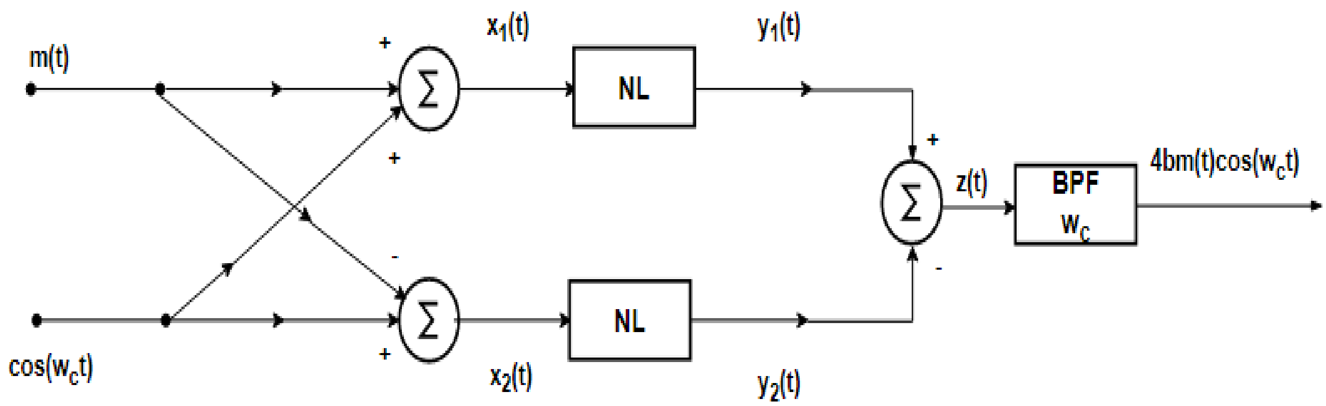
2- Nonlinear Modulator (Single Balance Modulator)

Modulation can also be achieved by using nonlinear devices, such as a semiconductor diode or a transistor. Figure below shows one possible scheme, which uses two identical nonlinear elements (boxes marked NL).
Let the input-output characteristics of either of the nonlinear elements be approximated by a power series

$$\boldsymbol{y(t) = ax(t) + bx^2(t)}$$



$$x_1(t) = m(t) + \cos(w_c\, t)$$

$$x_2(t) = -m(t) + \cos(w_c\, t)$$

$$y_1(t) = am(t) + a\cos(w_c\, t) + b[m(t) + \cos(w_c\, t)]^2$$

$$y_1(t) = am(t) + a\cos(w_c\, t) + bm^2(t) + 2bm(t)\cos(w_c\, t) + b\cos^2(w_c\, t)$$

$$y_2(t) = -am(t) + a\cos(w_c\, t) + b[-m(t) + \cos(w_c\, t)]^2$$

$$y_2(t) = -am(t) + a\cos(w_c\, t) + bm^2(t) - 2bm(t)\cos(w_c\, t) + b\cos^2(w_c\, t)$$

$$z(t) = y_1(t) - y_2(t)$$

$$z(t) = 2am(t) + 4bm(t)\cos(w_c\, t)$$

$$\boldsymbol{After\ BPF\ at\ \mp w_c}$$

$$\boldsymbol{output = 4bm(t)\cos(w_c\, t)}$$

3- Switch Modulator

The multiplication operation required for modulation can be replaced by a simpler switching operation if we realize that a modulated signal can be obtained by multiplying m(t) not only by a pure sinusoid but by any periodic signal $\phi(t)$ of the fundamental radian frequency w_c. Such a periodic signal can be expressed by a trigonometric Fourier series as

$$\phi(t) = \sum_{n=0}^{\infty} C_n \cos(n w_c t + \theta_n)$$

$$\boldsymbol{m(t)\phi(t) = \sum_{n=0}^{\infty} m(t) C_n \cos(n w_c t + \theta_n)}$$

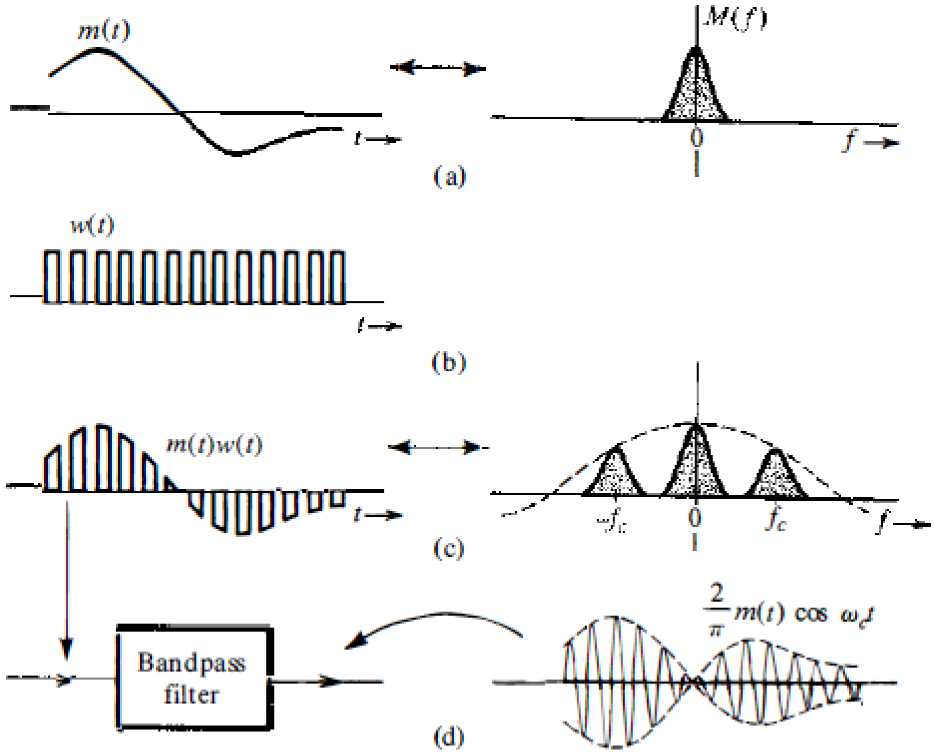
This shows that the spectrum of the product $m(t)\phi(t)$is the spectrum $M(w)$ shifted to $\pm w_c, \pm 2w_c, \dots, \pm nw_c, \dots$. If this signal is passed through a bandpass filter of bandwidth $\boldsymbol{2f_m}$Hz and tuned to We, then we get the desired modulated signal $m(t)C_1 \cos(w_c t + \theta_1)$. The square pulse train w(t) in **Fig.b** is a periodic signal whose Fourier series.

$$w(t) = \frac{1}{2} + \frac{2}{\pi}\left[\cos(w_c\, t) - \frac{1}{3}\cos(3w_c\, t) + \frac{1}{5}\cos(5w_c\, t) - \cdots\right]$$

The signal $m(t)w(t)$ is given by

$$\boldsymbol{m(t)w(t) = \frac{1}{2}m(t) + \frac{2}{\pi}\left[m(t)\cos(w_c\, t) - \frac{1}{3}m(t)\cos(3w_c\, t) + \frac{1}{5}m(t)\cos(5w_c\, t) - \cdots\right]}$$

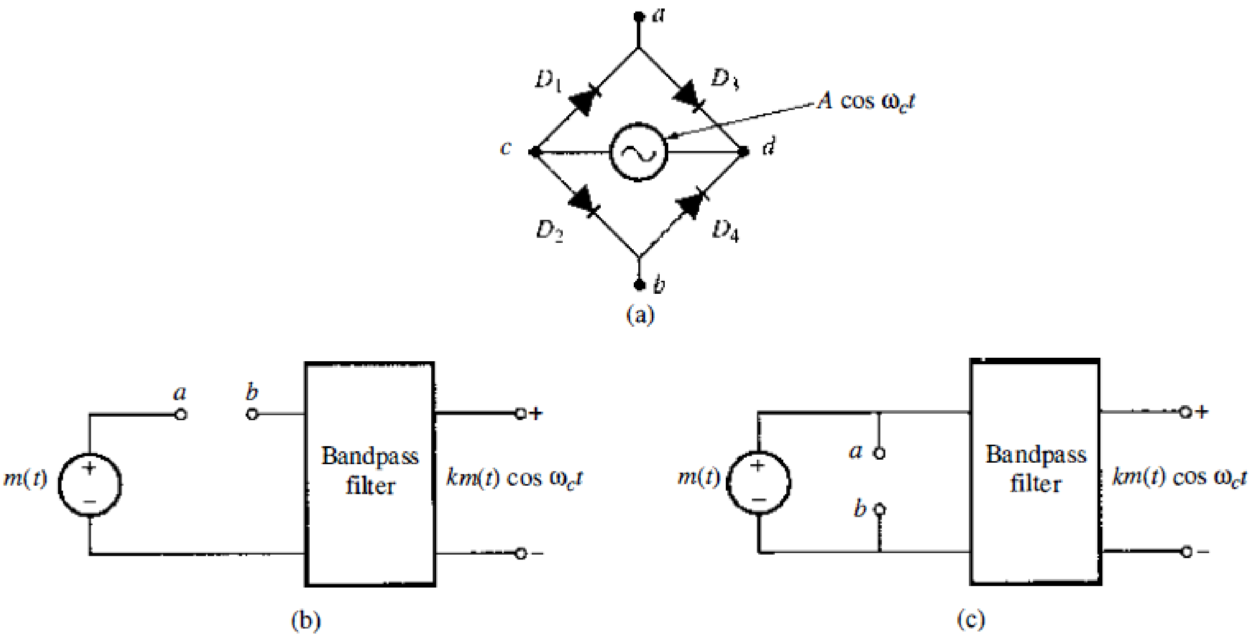
The signal $m(t)w(t)$ consists not only of the component $m(t)$ but also of an infinite number of modulated signals with carrier frequencies $w_c, 3w_c,, 5w_c, \dots, nw_c$. Therefore, the spectrum of $m(t)w(t)$ consists of multiple copies of the message spectrum $M(f)$, shifted to $0, \pm f_c, \pm 3f_c, \pm 5f_c, \dots$ (with decreasing relative weights), as shown in Fig.c. For modulation, we are interested in extracting the modulated component $\boldsymbol{m(t)\cos(w_c\, t)}$ only. To separate this component from the rest of the crowd, we pass the signal $m(t)w(t)$ through a bandpass filter of bandwidth $2f_m\, Hz$, centered at the frequency $\pm f_c$. Provided the carrier frequency $f_c \geq 2f_m$ this will suppress all the spectral components not centered at $\pm f_c$. to yield the desired modulated signal $\boldsymbol{\frac{2}{\pi}m(t)\cos(w_c\, t)}$ (Fig.d).



We now see the real payoff of this method. Multiplication of a signal by a square pulse train is in reality a switching operation in which the signal m(t) is switched on and off periodically; it can be accomplished by simple switching elements controlled by w(t).

A- Diode-Bridge Modulator

One such electronic switch driven by a sinusoid $\mathbf{A\cos(w_c\,t)}$ to produce the switching action. Diodes D1, D2 and D3, D4 are matched pairs. When the signal $\cos(w_c\,t)$ is of a polarity that will make terminal **c** positive with respect to **d**, all the diodes conduct. Because diodes D1 and D2 are matched, terminals **a** and **b** have the same potential and are effectively shorted. During the next half-cycle, terminal **d** is positive with respect to **c**, and all four diodes open, thus opening terminals **a** and **b**. The diode bridge in Fig.a, therefore, serves as a desired electronic switch, where terminals **a** and **b** open and close periodically with carrier frequency $\boldsymbol{f_c}$ when a sinusoid $A\cos(w_c\,t)$ is applied across terminals **c** and **d**. To obtain the signal $m(t)w(t)$, we may place this electronic switch (terminals a and b) in series (Fig.b) or across (in parallel) $m(t)$, as shown in Fig.c. These modulators are known as the **series-bridge diode modulator** and the **shunt-bridge diode modulator**, respectively. This switching on and off of $m(t)$ repeats for each cycle of the carrier, resulting in the switched signal $m(t)w(t)$, which when bandpass-filtered, yields the desired modulated signal $\boldsymbol{\frac{2}{\pi}m(t)\cos(w_c\,t)}$.



B- Ring Modulator(Double Balance Modulator)

Another switching modulator, known as the ***ring modulator,*** is shown in Fig.a. During the positive half-cycles of the carrier, diodes D1 and D3 conduct, and D2 and D4 are open. Hence, terminal ***a*** is connected to ***c***, and terminal **b** is connected to **d**. During the negative half-cycles of the carrier, diodes D1 and D3 are open, and D2 and D4 are conducting, thus connecting terminal ***a*** to ***d*** and terminal ***b*** to ***c***. Hence, the output is proportional to $m(t)$ during the positive half-cycle and to $-m(t)$ during the negative half-cycle. In effect, *m(t)* is multiplied by a square pulse train $w_o(t)$, as shown in Fig.b. The Fourier series for $w_o(t)$ can be found by using the signal $w(t)$ to yield $\boldsymbol{w_o(t) = 2w(t) - 1}$. Therefore, we can use the Fourier series of $w(t)$ to determine the Fourier series of $w_o(t)$ as

$$w_o(t) = 2w(t) - 1$$

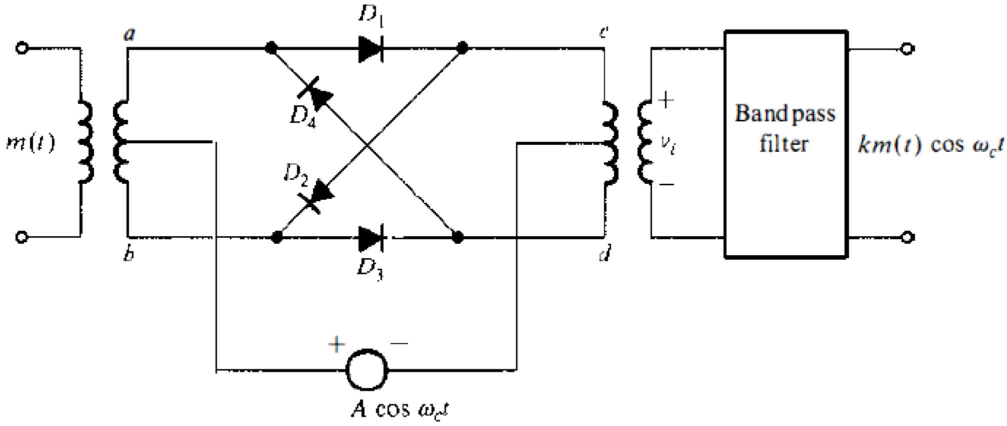
$$w_o(t) = \frac{4}{\pi}\left[\cos(w_c t) - \frac{1}{3}\cos(3w_c t) + \frac{1}{5}\cos(5w_c t) - \cdots\right] \quad \boldsymbol{H.W}$$

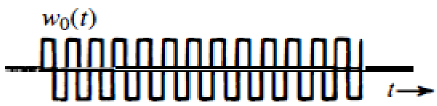
$$v_i(t) = m(t)w_o(t)$$

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

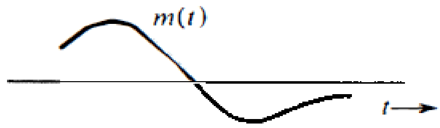
After BPF then

$$\boldsymbol{output = \frac{4}{\pi}m(t)\cos(w_c t)}$$

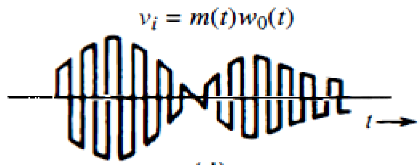




(b)



(c)



(d)

Demodulation of DSB-SC Signals

As discussed earlier, demodulation of a DSB-SC signal essentially involves multiplication by the carrier signal and is identical to modulation. At the receiver, we multiply the incoming signal by a local carrier of frequency and phase in synchronism with the incoming carrier. The product is then passed through a low-pass filter. The **only difference** between the modulator and the demodulator lies in the input signal and the output filter. In the modulator, message m(t) is the input while the multiplier output is passed through a bandpass filter tuned to w_c, whereas in the demodulator, the DSB-SC signal is the input while the multiplier output is passed through a **low-pass filter**. Therefore, all the modulators discussed earlier without multipliers can also be used as demodulators, provided the bandpass filters at the output are replaced by **low-pass filters of bandwidth f_m**. For demodulation, the receiver must generate a carrier in phase and frequency synchronism with the incoming carrier. These demodulators are synonymously called **synchronous** or **coherent** (also **homodyne)** demodulators

H.W: Analysis and draw the block diagram of demodulation DSB-SC

1- Nonlinear Modulator

2- Switch Modulator (A-Diode-Bridge Modulator B-Ring Modulator)