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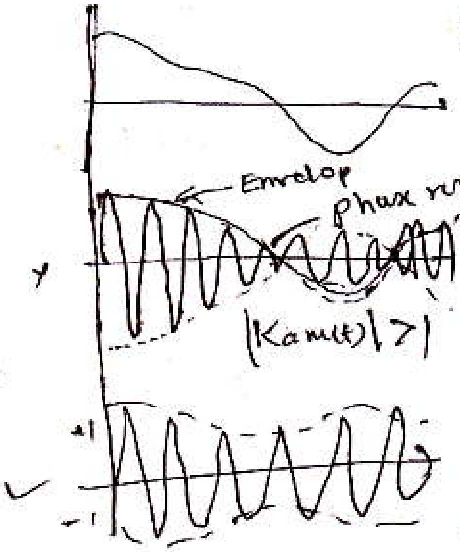
Amplitude Modulation:

Let $c(t) = A_c \cos(2\pi f_c t)$ (1) → Sinusoidal Carrier wave.

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

$m(t)$ → base band signal K_a → Amplitude sensitivity

$\uparrow$ V carrier (un modulated)

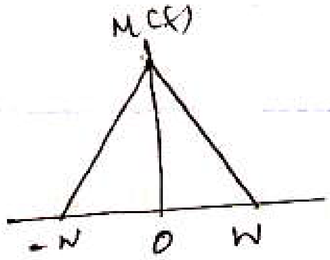


$|K_a m(t)| < 1$ for all t.

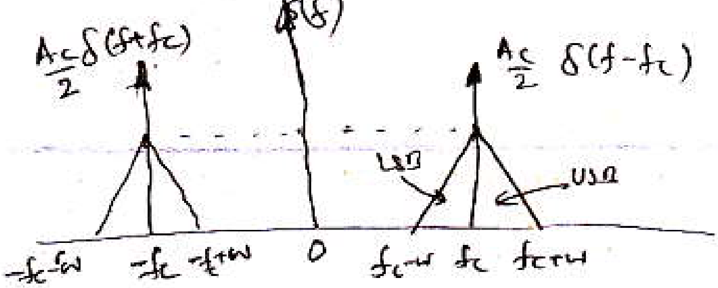
F.T of (2) s(t)

$$S(f) = \frac{A_c}{2}[\delta(f-f_c) + \delta(f+f_c)] + \frac{K_a A_c}{2}[M(f-f_c) + M(f+f_c)] \quad (3)$$

$m(t)$ is band limited to the interval $-W \le f \le W$



⇒

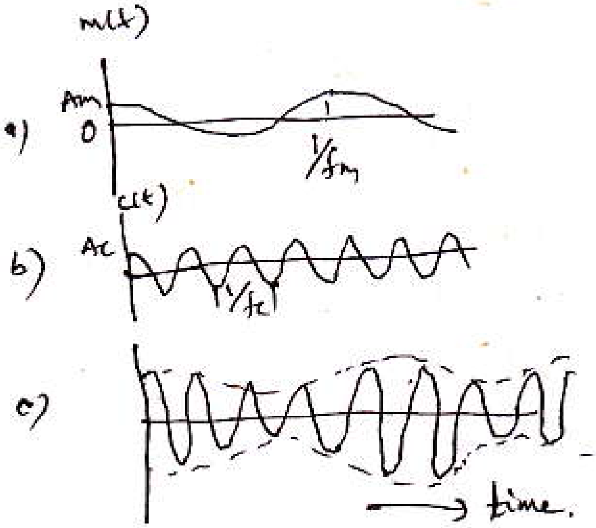


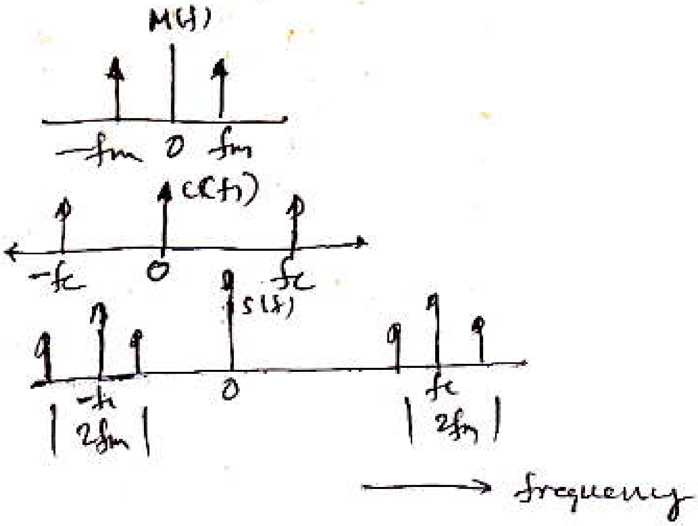
Example: Single tone Modulation: $m(t) = A_m \cos(2\pi f_m t)$

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

$\mu = K_a A_m$ → modulation factor or modulation index

& $\mu = \dfrac{V_{max} - V_{min}}{V_{max} + V_{min}}$ $\dfrac{A_{max}}{A_{min}} = \dfrac{A_c(1+\mu)}{A_c(1-\mu)}$





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

The fourier transform of $s(t)$ is therefore

$$S(f) = \frac{1}{2}A_c[\delta(f-f_c)+\delta(f+f_c)]$$
$$+\frac{1}{4}\mu A_c[\delta(f-f_c-f_m)+\delta(f+f_c+f_m)]$$
$$+\frac{1}{4}\mu A_c[\delta(f-f_c+f_m)+\delta(f+f_c-f_m)] \quad -(4)$$

Thus the spectrum of an AM wave, for the special case of sinusoidal modulation, consists of delta functions at $\pm f_c$, $f_c \pm f_m$, and $-f_c \mp f_m$.

⟹ $s(t)$ is current or voltage wave

⟹ Average power delivered to a 1Ω resistor by $s(t)$ is composed of three components:

- Carrier power $= \frac{1}{2}A_c^2$ — (5)
- USB power $= \frac{1}{8}\mu^2 A_c^2$ — (6)
- LSB power $= \frac{1}{8}\mu^2 A_c^2$ — (7)

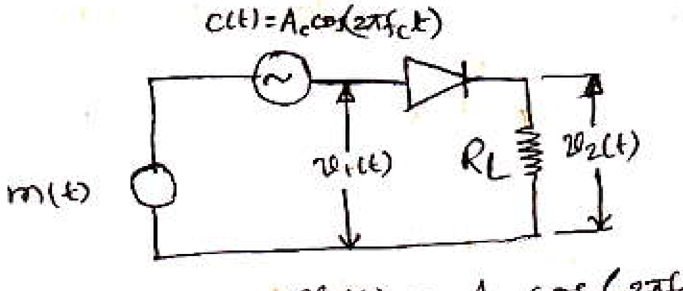
Note: When $R \neq 1\Omega$, has to be divided as per actual value.

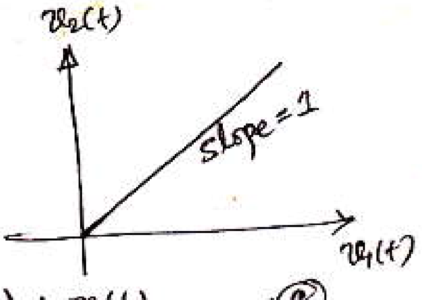
Switching Modulator: is an AM generator

⟹ It is assumed that the carrier wave $c(t)$ applied to the diode is large in amplitude, so that it swings right across the characteristic curve of the diode.

⟹ Assumed that diode acts as ideal switch, i.e., presents zero impedance when it is forward biased.

⟹ Transfer characteristics of the diode-load resistor combination by a piecewise-linear characteristics.





$$v_1(t) = A_c \cos(2\pi f_c t) + m(t) \quad -(8)$$

where $|m(t)| \ll A_c$, the resulting load voltage $v_2(t)$ is

$$v_2(t) \approx \begin{cases} v_1(t), & c(t) > 0 \\ 0, & c(t) < 0 \end{cases} \quad \rightarrow (9)$$

⇒ Since diode passes only positive half cycles of carrier, o/p may be written as

$$v_2(t) \cong [A_c \cos 2\pi f_c t + m(t)]\, g_{T_0}(t) \quad —(10)$$

where $g_{T_0}(t)$ is a periodic pulse train of duty cycle equal to one-half, and period $T_0 = 1/f_c$. Representing this by its Fourier series

$$g_{T_0}(t) = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos[2\pi f_c t(2n-1)] \quad (11)$$

Substituting (11) in (10), we find that the load voltage $v_2(t)$ consists of the sum of two components:

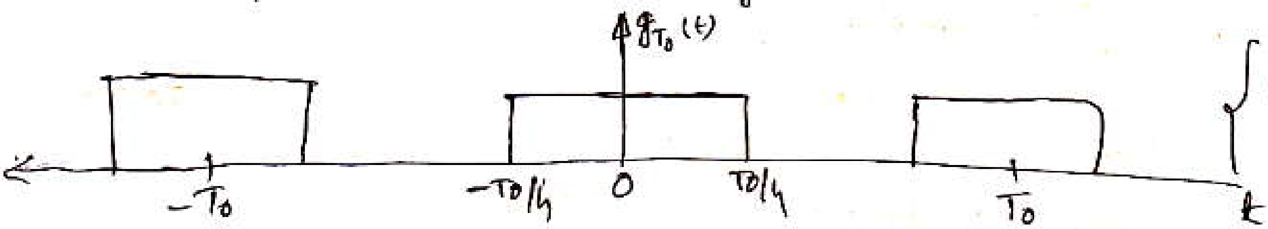
1. The component

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

which is the desired AM wave with amplitude sensitivity $k_a = 4/\pi A_c$

⇒ The switch modulator is therefore made more sensitive by reducing the carrier amplitude A_c; however, it must be maintained large enough to make the diode act like an ideal switch.

2. Unwanted components, the spectrum of which contains delta functions at $0, \pm 2f_c, \pm 4f_c$ and so on, and which occupy freq intervals of width $2W$ centered at $0, \pm 3f_c, \pm 5f_c$, and so on, where W is the message bandwidth.



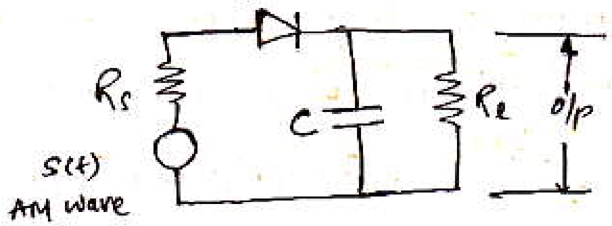
{Periodic pulse train}

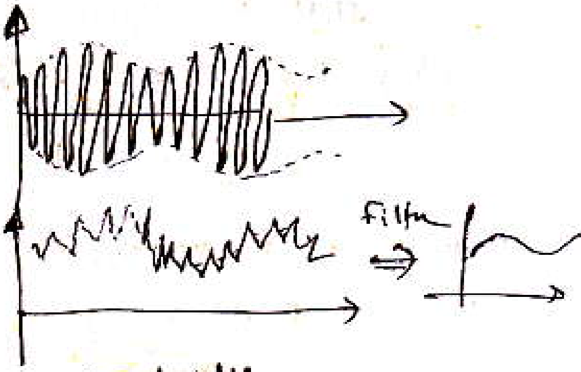
⇒ Unwanted terms are removed from the load voltage $v_2(t)$ by means of a bandpass filter with mid frequency f_c and bandwidth $2W$, provided that $f_c > 2W$.

⇒ This later condition ensures that the frequency separations between the desired AM wave and the unwanted components are large enough for the band-pass filter to suppress the unwanted components.

Envelope Detector: Is a demodulator (recovery cnt) which extracts original Modulating signal

$\Rightarrow$ Modulating signal lies in the envelope, hence envelope detector.





$$(r_f + R_s)C << \frac{1}{f_c}$$

$$\frac{1}{f_c} << R_L C << \frac{1}{W}$$

W $\rightarrow$ message bandwidth.

Virtues, Limitations, and Modifications of Amplitude Modulation

$\Rightarrow$ AM is wastefull of power

$\Rightarrow$ AM is " " BW.

% power saving:

m^2

$P_t = P_c(1+\frac{m^2}{2}) = 1.5 P_c$ for $m=1$ (100%)

a) $P_{SB} = P_c \frac{m^2}{4} = P_c/4 = 0.25 P_c$ only one SB

% Saving $= \frac{1.5P_c - 0.25P_c}{1.5P_c} = \frac{1.25}{1.5} = 0.833 \Rightarrow 83.3\%$

b) $P_t = P_c(1+\frac{0.5^2}{2}) = 1.125 P_c$ (50%)

$P_{SB} = P_c \cdot \frac{0.5^2}{4} = 0.0625 P_c$

% saving $= \frac{1.125 - 0.0625}{1.125} = \frac{1.0625}{1.125} = 0.944 \Rightarrow 94.4\%$