3. Double Side Band Suppressed Carrier (DSBSC) modulation

Consider the standard AM (ie double sideband with carrier) signal, defined by

$$s(t) = A_c[1 + \mathrm{k_a m(t)}]\cos(2\pi f_c t)$$

$$s(t) = \underbrace{A_c \cos(2\pi f_c t)}_{\substack{unmodulated \\ carreir\ signal}} + \underbrace{A_c\ \mathrm{k_a m(t)} \cos(2\pi f_c t)}_{DSBSC\ signal}$$

The unmodulated carrier signal consumes 66.66% of total power in AM. This reduces the efficiency considerably. Suppressing the carrier provides a power efficient AM technique, called "Double Side Band Suppressed Carrier (DSBSC)" modulation.

The DSBSC modulated signal is given by the product of modulating signal and the sinusoidal carrier signal ie

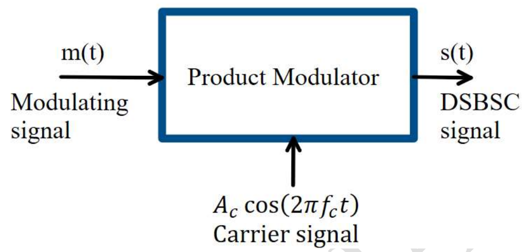


Figure 3.1 Block diagram of DSBSC Modulator

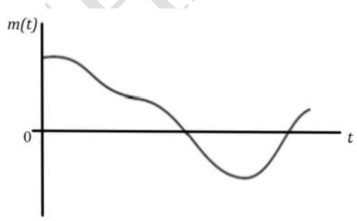
DSBSC signal, $\boxed{s(t) = A_c\ \mathrm{m(t)} \cos(2\pi f_c t)}$

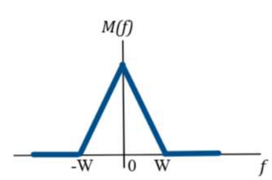
The Fourier transform of $s(t)$ is obtained as

$$\boxed{S(f) = \frac{A_c}{2}[\mathrm{M}(f - f_c) + \mathrm{M}(f + f_c)]}$$

Where

$$m(t) \xleftrightarrow{\text{FT}} M(f)$$





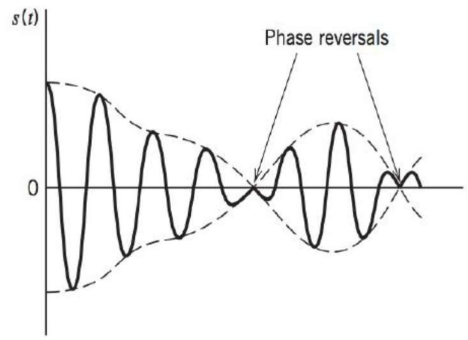


Figure 3.2 DSBSC Modulated waveform

This modulated wave undergoes a phase reversal whenever the m(t) crosses zero.

Frequency-domain description:

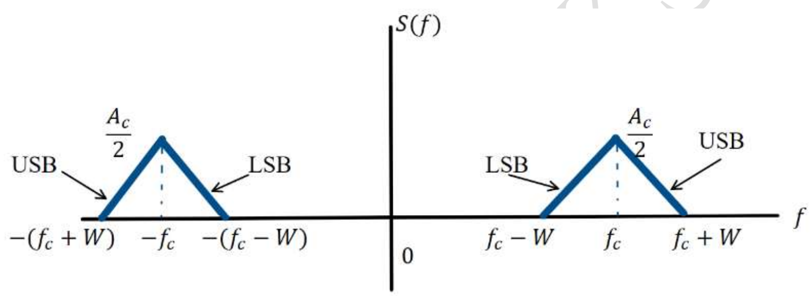


Figure 3.3 DSBSC signal spectrum

The bandwidth of DSBSC signal is

$$B = (f_c + W) - (f_c - W)$$

$$\boldsymbol{B = 2W}$$

Bandwidth of DSBSC = 2 × maximum frequency of message signal

The transmission bandwidth required by DSB-SC modulation is the same as that for amplitude modulation, namely, $2W$.

DSBSC generation:- RING MODULATOR

Ring modulator is a DSBSC signal generator.

Construction: The four diodes form a ring. The diodes are controlled by a square-wave carrier *c(t)* of frequency *fc,* which is applied longitudinally by means of two center-tapped transformers. The transformers are perfectly balanced and the diodes are ideal.

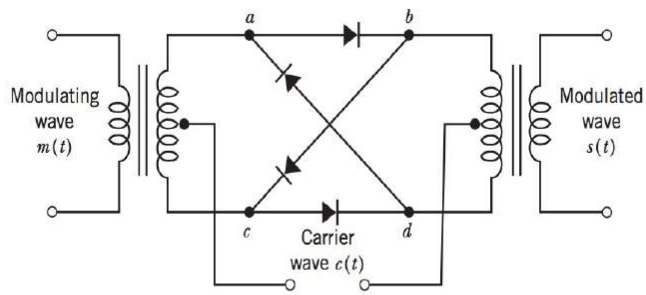


Figure 3.4 Ring Modulator

<u>Working:</u>

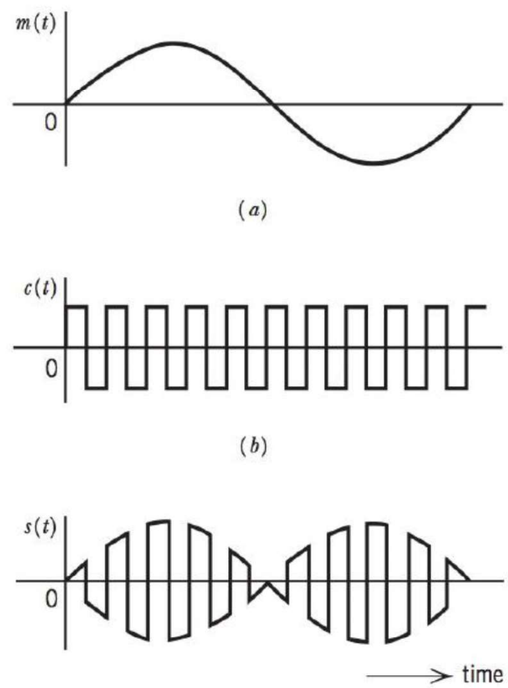
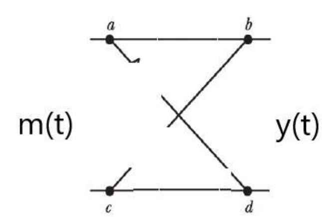


Figure 3.5 DSBSC waveform from Ring Modulator

In ring modulator, the diodes are biased by the square wave carrier signal.

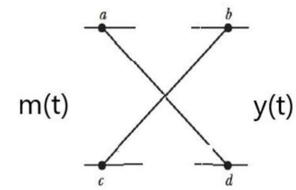
$$c(t) = \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos\big(2\pi f_c t(2n-1)\big)$$

During positive cycle of the carrier signal, the outer diodes are forward biased and inner diodes are reverse biased.



$$y(t) = m(t)$$

During negative cycle of the carrier signal, the inner diodes are forward biased and outer diodes are reverse biased.



$$y(t) = -m(t)$$

$$y(t) = \begin{cases} m(t), & c(t) > 0 \\ -m(t), & c(t) < 0 \end{cases}$$

$$y(t) = m(t)\, c(t)$$

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

$$y(t) = m(t)\left[\frac{4}{\pi}\cos\left(2\pi f_c t\right) + odd\ harmonics\right]$$

$$y(t) = \frac{4}{\pi}\, m(t)\, \cos\left(2\pi f_c t\right) + unwanted\ terms$$

Fourier transform of $y(t)$ is

$$Y(f) = \frac{2}{\pi}[\mathrm{M}(f - f_c) + \mathrm{M}(f + f_c)] + unwanted\ terms$$

A BPF with following specification can extract DSBSC signal from $y(t)$:

Centre frequency = f_c
Bandwidth $\geq 2W$
Cut-off frequency: $0 < f_0 < (f_c - W)$
Condition for distortion-less modulation: $(f_c - W) > 0$ or $f_c > W$

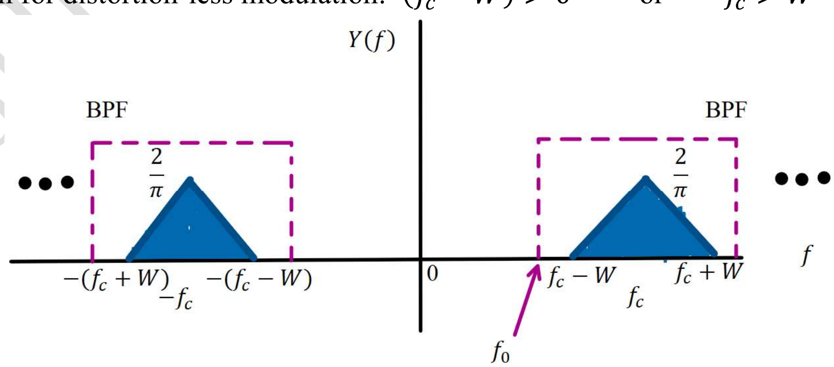


Figure 3.6 Spectrum of $y(t)$

The output of the BPF is the DSBSC signal ie $s(t) = \frac{4}{\pi}\, m(t)\, \cos\left(2\pi f_c t\right)$

COHERENT DETECTION

The baseband signal $m(t)$can be uniquely recovered from a DSB-SC wave $s(t)$ by first multiplying $s(t)$with a locally generated sinusoidal wave and then low-pass filtering the product.

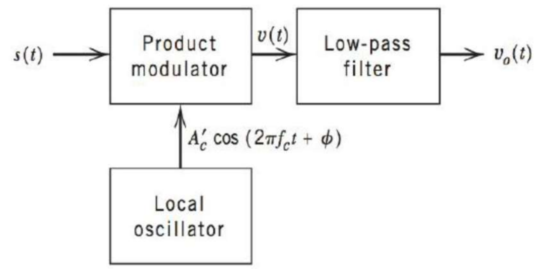


Figure 3.7 Block diagram of coherent detector

It is assumed that the local oscillator signal is exactly coherent or synchronized, in both frequency and phase, with the carrier wave $c(t)$ used in the product modulator to generate $s(t)$. Hence, this method of demodulation is known as *coherent detection* or *synchronous demodulation.*

The DSBSC signal is given by

$$s(t) = A_c \, \mathrm{m(t)} \cos(2\pi f_c t)$$

The output of the local oscillator is

$$v(t) = s(t) A_c' \cos(2\pi f_c t + \varphi)$$

$$v(t) = [A_c \, \mathrm{m(t)} \cos(2\pi f_c t)] A_c' \cos(2\pi f_c t + \varphi)$$

$$v(t) = A_c \, A_c' \, \mathrm{m(t)} [\cos(2\pi f_c t) \;\; \cos(2\pi f_c t + \varphi)]$$

$$v(t) = \frac{1}{2} A_c \, A_c' \, \mathrm{m(t)} [\cos(4\pi f_c t + \varphi) + \cos(\varphi)]$$

$$v(t) = \underbrace{\frac{1}{2} A_c \, A_c' \, \mathrm{m(t)} \cos(4\pi f_c t + \varphi)}_{DSBSC\ signal\ at\ 2f_c} + \underbrace{\frac{1}{2} A_c \, A_c' \, \cos(\varphi) \, \mathrm{m(t)}}_{Baseband\ signal}$$

The first term in $v(t)$ is centred at $2f_c$ and can be removed using a low pass filter (LPF). The second term is proportional to baseband signal, $m(t)$.

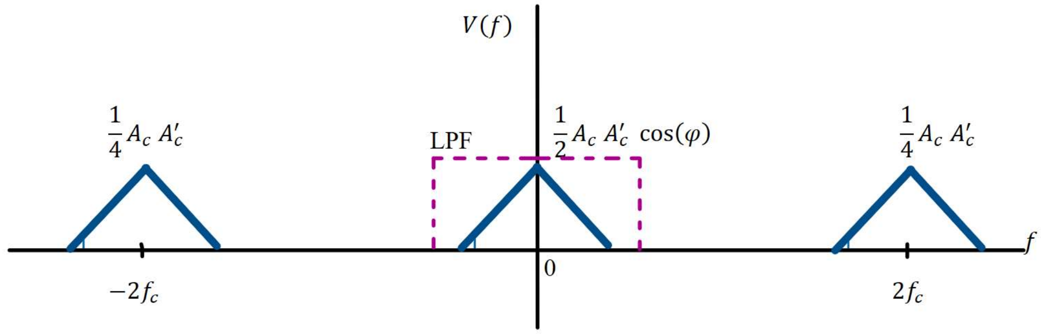


Figure 3.8 Spectrum of v(t)

The output of LPF is $v_0(t) = \frac{1}{2}A_c\,A_c'\ \cos(\varphi)\,\mathrm{m(t)}$

Case (i): φ = constant

The demodulated signal $v_0(t)$ is therefore proportional to $\mathrm{m(t)}$ when the phase error φ is a constant.

Case (ii): $\varphi = 0$

$$v_0(t) = \frac{1}{2}A_c\,A_c'\,\mathrm{m(t)}$$

The amplitude of this demodulated signal is maximum.

Case (iii): $\varphi = \pm\frac{\pi}{2}$

$$v_0(t) = 0$$

The zero demodulated signal, which occurs for $\varphi = \pm\frac{\pi}{2}$, represents the *quadrature null effect* of the coherent detector. Thus the phase error φ in the local oscillator causes the detector output to be attenuated by a factor equal to $\cos(\varphi)$.

The detector output, the multiplying factor cos φ varies randomly with time, which is obviously undesirable. Therefore, provision must be made in the system to maintain the local oscillator in the receiver in perfect synchronism, in both frequency and phase, with the carrier wave used to generate the DSB-SC modulated signal in the transmitter.
The resulting system complexity is the price that must be paid for suppressing the carrier wave to save transmitter power.