- Principles of Telecommunication
- Module 2_ Amplitude Modulation
- Lecture Plan _ Part3

1. Double Sideband Suppressed Carrier (DSB-SC) System .

(a) Explain The Generation of DSB-SC Signal using Balanced Modulator (2019)

Note- Definition and Mathematical Expression

The equation of AM wave in its simplest form i.e. single tone modulation, is

$$s(t) = A\cos\omega_c t + A\frac{m_a}{2}\cos(\omega_c + \omega_m)t + A\frac{m_a}{2}\cos(\omega_c - \omega_m)t$$

expressed as :

- From this equation, it is obvious that the carrier component in AM wave remains constant in amplitude and frequency .
- This means that the carrier of amplitude modulated wave does not convey any information .

In power calculation of AM signal, it has been observed that for single-tone sinusoidal modulation, the ratio of the total power to the carrier power is :

where ma is the modulating index

- Thus, for 100% modulation about 67%

$$\frac{P_t}{P_c} = 1 + \frac{m_a^{\,2}}{2}$$

  of the total power is required for transmitting the carrier which does not contain any information .

- Hence, if the carrier is supressed, only the sidebands remain and in this way a saving of two-third power may be achieved at 100% modulation .

The resulting signal obtained by supressing the carrier from the modulated wave is called **Double sideband supressed carrier (DSB-**

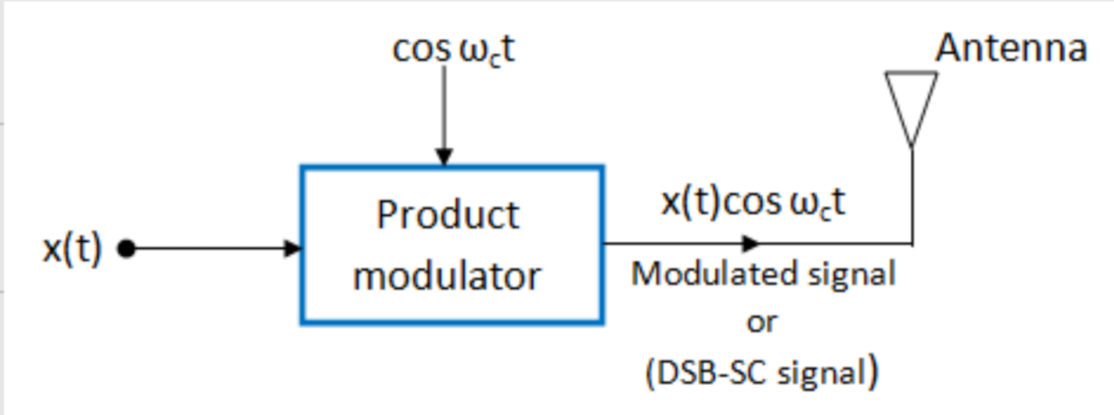
SC) system .

(a) Explain The Generation of DSB-SC Signal using Balanced Modulator

Answer -

Generation of DSB-SC Signal

A DSB-SC signal can be obtained by simply multiplying modulating signal x(t) with carrier signal cosωct . So we need to use a device called product modulator for the



generation of DSB-SC waves .

Fig 1

There are two forms of product modulators as under :

- Linear Modulator
- Non-linear Modulator

Linear Modulator for DSB-SC Generation

A linear modulator is a system whose gain or transfer function can be varied with time by applying a time varying signal at certain points .

The gain is proportional to signal f(t) .

$G = K f(t)$

Where G = gain

K = constant of proportionality

f(t) = gain varying signal

Let us consider fig.2 in which the carrier signal cosωct is applied at the input terminal and x(t) is applied as the gain varying signal .

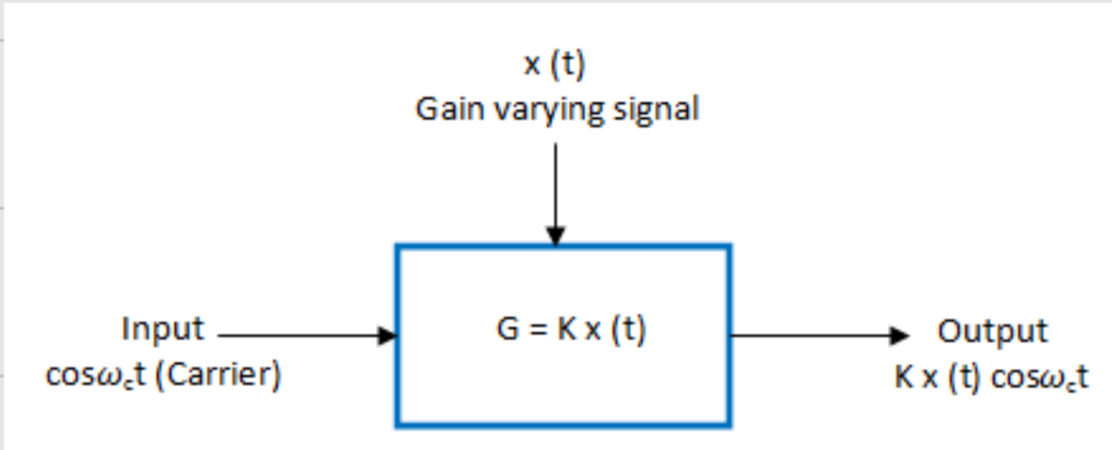


Fig 2 :Linear Modulator

The gain of the modulator is G = K x(t) .

Therefore, the output is given by :

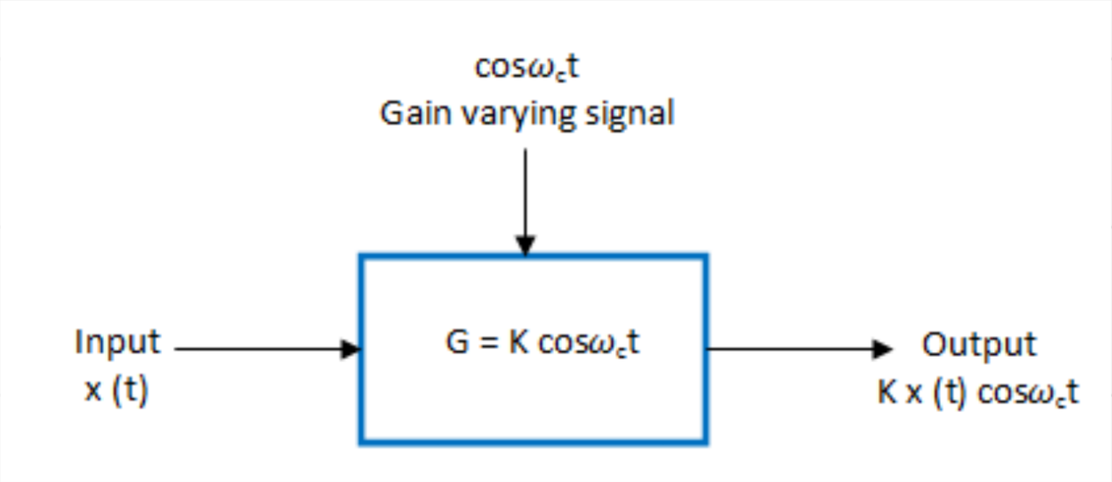
$$V_o = G \times input$$

$$V_o = Kx(t)cos\omega_c t$$

Or,

This is a modulated signal (DSB-SC) .

AS an alternative we can use the carrier as gain varying signal and x(t) as the input



signal as shown in fig 3.

Fig 3: Another variation of Linear Modulator

The gain of the modulator is given by :

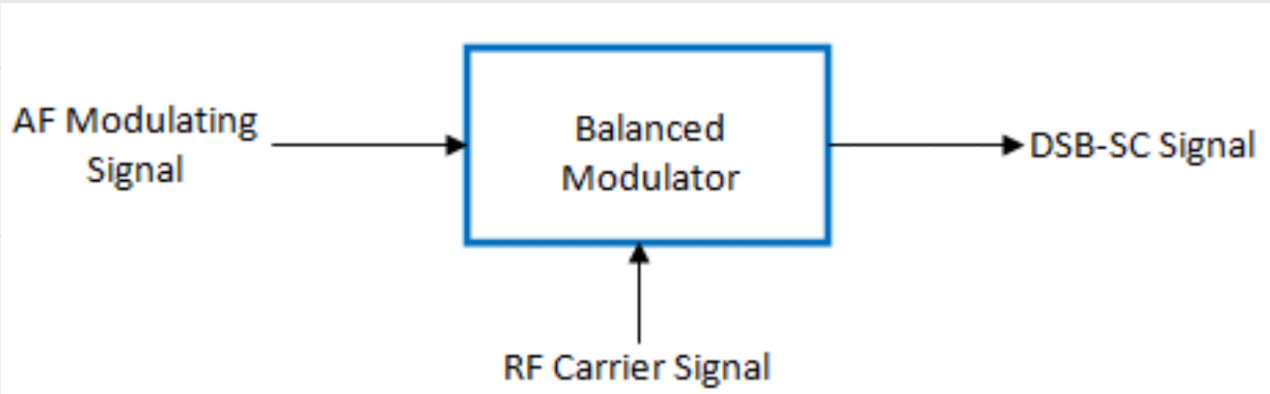
G = K cosωct

$$V_o = Kx(t)cos\omega_c t$$

Therefore,
This is same version as before in figure 1.
The diode ring modulator used for dscbsc generation is another version of Linear Modulator.

Balanced Modulator (Suppression of Carrier)

The balanced modulators are used to suppress the unwanted carrier in AM



wave .

Fig.4 : Block Diagram of Balanced Modulator

The carrier and modulating signals are applied to the inputs of the balanced modulator and we get the DSB signal with supressed carrier at the output of the balanced modulator . Hence, the output consists of the upper and lower sidebands only .

Principle of Operation

The principle of operation of a balanced modulator states that if two signals at different frequencies are passed through a non-linear resistance then at the output, we get an AM signal with suppressed carrier . The device having a non-linear resistance can be a diode or a JFET or even a bipolar transistor .

Types of Balanced Modulator

The suppression of carrier can be done using the following two balanced modulators :

- Using the diode ring modulator or lattice modulator

- Using the FET balanced modulator

(i) Balanced Modulator using AM Modulator

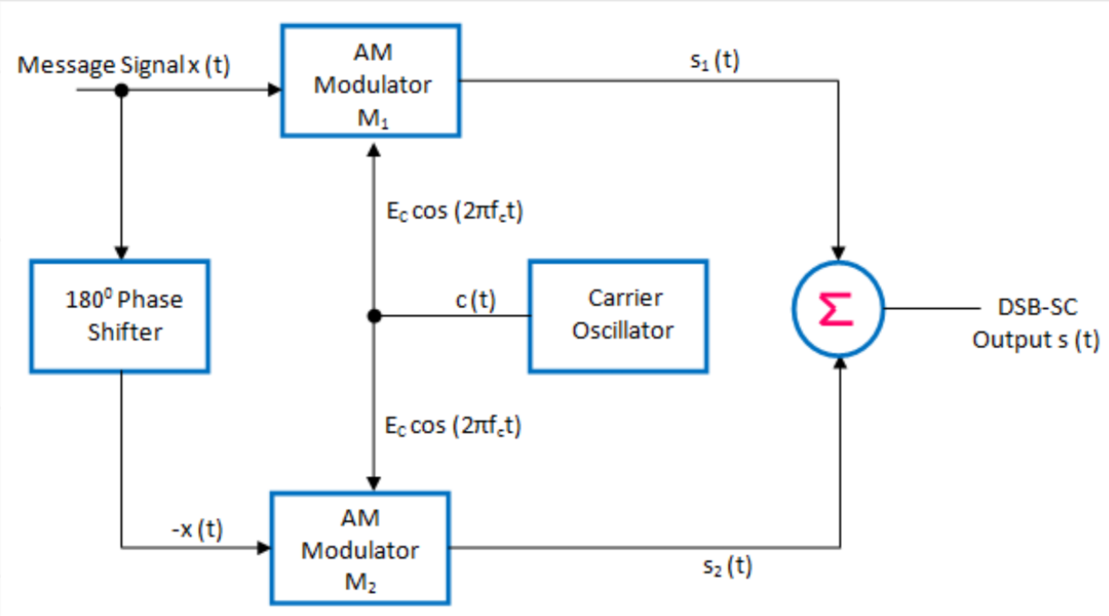


Fig 5 : Balanced Modulator for DSB-SC genaration

It consists of two standard amplitude modulators arranged in the balanced configuration so as to suppress the carrier completely .The block diagram of a balanced modulator is shown in fig.5 .

Working Operation and Analysis

The carrier signal c(t) is connected to both AM modulators M1 and M2 .

The message signal x(t) is applied as it is to M1 and its inverted version -x(t) is applied to M2.
At the outputs of modulators M1 and M2 , we get standard AM signals s1(t) and s2(t) as under :

output of M1 :
$s_1(t) = E_c[1 + m\, x(t)] \cos(2\pi f_c t)$

output of M2 :
$s_2(t) = E_c[1 - m\, x(t)] \cos(2\pi f_c t)$

These are then applied to a subtractor and the subtractor produces the desired DSB-SC signal as under :

Subtractor output =

$s_1(t) - s_2(t) = E_c[1 + m\,x(t)] \cos(2\pi f_c t) - E_c[1 - m\,x(t)] \cos(2\pi f_c t)$

$= E_c \cos(2\pi f_c t)[\{1 + m\,x(t)\} - \{1 - m\,x(t)\}]$

$= E_c \cos(2\pi f_c t)[1 + m\,x(t) - 1 + m\,x(t)]$

$= 2m\,E_c x(t) \cos(2\pi f_c t)$

The R.H.S. of this expression consists of product of x(t) and $c(t) = E_c \cos(2\pi f_c t)$.

Hence, it represents a DSB-SC signal .

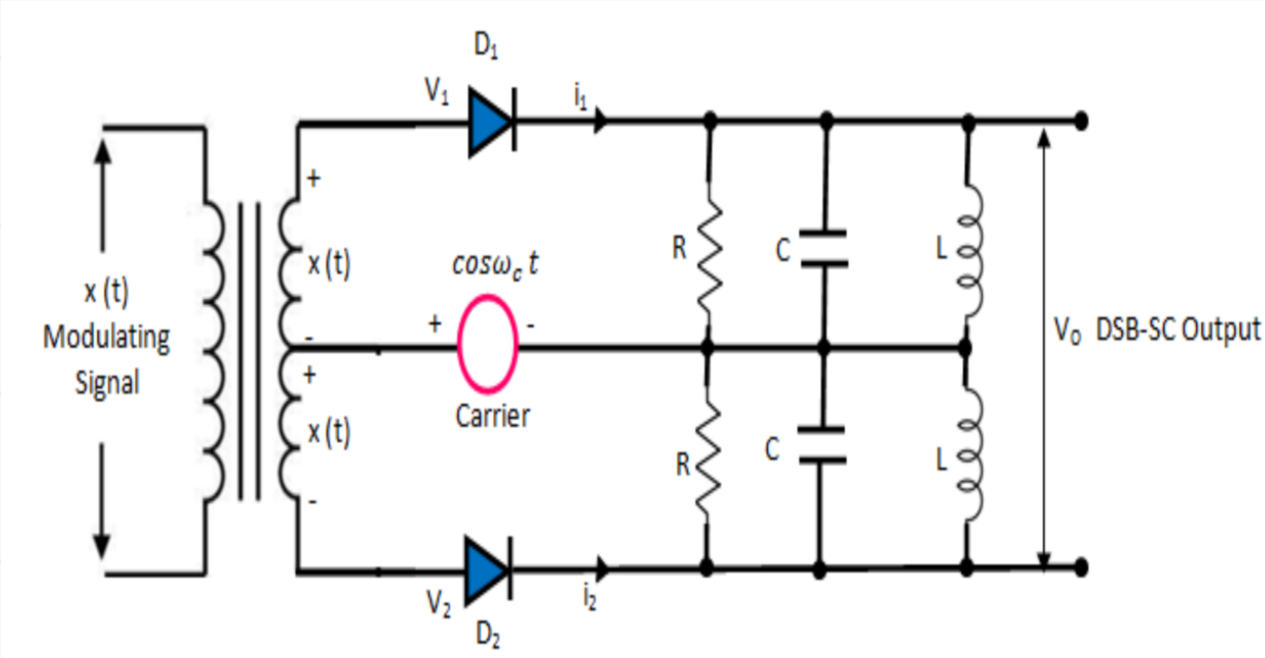
(ii) Balanced Modulator Using Diodes

- We already know that a non-linear resistance or 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 . Thus, if two non-linear devices such as diodes, transistors etc. are connected in a balanced mode so that they suppress the carriers of each other, then only sidebands are left and a DSB-SC signal is generated .

Therefore, a balanced modulator may be defined as a circuit in which two non-linear devices are connected in a balanced mode

to produce a DSB-SC signal .
Fig.1 shows the balanced modulator using



diodes as non-linear device .

Fig 1

The modulating signal x(t) is applied equally with 180 degree phase reversal at the inputs of both the diodes through the input center tapped transformer .

The carrier is applied to the center tap of the secondary .

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

Hence, input voltage to D1 is given by :

........(1)

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

And the input voltage to D2 is given by :

..........(2)

The parallel RLC circuits on the output side form the band pass filters .

Analysis:

$$i_1 = av_1 + bv_1^{\,2}$$

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

The diode current i1 and i2 are given by :

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

..................(3)

$$i_2 = av_2 + bv_2{}^2$$

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

$$i_2 = av_2 + bv_2{}^2 = ax(t) - a\cos\omega_c t + bx^2(t) - 2bx(t)\cos\omega_c t + b\cos^2\omega_c t$$

Similarly,

............(4)

$$v_o = i_1 R - i_2 R$$

The output voltage is given by :

Substituting the expression
for i1 and i2 from equations (3) and (4), we

$$v_o = R[2\,a\,x(t) + 4\,b\,x(t)\,\cos\omega_c\,t]$$

get

$$v_o = \underbrace{2aRx(t)}_{\text{Modulating Signal}} + \underbrace{4bRx(t)\cos\omega_c t}_{\text{DSB-SC Signal}}$$

Or

Hence, the output voltage contains a modulating signal term and the DSB-SC signal .

The modulating signal term is eliminated and the second term is allowed to pass through to the output by the LC band pass filter section .

Therefore, **final output** = 4 b R x(t) cos ωct

= K x(t) cos ωct

Thus, the diode balanced modulator produces the DSB-SC signal at its output .