Single Sideband and Ring Modulator

Prepared by

D. Wael Hashlamoun

Normal AM

- The AM modulated signal is given by:

$$s(t) = A_C\left(1 + k_a m(t)\right)\cos 2\pi f_C t$$

- Low power efficiency of the normal AM signal. Most of the transmitted power is allocated to the carrier frequency, which does not carry information.
- Information resides in the sidebands.

DSB-SC:

- In a DSB-SC, there is no transmitted carrier.
- All power is allocated to the two sidebands.
- The transmission bandwidth is twice the message bandwidth.
- Information about the message is contained both in the upper and lower sidebands.

$$s(t) = A_C m(t) \cos 2\pi f_C t$$

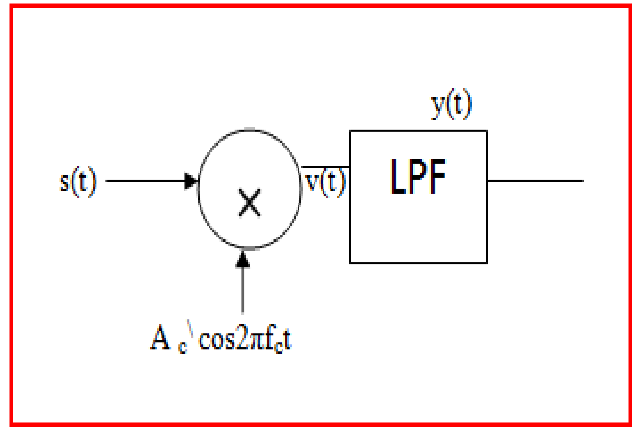
DSB-SC Modulation and Demodulation

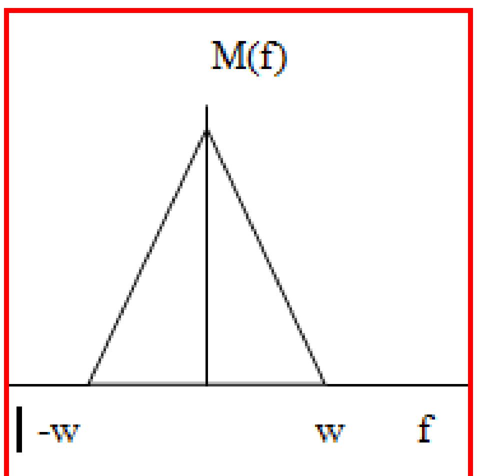
Modulation

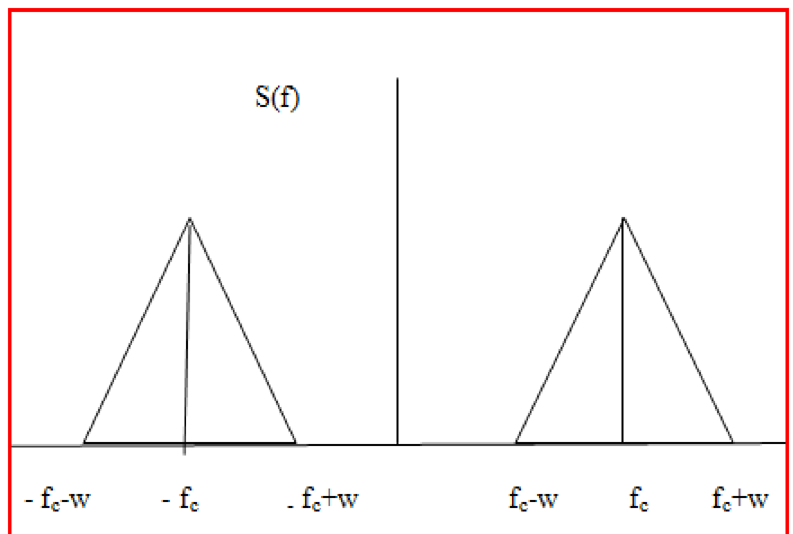
$$s(t) = A_C m(t) \cos 2\pi f_C t$$

The ring modulator is used to perform modulation. Its operation will be explained later.

Coherent Demodulation is used to recover the message







Single Sideband Modulation

- The information represented by the modulating signal is contained in both the upper and the lower sidebands.
- It is not necessary to transmit both side-bands. Either one can be suppressed at the transmitter without any information lost
- In SSB-SC the carrier is suppressed and one of the two sideband is transmitted
- Hence, power saving and bandwidth saving
- Sometimes, an attenuated part of the carrier is transmitted that will ease the process of demodulation.

Single Sideband Modulation

- The SSB modulated signal is represented in the time domain as:

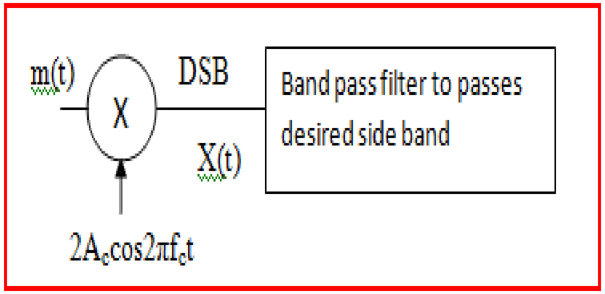
$$s(t) = A_C m(t) \cos 2\pi f_C t - A_C \widehat{m}(t) \sin 2\pi f_C t$$

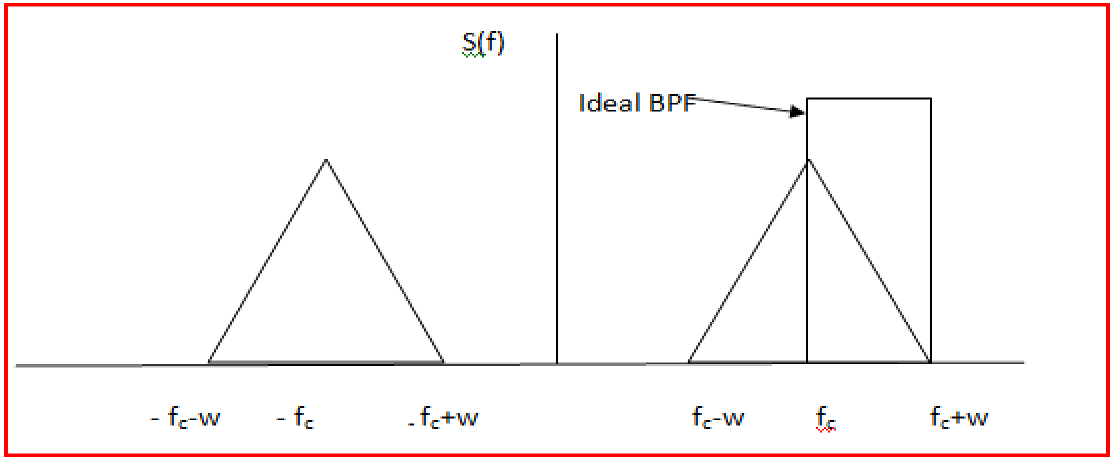
$Here, \widehat{m}(t)$ is the Hilbert transform of $m(t)$ and is obtained by passing $m(t)$ through a 90 degrees phase shifter.

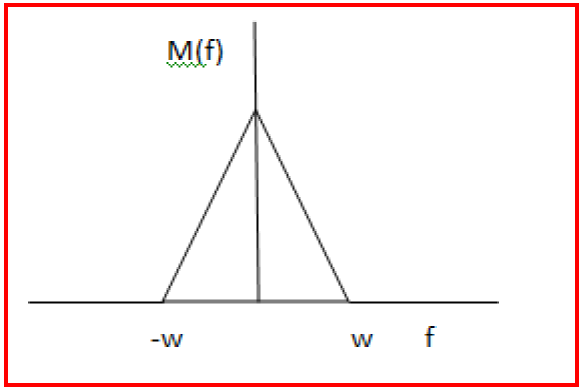
Generating a SSB signal

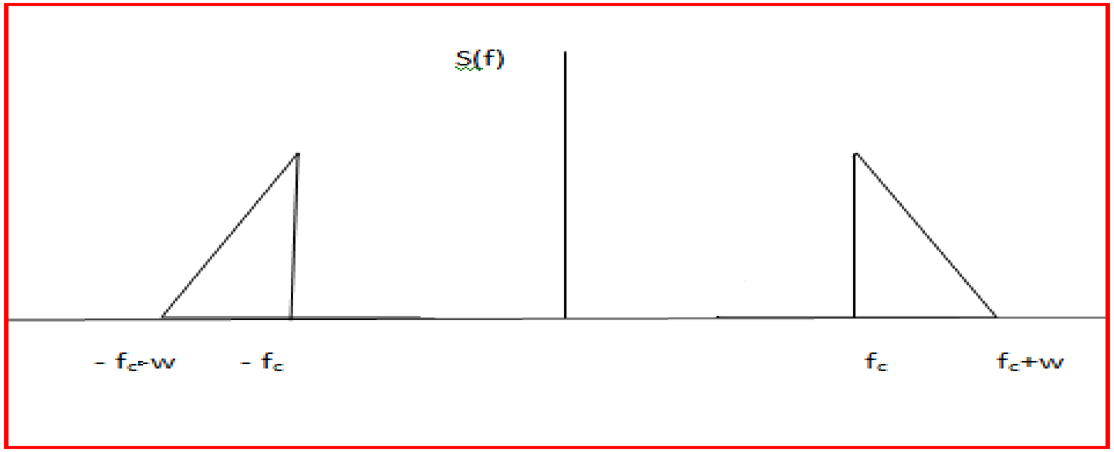
- The Frequency discrimination method (Filtering Method) is used in this experiment to generate the SSB signal.
- Here, A DSB-SC carrier signal is generated first, and then the desired sideband is selected using the appropriate bandpass filter.
- Another method for generating the SSB signal is called the phasing method: The SSB can be generated means of two DSB-SC modulators that are out of phase by 90 degrees.

Generating a SSB signal

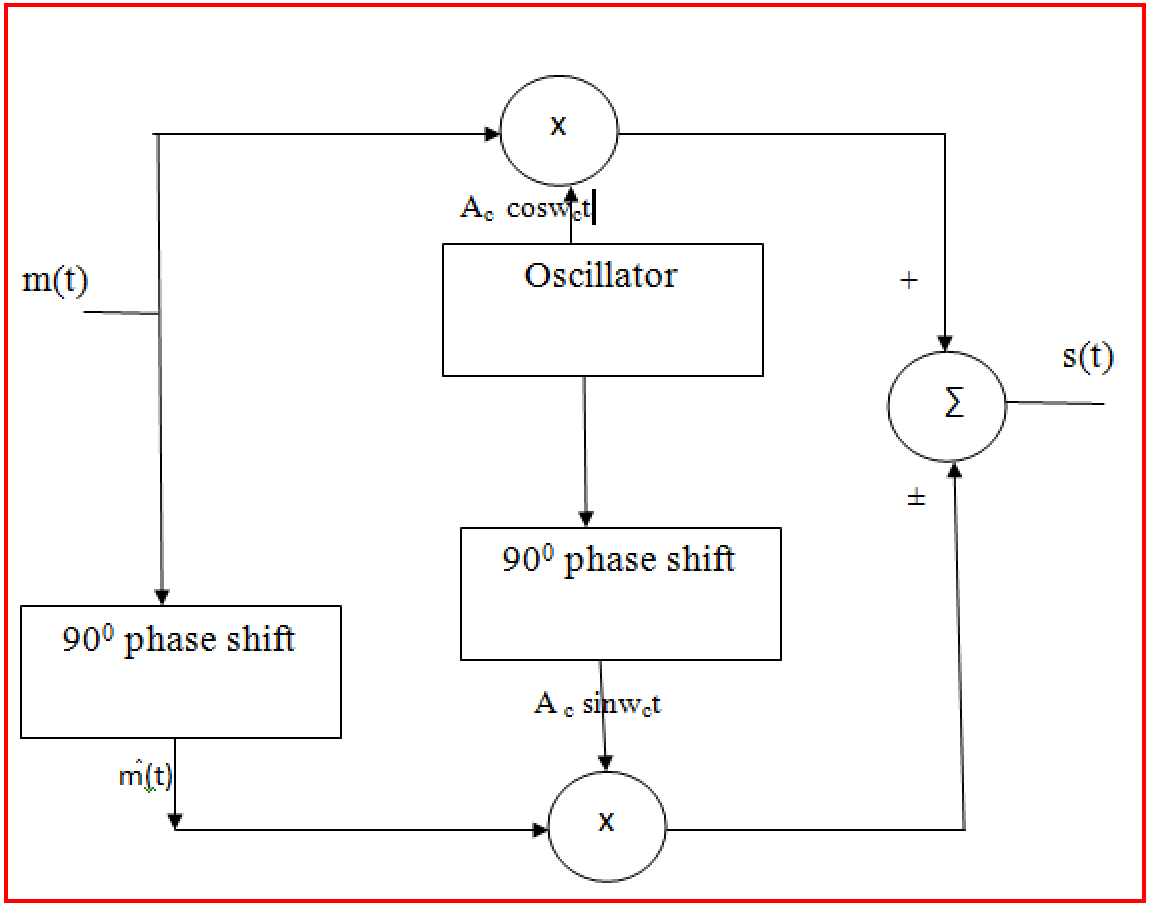








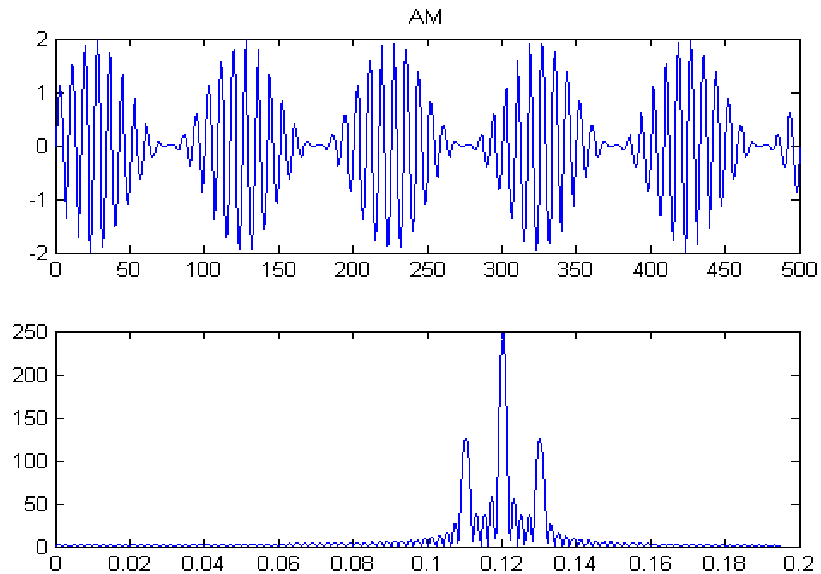
SSB Generation: Phasing Method



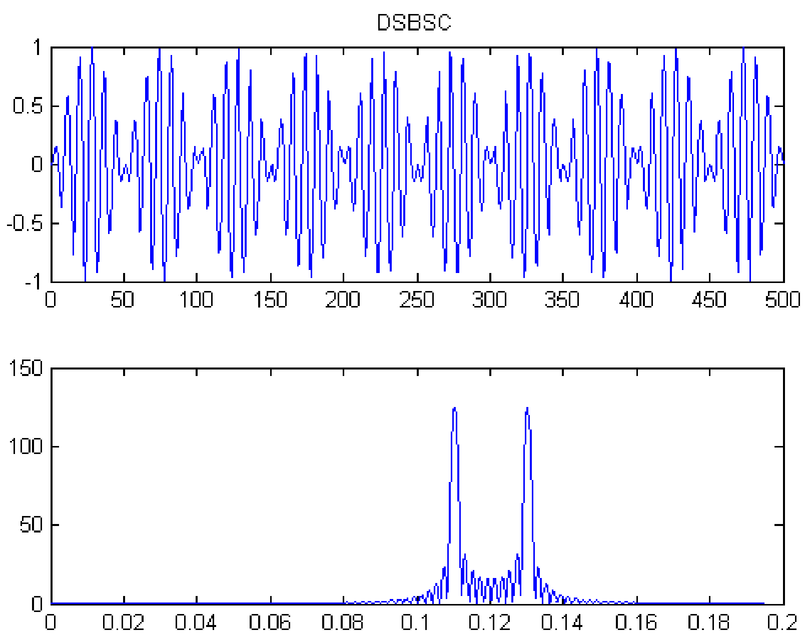
(DSB-SC)I = cos2π(fc-fm)t+ cos2π(fc+fm)t

(DSB-SC)Q = cos2π(fc-fm)t - cos2π(fc+fm)t

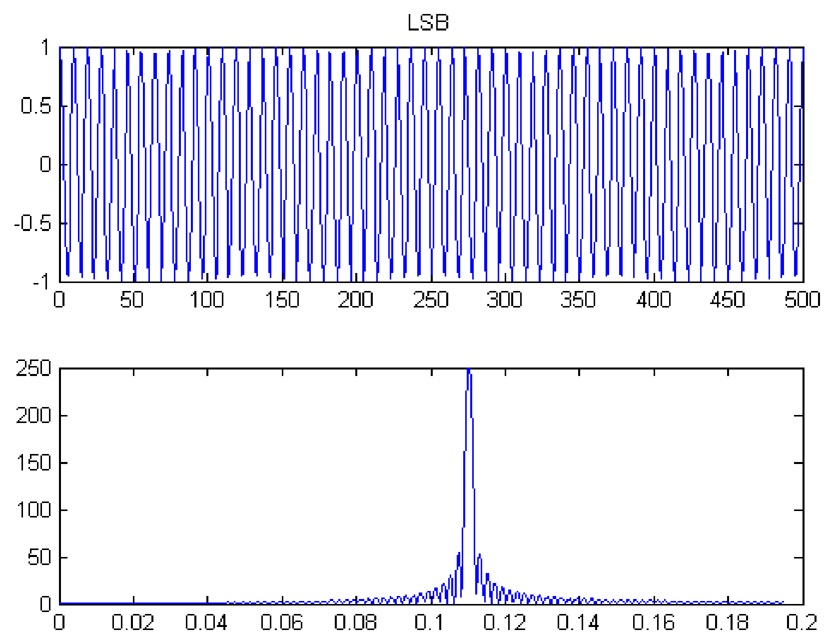
AM in time and frequency domains



DSB in time and frequency domains



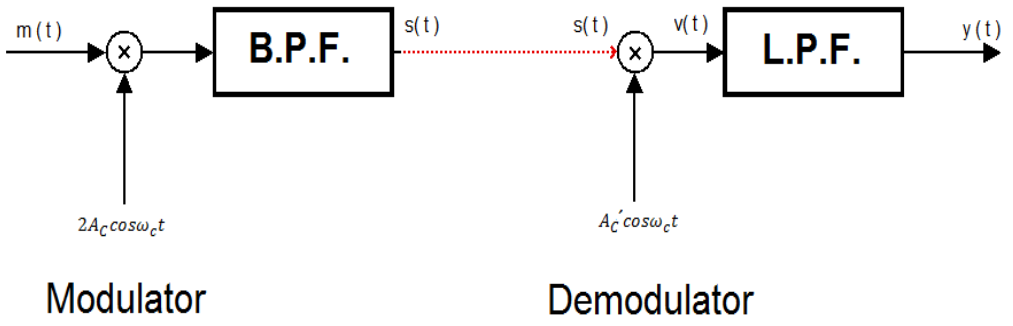
SSB in time and frequency domains



SSB Demodulation

- Coherent Demodulation is used to retrieve the baseband message signal
- A coherent detector uses the knowledge of the phase and frequency of the carrier wave to demodulate the signal.
- It is simply a product device, which multiplies the SSB signal by a sinusoidal signal having the same frequency as the transmitted carrier, followed by a low pass filter (LPF).

SSB Coherent Demodulation



$$v(t) = s(t)A_C' cos\omega_c t$$

$$= A_C' \left[A_C m(t)cos\omega_c t - A_C \hat{m}(t)sin\omega_c t\right]cos\omega_c t$$

$$= A_C A_C' m(t)cos2\omega_c t - A_C A_C' \hat{m}(t)\ sin\omega_c t\ cos\omega_c t$$

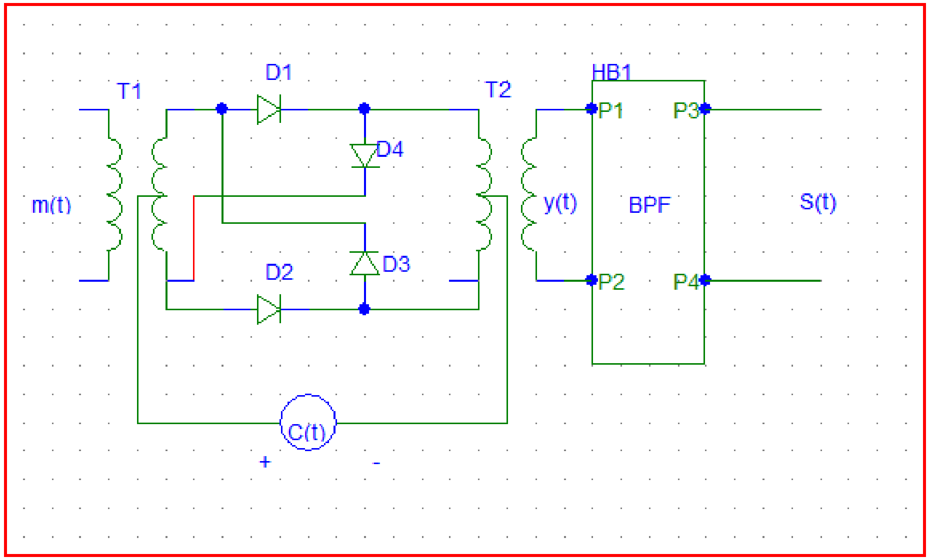
$$= \frac{A_C A_C'}{2} m(t) + \frac{A_C A_C'}{2} m(t)cos2\omega_c t - \frac{A_C A_C'}{2} \hat{m}(t)\ sin2\omega_c t$$

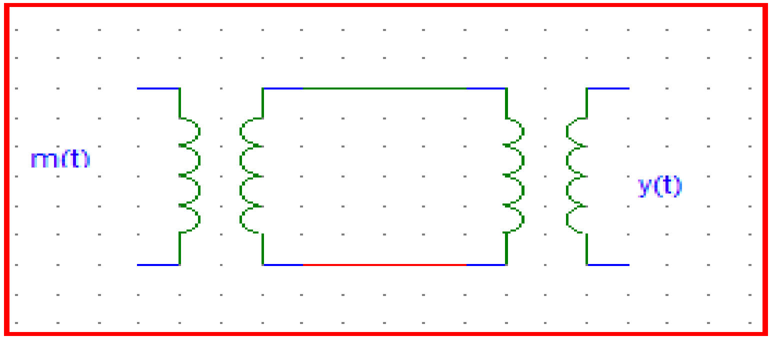
The low pass filter admits only the first terms. The output is:

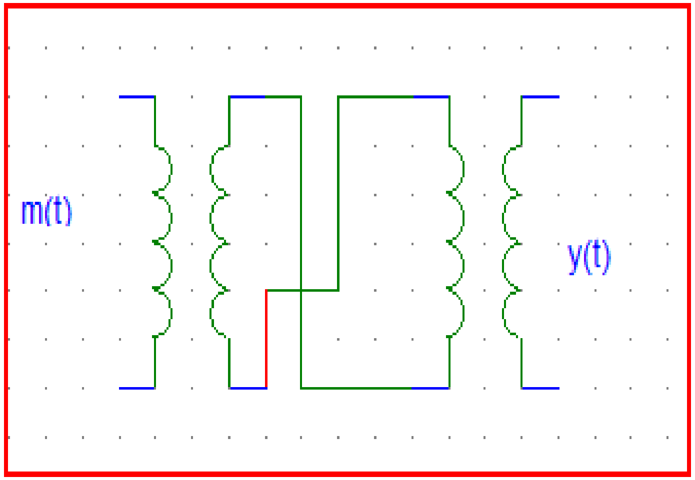
$$y(t) = \frac{A_C A_C'}{2} m(t)$$

Ring Modulator

Used for the generation of a DSB signal. It consists of a ring of 4 diodes and two transformers.







Ring Modulator

- During +ve half cycle of the carrier, message multiplied by +1
- During – ve half cycle, it is multiplied by -1.
- Net effect, as if message is multiplied by a square function.

$$y(t) = m(t)[\frac{4}{\pi} \cos 2\pi f_c t - \frac{4}{3\pi} \cos 3(2\pi f_c t) + \frac{4}{5\pi} \cos 5(2\pi f_c t)]$$

$$= m(t)\frac{4}{\pi} \cos 2\pi f_c t - m(t)\frac{4}{3\pi} \cos 3(2\pi f_c t) + m(t)\frac{4}{5\pi} \cos 5(2\pi f_c t)$$

When y(t) passes through the BPF, the only component that appears at the output is the desired DSB-SC signal, which is

$$s(t) = m(t)\frac{4}{\pi} \cos 2\pi f_c t$$

Ring Modulator

- Net operation of the ring modulator can be modeled as multiplying the message by a periodic square function.