Double Side Band Suppressed Carrier (DSB-SC) System:⇒

* For 100% modulation about 67% of the total power is required for transmitting the carrier which does not contain any information.
* Hence, if the carrier is suppressed, only the sidebands remain and in this way a saving of two-third power may be achieved at 100% modulation.
* This type of suppression of carrier does not effect the base-band signal in any way. The resulting signal obtained by suppressing the carrier from the modulated wave is called DSB-SC system.
* Thus, in a DSB-SC modulation there is no carrier signal only sidebands are present.

$$\text{If } x(t) \longleftrightarrow X(\omega)$$

$$\text{then } e^{j\omega_c t} \cdot x(t) \longleftrightarrow X(\omega-\omega_c)$$

This property state that if a signal $x(t)$ is multiplied by $e^{j\omega_c t}$ in time-domain then its spectrum $X(\omega)$ in frequency-domain is shifted by an amount ω_c.

Similarly,

$$e^{-j\omega_c t} \cdot x(t) \longleftrightarrow X(\omega+\omega_c)$$

* But $e^{j\omega_c t}$ is not real function, and can not be generated practically, therefore, frequency-shifting is achieved by multiplying $x(t)$ by sinusoid such as $\cos\omega_c t$.

hence,

$$x(t)\cos\omega_c t = x(t)\cdot\frac{1}{2}\left(e^{j\omega_c t} + e^{-j\omega_c t}\right)$$

$$= \frac{1}{2}x(t)e^{j\omega_c t} + \frac{1}{2}x(t)e^{-j\omega_c t}$$

using frequency-shifting property

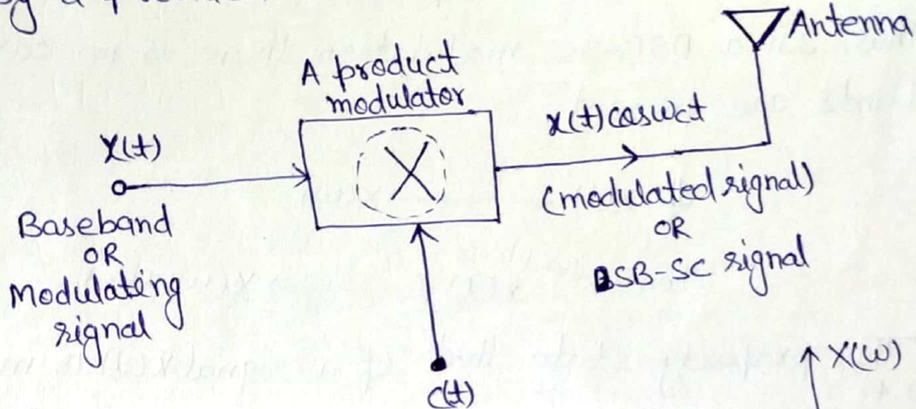
$$x(t)\cos\omega_c t \longleftrightarrow \frac{1}{2}\left[X(\omega-\omega_c)+X(\omega+\omega_c)\right]$$

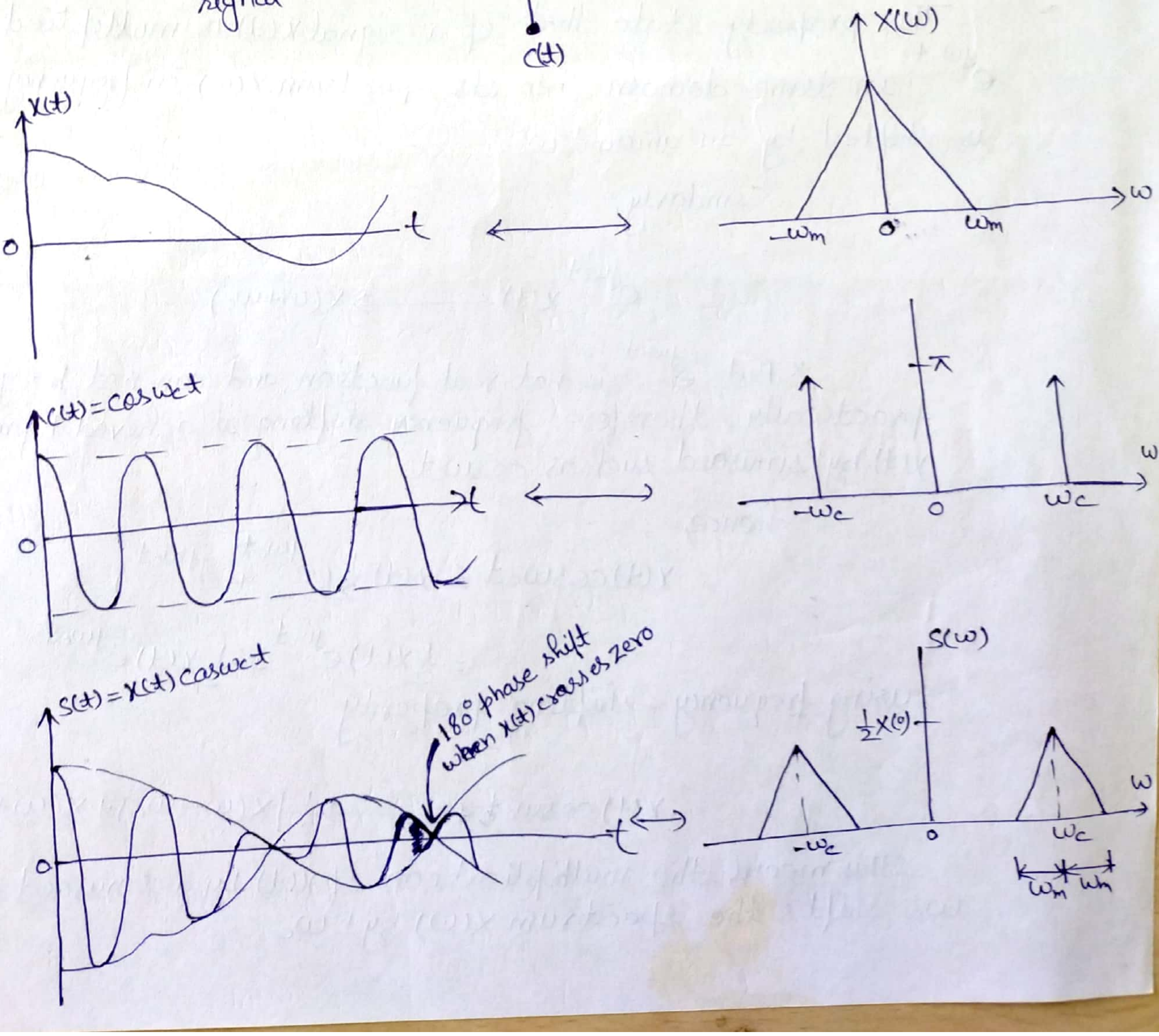
This means, the multiplication of $x(t)$ by a sinusoid of frequency ω_c shifts the spectrum $X(\omega)$ by $\pm\omega_c$.

* Now if $x(t)$ is taken as modulating or baseband signal and $\cos\omega_c t$ is taken as carrier signal, then $x(t)\cos\omega_c t$ represents the modulated signal.

* The fourier transform of this modulated signal shows the spectrum of modulated signal contains only shifted spectrum of two side band signal and there is no carrier components, therefore DSB-SC modulation.

* The term $x(t)\cos\omega_c t$ represents a DSB-SC signal, this is achieved by a product modulator.





* The DSB-SC signal exhibits phase-reversal at zero crossings, i.e. whenever the baseband signal $x(t)$ crosses zero. Because of this the envelope of a DSB-SC modulated signal is different from the message signal. This is unlike the case of an AM wave.

* It is also clear that the impulses at $\pm\omega_c$ are missing which means that the carrier term is suppressed in the spectrum and only two sideband, USB and LSB are left.

* The difference of these two sideband frequency is equal to the transmission bandwidth of DSB-SC signal. i.e.

$$B = (\omega_c + \omega_m) - (\omega_c - \omega_m)$$

$$B = 2\omega_m$$

* It is the same as that of general AM wave

Generation of DSB-SC signal :⇒

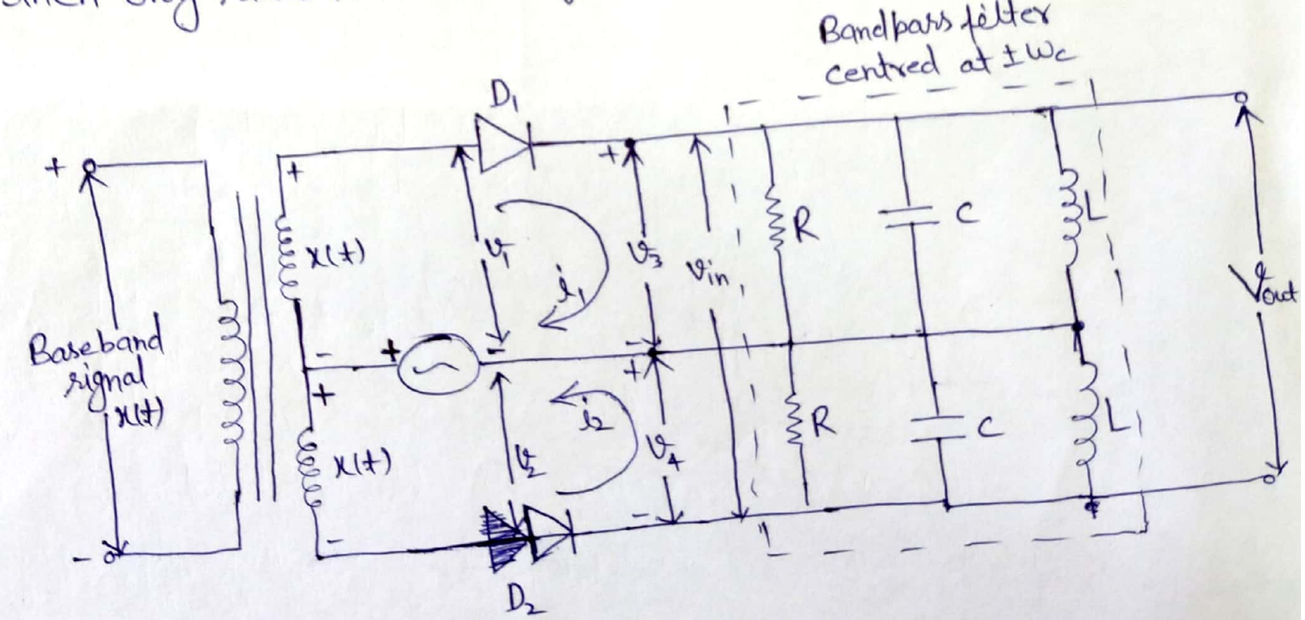
A DSB-SC signal is basically the product of the modulating or base band signal and the carrier signal. A circuit to achieve the generation of a DSB-SC signal is called a product modulator.

There are two type of product modulator for generating DSB-SC signal –

1. Balanced Modulator
2. Ring Modulator.

1. Balanced Modulator :⇒

We know that a non-linear device may be used to produce Amplitude Modulation, i.e., one carrier and two sidebands. However, a DSB-SC signal contains only two sidebands. If two non-linear devices such as diodes, transistors etc. are connected in balanced mode so as to suppress the carriers of each other, then only sidebands are left, i.e. a DSB-SC signal is generated.



Balanced modulator circuit using two diodes. A modulating signal $x(t)$ is applied to the two diodes through a centre-tapped transformer with the carrier signal $\cos \omega_c t$.

A non-linear v-I relationship is given as

$$i = av + bv^2$$

here, we have neglected the higher power terms.

where,

v = the input valtage applied across a non-linear devices

i = the current flows through the non-linear devices.

a and b = any constant of proportionality

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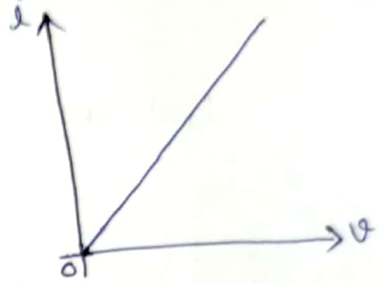
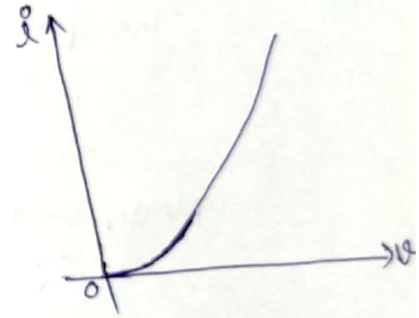
* the relationship b/w v and i in a linear resistance



$$i = bv$$

* the relationship b/w v and i in a non-linear resistance



$$i = a + bv + cv^2 + dv^3 + \text{---}$$

where, a is the dc component of the current, and for simplicity, neglecting the higher power terms, therefore

$$i = a + bv + cv^2$$

$\Rightarrow$ The two input valtages v_1 and v_2 across the diodes

$$v_1 = \cos w_c t + x(t)$$

$$v_2 = \cos w_c t - x(t)$$

For diode D_1, the non-linear v-i relationship

$$i_1 = av_1 + bv_1^2$$

substituting the value of v_1

$$i_1 = a[\cos w_c t + x(t)] + b[\cos w_c t + x(t)]^2$$

$$i_1 = a\cos w_c t + ax(t) + b[\cos^2 w_c t + x^2(t) + 2x(t)\cos w_c t]$$

$$i_1 = a\cos w_c t + ax(t) + b\cos^2 w_c t + bx^2(t) + 2bx(t)\cos w_c t$$

Similarly, for diode D_2, the nonlinear v-i relationship becomes

$$i_2 = av_2 + bv_2^2$$

substituting the value of v_2

$$i_2 = a[\cos\omega_c t - x(t)] + b[\cos\omega_c t - x(t)]^2$$

$$i_2 = a\cos\omega_c t - ax(t) + b\cos^2\omega_c t + bx^2(t) - 2bx(t)\cos\omega_c t$$

Due to current i_1 and i_2, the net voltage v_i at the input of band pass filter is

$$v_i = v_3 - v_4$$

But from the circuit diagram, we have

$$v_3 = i_1 R$$

and $$v_4 = i_2 R$$

Therefore,

$$v_i = i_1 R - i_2 R$$

$$v_i = R(i_1 - i_2)$$

Now, we get

$$v_i = R[2ax(t) + 4bx(t)\cos\omega_c t]$$

OR $$v_i = 2R[ax(t) + 2bx(t)\cos\omega_c t]$$

This voltage v_i is the input to the band pass filter centered around $\pm\omega_c$

The band pass filter is that type of filter which allows to pass a band of frequencies. here, since the band pass filter is centred around $\pm\omega_c$, it will pass a narrow band of frequencies centered at $\pm\omega_c$ with a small bandwidth of $2\omega_m$ to preserve the sidebands.

Therefore, the output of BPF centered around $\pm\omega_c$ is given by

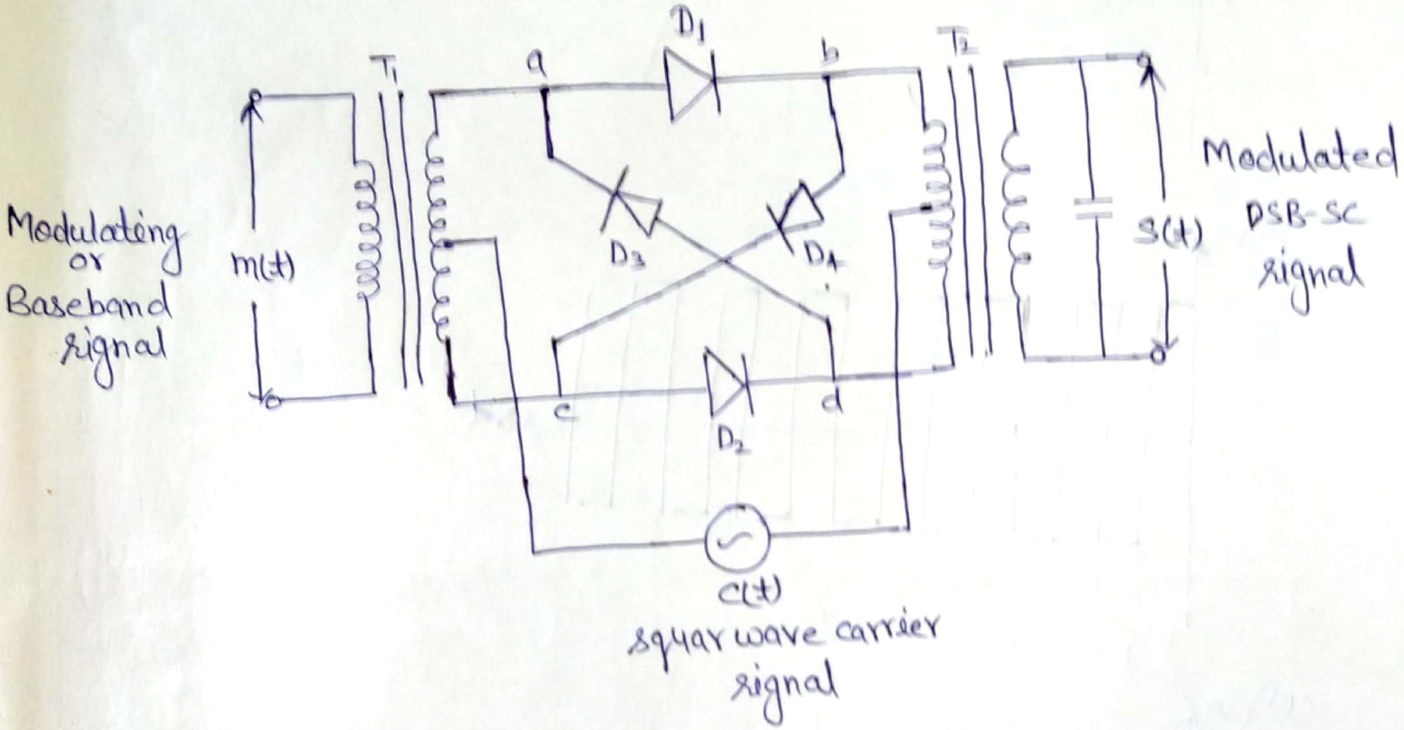
$$v_o = 4bRx(t)\cos\omega_c t$$

OR $$v_o = K\,x(t)\cos\omega_c t$$

which is the expression for a DSB-SC signal.

Ring Modulator :⇒

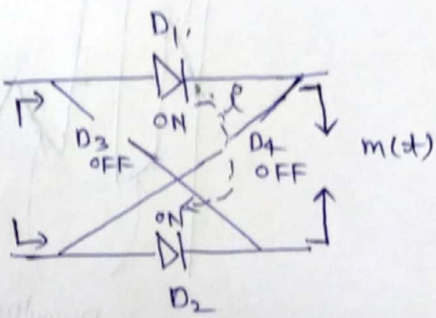
Ring modulator is another product modulator, which is used to generate DSB-SC signal. In a ring modulator circuit, four diodes are connected in the form of a ring in which all diodes point in same manner, and controlled by a squar wave carrier signal c(t) of frequency fc applied through a center-tapped transformer



Case 1. For +ve half cycle of m(t) and c(t)

D_1 and D_2 = ON

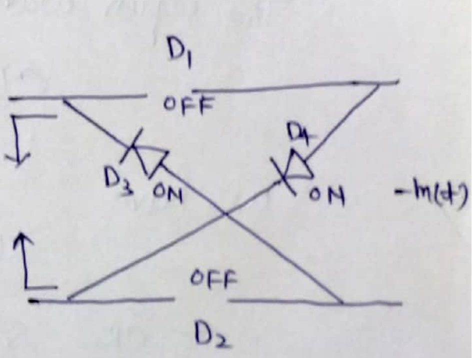
D_3 and D_4 = OFF



Case 2. For -ve half cycle of m(t) and c(t)

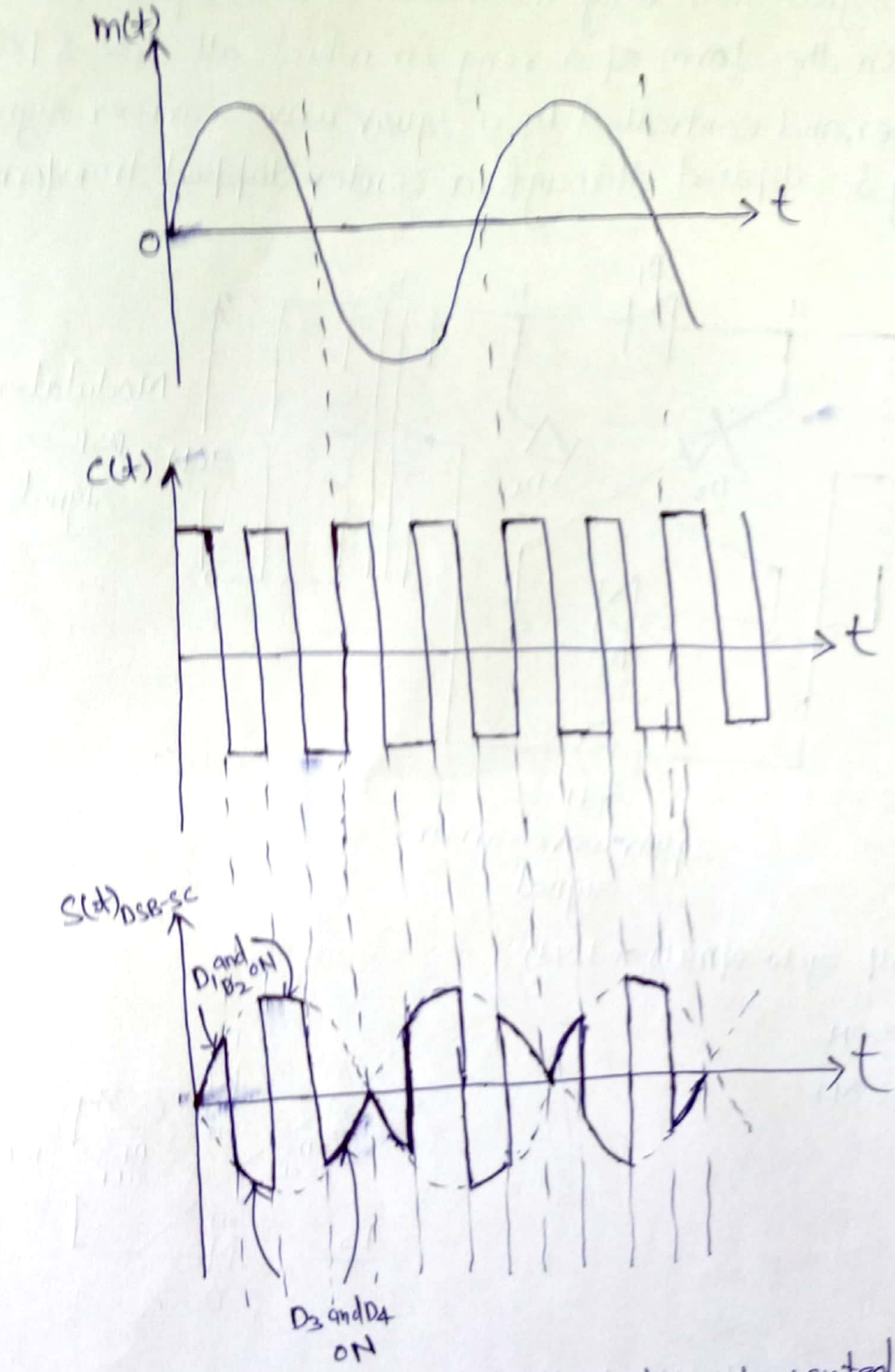
D_1 and D_2 = OFF

D_3 and D_4 = ON



* In both cases at T_1 and T_2 the currents are equal and aposite, therefore they are going to cancel magnetic field, so output mode is zero, Thus carrier wave suppressed in both cases.

Hence, the ring modulator is a product modulator for a squar wave carrier and modulating signal (assuming a sinusoidal), therefore the resulting signal is the modulated signal or DSB-SC signal.



The sequar wave carrier may be represented in fourier series

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

we have

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

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

Power Saving in DSB-SC Modulation :-

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

therefore,

total saving power = P_c

$$\%\ \text{of power saving} = \frac{\text{Total power saved}}{\text{total transmitted power}} \times 100$$

$$= \frac{P_c}{P_c\left(1+\frac{m^2}{2}\right)} \times 100$$

$$= \frac{2}{2+m^2} \times 100$$

when

$m=1$

$$\Rightarrow \frac{2}{3} \times 100 = 66.67\%$$

and $m = 0.5$

$$\Rightarrow \frac{2}{2+(0.5)^2} \times 100 = 88.88\%$$