SECTION-B

Amplitude Modulation (AM):

- AM Generation (Modulation)
- AM Demodulation
- Generation of DSBSC wave
- Detection of DSBSC wave
- Generation of SSB wave
- Detection of SSB wave
- VSB Modulation

Amplitude Modulation

- The **Complex Envelope** of an AM signal is given by

$$g(t) = A_c[1+m(t)]$$

A_c indicates the power level of AM and $m(t)$ is the Modulating Signal

- Representation of an **AM signal** is given by

$$s(t) = A_c[1+m(t)]\cos\omega_c t$$

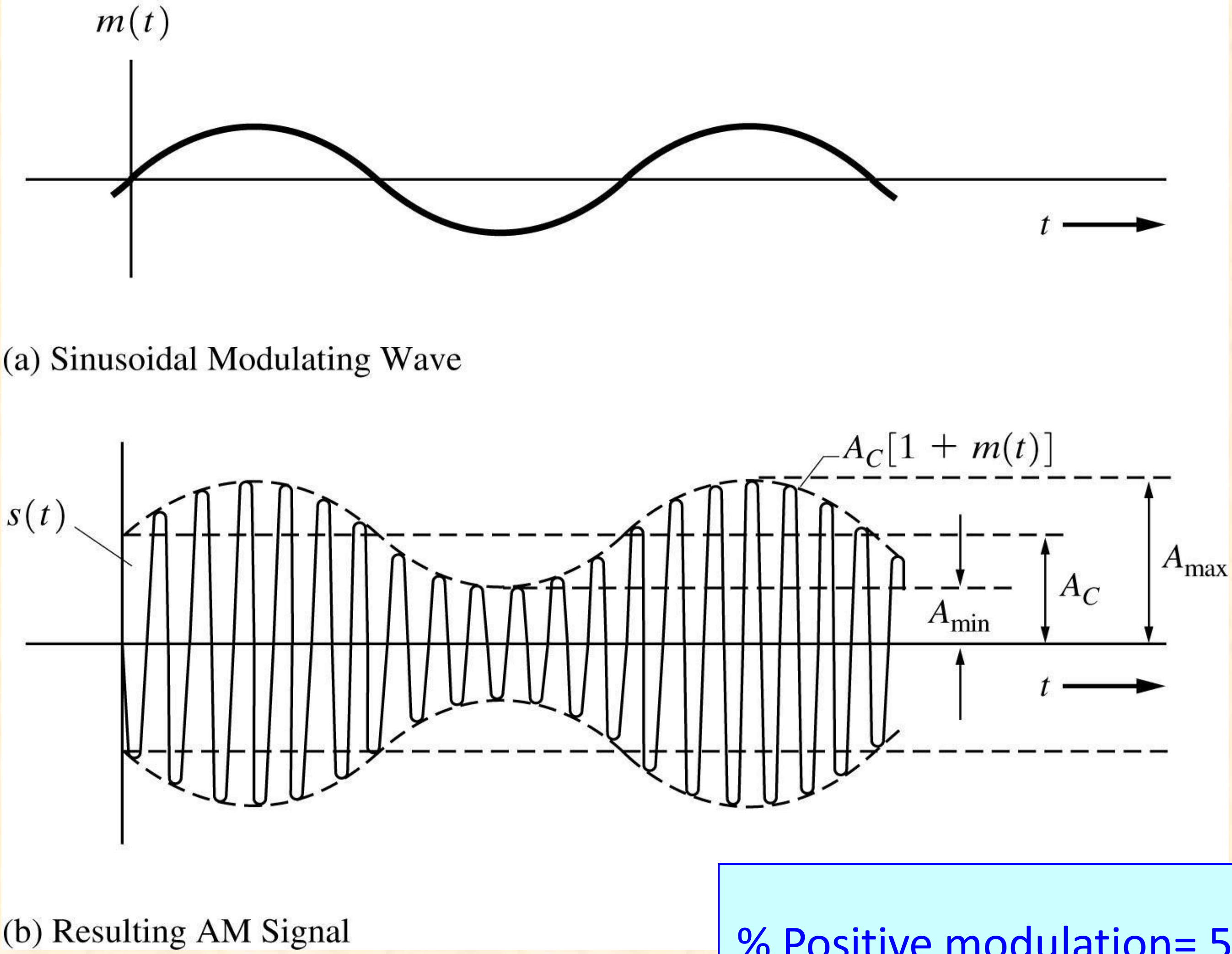
- $A_c[1+m(t)]$ In-phase component x(t)

- **If** $m(t)$ has a peak positive values of +1 and a peak negative value of -1

  AM signal → 100% modulated

- **Envelope detection can be used if % modulation is less than 100%.**

AM Signal Waveform

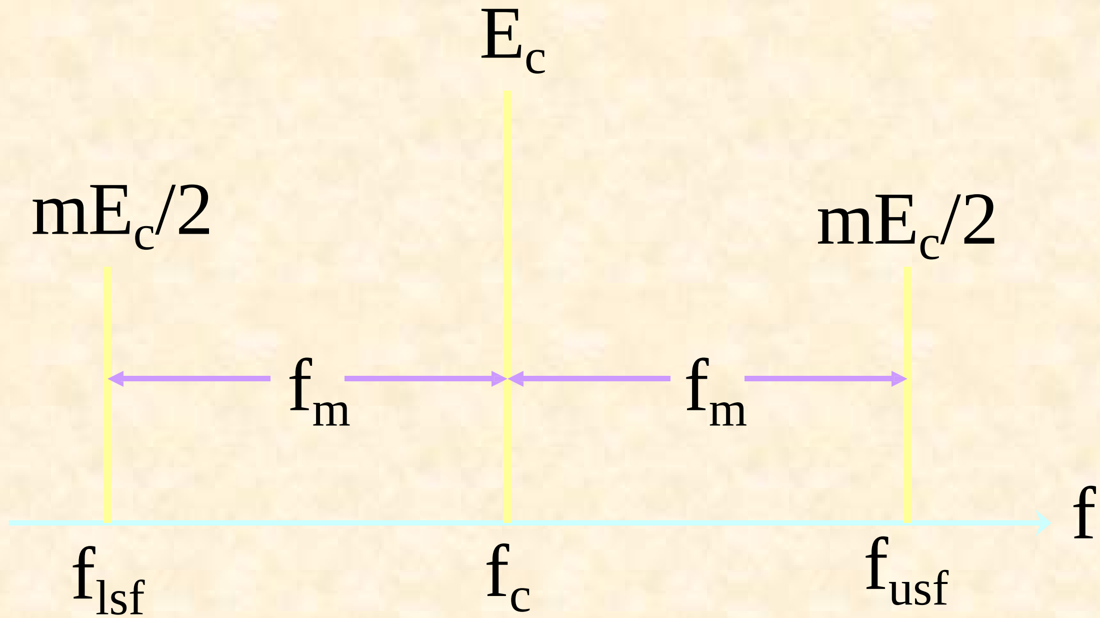


$A_{max} = 1.5A_c$

$A_{min} = 0.5\ A_c$

% Positive modulation= 50%
% Negative modulation =50%
Overall Modulation = 50%

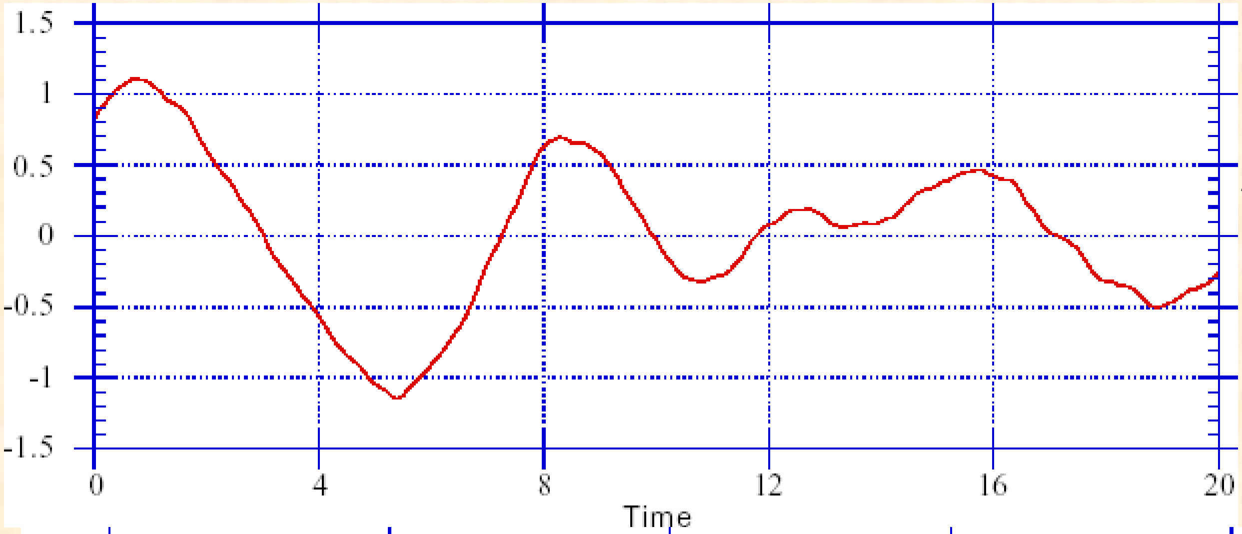
AM Spectrum



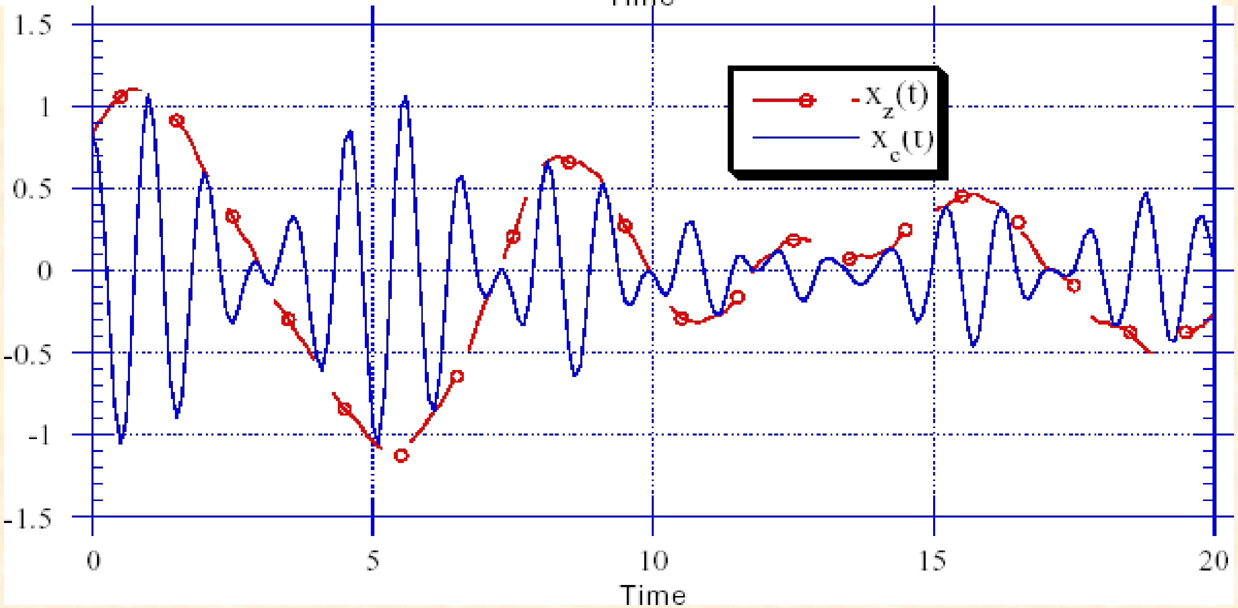
$$f_{usf} = f_c + f_m \; ; \; f_{lsf} = f_c - f_m \; ; \; E_{sf} = mE_c/2$$

Bandwidth, $B = 2f_m$

Amplitude Modulation



An Example of a message signal *m*(*t*)



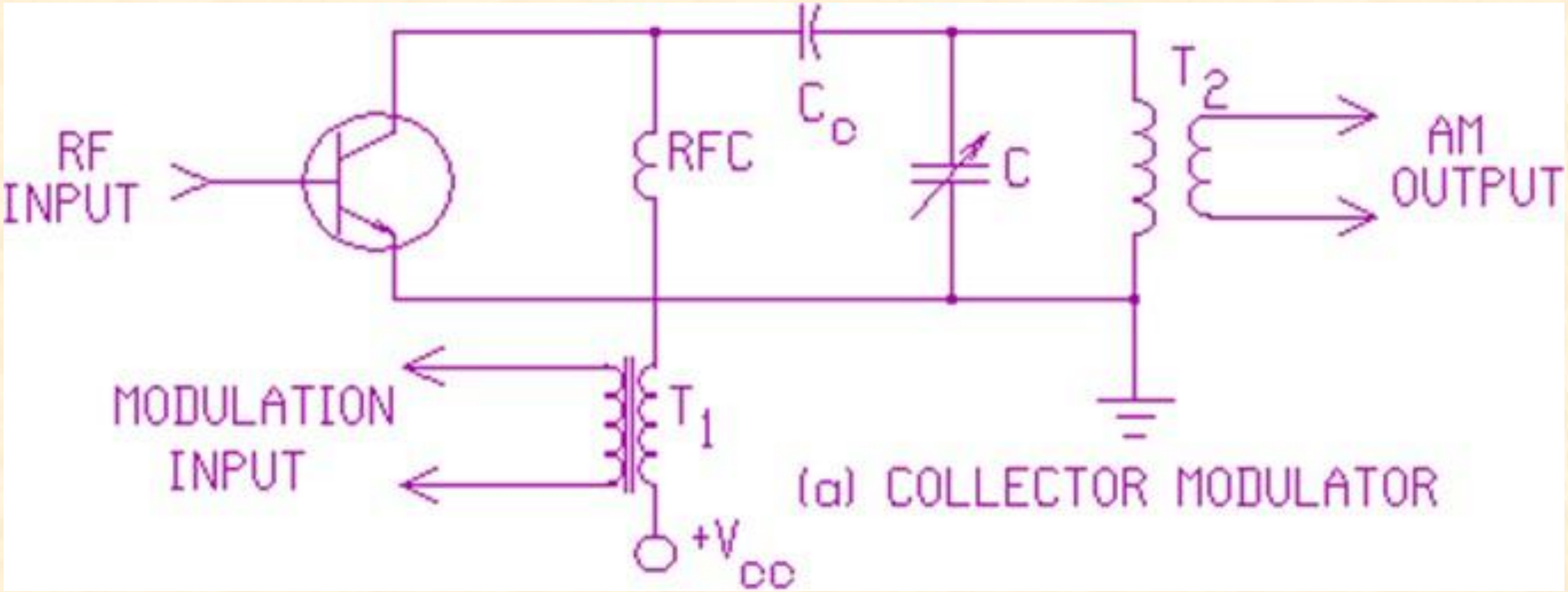
Waveform for Amplitude modulation of the message signal *m*(*t*)

Low-level generation

- In modern radio systems, modulated signals are generated via digital signal processing (DSP).
- With DSP many types of AM modulation are possible with software control

(including DSB with carrier, SSB suppressed-carrier and independent sideband, or ISB).

Collector Modulation



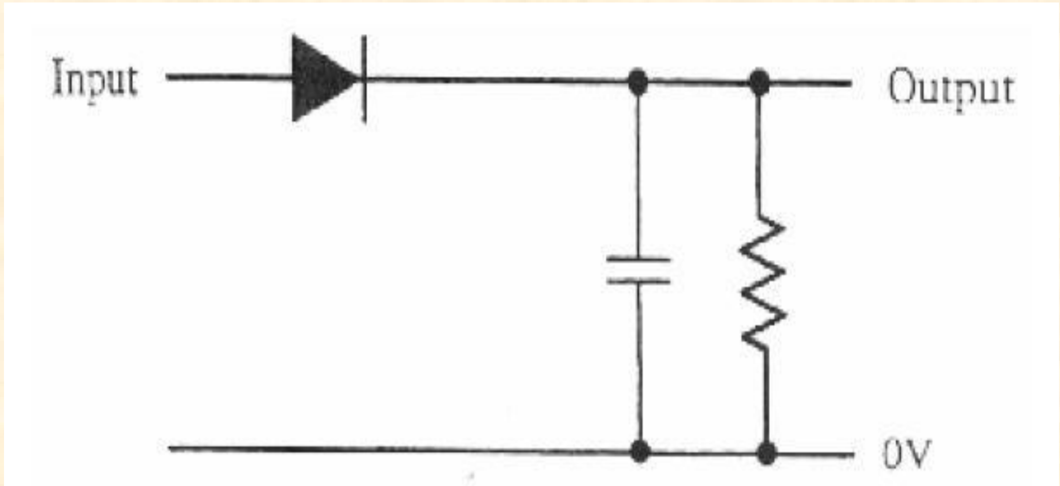
High-level generation

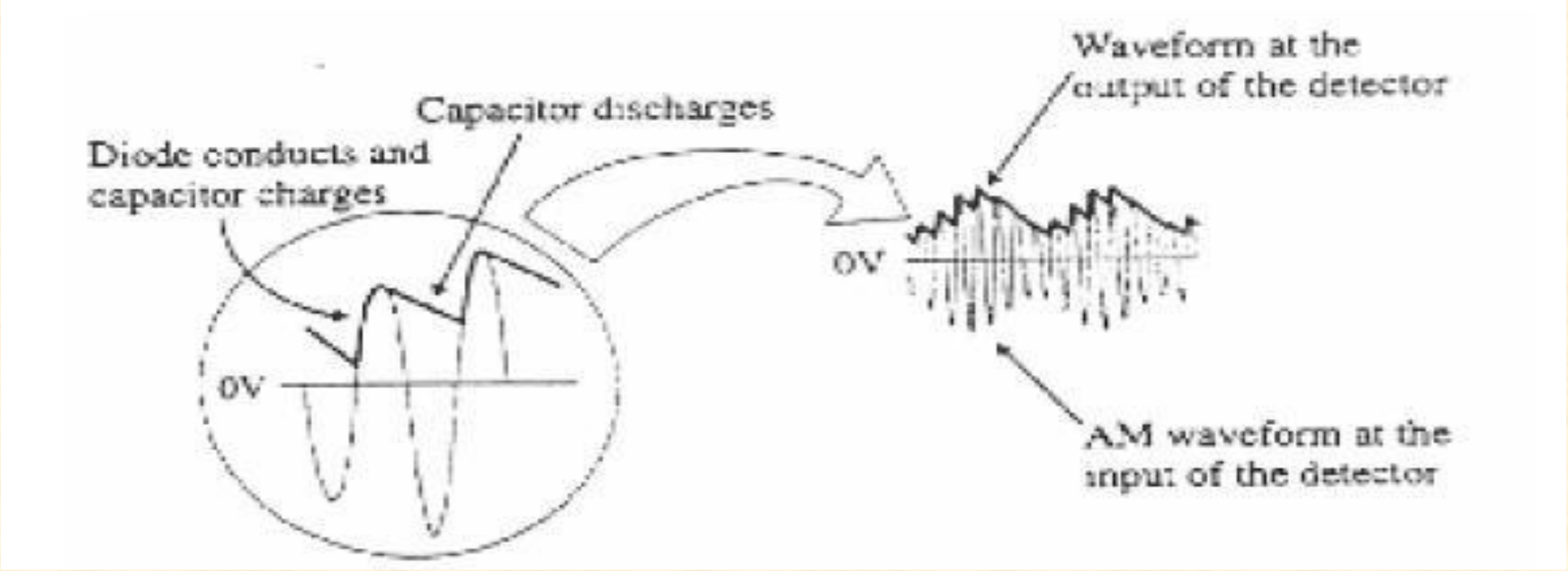
- High-power AM transmitters (such as those used for AM broadcasting) are based on high-efficiency class-D and class-E power amplifier stages, modulated by varying the supply voltage.
- Older designs (for broadcast) also generate AM by controlling the gain of the transmitter's final amplifier (generally class-C, for efficiency). The following types are for vacuum tube transmitters (but similar options are available with transistors):

AM Demodulation

- Square law Detector
- Linear Diode (Envelope) Detector

Linear Diode detector





- **Linear detector** utilizes the rectification characteristic of a diode.
- The modulated carrier voltage is applied to the series combination of diode and the load impedance consisting of resistor R in shunt with capacitor C.
- Since applied voltage is of large magnitude, the operation takes place essentially over the linear region of the dynamic current-voltage characteristic of the diode.
- The idealized linear dynamic current-voltage characteristic of the diode detector. Assuming capacitor C to be absent, the total impedance in series circuit is (ra + R) where ra is the dynamic anode resistance of the diode.

- O/P voltage curve is of spiky nature but it almost traces the envelope of the modulated carrier voltage and hence it is nothing but the original modulation voltage

- The departure of this output voltage from the envelope may be reduced by proper choice of R and C depending upon the modulation frequency and depth of modulation

Double Side Band Suppressed Carrier (DSBSC)

- Power in a AM signal is given by $$\langle s^2(t)\rangle = \underbrace{\frac{1}{2}A_c^2}_{\text{Carrier Power}} + \underbrace{\frac{1}{2}A_c^2\langle m^2(t)\rangle}_{\text{Sideband power}}$$

➢DSBSC is obtained by eliminating carrier component

If ***m*(*t*)** is assumed to have a zero DC level, then

$$s(t) = A_c m(t)\cos\omega_c t$$

Spectrum ➔ $$S(f) = \frac{A_c}{2}\left[M(f - f_c) + M(f + f_c)\right]$$

Power ➔ $$\langle s^2(t)\rangle = \frac{1}{2}A_c^2\langle m^2(t)\rangle$$

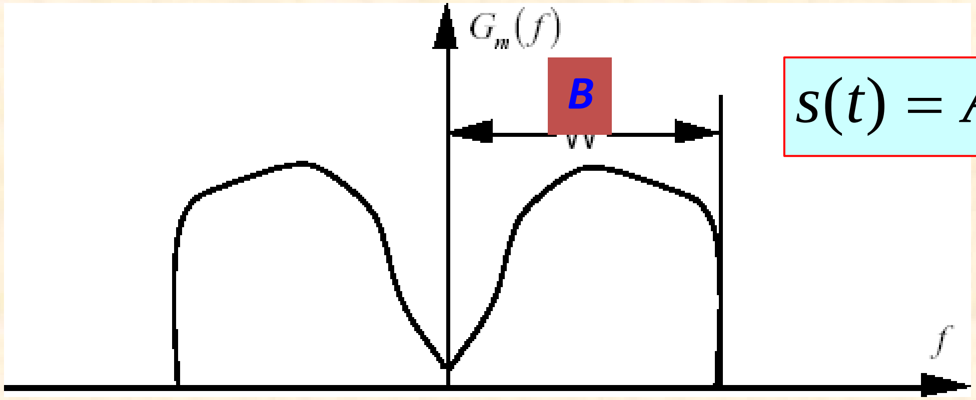
Modulation Efficiency ➔ $$E = \frac{\langle m^2(t)\rangle}{\langle m^2(t)\rangle}\times 100 = 100\%$$

Disadvantages of DSBSC:

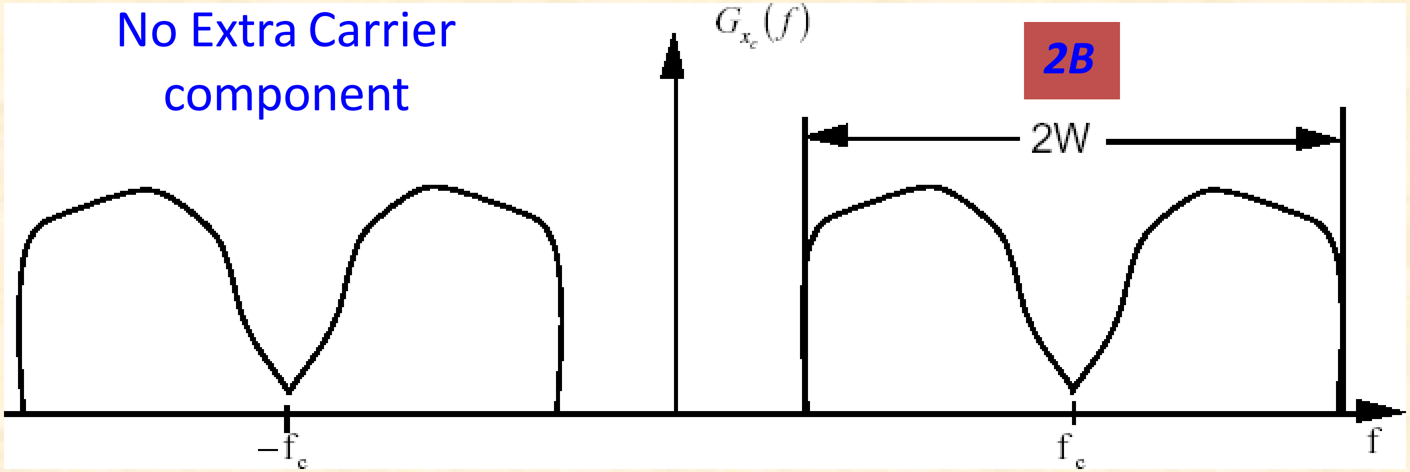
- Less information about the carrier will be delivered to the receiver.

DSBSC Modulation

$$s(t) = A_c m(t)\cos\omega_c t$$

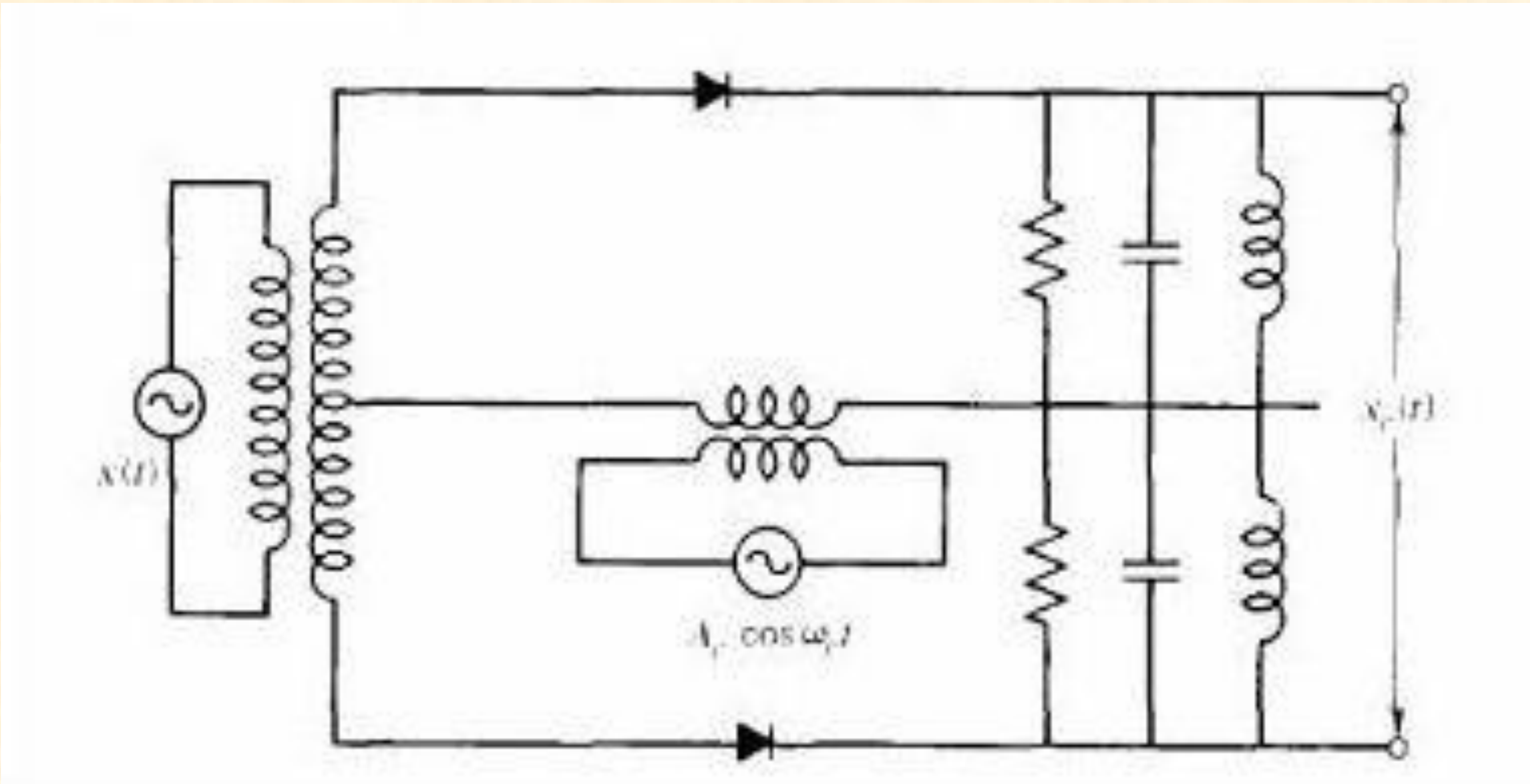


An Example of message energy spectral density.

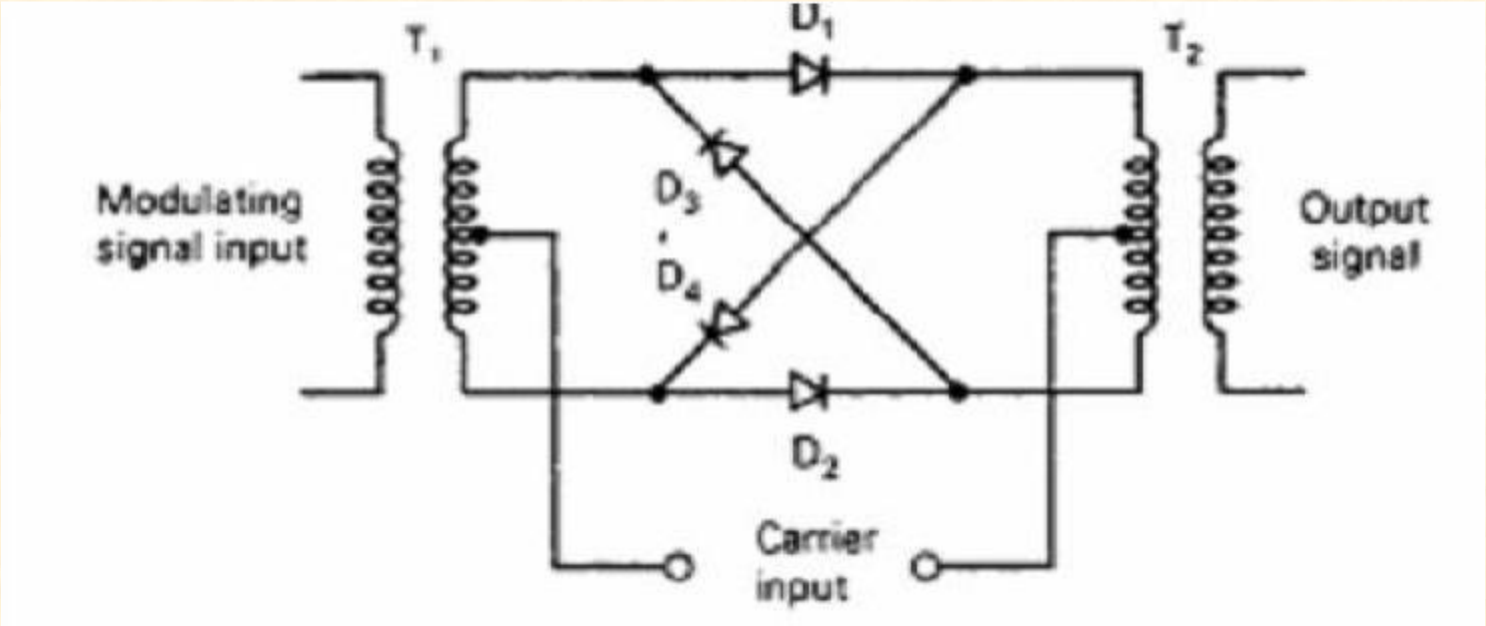


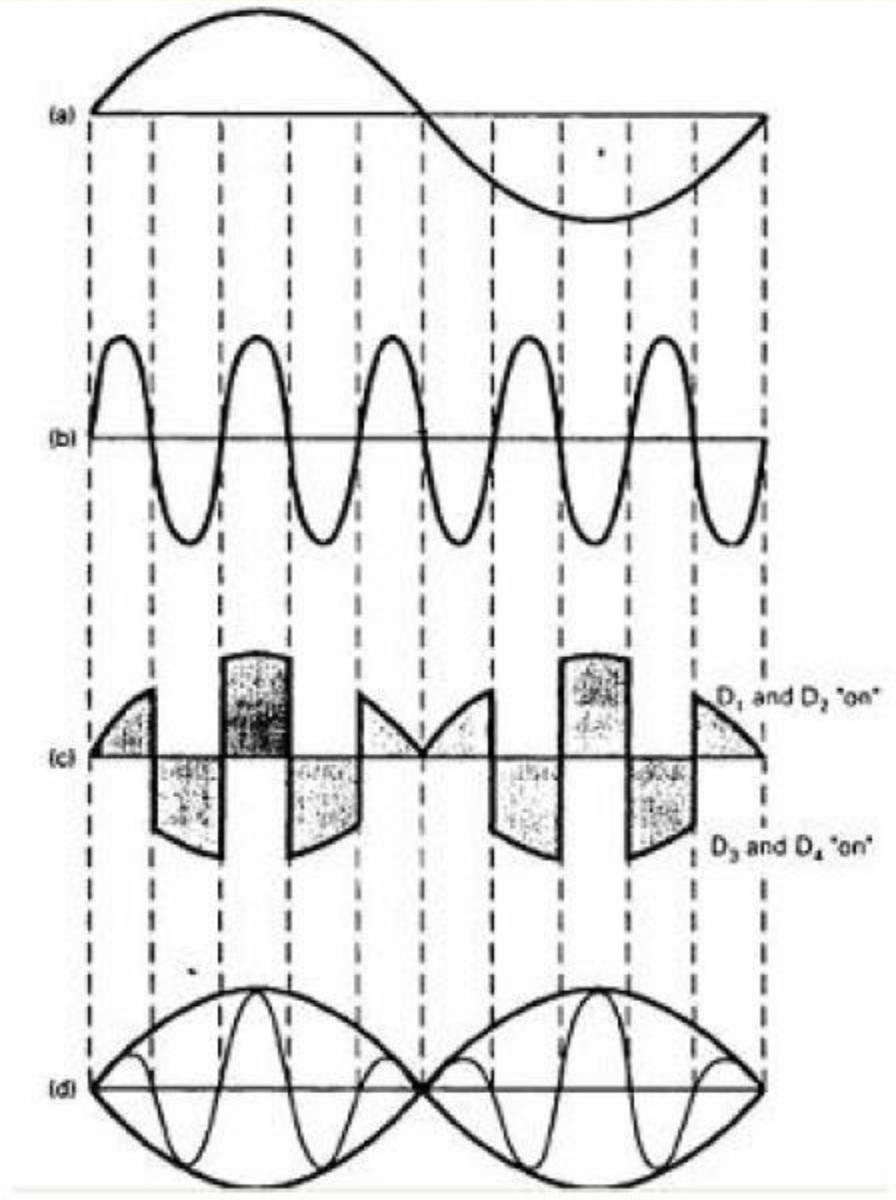
Energy spectrum of the DSBSC modulated message signal.

DSBSC Generation using Balanced Modulator



DSBSC Generation using Ring Modulator





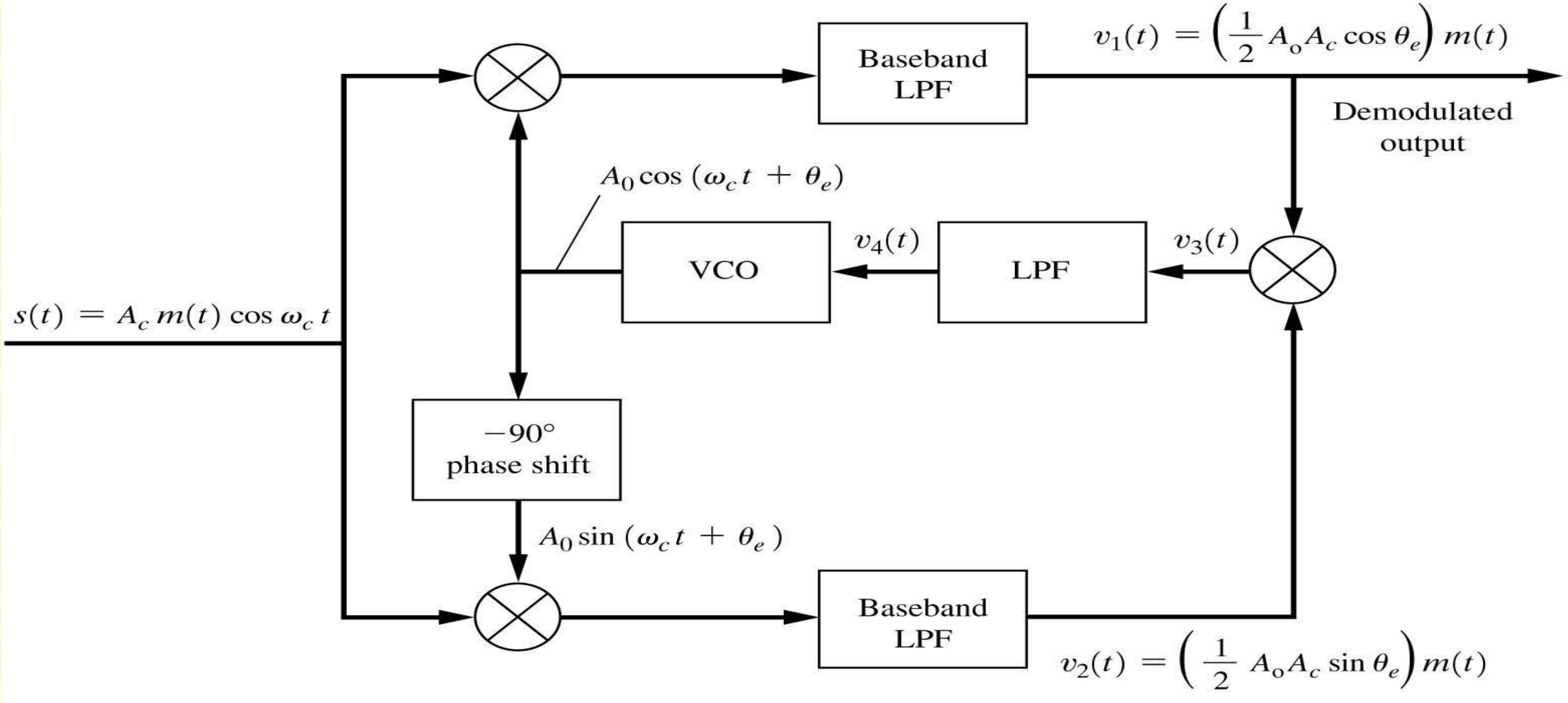
(a)
(b)
(c)
D₁ and D₂ "on"
D₃ and D₄ "on"
(d)

DSBSC Demodulation

- Synchronous Detection
- Envelope Detection after suitable carrier reinsertion

Carrier Recovery for DSBSC Demodulation

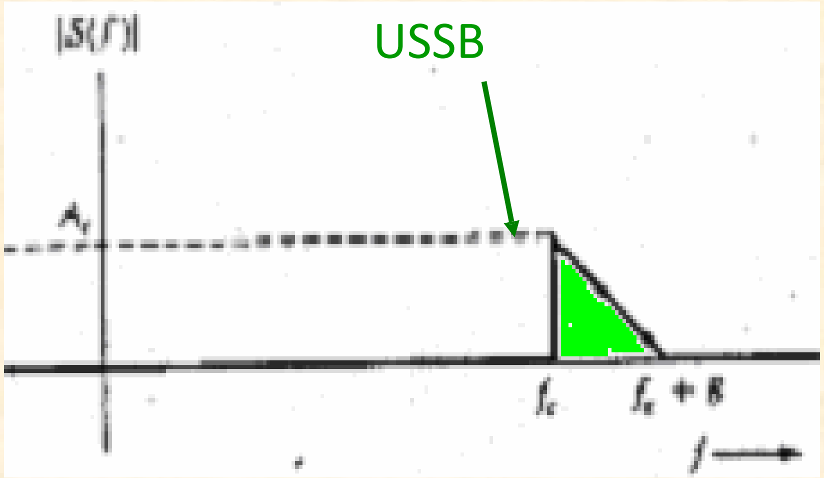
➢ Coherent reference for product detection of DSBSC can not be obtained by the use of ordinary PLL because there are no spectral line components at f_c.

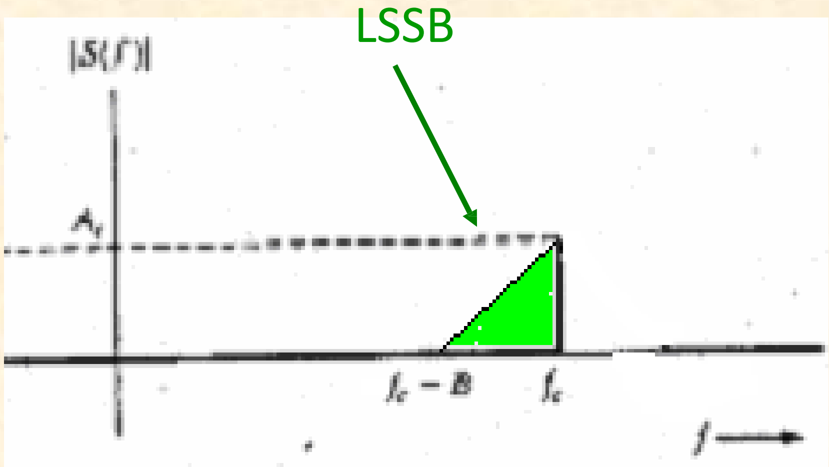


(a) Costas Phase-Locked Loop

Single Sideband (SSB) Modulation

- An **upper single sideband** (USSB) signal has a zero-valued spectrum for $|f| < f_c$
- A **lower single sideband** (LSSB) signal has a zero-valued spectrum for $|f| > f_c$
- **SSB-AM** – popular method ~ **BW** is *same* as that of the modulating signal. Note: Normally SSB refers to SSB-AM type of signal





Single Sideband Signal

➢ **Theorem :** A SSB signal has **Complex Envelope** and bandpass form as:

$$g(t) = A_c\left[m(t) \pm j\hat{m}(t)\right]$$

$$s(t) = A_c\left[m(t)\cos\omega_c t \mp \hat{m}(t)\sin\omega_c t\right]$$

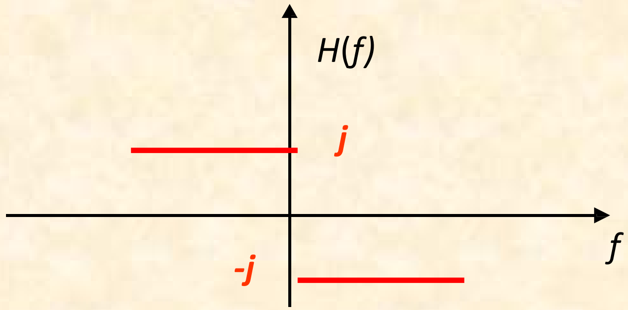
Upper sign (-) → USSB

Lower sign (+) → LSSB

$\hat{m}(t)$ – **Hilbert transform** of *m(t)* ➔ $\hat{m}(t) \equiv m(t) * h(t)$ Where $h(t) = \dfrac{1}{\pi t}$

$H(f) = \Im\left[h(t)\right]$ and $H(f) = \begin{cases} -j, & f > 0 \\ j, & f < 0 \end{cases}$

Hilbert Transform corresponds to a -90^0 phase shift



Single Sideband Signal

Proof: **Fourier transform of the complex envelope**

$$G(f) = A_c\left\{M(f) \pm j\Im\left[\hat{m}(t)\right]\right\} = A_c\left\{M(f) \pm j\hat{M}(f)\right\}$$

Upper sign → USSB
Lower sign → LSSB

Using $\hat{m}(t) \equiv m(t) * h(t) \quad \Rightarrow G(f) = A_c M(f)\left[1 \pm jH(f)\right]$

$$G(f) = \begin{cases} 2A_c M(f), & f > 0 \\ 0, & f < 0 \end{cases}$$

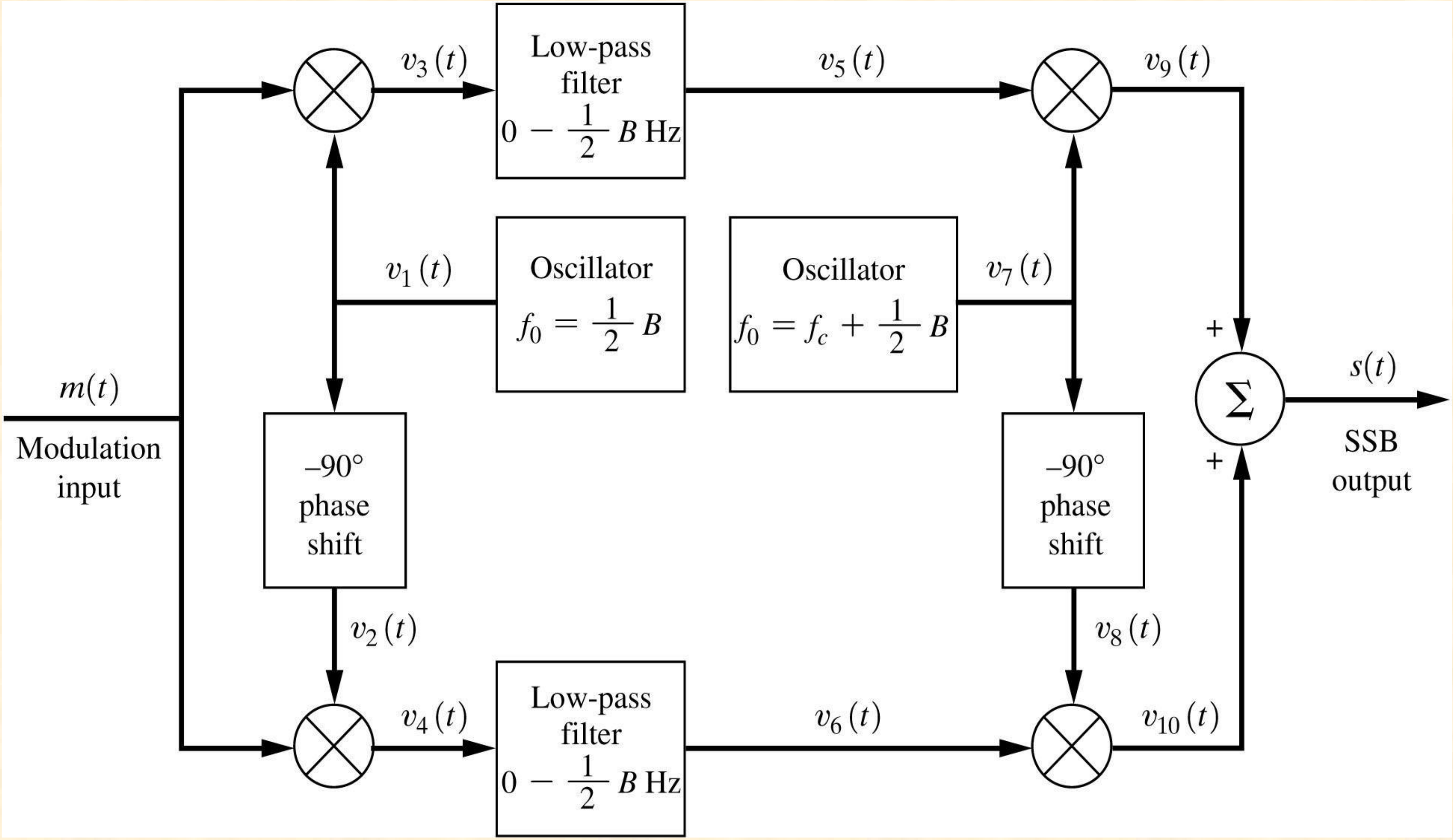
Recall $V(f) = \frac{1}{2}\left\{G(f - f_c) + G^*[-(f + f_c)]\right\}$

$$S(f) = A_c\begin{cases} M(f - f_c), & f > f_c \\ 0, & f < f_c \end{cases} + A_c\begin{cases} 0, & f > -f_c \\ M(f + f_c), & f < -f_c \end{cases}$$

Upper sign → USSB

If **lower signs** were used → **LSSB** signal would have been obtained

Weaver's Method for Generating SSB.



Generation of VSB