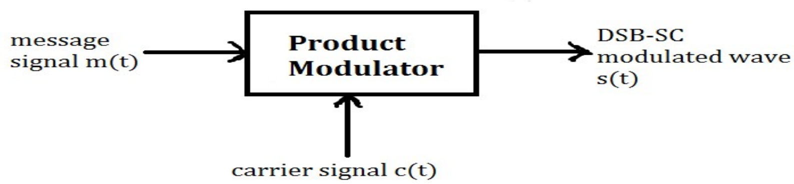
Lecture 07: DSB-SC Generation

Generation of DSB-SC

DSB-SC wave is generated by simply multiplying the message signal $m(t)$ and the carrier signal. Hence the devices used to generate DSB-SC wave are also known Product Modulators.



There are two types of product modulators:

1. Balanced Modulator and
2. Ring Modulator

1. <u>Balanced Modulator:</u>

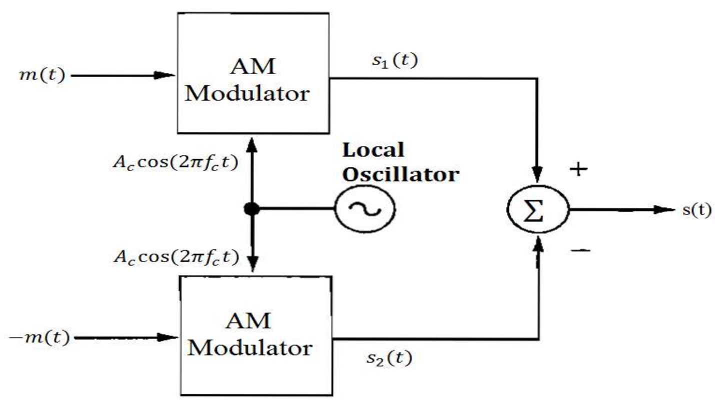


Fig.1. Block diagram of Balanced Modulator

It consists 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 th bottom path is $-m(t)$.

The o/p of two AM modulators are as follows:

$$\mathbf{s_1(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t) \rightarrow (1)}$$

and

$$\mathbf{s_2(t) = A_c[1 - k_a m(t)]\cos(2\pi f_c t) \rightarrow (2)}$$

∴The o/p of the summer is, $\mathbf{s(t) = s_1(t) - s_2(t)}$

$$\Rightarrow \mathbf{s(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t) - A_c[1 - k_a m(t)]\cos(2\pi f_c t)}$$

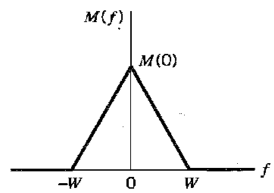
$$\Rightarrow \mathbf{s(t)} = \cancel{\mathbf{A_c\cos(2\pi f_c t)}} + \mathbf{k_a m(t) A_c \cos(2\pi f_c t)} - \cancel{\mathbf{A_c\cos(2\pi f_c t)}} + \mathbf{k_a m(t) A_c \cos(2\pi f_c t)}$$

$$\Rightarrow \mathbf{s(t) = 2k_a A_c m(t) \cos(2\pi f_c t) \rightarrow (3)}$$

The balanced modulator o/p is equal to the product of the modulating signal $m(t)$& the carrier $c(t)$ except the scaling factor $\mathbf{2k_a}$.

Taking Fourier Transform on both sides of equation (3), we get

$$\mathbf{S(f) = k_a A_c [M(f - f_c) + M(f + f_c)] \rightarrow (4)}$$



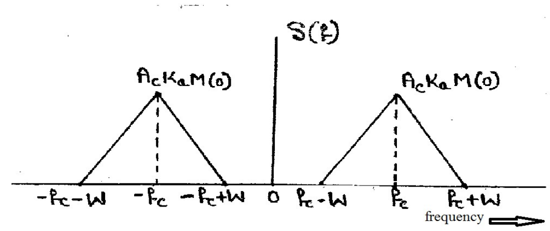


Fig.(a) Message signal Spectrum **Fig.(b) DSB-SC Spectrum**

Since the carrier component is eliminated, the o/p is called DSB-SC signal and its transmission bandwidth is 2W Hz.

2. <u>Ring Modulator:</u>

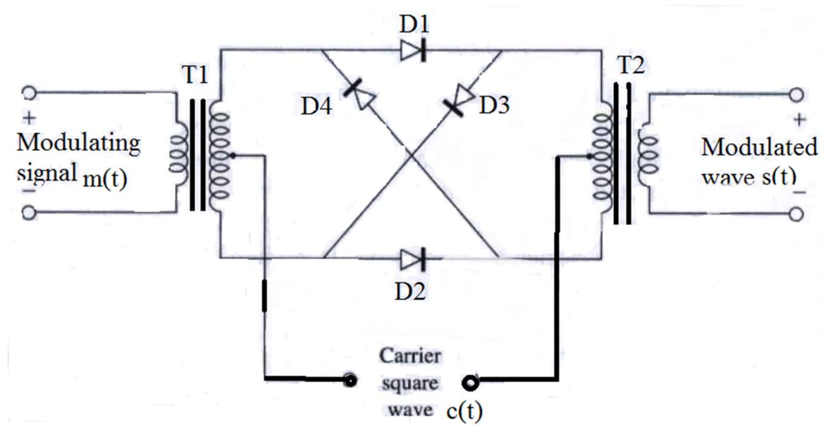


Fig.1. Ring Modulator

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

i) I/P transformer ‘T_1’,

ii) O/P transformer ‘T_2’, and

iii) 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 the carrier frequency $'f_c'$ is greater than the modulating signal frequency $'f_m'$ (=W) i.e. $f_c > W$, to ensure the diode operation is controlled by $c(t)$ only.

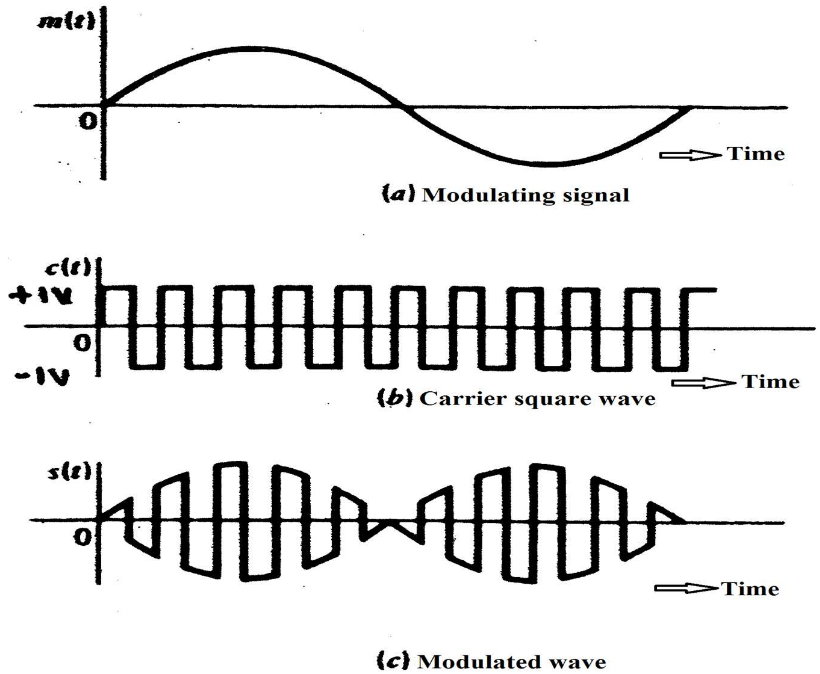


Fig.2.Waveforms in the operation of ring modulator

The diodes are controlled by a carrier square wave $\mathrm{c(t)}$ of frequency $'f_c'$ which is applied by means of two centre-tapped transformers.

The modulating signal $\mathrm{m(t)}$ is applied to the primary of i/p RF transformer 'T_1'. The o/p appears across the secondary of the AF transformer 'T_2'.

Operation:

i) When the carrier is positive, 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 $\mathrm{m(t)}$ by +1(the maximum value of $|\mathrm{c(t)}|$) i.e. $V_o(t) = c(t)m(t) = +m(t)$.

ii) When the carrier is negative, the diodes D_1& D_2 are reverse-biased and diodes D_3& D_4 are forward-biased. Hence the modulator multiplies the message signal $\mathrm{m(t)}$ by -1(the negative maximum value of $|\mathrm{c(t)}|$) i.e. $V_o(t) = c(t)m(t) = -\,m(t)$.

The carrier square wave $\mathrm{c(t)}$ can be represented by a Fourier series as:

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

$$\Rightarrow c(t) = \frac{4}{\pi}\left[\cos(2\pi f_c t) - \frac{1}{3}\cos(6\pi f_c t) + \cdots\right] \rightarrow (2)$$

The ring modulator output is $s(t) = c(t).\,m(t) \rightarrow (3)$

Substituting equation (2) in equation (3), we get

$$s(t) = \frac{4}{\pi}\left[\cos(2\pi f_c t) - \frac{1}{3}\cos(6\pi f_c t) + \cdots\right].m(t)$$

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

Taking Fourier transform on both sides of equation (4), we get

$$S(f) = \frac{4}{2\pi}[M(f - f_c) + M(f + f_c)] - \frac{4}{6\pi}[M(f - 3f_c) + M(f + 3f_c)]$$

$$\Rightarrow S(f) = \frac{2}{\pi}[M(f - f_c) + M(f + f_c)] - \frac{2}{3\pi}[M(f - 3f_c) + M(f + 3f_c)] \longrightarrow (5)$$

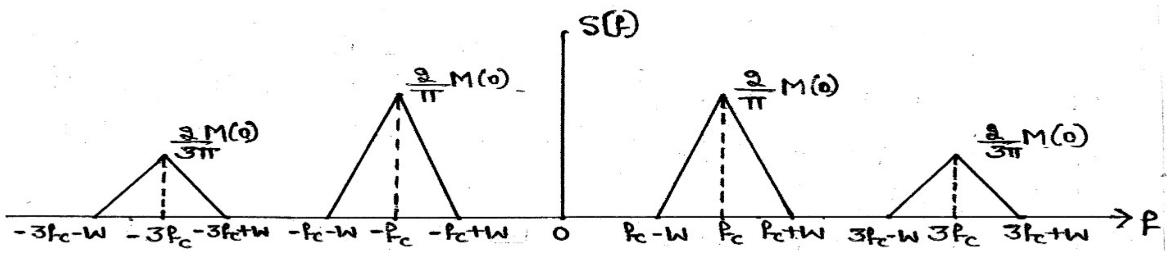


Fig.3. Amplitude spectrum of $S(f)$

The DSB-SC wave is extracted from $s(t)$ by passing equation (4) through an ideal BPF having centre frequency f_c and bandwidth equal to 2W Hz.

The O/P of the BPF is

$$\mathbf{s(t) = \frac{4}{\pi} m(t)\cos(2\pi f_c t).}$$