Communication Electronics (Lecture 8)

DSB-SC Modulators

Double sideband-suppressed carrier (DSB-SC) is a type of modulation, in which the transmitted wave consists of only the upper and lower sidebands. Transmitted power is saved through the suppression of the carrier wave, but the channel bandwidth requirement is same as in AM (i.e. twice the bandwidth of the message signal). Basically, double sideband-suppressed (DSB-SC) modulation consists of the product of both the message signal m (t) and the carrier signal, as follows:

- The modulated signal s (t) undergoes a phase reversal whenever the message signal m (t) crosses zero. The envelope of a DSB-SC modulated signal is different from the message signal.
- The transmission bandwidth required by DSB-SC modulation is the same as that for amplitude modulation which is twice the bandwidth of the message signal, $2\omega_m$.

There are three methods to generate DSB-SC waves. They are:

1. Product Modulator
2. Balanced modulator
3. Ring modulator

Product Modulator

A Product modulator is a circuit that generates a DSB-SC signal, suppressing the carrier and leaving only the sum and difference frequencies at the output. This modulation process does not introduce sinusoid at fc and as a result, it is called Double-sideband, suppressed-carrier (DSB-SC modulation). The output of a DSB-SC modulator can be further processed by filters or phase-shifting circuitry to eliminate one of the sidebands, resulting in a SSB signal.

In the time domain, for the baseband signal m(t) = $V_m \cos\omega_m t$, the DSB-SC signal

$$\begin{aligned} v_{DSB}(t) &= m(t) \times \cos\omega_c t \\ &= V_m \cos\omega_m t \times V_c \cos\omega_c t \\ &= \frac{VmVc}{2}[\cos(\omega_c - \omega_m) + \cos\ (\omega_c + \omega_m)] \end{aligned}$$

When the baseband is a single sinusoid of frequency fm, the modulated signal consists of two sinusoids; the component of frequency $\omega_c+\omega_m$ (USB) and the component of frequency $\omega_c+\omega_m$ (LSB).

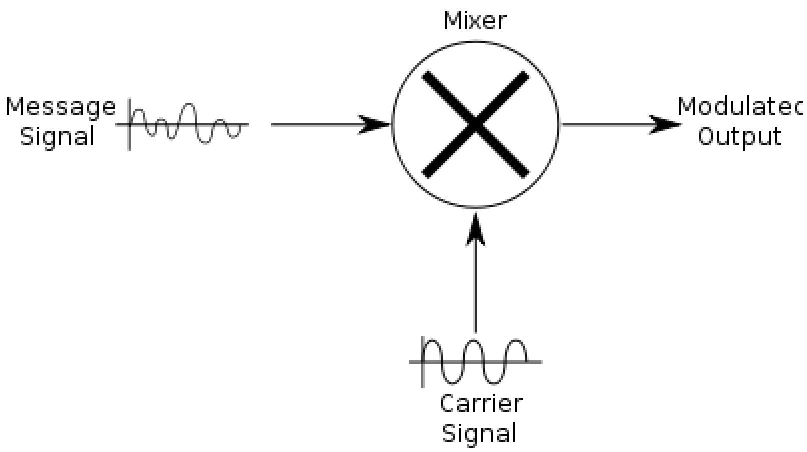

Fig 7-14 Product modulator to generate DSB-SC signal

Fig 7-14 shows the schematic diagram of product modulator for the realization of DSB-SC signal. This scheme is also known as heterodyning. The operation of frequency mixing/conversion is known as heterodyning. This is basically a shifting of spectra by an additional ωc. This is also equivalent to the operation of modulation with modulating carrier frequency that differs from incoming carrier frequency by ωm.

Balance Modulator

One possible scheme for generating a DSBSC wave is to use two AM modulators arranged in a balanced configuration so as to suppress the carrier wave, as shown in

Fig. 7-14. Assume that two AM modulators are identical, except for the sign reversal of the modulating signal applied to the input of one of the modulators. Thus the outputs of the two AM modulators can be expressed as follows

$$S_1(t) = A_c\,[1+k_a m\,(t)]\cos \omega_c t$$

and

$$S_2\,(t) = A_c\,[1-k_a m\,(t)]\cos \omega_c t$$

Subtracting S_2 (t) from S_1 (t), we obtain

$$S\,(t) = S_1\,(t) - S_2\,(t)$$

$$S\,(t) = 2A_c\,k_a\,m(t)\cos \omega_c t$$

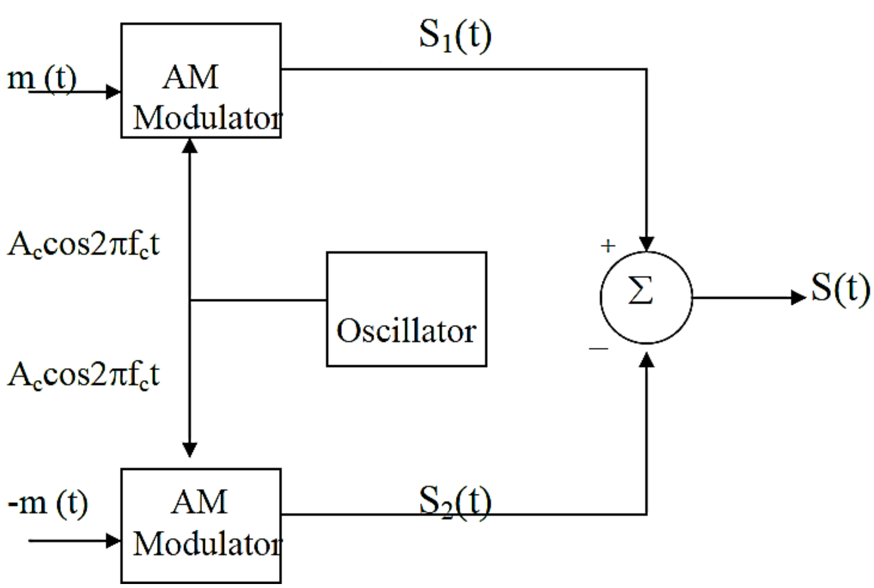

Fig 7-14 Balanced Modulator

Hence, except for the scaling factor 2ka the balanced modulator output is equal to product of the modulating signal and the carrier signal as in product modulator.

Ring Modulator

The DSB-SC can be generated using either the balanced modulator or and the 'ring-modulator'. The balanced modulator uses two identical AM generators along with an adder. The two amplitude modulators have a common carrier with one of them modulating the input message, and the other modulating the inverted message. Generation of AM is not simple, and to have two AM generators with identical operating conditions is extremely difficult. Hence, laboratory implementation of the DSB-SC is usually using the 'ring-modulator', shown in figure (7-15)

Ring modulator is one of the most useful product modulator, well suited for generating a DSB-SC wave. The diodes are controlled by a square-wave carrier of frequency f_c, which is applied longitudinally by means of two center-tapped transformers. If the transformers are perfectly balanced and the diodes are identical, there is *no* leakage of the modulation frequency into the modulation output . To understand the operation of the circuit, assume that the diodes have a constant forward resistance r_f when switched on and a constant backward resistance r_b when switched off; and they switch as the carrier wave crosses through zero axis. On one half-cycle of the carrier wave, the outer diodes (D1-D3) are switched to their forward resistance r_f and the inner diodes (D2-D4) are switched to their backward resistance r_b. On other half-cycle of the carrier wave, the diodes operate in the opposite condition

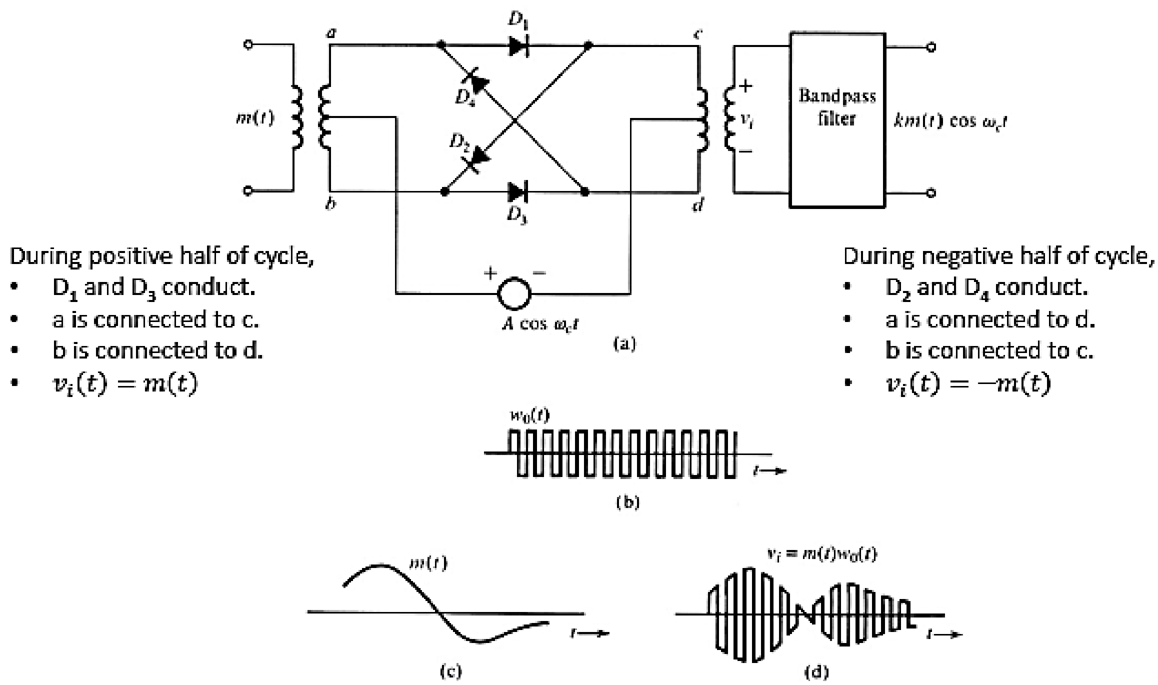

Fig (7-15) The ring modulator used for the generation of DSB-SC

$$X(t) = \sum_{n=0}^{\infty} C_n \cos(n\omega_c t + \theta c)$$

$$W_0(t) = \frac{4}{\pi}\left(\cos\omega_c t - \frac{1}{3}\cos 3\omega_c t + \frac{1}{5}\cos 5\omega_c t - \cdots\right)$$

$$V_i(t) = m(t) \times w_0(t)$$

$$= \frac{4}{\pi}\left(m(t)\cos\omega_c t - \frac{1}{3}m(t)\cos 3\omega_c t + \frac{1}{5}m(t)\cos 5\omega_c t - \cdots\right)$$

The output of band-pass filter will be:

$$= \frac{4}{\pi}m(t)\cos\omega_c t$$

The modulator output consists of modulation products. The ring modulator is sometimes referred to as a double-balanced modulator, because it is balanced with respect to both the message signal and the square wave carrier signal.