

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

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

$$s(t) = 50 \cos 2\pi(50) t + 37.5 \underline{\cos 2\pi(50) t \cdot \cos 2\pi(1) t}$$

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

$$s(t) = 50 \cos 2\pi(50) t + \frac{37.5}{2} \cos 2\pi(50-1) t + \frac{37.5}{2} \cos 2\pi(50+1) t$$

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

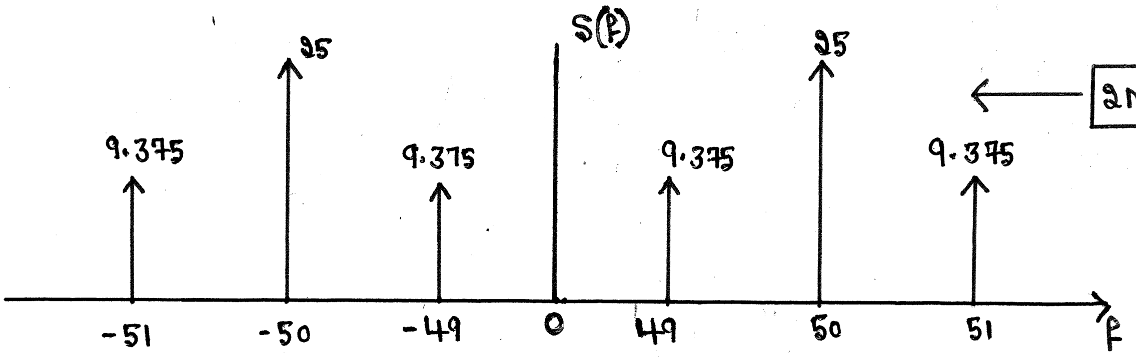
3 Marks

ii) Taking FT of eq ①, we get

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

$$\boxed{\begin{aligned} S(f) = 25[\delta(f-50)+\delta(f+50)] &+ 9.375[\delta(f-49)+\delta(f+49)] \\ &+ 9.375[\delta(f-51)+\delta(f+51)] \end{aligned}}$$

2 Marks



2 Marks

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

$$P_c = \frac{A_c^2}{2R} = \frac{(50)^2}{2\times100} = \underline{12.5\,W}$$

$$P_T = 12.5\left(1+\frac{0.75^2}{2}\right) = \underline{16\,W}$$

3 Marks

The antenna current of an AM broadcast transmitter modulated to a depth of 40% by an audio sine wave is 11A. It increases to 12A as a result of sinusoidal modulation by another audio sine wave. What is the modulation index due to second wave?

OLD June-10,6M

Given : i) $\mu_1 = 0.4$, $I_{\pm 1} = 11A$, $I_c = ?$

ii) $I_{\pm 2} = 12A$, $\mu_2 = ?$

Sol :

i) $I_{\pm 1} = I_c \sqrt{1 + \frac{\mu_1^2}{2}}$

$$I_c = \frac{I_{\pm 1}}{\sqrt{1 + \frac{\mu_1^2}{2}}} = \frac{11}{\sqrt{1 + \frac{0.4^2}{2}}}$$

$$\boxed{I_c = 10.58A}$$

ii) $I_{\pm 2} = I_c \sqrt{1 + \frac{\mu_t^2}{2}}$

$$I_{\pm 2}^2 = I_c^2 \left(1 + \frac{\mu_t^2}{2}\right)$$

$$\frac{I_{\pm 2}^2}{I_c^2} = 1 + \frac{\mu_t^2}{2}$$

$$\frac{\mu_t^2}{2} = \left(\frac{I_{\pm 2}^2}{I_c^2}\right) - 1$$

$$\frac{\mu_t^2}{2} = \left(\frac{12^2}{10.58^2}\right) - 1$$

$$\frac{\mu_t^2}{2} = 1.286 - 1$$

$$\frac{\mu_t^2}{2} = 0.286$$

$$\mu_t^2 = 0.572$$

$$\boxed{\mu_t = 0.757}$$

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

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

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

$$= 0.757^2 - 0.4^2$$

$$\mu_2^2 = 0.4130$$

$$\boxed{\mu_2 = 0.642}$$

Find the ratio of maximum average power to unmodulated carrier power in AM

Sol :- Jan-07,4M

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

When $\mu = 1$ i.e. for 100% modulation

$$P_{T(max)} = P_c\left[1+\frac{(1)^2}{2}\right]$$

$$P_{T(max)} = 1.5 P_c$$

$$\frac{P_{T(max)}}{P_c} = 1.5$$

$$\frac{P_{T(max)}}{P_c} = \frac{1.5}{1}$$

$$\therefore \boxed{P_{T(max)} : P_c \text{ is } 1.5 : 1}$$

An audio frequency signal 5sin2π(1000)t is used to amplitude modulate a carrier of 100sin2π(10⁶)t. Assume modulation index of 0.4. Find

i. Sideband frequencies **iii. Amplitude of each sideband**

ii. Bandwidth required **iv. Total power delivered to a load of 100Ω**

Jan-05,10M

Sol:- Given:

$A_m = 5$, $A_c = 100$, $\mu = 0.4$, $f_m = 1000\,Hz$, $f_c = 1 \times 10^6\,Hz$.

i) Sideband Frequencies:

$f_{USB} = f_c + f_m = 1MHz + 1000Hz = 1.001\,MHz$

$f_{LSB} = f_c - f_m = 1MHz - 1000Hz = 999\,000\,Hz = 0.999\,MHz$

ii) Amplitude of each Sideband Frequencies:

$$\frac{\mu A_c}{2} = \frac{0.4 \times 100}{2} = 20V.$$

∴ Amplitude of upper & lower Sideband is 20V.

iii) Bandwidth required:

$BW = 2f_m = 2 \times 1KHz = 2KHz$

or

$BW = f_{USB} - f_{LSB} = 1.001\,MHz - 999000\,Hz = 2KHz$

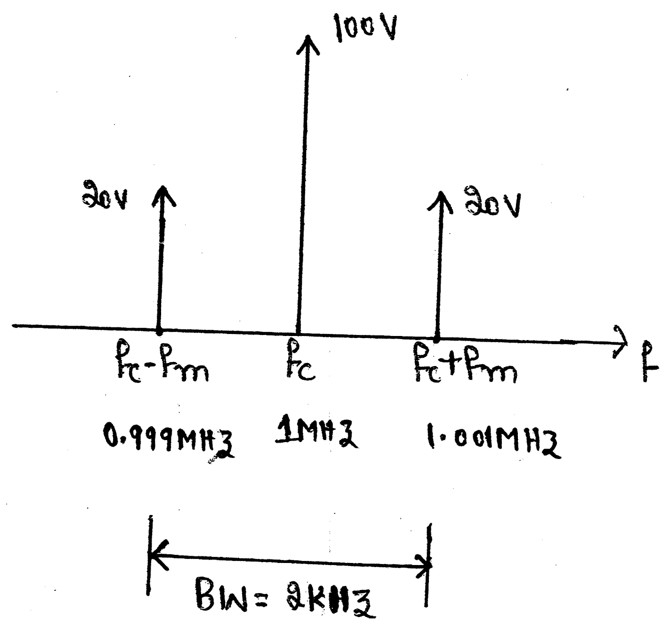
iv) Total power delivered to a load of 100 Ω:

W.K.T
$$P_T = P_c\left[1 + \frac{\mu^2}{2}\right] = \frac{A_c^2}{2R}\left[1 + \frac{\mu^2}{2}\right]$$

$$= \frac{(100)^2}{2 \times 100}\left[1+\frac{(0.4)^2}{2}\right]$$

$$\boxed{P_T = 54W}$$

v) Spectrum of AM wave:



A 1000KHz carrier is simultaneously modulated by 300Hz, 800Hz and 2KHz audio sine waves. What will be the frequency content of AM signals. **July-05,6M**

Sol:

Given: $f_c = 1000KHz$

$f_{m1} = 300Hz$, $f_{m2} = 800Hz$ & $f_{m3} = 2000Hz$

* $f_{USB1} = f_c + f_{m1} = 1000KHz + 300Hz = 1000.3KHz$
* $f_{LSB1} = f_c - f_{m1} = 1000KHz - 300Hz = 999.7KHz$.
* $f_{USB2} = f_c + f_{m2} = 1000KHz + 800Hz = 1000.8KHz$
* $f_{LSB2} = f_c - f_{m2} = 1000KHz - 800Hz = 999.2KHz$
* $f_{USB3} = f_c + f_{m3} = 1000KHz + 2KHz = 1002KHz$
* $f_{LSB3} = f_c - f_{m3} = 1000KHz - 2KHz = 998KHz$

A carrier wave 4sin(2πx500x10^3t)volts is amplitude modulated by an audio wave [0.2 sin 3(2πx500t) + 0.1 sin 5(2πx500t)] volts. Determine the upper and lower sideband and sketch the complete spectrum of the modulated wave. Estimate the total power in the sideband. June-09,6M

Sol: Given : $c(t) = 4\sin(2\pi \times 500\times10^3 t) \rightarrow A_c = 4V,\ f_c = 500KHz$

$$m(t) = \underset{A_{m1}}{0.2}\sin 2\pi(\underset{f_{m1}}{1500})t + \underset{A_{m2}}{0.1}\sin 2\pi(\underset{f_{m2}}{2500})t$$

The message signal consists of two sinewaves.

$A_{m1} = 0.2V$, $f_{m1} = 1500Hz$

$A_{m2} = 0.1V$, $f_{m2} = 2500Hz$

* USB & LSB :-

i) $USB_1 = (f_c + f_{m1}) = 500KHz + 1.5KHz = 501.5KHz$

$LSB_1 = (f_c - f_{m1}) = 500KHz - 1.5KHz = 498.5KHz$

ii) $USB_2 = (f_c + f_{m2}) = 500KHz + 2.5KHz = 502.5KHz$

$LSB_2 = (f_c - f_{m2}) = 500KHz - 2.5KHz = 497.5KHz.$

* Modulation Index of individual modulating Signals :

i) Modulation Index for 1st Signal $\mu_1 = \frac{A_{m1}}{A_c} = \frac{0.2}{4} = 0.05$

ii) Modulation Index for 2nd Signal $\mu_2 = \frac{A_{m2}}{A_c} = \frac{0.1}{4} = 0.025$

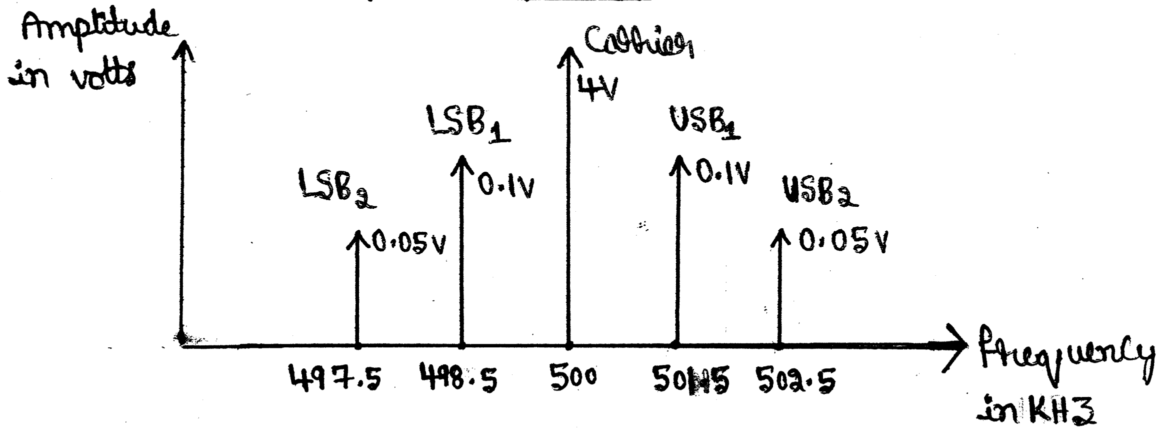
* Sideband amplitudes:

In general, amplitude of each Sideband is given by $\frac{\mu A_c}{2}$

i) Amplitude of USB_1 & LSB_1 will be: $\frac{\mu_1 A_c}{2} = \frac{0.05 \times 4}{2} = 0.1V$

ii) Amplitude of USB_2 & LSB_2 will be: $\frac{\mu_2 A_c}{2} = \frac{0.025 \times 4}{2} = 0.05V$

* Complete Spectrum of AM Signal:



* Total power in the Sidebands:-

WKT, the total power in the Sidebands is given by

$$P_{SB} = P_{USB} + P_{LSB} = P_c\left(\frac{\mu^2}{2}\right)$$

for two Signals,

$$P_{SB} = P_c\left(\frac{\mu_t^2}{2}\right)$$

Where,

μ_t = total modulation Index =

i.e. $\mu_t = \sqrt{\mu_1^2 + \mu_2^2} = \sqrt{(0.05)^2 + (0.025)^2} = 0.0559$

$$\therefore P_{SB} = P_c\left[\frac{\mu_t^2}{2}\right]$$

W.K.T. $P_c = \frac{A_c^2}{2R}$

$$= \frac{A_c^2}{2R}\left[\frac{\mu_t^2}{2}\right]$$

$$= \frac{(4)^2}{2R}\left[\frac{(0.0559)^2}{2}\right]$$

$$= \frac{\cancel{16}\,8}{\cancel{2}R}\left[1.56\times10^{-3}\right]$$

$$= \frac{8}{R}\left[1.56\times10^{-3}\right]$$

$$\boxed{P_{SB} = \frac{0.0125}{R}}$$

A broadcast AM transmitter radiates 50Kw of carrier power. What will be the radiated power at 85% modulation? June-08,2M

Sol:-

Given: $P_c = 50KW$ & $\mu = 0.85$

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

$$= 50\times10^3\left[1 + \frac{(0.85)^2}{2}\right]$$

$$\boxed{P_T = 68.0625\ KW}$$

* Consider the message signal $m(t) = 20\cos(2\pi t)$ volts & carrier wave $c(t) = 50\cos(100\pi t)$ volts. Derive an expression for the resulting AM wave for 75% modulation. August - 2002

Sol: Given: $A_m = 20V$, $f_m = 1Hz$

$A_c = 50V$, $f_c = 50Hz$ & $\mu = 0.75$

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

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

An audio frequency signal 10sin2π(500)t is used to amplitude modulate a carrier of 50sin2π(10^5)t. Assume modulation index = 0.2. Find

- **i. Sideband frequencies**
- **ii. Amplitude of each sideband**
- **iii. Bandwidth required** **OLD June-09,6M**

Given : $\mu = 0.2$, $f_m = 500\,Hz$, $f_c = 10^5\,Hz$, $A_m = 10V$, $A_c = 50V$

Sol :-

i) Sideband frequencies :

$$f_{USB} = f_c + f_m = 10^5 + 500 = \underline{1.0005 \times 10^6\ Hz}$$

$$f_{LSB} = f_c - f_m = 10^5 - 500 = \underline{0.9995 \times 10^6\ Hz}$$

ii) Amplitude of each Sideband :

$$\frac{\mu A_c}{2} = \frac{0.2 \times 50}{2} = \underline{5V}$$

iii) Bandwidth 'B' $= 2f_m = 2 \times 500 = \underline{1000\ Hz}$

An amplitude modulated signal is given by

s(t)=10cos2π10^{6}t + 5cos2πx10^{6}t cos 2π10^{3}t+ 2cos2π10^{6}t cos4π10^{3}t volts.

Find various frequency components present and the corresponding modulation indices. Draw the line spectrum and find the bandwidth. **Jan-07,12M**

Given :-

$$S(t) = 10\cos 2\pi 10^6 t + 5\cos 2\pi 10^6 t \cos 2\pi 10^3 t + 2\cos 2\pi 10^6 t \cos 4\pi 10^3 t$$

$$S(t) = 10\cos 2\pi(10^6)t\left[1 + \frac{5}{10}\cos 2\pi(10^3)t + \frac{2}{10}\cos 2\pi(2\times 10^3)t\right.$$

$$S(t) = 10\cos 2\pi(10^6)t\left[1 + 0.5\cos 2\pi(10^3)t + 0.2\cos 2\pi(2\times 10^3)t\right] \longrightarrow (1)$$

WKT

$$s(t) = A_c \cos 2\pi f_c t \left[1 + \mu_1 \cos 2\pi f_1 t + \mu_2 \cos 2\pi f_2 t \right] \longrightarrow (2)$$

Comparing eq (1) & eq (2), we get

$A_c = 10V$, $\mu_1 = 0.5$, $\mu_2 = 0.2$, $f_1 = 10^3 Hz$, $f_2 = 2 \times 10^3 Hz$ & $f_c = 10^6 Hz$

Equation (1) can be rewritten as

$$s(t) = 10 \cos 2\pi (10^6) t + 5 \cos 2\pi (10^6) t \cdot \cos 2\pi (10^3) t + 2 \cos 2\pi (10^6) t \cdot \cos 2\pi (2 \times 10^3) t$$

By using trignometric identity

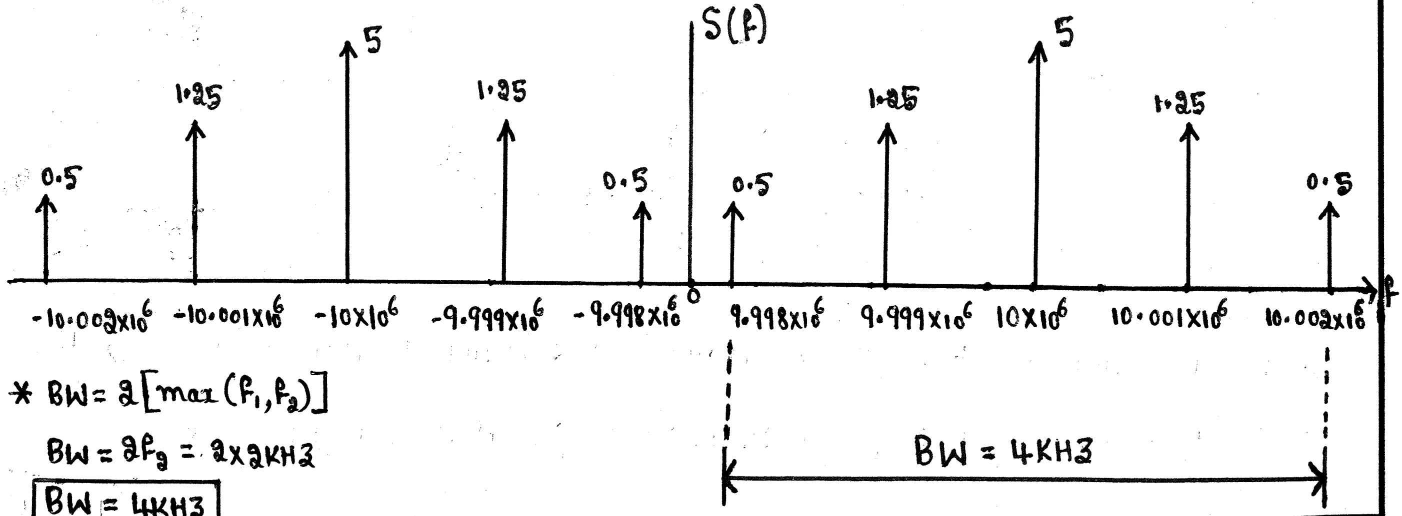
$$\boxed{\cos A \cdot \cos B = \frac{1}{2} \cos (A-B) + \frac{1}{2} \cos (A+B)}$$

$$s(t) = 10 \cos 2\pi (10^6) t + \frac{5}{2} \cos 2\pi (10^6 - 10^3) t + \frac{5}{2} \cos 2\pi (10^6 + 10^3) t + \frac{2}{2} \cos 2\pi (10^6 - 2 \times 10^3) t + \frac{2}{2} \cos 2\pi (10^6 + 2 \times 10^3) t$$

$$s(t) = 10 \cos 2\pi (10^6) t + 2.5 \cos 2\pi (9.99 \times 10^6) t + 2.5 \cos 2\pi (10.001 \times 10^6) t + \cos 2\pi (9.998 \times 10^6) t + \cos 2\pi (10.002 \times 10^6) t \longrightarrow (3)$$

Taking FT of eq (3), we get

$$S(f) = \frac{10}{2} \left[\delta(f - 10^6) + \delta(f + 10^6) \right] + \frac{2.5}{2} \left[\delta(f - 9.999 \times 10^6) + \delta(f + 9.999 \times 10^6) \right] + \frac{2.5}{2} \left[\delta(f - 10.001 \times 10^6) + \delta(f + 10.001 \times 10^6) \right] + \frac{1}{2} \left[\delta(f - 9.998 \times 10^6) + \delta(f + 9.998 \times 10^6) \right] + \frac{1}{2} \left[\delta(f - 10.002 \times 10^6) + \delta(f + 10.002 \times 10^6) \right]$$



* $BW = 2[\max(f_1, f_2)]$

$BW = 2f_2 = 2 \times 2 KHz$

$\boxed{BW = 4KHz}$

iii) W.K.T.

$$A_{max} = A_c(1+\mu) = 50(1+0.75) = 87.5V$$

$$A_{min} = A_c(1-\mu) = 50(1-0.75) = 12.5V$$

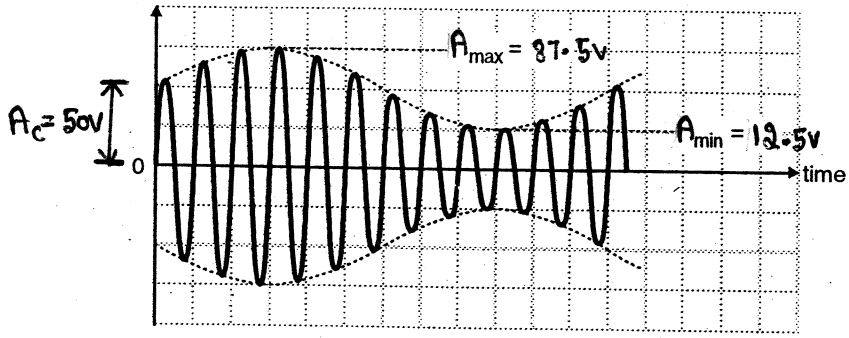


Fig. : AM wave for m = 0.75

An amplitude modulated waveform has the form

$$x_c(t) = 10[1 + 0.5\cos 2000\pi t + 0.5\cos 4000\pi t]\cos(20000\pi t).$$

i) Sketch the amplitude Spectrum of $x_c(t)$

ii) Find the average power content of each Spectral Component including the Carrier

iii) Modulation Index

August - 2002.

Sol: Given : $A_c = 10V$, $\mu_1 = 0.5$, $\mu_2 = 0.5$

$2\pi f_{m1} = 2000\pi$, $f_{m1} = \frac{2000\pi}{2\pi} = 1000Hz$

$2\pi f_{m2} = 4000\pi$, $f_{m2} = \frac{4000\pi}{2\pi} = 2000Hz$

$2\pi f_c = 20000\pi$, $f_c = \frac{20000\pi}{2\pi} = 10KHz.$

$\therefore$ $f_{m1} = 1000Hz$, $f_{m2} = 2000Hz$, $f_c = 10KHz.$

* Consider a message signal $m(t) = 20\cos(2\pi t)$ V & the carrier wave $c(t) = 50\cos(100\pi t)$ V.

i) Write an expression for the resulting AM wave for 75% modulation in time domain.

ii) Draw the spectrum of AM wave.

iii) Sketch the resulting wave for 75% modulation.

July-06, 8M

Sol:- Given: $A_m = 20V$, $f_m = 1Hz$

$A_c = 50V$, $f_c = 50Hz$

$\mu = 0.75$

$\because 2\pi f_c = 100\pi$

$f_c = \frac{100\pi}{2\pi} = 50$

i) The AM signal is given by:

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

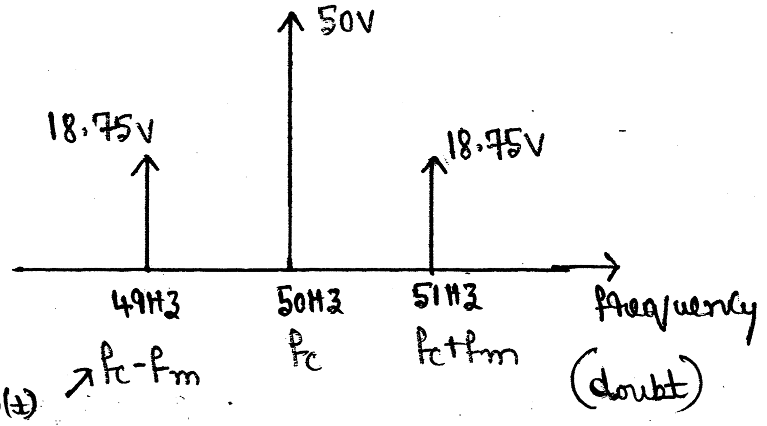
$$\boxed{S(t) = 50[1 + 0.75\cos 2\pi t]\cos 2\pi(50)t.}$$

ii) Spectrum of AM wave:-

$f_{USB} = f_c + f_m = 50 + 1 = 51Hz$

$f_{LSB} = f_c - f_m = 50 - 1 = 49Hz.$

* Amplitude of each sideband is $\frac{\mu A_c}{2} = \frac{(0.75)\times 50}{2} = 18.75V$



NOTE:- By taking FT of $S(t)$ plot the spectrum

* Spectrum of AM wave:-

i) $f_{USB1} = f_c + f_{m1} = 10KHz + 1KHz = 11KHz$

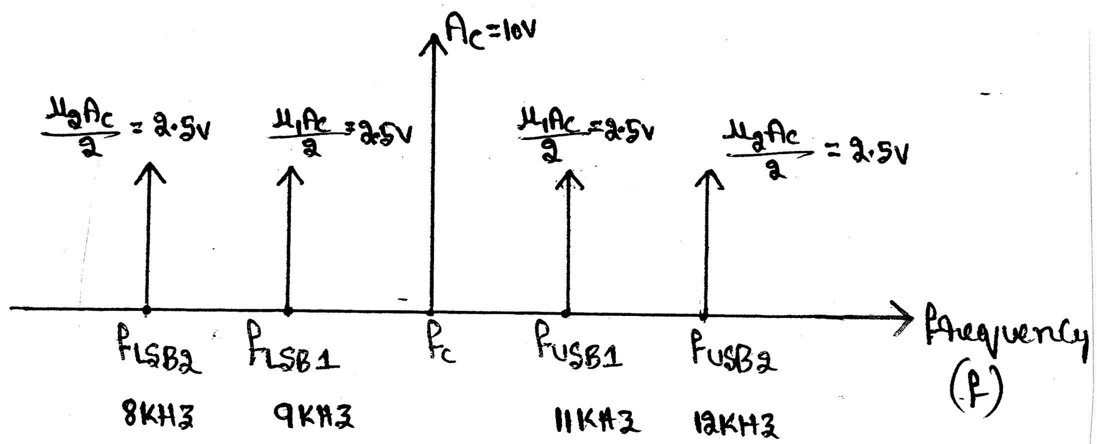
$f_{LSB1} = f_c - f_{m1} = 10KHz - 1KHz = 9KHz$

ii) $f_{USB2} = f_c + f_{m2} = 10KHz + 2KHz = 12KHz$

$f_{LSB2} = f_c - f_{m2} = 10KHz - 2KHz = 8KHz$

* Amplitude of each Side band is i) $\frac{\mu_1 A_c}{2} = \frac{0.5 \times 10}{2} = 2.5V$

ii) $\frac{\mu_2 A_c}{2} = \frac{0.5 \times 10}{2} = 2.5V$



ii) Average power (P_T) :-

$$P_T = P_c + P_{USB1} + P_{USB2} + P_{LSB1} + P_{LSB2}$$

$$P_T = \frac{A_c^2}{2R} + \frac{\mu_1^2 A_c^2}{8R} + \frac{\mu_2^2 A_c^2}{8R} + \frac{\mu_1^2 A_c^2}{8R} + \frac{\mu_2^2 A_c^2}{8R}$$

$$= \frac{(10)^2}{2R} + \frac{(0.5)^2 (10)^2}{8R} + \frac{(0.5)^2 \times (10)^2}{8R} + \frac{(0.5)^2 \times (10)^2}{8R} + \frac{(0.5)^2 \times (10)^2}{8R}$$

$$\boxed{P_T = \frac{50}{R} + \frac{3.125}{R} + \frac{3.125}{R} + \frac{3.125}{R} + \frac{3.125}{R}}$$

iii) Modulation Index:-

$$\mu_t = \sqrt{\mu_1^2 + \mu_2^2} = \sqrt{(0.5)^2 + (0.5)^2} = \underline{0.707}$$

Using message Signal $m(t) = \frac{t}{1+t^2}$, determine & Sketch the modulated wave for AM whose percentage modulation is equal to the following values.

i) $\mu = 50\%$ ii) $\mu = 100\%$ iii) $\mu = 125\%$

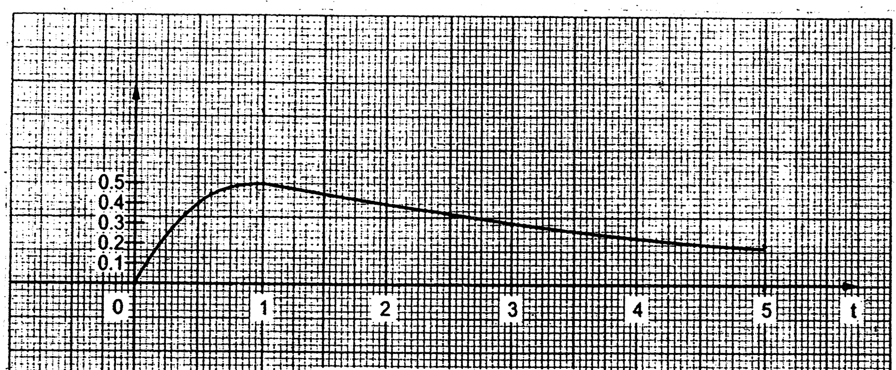
Feb, 2002, 6M

Sol: Message Signal m(t) :-

The modulating Signal is determined from the following table & is Shown in fig ①.

t	0	0.2	0.4	0.6	0.8	1.0	2.0	3.0	4.0	5.0
m (t)	0	0.192	0.345	0.44	0.49	0.5	0.4	0.3	0.235	0.192

Peak or maximum value of m (t) at t = 1.0



(a) Modulating Signal

From above figure, the maximum amplitude of $m(t) = 0.5V$

* Calculate A_c for different values of μ :-

Given : $A_m = 0.5V$

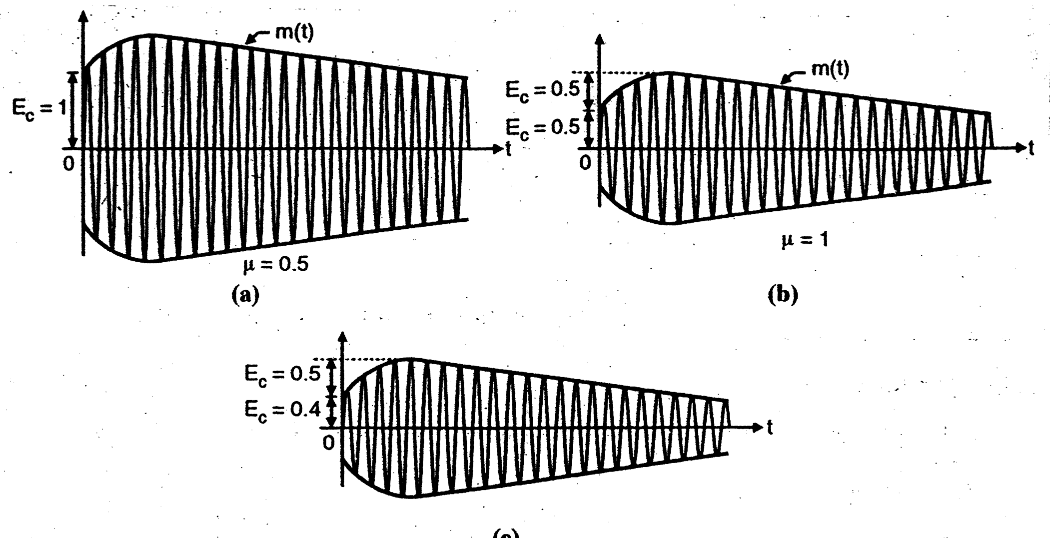
W.K.T $\boxed{\mu = \frac{A_m}{A_c}}$ & $\boxed{A_c = \frac{A_m}{\mu}}$

i) $\mu = 0.5$, $A_c = \frac{A_m}{\mu} = \frac{0.5V}{0.5} = 1V$

ii) $\mu = 1$, $A_c = \frac{A_m}{\mu} = \frac{0.5V}{1} = 0.5V$

iii) $\mu = 1.25$, $A_c = \frac{A_m}{\mu} = \frac{0.5V}{1.25} = 0.4V$

The Waveforms of the AM wave for different values of μ are shown below



(a) AM wave for $\mu = 0.5$ (b) AM wave for $\mu = 1.0$ (c) AM wave for $\mu = 1.25$

Draw the Spectrum of an AM Signal with $c(t) = A_c \cos^2(\pi f_c)t$ & $m(t) = A_m \cos^2(\pi f_m t)$.

June-02, 6M

Sol: Given: $c(t) = A_c \cos^2(\pi f_c t)$

W.K.T $\boxed{\cos^2\theta = \frac{1}{2} + \frac{\cos 2\theta}{2}}$

$$c(t) = A_c\left[\frac{1}{2} + \frac{\cos 2\pi f_c t}{2}\right]$$

$$\therefore \quad c(t) = \frac{A_c}{2} + \frac{A_c}{2}\cos 2\pi f_c t. \longrightarrow (1)$$

Similarly

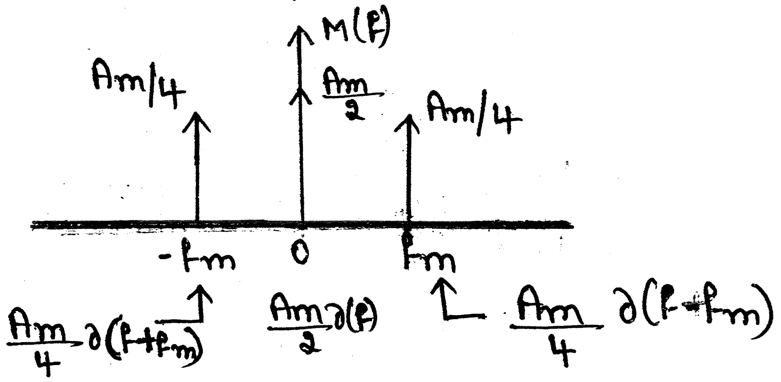
$$m(t) = A_m \cos^2(\pi f_m t)$$

$$m(t) = \frac{A_m}{2} + \frac{A_m}{2}\cos 2\pi f_m t. \rightarrow (2)$$

* Spectrum of m(t) :-

We can get Spectrum of m(t) by taking its Fourier transform i.e. eq ②.

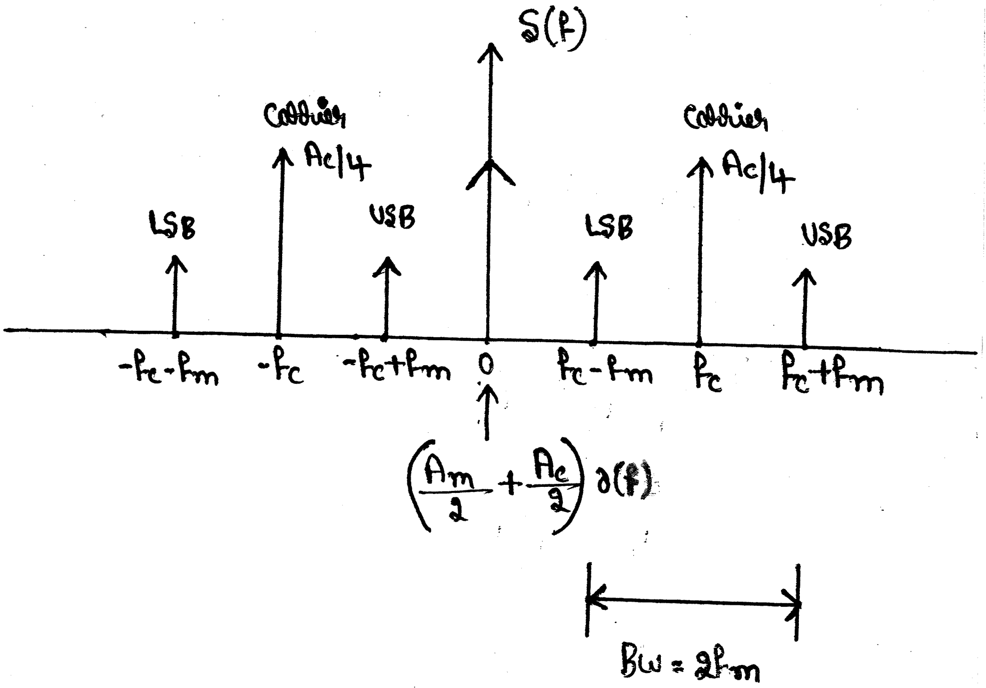
$$M(f) = \frac{A_m}{2}\delta(t) + \frac{A_m}{4}\left[\delta(f+f_m) + \delta(f-f_m)\right]$$



* Spectrum of AM Signal :-

Taking Fourier transform of c(t) i.e. eq ①, we get

$$C(f) = \frac{A_c}{2}\delta(t) + \frac{A_c}{4}\left[\delta(f+f_c) + \delta(f-f_c)\right]$$



Latha H N, Dept of E and C.

For a PN junction diode, the current 'i' through the diode and the voltage 'v' across it are related by

$$i = I_0\left[e^{-v/V_T} - 1\right]$$

Where 'I_0' is the reverse saturation current and 'V_T' is the thermal voltage. At room temperature, $V_T = 0.026$ volts.

(a) Expand 'i' as a power series in v, retaining terms upto v^2.

(b) Let $v = 0.01\cos 2\pi f_m t + 0.01 \cos 2\pi f_c t$ volts, where $f_m = 1KHz$ & $f_c = 100KHz$. Sketch the spectrum of the diode current 'i'.

c) Specify the required bandpass filter to extract from 'i', an AM wave with carrier frequency 'f_c'.

d) What is the percentage modulation Index.

Jan-06, 12M

Solution :- (a) Given $v = 0.01\cos 2\pi f_m t + 0.01\cos 2\pi f_c t$ & $V_T = 0.026$ V.

$$i(t) = I_0\left[e^{-v/V_T} - 1\right] \longrightarrow ①$$

$$\frac{i(t)}{I_0} = \left[e^{-v/V_T} - 1\right] \longrightarrow ②$$

We can write $\boxed{e^{-x} = 1 - x + \frac{1}{2}x^2}$ Put $x = +v/V_T$

$$\boxed{e^{-v/V_T} = 1 - \frac{v}{V_T} + \frac{1}{2}\left(\frac{v}{V_T}\right)^2} \longrightarrow ③$$

Substituting equation ③ in eq ②, we get

$$\frac{i(t)}{I_0} = \cancel{1} - \frac{v}{V_T} + \frac{1}{2}\left(\frac{v}{V_T}\right)^2 - \cancel{1}$$

$$\boxed{\frac{i(t)}{I_0} = -\frac{v}{V_T} + \frac{1}{2}\left(\frac{v}{V_T}\right)^2} \longrightarrow (4)$$

b) Let $v = 0.01 \cos 2\pi f_m t + 0.01 \cos 2\pi f_c t$ volts. $\rightarrow$ (5)

divide both RHS and LHS of equation (5) by V_T

$$\frac{v}{V_T} = \frac{0.01}{V_T} \cos 2\pi f_m t + \frac{0.01}{V_T} \cos 2\pi f_c t.$$

given, $V_T = 0.026V$

$$\frac{v}{V_T} = \frac{0.01}{0.026} \cos 2\pi f_m t + \frac{0.01}{0.026} \cos 2\pi f_c t$$

$$\frac{v}{V_T} = 0.384 \cos 2\pi f_m t + 0.384 \cos 2\pi f_c t \longrightarrow (6)$$

Substituting equation (6) in equation (4), we get

$$\frac{i(t)}{I_0} = -0.384 \cos 2\pi f_m t - 0.384 \cos 2\pi f_c t + \frac{1}{2}\left[0.384 \cos 2\pi f_m t + 0.384 \cos 2\pi f_c t\right]^2$$

W.K.T. $(a+b)^2 = a^2 + b^2 + 2ab$

$$\frac{i(t)}{I_0} = -0.384 \cos 2\pi f_m t - 0.384 \cos 2\pi f_c t + \frac{1}{2}\left[(0.384)^2 \cos^2 2\pi f_m t + (0.384)^2 \cos^2 2\pi f_c t + 2(0.384) \cos 2\pi f_m t \cdot (0.384) \cos 2\pi f_c t\right]$$

$$\frac{i(t)}{I_0} = -0.384 \cos 2\pi f_m t - 0.384 \cos 2\pi f_c t + \frac{(0.384)^2}{2} \cos^2 2\pi f_m t + \frac{(0.384)^2}{2} \cos^2 2\pi f_c t + \frac{1 \cdot \cancel{2}}{\cancel{2}} (0.384)^2 \cos 2\pi f_c t \cdot \cos 2\pi f_m t.$$

$$\frac{i(t)}{I_0} = -0.384 \cos 2\pi f_m t - 0.384 \cos 2\pi f_c t + 0.073 \cos^2 2\pi f_m t + 0.073 \cos^2 2\pi f_c t + 0.147 \cos 2\pi f_c t \cdot \cos 2\pi f_m t.$$

W.K.T

$$\boxed{\cos^2\theta = \frac{1}{2} + \frac{\cos 2\theta}{2}}$$

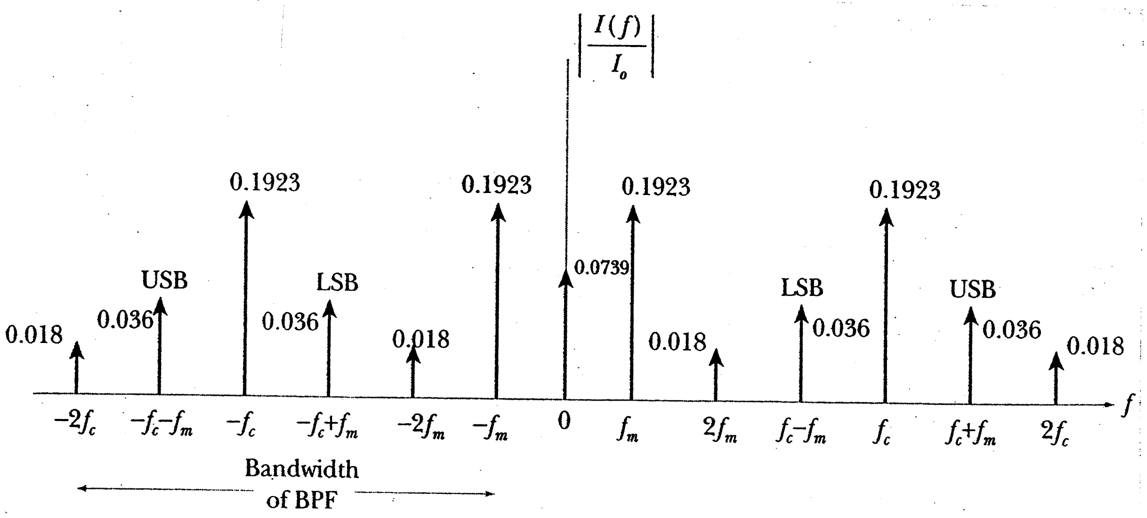
$$\boxed{\cos A \cdot \cos B = \frac{1}{2}\cos(A-B) + \frac{1}{2}\cos(A+B)}$$

$$\frac{i(t)}{I_0} = -0.384 \cos 2\pi f_m t - 0.384 \cos 2\pi f_c t + \frac{0.073}{2} + \frac{0.073}{2} \cos 4\pi f_m t$$
$$+ \frac{0.073}{2} + \frac{0.073}{2} \cos 4\pi f_c t + \frac{0.147}{2} \cos[2\pi(f_c - f_m)t]$$
$$+ \frac{0.147}{2} \cos[2\pi(f_c + f_m)t] \rightarrow (7)$$

$\boxed{\text{NOTE:- } \frac{0.073}{2} + \frac{0.073}{2} = 0.073}$

Taking Fourier transform on both side of equation (7), we get

$$\frac{I(f)}{I_0} = -\frac{0.384}{2}\left[\delta(f - f_m) + \delta(f + f_m)\right] - \frac{0.384}{2}\left[\delta(f - f_c) + \delta(f + f_c)\right]$$
$$+ 0.073\,\delta(f) + \frac{0.073}{4}\left[\delta(f - 2f_c) + \delta(f + 2f_c)\right]$$
$$+ \frac{0.147}{4}\left\{\delta[f - (f_c - f_m)t] + \delta[f + (f_c + f_m)]\right\}$$
$$+ \frac{0.147}{4}\left\{\delta[f - (f_c + f_m)t] + \delta[f + (f_c + f_m)]\right\}$$



Magnitude spectrum of $\frac{I(f)}{I_o}$

c) The required AM wave centred at f_c is obtained by passing the diode current through an ideal BPF having center frequency, $f_c = 100KHz$ and $BW = 2f_m$. $f_m = 1KHz$

$$\boxed{BW = 2KHz}$$

d)

W.K.T

$$\boxed{s(t) = A_c \cos 2\pi f_c t + \frac{\mu A_c}{2} \cos 2\pi (f_c - f_m) t + \frac{\mu A_c}{2} \cos 2\pi (f_c + f_m) t}$$

∴ The time-domain expression from the o/p of the BPF is

$$s(t) = -0.3846 \cos 2\pi f_c t + \frac{0.1479}{2} \cos 2\pi (f_c + f_m) t + \frac{0.1479}{2} \cos 2\pi (f_c - f_m) t.$$

$$s(t) = -0.3846 \cos 2\pi f_c t + 0.0739 \cos 2\pi (f_c + f_m) t + 0.0739 \cos 2\pi (f_c - f_m) t \rightarrow (8)$$

From eq (8), we get

$$|A_c| = 0.3846, \quad \frac{\mu A_c}{2} = 0.0739$$

$$\frac{\mu A_c}{2} = 0.0739$$

$$\mu A_c = 0.1479$$

$$\mu = \frac{0.1479}{A_c} = \frac{0.1479}{0.3846}$$

$$\mu = 0.384$$

$$\boxed{\% \, \mu = 38.4\%}$$

10) An audio frequency Signal $10 \sin 2\pi \times 500 t$ is used to amplitude modulate a Carrier of $50 \sin 2\pi \times 10^5 t$. Calculate

Calculate

i) Modulation Index

ii) Sideband frequencies

iii) Amplitude of each Sideband frequencies

iv) Bandwidth required

v) Total power delivered to the load of 600Ω.

vi) plot frequency spectrum.

Sol: W.K.T modulating Signal $m(t)$ is given by

$$m(t) = A_m \cos 2\pi f_m t \text{ or } m(t) = A_m \sin 2\pi f_m t. \text{ and}$$

$$c(t) = A_c \cos 2\pi f_c t \text{ or } c(t) = A_c \sin 2\pi f_c t.$$

Given:

$$m(t) = 10 \sin 2\pi \times 500 t$$

$$c(t) = 50 \sin 2\pi \times 10^5 t.$$

$$\therefore \quad A_m = 10V, \quad A_c = 50V$$

i) Modulation Index:

$$\mu = \frac{A_m}{A_c} = \frac{10}{50} = 0.2$$

$$\% \ \mu = 0.2 \times 100 = 20$$

ii) Sideband frequencies:

W.K.T $\quad W_m = 2\pi f_m = 2\pi \times 500$

$$\therefore \boxed{f_m = 500 Hz}$$

$$W_c = 2\pi f_c = 2\pi \times 10^5$$

$$\therefore \boxed{f_c = 100 KHz}$$

$$f_{USB} = f_c + f_m = 100\,KHz + 500\,Hz = 100.5\,KHz$$

$$f_{LSB} = f_c - f_m = 100\,KHz - 500\,Hz = 99.5\,KHz$$

iii) Amplitude of each Sideband frequencies

$$\frac{\mu A_c}{2} = \frac{0.2 \times 50}{2} = 5V.$$

iv) Bandwidth required.

$$BW = 2f_m = 2 \times 500 = 1000\,Hz$$

or

$$BW = f_{USB} - f_{LSB} = 100.5\,KHz - 99.5\,KHz = 1000\,Hz$$

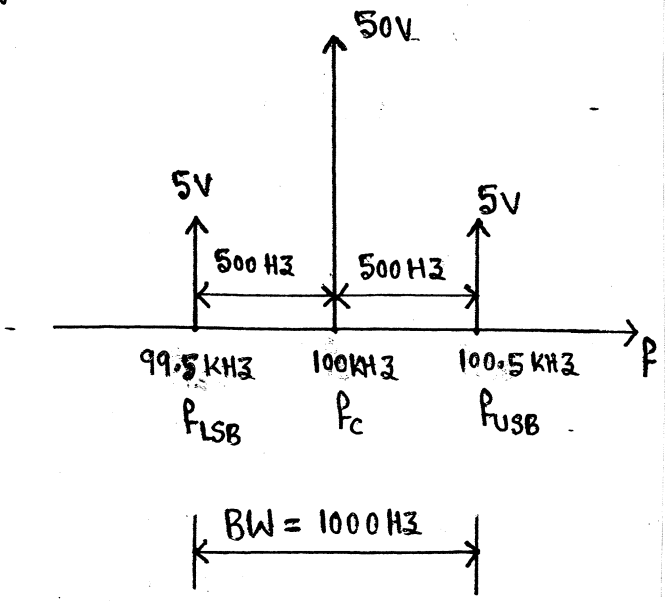
v) Total power delivered into a load of 600 Ω.

$$P_T = P_c\left[1 + \frac{\mu^2}{2}\right] = \frac{A_c^2}{2R}\left[1 + \frac{\mu^2}{2}\right] \qquad \because P_c = \frac{A_c^2}{2R}$$

$$= \frac{(50)^2}{2 \times 600}\left[1 + \frac{(0.2)^2}{2}\right]$$

$$\boxed{P_T = 2.125\ \text{Watts}}$$

vi) Frequency Spectrum of AM Wave:-



A carrier wave with the amplitude 12V and frequency 10MHz is amplitude modulated to 50%. with modulating frequency 1KHz. Write down equations of the above wave and sketch the waveform in frequency domain and also find its bandwidth.

Sol:- Given: $A_c = 12V$, $f_c = 10\times10^6 Hz$, $\mu = 50\% = 0.5$

* Equation of carrier wave is

$$c(t) = A_c \cos 2\pi f_c t$$

$$\therefore \boxed{c(t) = 12 \cos[2\pi\times10\times10^6]t}$$

* W.K.T $\mu = \frac{A_m}{A_c}$

$$A_m = \mu \times A_c = 0.5\times12$$

$$\boxed{A_m = 6V}$$

The Amplitude of modulating wave is 6V with the frequency 1KHZ

∴ Modulating wave is

$$m(t) = A_m \cos 2\pi f_m t$$

$$\boxed{m(t) = 6 \cos[2\pi\times1\times10^3]t}$$

∴ The amplitude modulated wave is given by

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

$$\boxed{S(t) = 12[1+0.5\cos(2\pi\times1\times10^3)t]\cos(2\pi\times10\times10^6)t}$$

To sketch the frequency spectrum we need f_{USB} & f_{LSB}.

$f_{USB} = f_c + f_m = 10 \times 10^6 + 1 \times 10^3$

$$\boxed{f_{USB} = 10.001 \times 10^6 \text{ Hz}}$$

$f_{LSB} = f_c - f_m = 10 \times 10^6 - 1 \times 10^3$

$$\boxed{f_{LSB} = 9.999 \times 10^6}$$

Sideband amplitude is $= \dfrac{\mu A_c}{2} \rightarrow (1)$

W.K.T $\mu = \dfrac{A_m}{A_c} \rightarrow (2)$

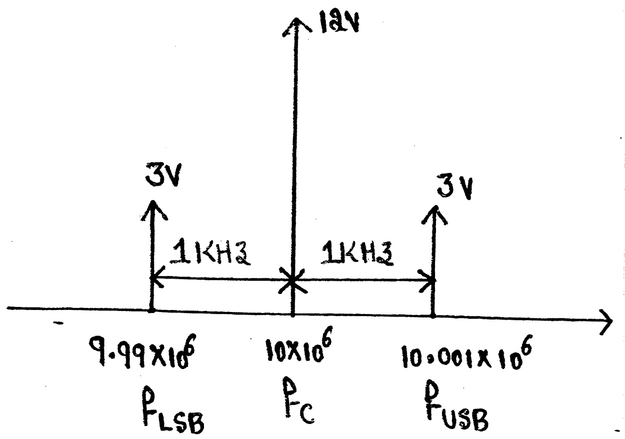
Substituting 'μ' value in eq (1)

$$= \frac{A_m}{\cancel{A_c}} \cdot \frac{\cancel{A_c}}{2}$$

$$= \frac{A_m}{2}$$

$$= \frac{6}{2}$$

$$\boxed{\text{Sideband amplitude} = 3V}$$



Bandwidth :-

$BW = 2 f_m = 2 \times 1 \times 10^3$

$$\boxed{BW = 2 \text{KHz}}$$

Prove that efficiency of ordinary AM is given by:

$$\eta = \frac{P_S}{P_T} \times 100 = \frac{\mu^2}{2+\mu^2} \times 100 \text{ for } \mu \leq 1.$$

Where,

P_S; Power carried by the Sidebands

P_T; Power (total) in the AM Signal.

Further i) Find η for $\mu = 0.5$ or 50% modulation

ii) Show that for a Single tone AM η_{max} is 33.3% at $\mu = 1$.

* Efficiency is given by,

$$\eta = \frac{P_S}{P_T} = \frac{P_{USB} + P_{LSB}}{P_T} \rightarrow (1)$$

W.K.T

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

i.e. $P_{USB} = \dfrac{\mu^2 A_c^2}{8R}$

$P_{LSB} = \dfrac{\mu^2 A_c^2}{8R}$ &

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

Substituting the value of P_T, P_{USB} & P_{LSB} in eq (1), we get

$$\eta = \frac{\frac{\mu^2 A_c^2}{8R} + \frac{\mu^2 A_c^2}{8R}}{P_c(1+\mu^2/2)}$$

$$= \frac{\frac{\cancel{2}\mu^2 A_c^2}{4 \cancel{8}R}}{P_c\left[\frac{2+\mu^2}{2}\right]} = \frac{\frac{\mu^2 A_c^2}{4R}}{P_c\left[\frac{2+\mu^2}{2}\right]}$$

$$= \frac{\frac{\mu^2}{2}\left[\frac{A_c^2}{2R}\right]}{P_c\left[\frac{2+\mu^2}{2}\right]} \qquad \because P_c = \frac{A_c^2}{2R}$$

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

$$= \frac{\frac{\mu^2}{\cancel{2}}}{\frac{2+\mu^2}{\cancel{2}}}$$

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

i) For $\mu = 0.5$

$$\eta = \frac{\mu^2}{2+\mu^2} = \frac{(0.5)^2}{2+(0.5)^2} = 0.111$$

$$\boxed{\% \eta = 11.11\%}$$

ii) For $\mu = 1$

$$\eta = \frac{\mu^2}{2+\mu^2} = \frac{(1)^2}{2+(1)^2} = 0.33$$

$$\boxed{\% \eta = 33.33\%}$$

Draw the AM waveforms for less than 100%, with 100%, more than 100% & with 0% percentage modulation.
Assume that the modulating Signal is a pure Sine wave.

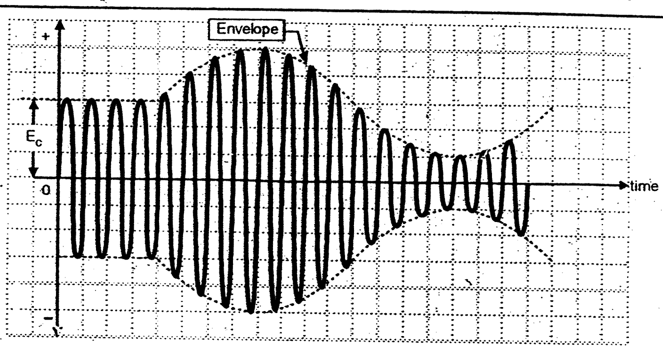
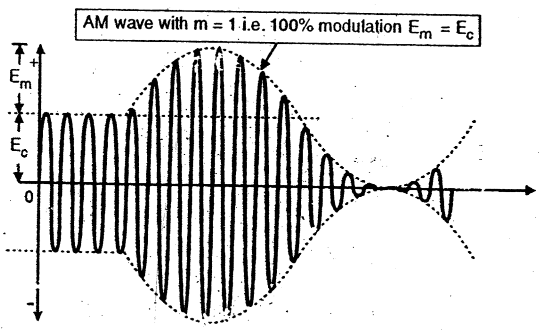
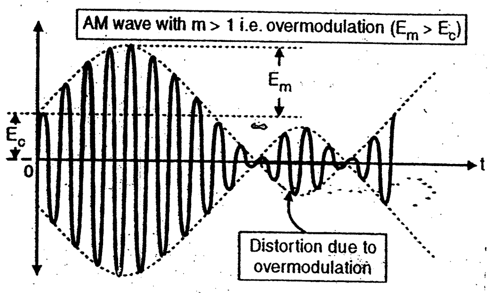


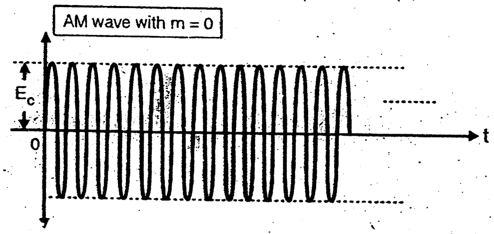
Fig. P. 2.2.1(a) : AM wave for percentage modulation less than 100 %



(b) AM wave with 100% modulation



(c) AM with over modulation



(d) AM wave with m = 0

Envelope Detector

* For minimum clippings, the time constant $R_L C_S$ should be in between the time period of I/p & o/p signal. If o/p signal m(t) ranges from 0 to W Hz & I/p is at frequency f_c,

$$\boxed{\frac{1}{f_c} < R_L C_S < \frac{1}{W}}$$

Formula :

* The condition for minimum distortion is :

$$\boxed{R_L C_S \leq \frac{1}{2\pi f_m} \cdot \frac{\sqrt{1-\mu^2}}{\mu}}$$

Show that in an envelope detector circuit the demodulator is to follow the envelope of m(t), it is required that at any time

$$\frac{1}{R_L C_S} \geq \frac{\omega_m \mu \sin \omega_m t}{1+\mu \cos \omega_m t}$$

Sol :- Let us assume that the capacitor discharges from the peak value 'E' at some arbitrary instant t=0. Then the voltage across the capacitor 'V_c' is given by

$$V_c = E e^{-t/R_L C_S} \rightarrow (1)$$

using Taylor's Series

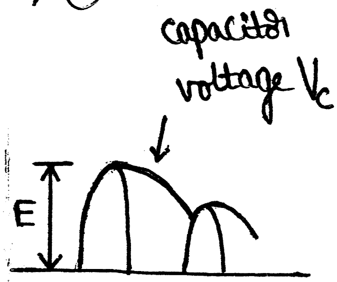
$$V_c \cong E\left[1 - \frac{t}{R_L C_S}\right] \rightarrow (2)$$

(differentiating equation ② w.r.to dt)

* The Slope of discharge is

$$\frac{dV_c}{dt} = -\frac{E}{R_L C_s} \rightarrow ③$$

* The amplitude 'E' at any instant is



$$E = A_c[1 + \mu \cos 2\pi f_m t] \rightarrow ④$$

* The Slope of this envelope is (differentiating eq ④)

$$\frac{dE}{dt} = -\mu A_c \sin 2\pi f_m t.(2\pi f_m) \rightarrow ⑤$$

* In order for the capacitor to follow the envelope 'E(t)', the magnitude of the slope of the $R_L C_s$ discharge must be greater than the magnitude of the Slope of the envelope E(t). Hence

$$\left|\frac{dV_c}{dt}\right| \geq \left|\frac{dE}{dt}\right| \rightarrow ⑥$$

Substituting eq ③ & ⑤ in eq ⑥, we get

$$\frac{E}{R_L C_s} \geq \mu A_c \sin 2\pi f_m t.(2\pi f_m) \rightarrow ⑦$$

Substituting eq ④ in eq ⑦, we get

$$\frac{A_c[1 + \mu \cos 2\pi f_m t]}{R_L C_s} \geq \mu A_c \sin 2\pi f_m t.(2\pi f_m)$$

$$\frac{1}{R_L C_s} \geq \frac{\mu \cancel{A_c} \sin 2\pi f_m t.(2\pi f_m)}{\cancel{A_c}[1 + \mu \cos 2\pi f_m t]}$$

$$\boxed{\frac{1}{R_L C_s} \geq \frac{\omega_m \mu \sin \omega_m t}{1 + \mu \cos \omega_m t}}$$

W.K.T

$$\boxed{\omega_m = 2\pi f_m}$$

* The AM wave $10[1+0.5\cos(2\pi 500t)]\cdot\cos(2\pi 10^6 t)$ is demodulated by an envelope detector. Find the time constant τ and the resistor if capacitor used is 100 pF.

Sol:-

Given : $f_m = 500\,Hz$, $f_c = 10^6\,Hz$, $\mu = 0.5$ & $C_s = 100\,pF$

The time constant $\tau = R_L C_s$ should satisfy the condition

$$\frac{1}{f_c} < R_L C_s < \frac{1}{f_m} \quad \text{and}$$

$$R_L C_s \leq \frac{1}{2\pi f_m}\,\frac{\sqrt{1-\mu^2}}{\mu}$$

$$\leq \frac{1}{2\pi \times 500}\cdot\frac{\sqrt{1-(0.5)^2}}{0.5} \leq \frac{\sqrt{0.75}}{500\pi}$$

$$R_L C_s \leq 5.51\times10^{-4}$$

Time Constant $\tau = 5.51\times10^{-4}$ Sec

for $C_s = 100\,pF$

$$R_L \leq \frac{5.51\times10^{-4}}{C_s} \leq \frac{5.51\times10^{-4}}{100\times10^{-12}}$$

$$\boxed{R_L = 5.51\,M\Omega}$$

Explain the detection of message signal from the amplitude modulated signal using an envelope detector and bringout the significance of the RC time constant of the circuit in detection of the message signal without distortion. Estimate this for fm=3KHz and fc=100KHz. **Jan-06,6M**

Sol :- i) Explain envelope detector

ii) Given : $f_m = 3KHz$, $f_c = 100KHz$.

W.K.T for correct demodulation, it is required that,

$$\frac{1}{f_c} \ll RC \ll \frac{1}{f_m}$$

$$\frac{1}{100\times10^3} \ll RC \ll \frac{1}{3\times10^3}$$

$$\boxed{0.01\,msec \ll RC \ll 0.33\,msec.}$$

* The time constant $\tau = RC$ Should Satisfy the Condition

$$RC \leq \frac{1}{2\pi f_m} \quad \frac{\sqrt{1-\mu^2}}{\mu}$$

assuming $\mu = 0.5$

$$RC \leq \frac{1}{2\pi\times3\times10^3} \cdot \frac{\sqrt{1-(0.5)^2}}{0.5}$$

$$\boxed{RC \leq 0.27\,msec}$$

* In the absence of modulation Index,

$$RC \leq \frac{1}{2\pi f_m}$$

$$RC \leq \frac{1}{2\pi\times3\times10^3}$$

$$\boxed{RC = 0.05\,msec}$$

Latha H N, Dept of E and C.

DSB-SC Modulator Problems

1. A message signal m(t) with spectrum shown in fig.1 is applied to a product modulator with a carrier wave $A_c\cos(2\pi f_c t)$ producing the DSB-SC modulated wave s(t). This modulated wave is next applied to a coherent detector. Assuming a perfect coherence between the transmitter and the receiver, determine the spectrum of the detector output when

   i. fc=1.25KHz **Jan-06,6M**
   ii. fc=.75KHz and sketch the same
   iii. The lowest fc so that m(t) is uniquely determined from s(t)

2. Consider a message signal m(t) with a spectrum shown in fig.2. The message bandwidth w=1KHz. This signal is applied to a product modulator, together with a carrier wave $A_c\cos(2\pi f_c t)$, producing the DSB-SC modulated signal s(t). The modulated signal is next applied to a coherent detector. Assuming perfect synchronism between the carrier waves in the modulator and detector. Determine the spectrum of the detector output when:

   i. fc = 1.25KHz ii. fc= 0.75KHz.

   What is the lowest carrier frequency for which each component of the modulated signal s(t) is uniquely determined by m(t).

Jan-09,6M

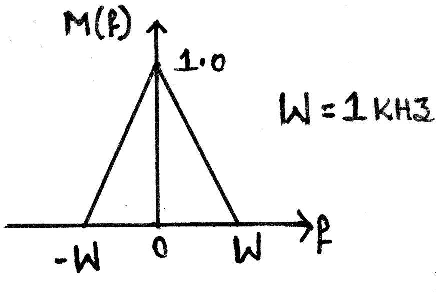


fig ①

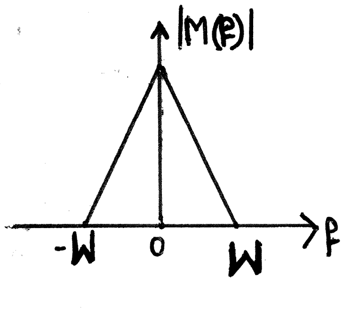


fig ②

Given :- $W = f_m = 1\,KHz$

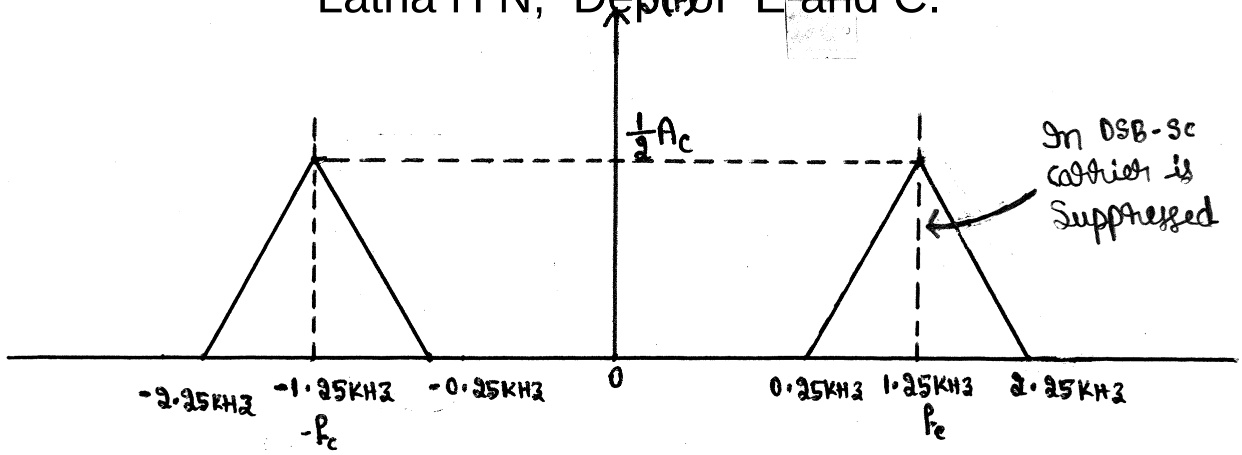
i) When $f_c = 1.25\,KHz$

$f_c + W = 1.25\,KHz + 1\,KHz = 2.25\,KHz$

$f_c - W = 1.25\,KHz - 1\,KHz = 0.25\,KHz$

$-f_c + W = -1.25\,KHz + 1\,KHz = -0.25\,KHz$

$-f_c - W = -1.25\,KHz - 1\,KHz = -2.25\,KHz$



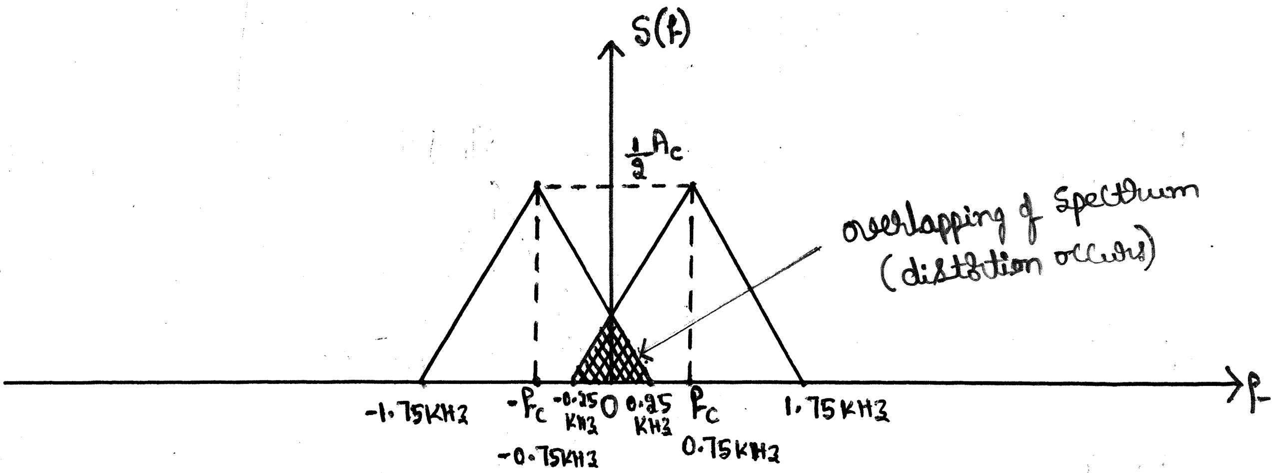
ii) When $f_c = 0.75\,KHz$:

$$f_c + W = 0.75\,KHz + 1\,KHz = 1.75\,KHz$$

$$f_c - W = 0.75\,KHz - 1\,KHz = -0.25\,KHz$$

$$-f_c + W = -0.75\,KHz + 1\,KHz = 0.25\,KHz$$

$$-f_c - W = -0.75\,KHz - 1\,KHz = -1.75\,KHz$$



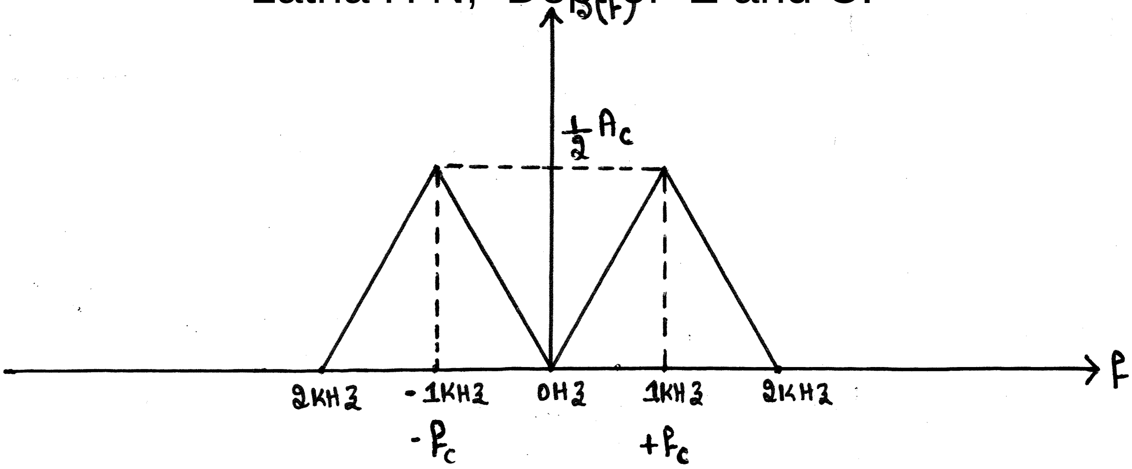
iii) The lowest f_c So that $m(t)$ is uniquely determined from $S(t)$ is 1KHz i.e. $\boxed{f_c = 1\,KHz}$

$$f_c + W = 1\,KHz + 1\,KHz = 2\,KHz$$

$$f_c - W = 1\,KHz - 1\,KHz = 0\,Hz$$

$$-f_c + W = -1\,KHz + 1\,KHz = 0\,Hz$$

$$-f_c - W = -1\,KHz - 1\,KHz = -2\,KHz$$



$\therefore$ Lowest f_c is 1KHz so that m(t) is uniquely determined from S(t).

❖ **Consider a resultant wave obtained by adding a non-coherent carrier $A_c\cos(2\pi f_c t + \phi)$ to a DSB-SC wave $\cos(2\pi f_c t)\, m(t)$. This composite wave is applied to an ideal envelope detector. Find the resulting detector output. Evaluate this output for ϕ=0.**

Jan-10,8M

Sol:-

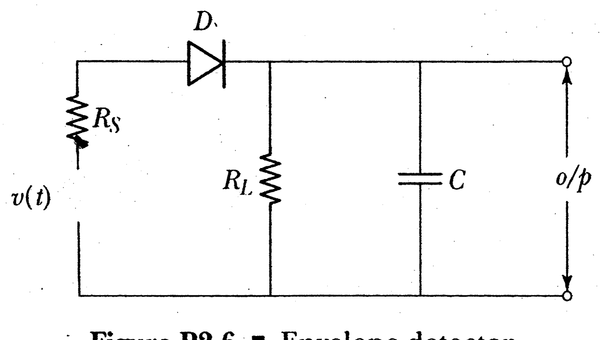


Figure P2.6 ■ Envelope detector

The I/p to the envelope detector is the sum of non-coherent carrier and a DSBSC wave:

$$V(t) = A_c \cos(2\pi f_c t + \phi) + m(t) \cos 2\pi f_c t$$

WKT

$$\cos(A+B) = \cos A \cdot \cos B - \sin A \sin B$$