BITT POLYTECHNIC, RANCHI

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Communication Systems

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Amplitude Modulation Types:

1. Double-sideband with carrier(DSB+C)
2. Double-sideband suppressed carrier(DSB-SC)
3. Single-sideband suppressed carrier(SSB-SC)
4. Vestigial sideband(VSB)

Double-sideband with carrier (DSB+C)

Let there be a sinusoidal carrier signal $c(t) = ACos(2\pi f_c t)$, of frequency f_c. With the concept of amplitude modulation, the instantaneous amplitude of the carrier signal will be modulated (changed) proportionally according to the instantaneous amplitude of the baseband or modulating signal *x(t)*. So the expression for the Amplitude Modulated (AM) wave becomes:

$$s(t) = \left[A + x(t)\right] Cos(2\pi f_c t) = E(t)Cos(2\pi f_c t)$$

$$E(t) = A + x(t)$$

The time varying amplitude *E(t)* of the AM wave is called as the envelope of the AM wave. The envelope of the AM wave has the same shape as the message signal or baseband signal.

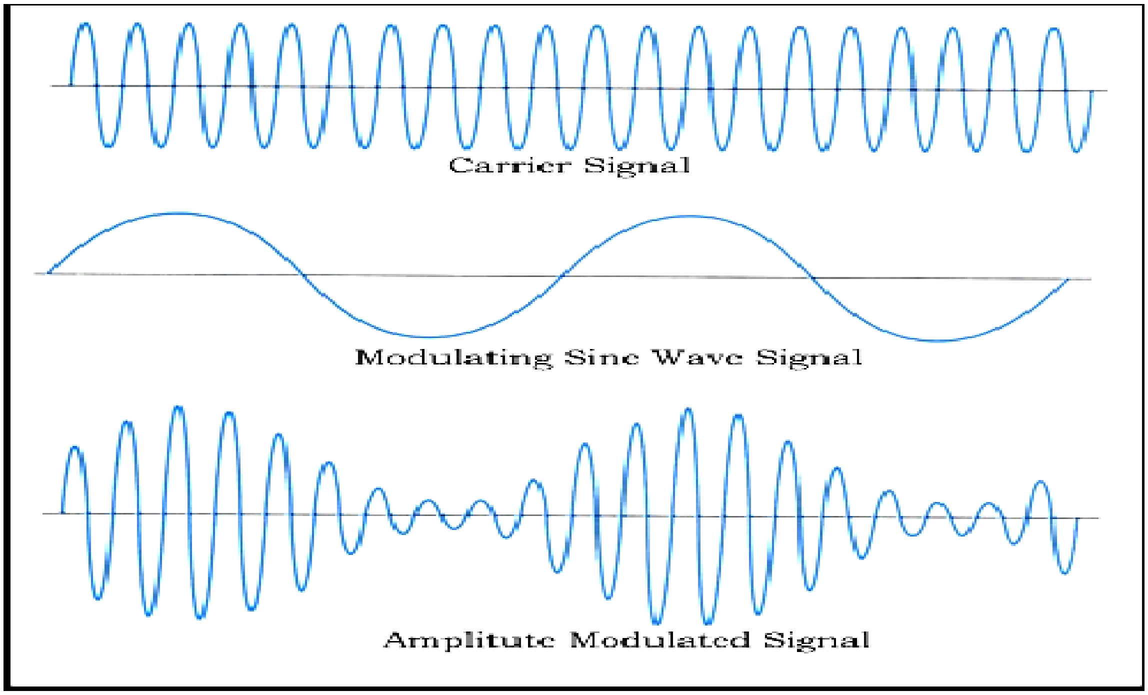


Figure 3 Amplitude modulation time-domain plot

Generation of DSBSC AM by Square Law Modulation

Square law diode modulation makes use of non-linear current-voltage characteristics of diode. This method is suited for low voltage levels as the current-voltage characteristic of diode is highly non- linear in the low voltage region. So the diode is biased to operate in this non-linear region for this application. A DC battery V_c is connected across the diode to get such a operating point on the characteristic. When the carrier and modulating signal are applied at the input of diode, different frequency terms appear at the output of the diode. These when applied across a tuned circuit tuned to carrier frequency and a narrow bandwidth just to allow the two pass-bands, the output has the carrier and the sidebands only which is essentially the DSBSC AM signal.

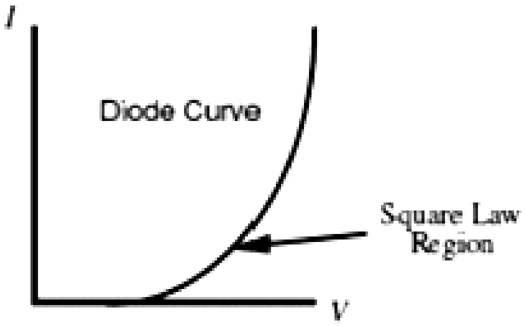


Figure : Current-voltage characteristic of diode

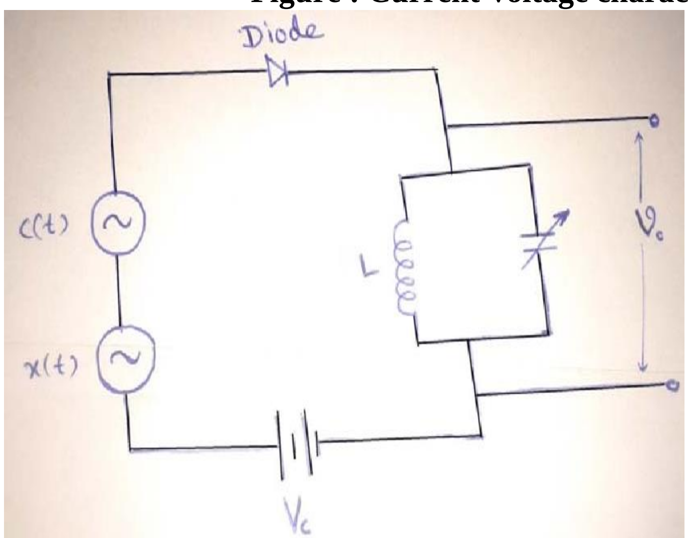


Figure : Square Law Diode Modulator

The non-linear current voltage relationship can be written in general as:

$i = av + bv^2$

I this application $v = c(t) + x(t)$

So

$i = a[A\text{Cos}(2\pi f_c t) + x(t)] + b[A\text{Cos}(2\pi f_c t) + x(t)]^2$

$\Rightarrow i = a\, A\text{Cos}(2\pi f_c t) + a\, x(t) + bA^2\, \text{Cos}^2\, (2\pi f_c t) + b\, x^2\, (t) + 2bA\, x(t)\, \text{Cos}(2\pi f_c t)$

$\boxed{2bA\, x(t)\, \text{Cos}(2\pi f_c t)}$

Demodulation of DSBSC by Square Law Detector

It can be used to detect modulated signals of small magnitude, so that the operating point may be chosen in the non-linear portion of the V-I characteristic of diode. ADC fixed operating point in the non-linear region of diode characteristics. The output diode current is hence

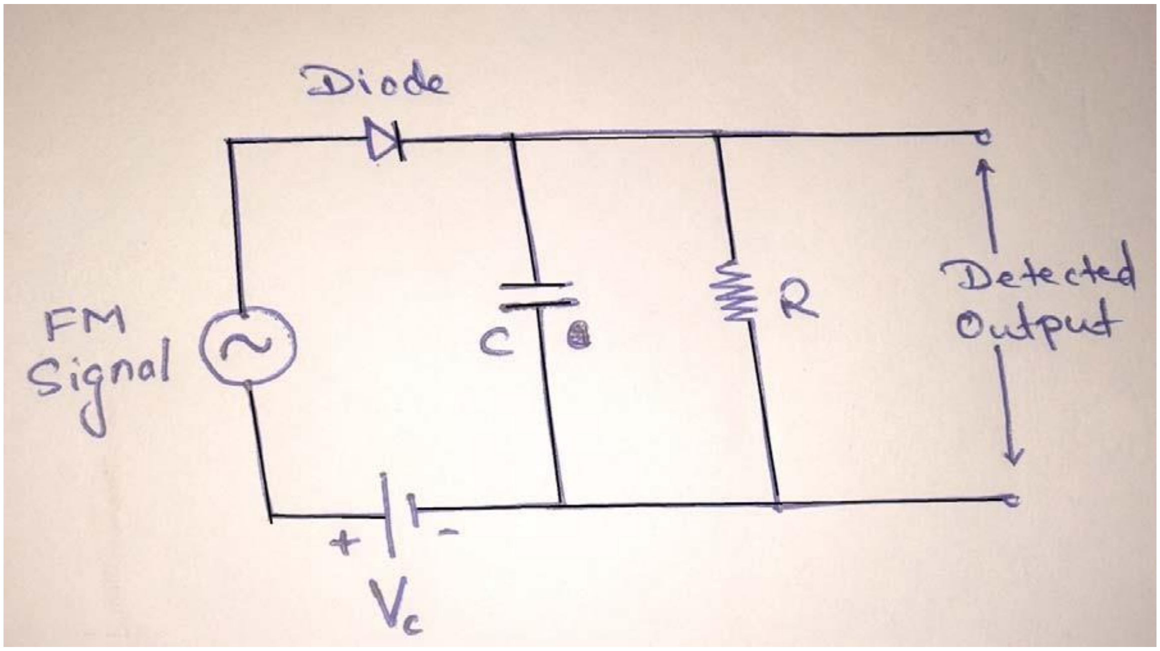


Figure : Square Law Detector

$i = a v_{FM}(t) + b v^2_{FM}(t)$

Where $v_{FM}(t) = [A + x(t)]\mathrm{Cos}(2\pi f_c t)$

This current will have terms at baseband frequencies as well as spectral components at higher frequencies. The low pass filter comprised of the RC circuit is designed to have cut-off frequency as the highest modulating frequency of the band limited baseband signal. It will allow only the baseband frequency range, so the output of the filter will be the demodulated baseband signal.

Linear Diode Detector or Envelope Detector

This is essentially just a half-wave rectifier which charges a capacitor to a voltage to the peak voltage of the incoming AM waveform. When the input wave's amplitude increases, the capacitor voltage is increased via the rectifying diode quickly, due a very small RC time-constant (negligible *R*) of the charging path. When the input's amplitude falls, the capacitor voltage is reduced by being discharged by a 'bleed' resistor *R* which causes a considerable RC time constant in the discharge path making discharge process as lower one as compared to charging. The voltage across *C* does not fall appreciably during the small period of negative half-cycle, and by the time next positive half cycle appears. This cycle again charges the capacitor *C* to peak value of carrier voltage and thus this process repeats on. Hence the output voltage across capacitor *C* is a spiky envelope of the AM wave, which is same as the amplitude variation of the modulating signal.

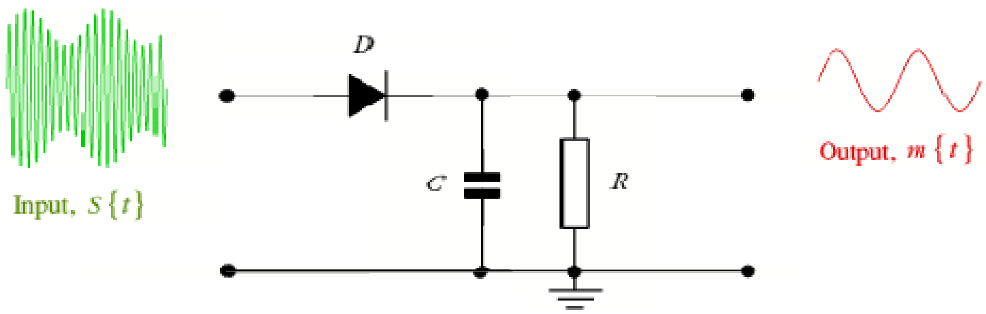


Figure 7 Envelope Detector

Double Sideband Suppressed Carrier (DSB-SC)

If the carrier is suppressed and only the sidebands are transmitted, this will be away to saving transmitter power. This will not affect the information content of the AM signal as the carrier component of AM signal do not carry any information about the baseband signal variation. A DSB+C AM signal is given by:

$$s_{DSB+C}(t) = A\text{Cos}(2\pi f_c t) + x(t)\text{Cos}(2\pi f_c t)$$

So, the expression for DSB-SC where the carrier has been suppressed can be given as:

$$s_{DSB-SC}(t) = x(t)\text{Cos}(2\pi f_c t)$$

Therefore, a DSB-SC signal is obtained by simply multiply ng modulating signal *x(t)* with the carrier signal. This is accomplished by a **product modulator** or **mixer**.

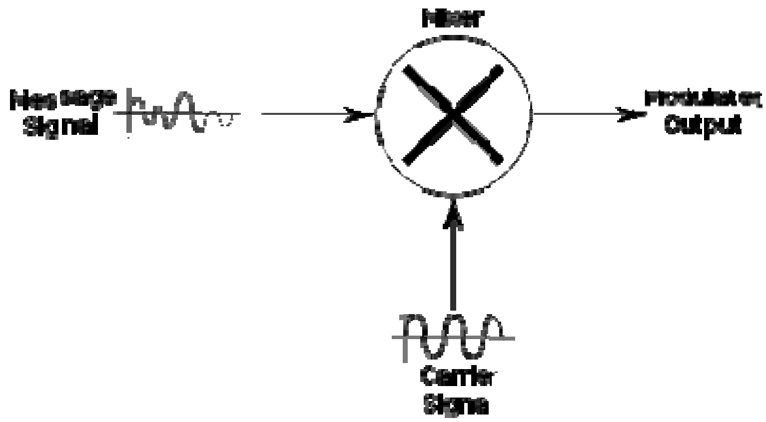
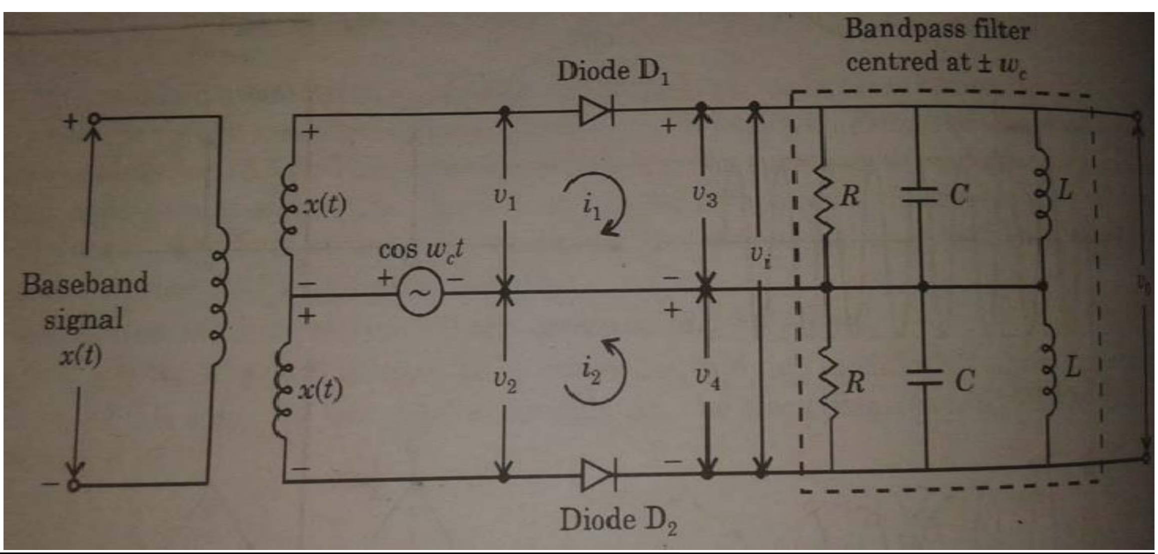


Figure : Product Modulator

Difference from the DSBSC being only the absence of carrier component, and since DSBSC has still both the sidebands, spectral span of this DSBSC wave is still bandwidth of $2\,f\,m$.

A circuit which can produce an output which is the product of two signals input to it is called a product modulator. Such an output when the inputs are the modulating signals and the carrier signal is a DSBSC signal. One such product modulator is a balanced modulator.

Balanced modulator:



$v_1 = Cos(2\pi f_c t) + x(t)$

$v_2 = Cos(2\pi f_c t) - x(t)$

For diode D_1, the nonlinear v-i relationship becomes:

$$i_1 = av_1 + bv_1^2 = a[Cos(2\pi f_c t) + x(t)] + b[Cos(2\pi f_c t) + x(t)]^2$$

Similarly, for diode D_2,

$$i_2 = av_2 + bv_2^2 = a[Cos(2\pi f_c t) - x(t)] + b[Cos(2\pi f_c t) - x(t)]^2$$

Now, $v_i = v_3 - v_4 = (i_1 - i_2)R$

$\Rightarrow v_i = 2R[ax(t) + 2\ bx(t)\ Cos(2\pi f_c t)]$ (substituting for i_1 and i_2)

This voltage is input to the band pass filter center frequency f_c and bandwidth $2f_m$. Hence it allows the component corresponding to the second term of the v_i, which is our desired DSB-SC signal.

Demodulation of DSBSC signal

Synchronous Detection: DSB-SC signal is generated at the transmitter by frequency up-translating the baseband spectrum by the carrier frequency f_c. Hence the original baseband signal can be recovered.

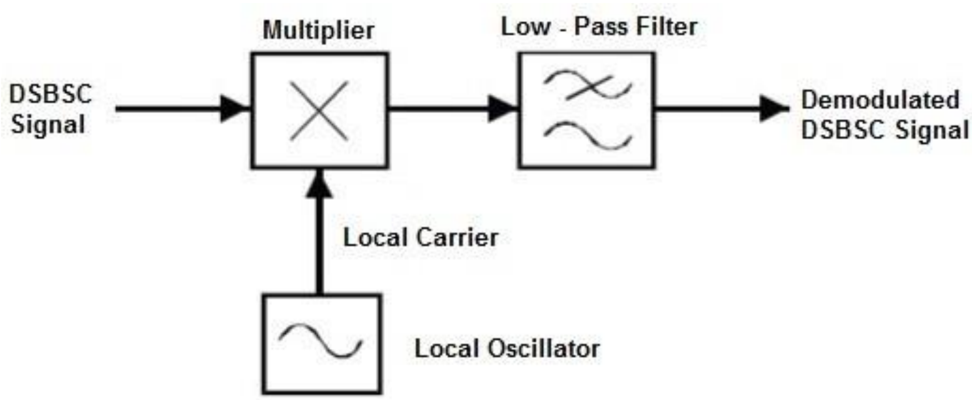


Figure 9 Synchronous Detection of DSBSC

Let the received DSB-SC signal is :

$$r(t) = x(t)\mathrm{Cos}(2\pi f_c t)$$

So after carrier multiplication, the resulting signal:

$$e(t) = x(t)\ \mathrm{Cos}(2\pi f_c t).\mathrm{Cos}(2\pi f_c t)$$

$$\Rightarrow e(t) = x(t)\ \mathrm{Cos}^2(2\pi f_c t)$$

$$\Rightarrow e(t) = \frac{1}{2}x(t)\left[1 + \mathrm{Cos}(2\pi(2f_c)t)\right]$$

$$\Rightarrow e(t) = \frac{1}{2}x(t) + \frac{1}{2}x(t)\ \mathrm{Cos}(2\pi(2f_c)t)$$

The low-pass filter having cut-off frequency f_m will only allow the baseband term x(t), which is in the pass-band of the filter and is the demodulated signal.