APECE-302: Radio & Television Engineering

Applied Physics, Electronics & Communication Engineering

Lecture # 10

University of Dhaka | APECE DU

Course Teacher: Dr. S.M. Riazul Islam

Date: 2012 Year, 07 Month, 17 Day

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- Linear Modulation Schemes: DSB-SC, SSB, VSB
- DSB-SC Modulation
- Coherent Detection
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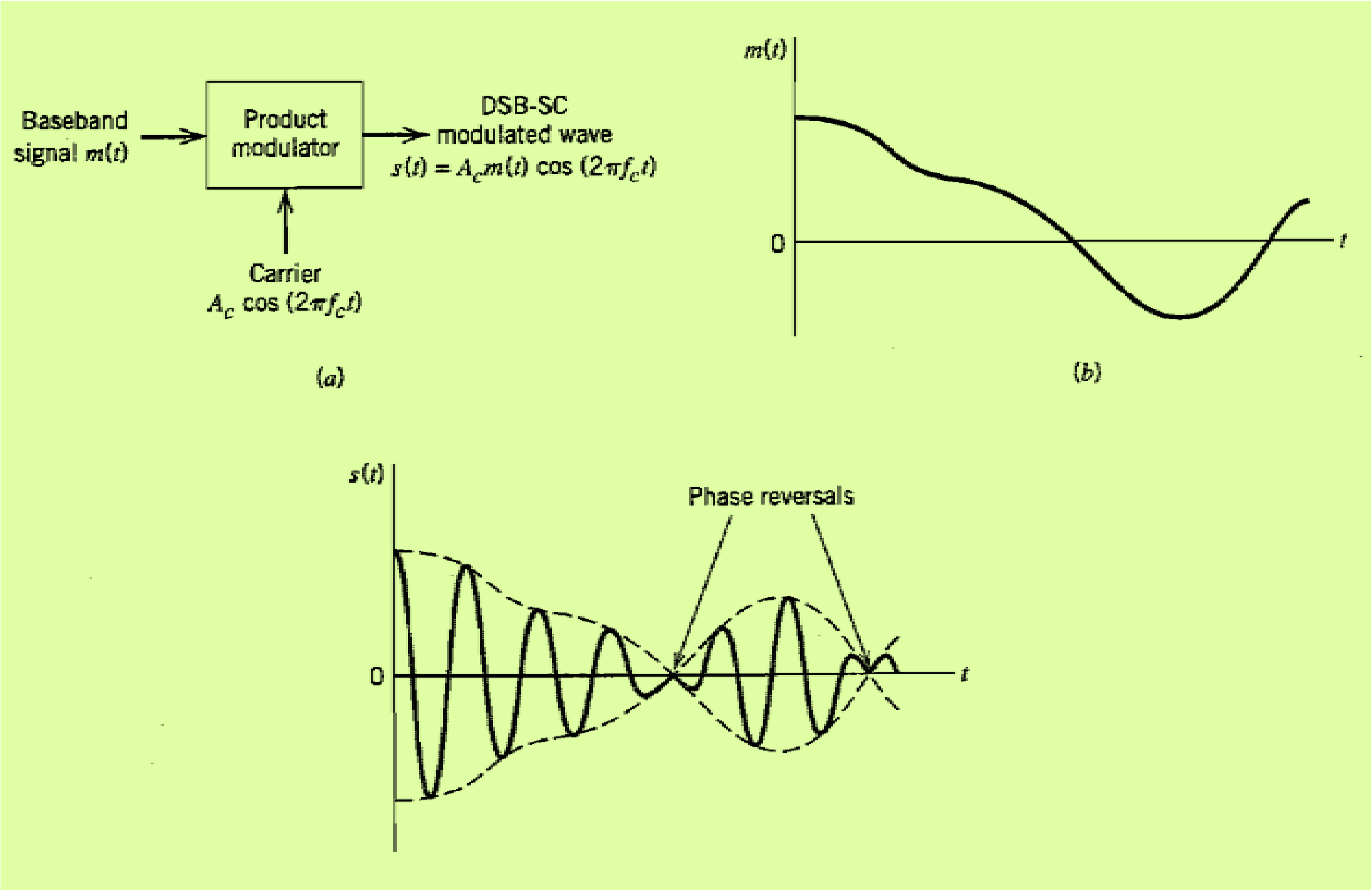
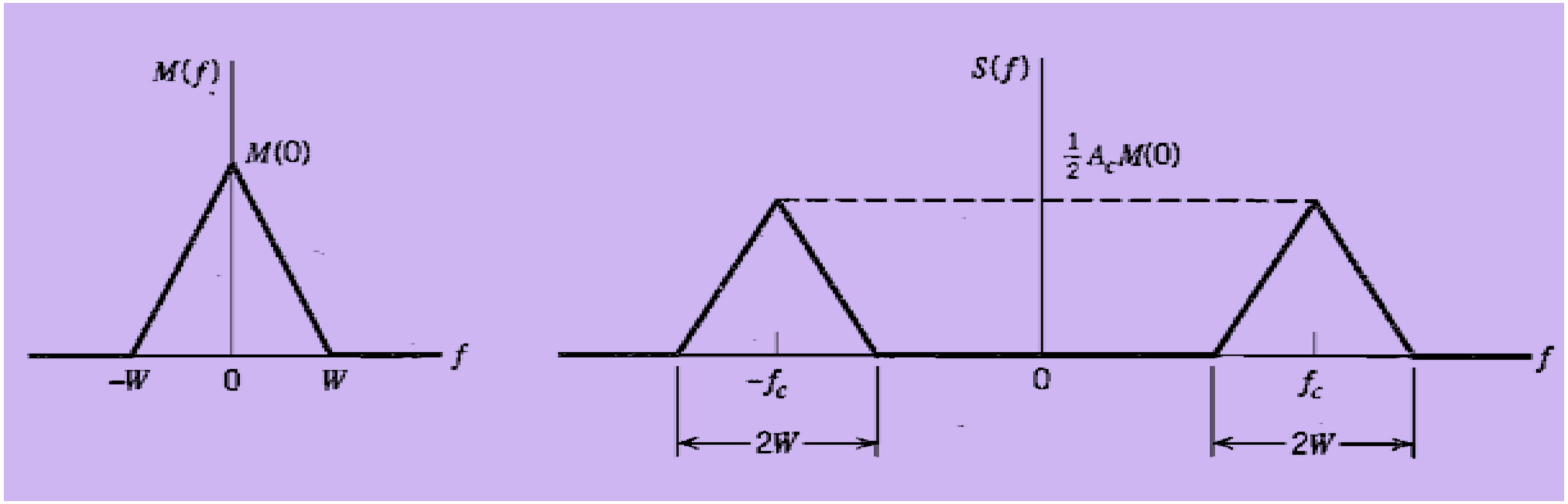
- Quadrature-Carrier Multiplexing
- Hilbert Transform and Canonical Representations of Signals
- Filtering of Sidebands

DSB-SC Modulation

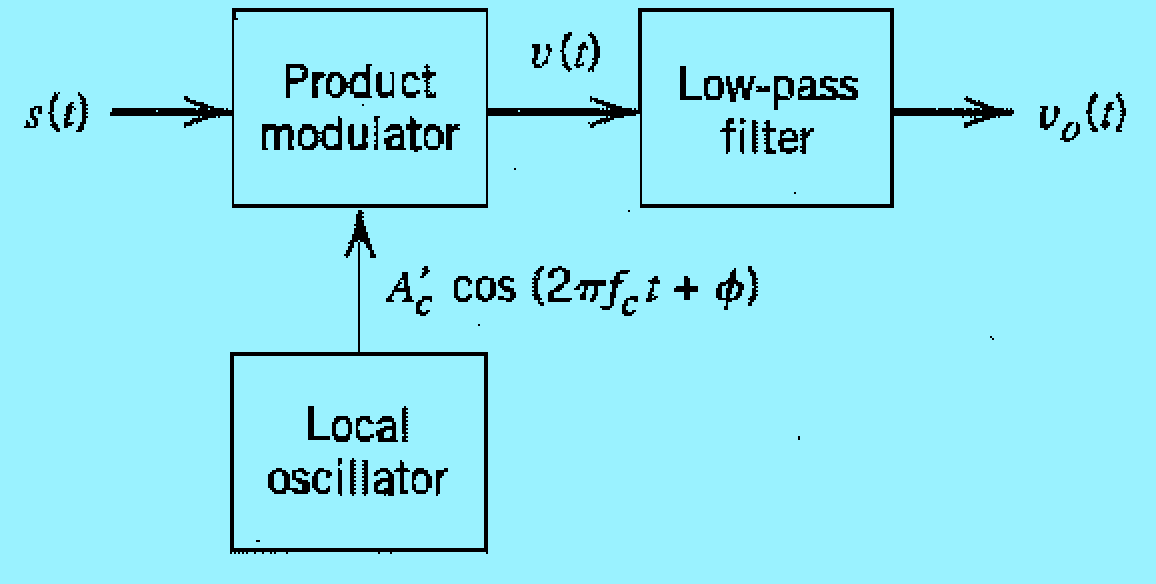


DSB-SC Modulation



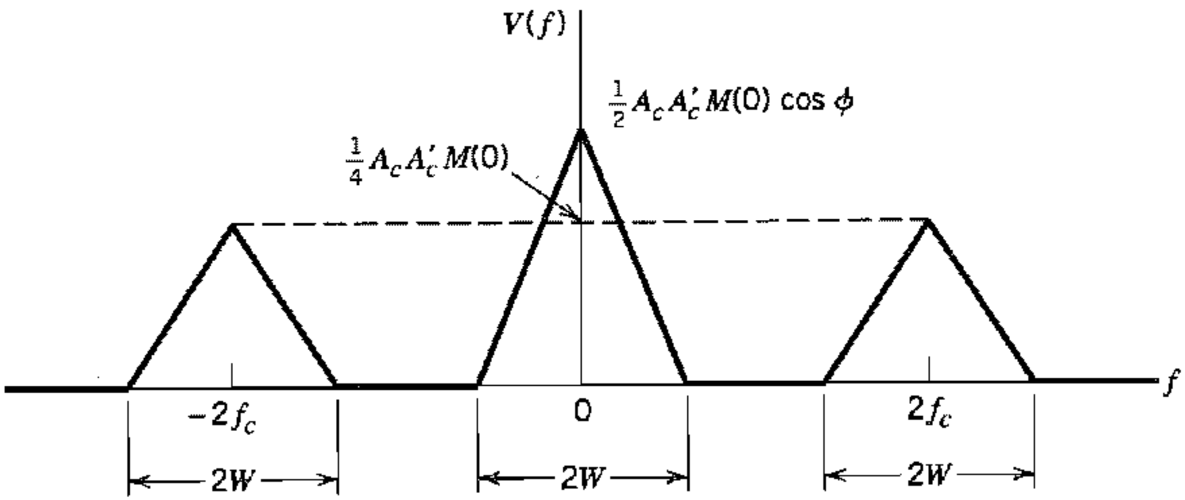
$$S(f) = \frac{1}{2} A_c[M(f - f_c) + M(f + f_c)]$$

Coherent Detection



$$
\begin{aligned}
v(t) &= A_c' \cos(2\pi f_c t + \phi) s(t) \\
&= A_c A_c' \cos(2\pi f_c t) \cos(2\pi f_c t + \phi) m(t) \\
&= \frac{1}{2} A_c A_c' \cos(4\pi f_c t + \phi) m(t) + \frac{1}{2} A_c A_c' \cos\phi \, m(t)
\end{aligned}
$$

Coherent Detection

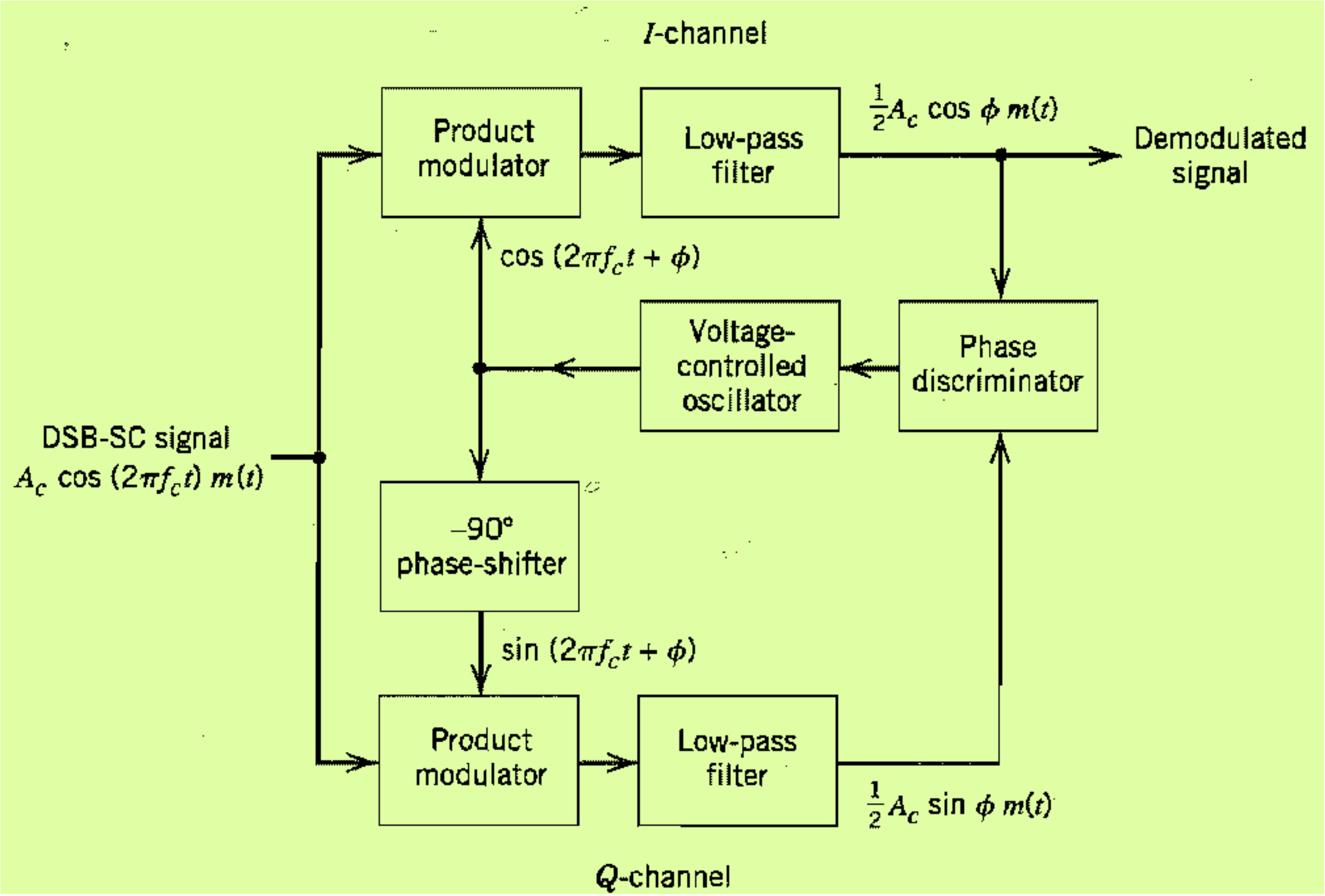


- Cut-off frequency > W but less than $2f_c$-W

$$v_o(t) = \frac{1}{2} A_c A_c' \cos\phi \, m(t)$$

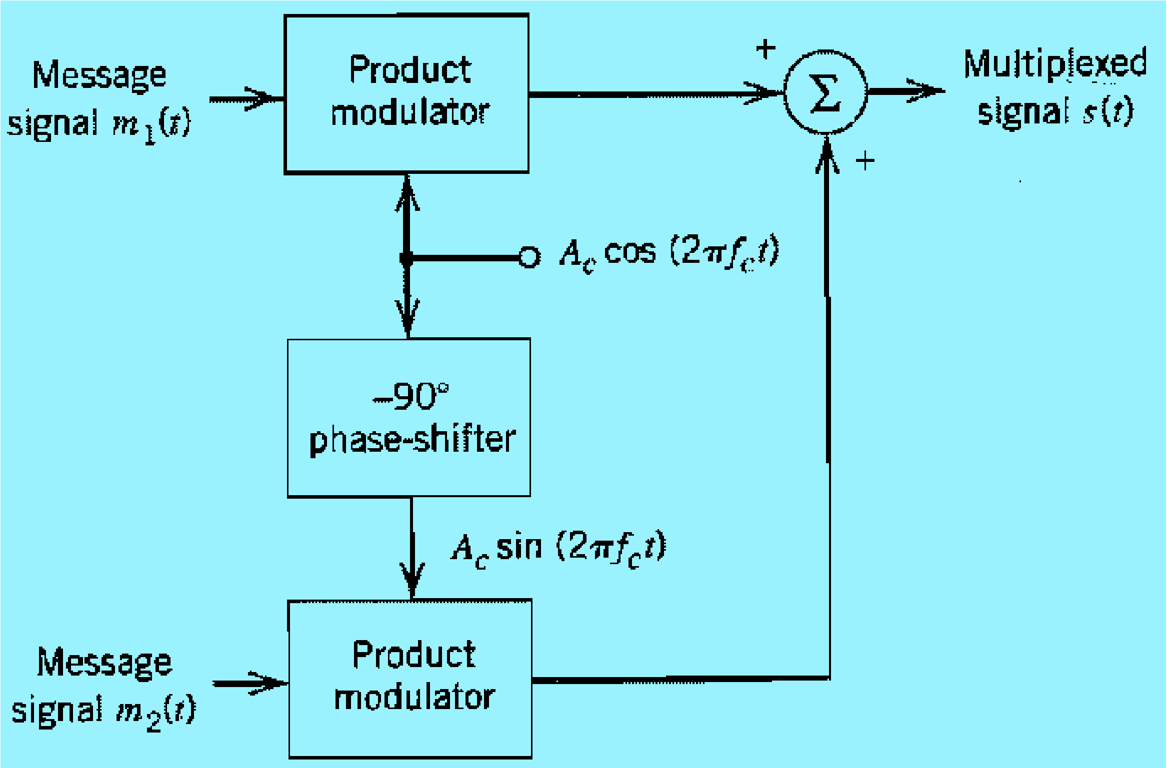
- Quadrature null effect of coherent detector? >> perfect Synch.

COSTAS Receiver



Quadrature-carrier multiplexing

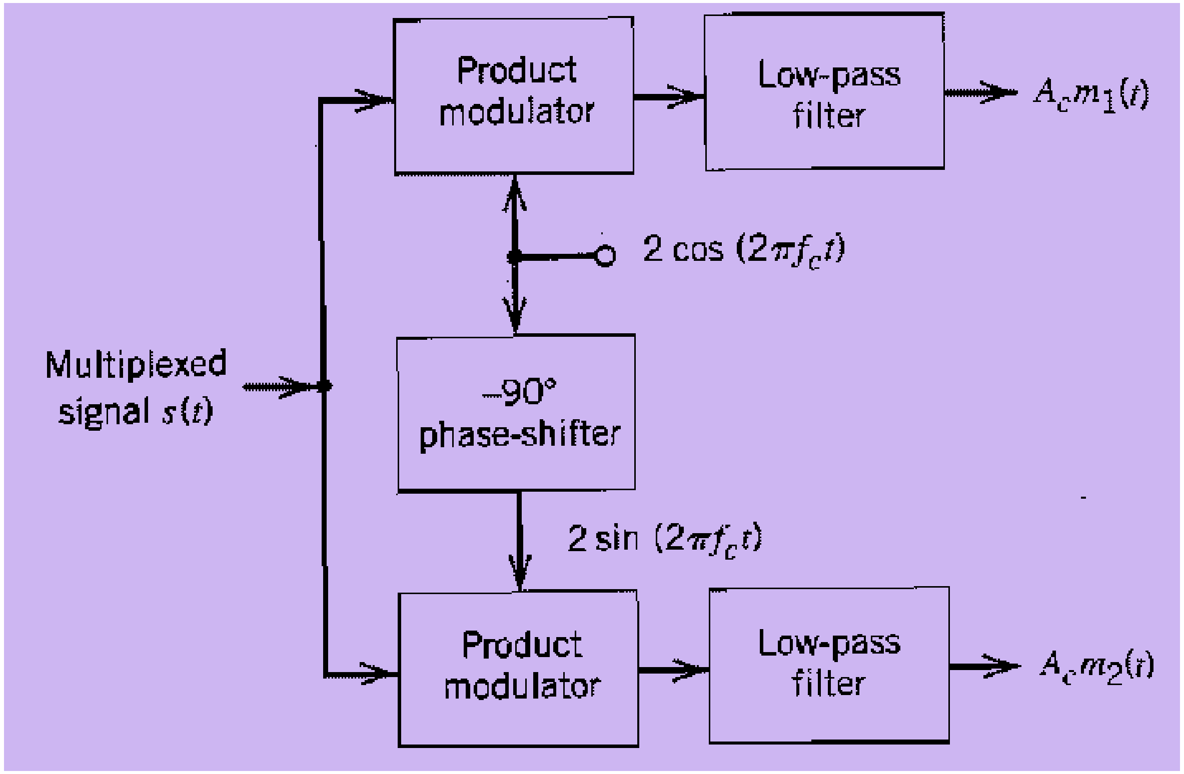
- Tx:



$$s(t) = A_c m_1(t) \cos(2\pi f_c t) + A_c m_2(t) \sin(2\pi f_c t)$$

Quadrature-carrier multiplexing

- Rx:



Representations of Signals and Systems

$$G(f) = \int_{-\infty}^{\infty} g(t) \exp(-j2\pi ft)\, dt$$

$$g(t) = \int_{-\infty}^{\infty} G(f) \exp(j2\pi ft)\, df$$

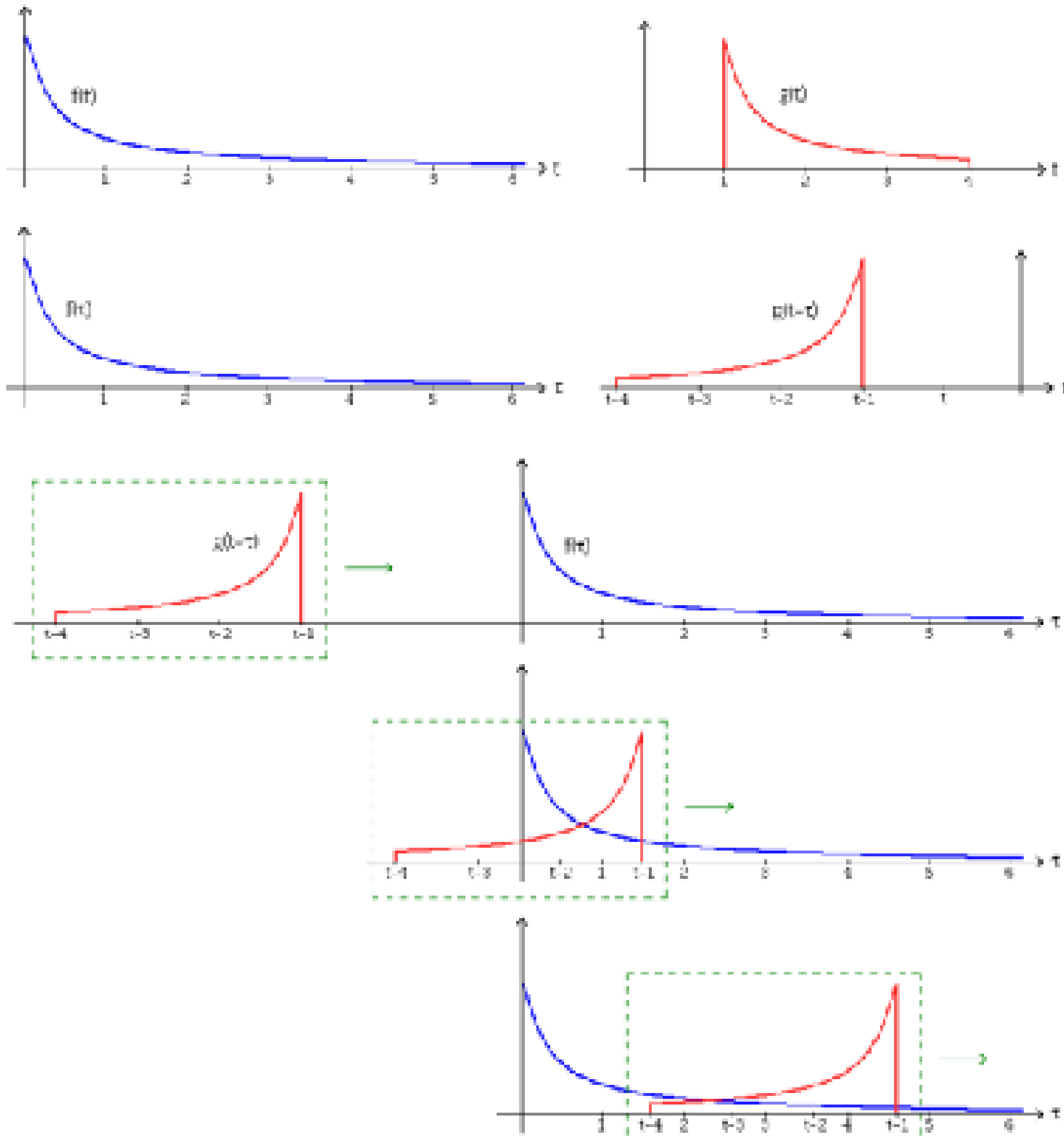
$$\int_{-\infty}^{\infty} |g(t)|^2\, dt < \infty$$

$$(f * g)(t) \stackrel{\text{def}}{=} \int_{-\infty}^{\infty} f(\tau)\, g(t-\tau)\, d\tau = \int_{-\infty}^{\infty} f(t-\tau)\, g(\tau)\, d\tau.$$

$$a g_1(t) + b g_2(t) \rightleftharpoons a G_1(f) + b G_2(f)$$

where a and b are constants

$$\int_{-\infty}^{\infty} g_1(\tau) g_2(t-\tau)\, d\tau \rightleftharpoons G_1(f) G_2(f)$$


f(t)
g(t)
f(τ)
g(t−τ)
f(τ)

Representations of Signals and Systems

$$\hat{g}(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{g(\tau)}{t-\tau}\, d\tau$$

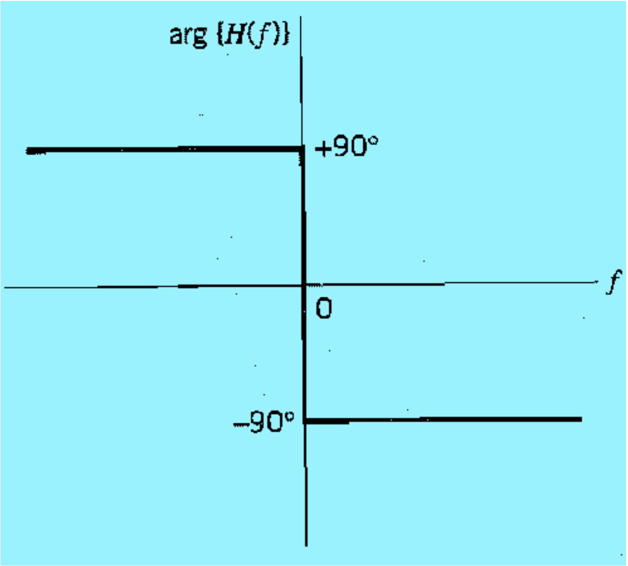
$$g(t) = -\frac{1}{\pi}\int_{-\infty}^{\infty} \frac{\hat{g}(\tau)}{t-\tau}\, d\tau$$

$$\frac{1}{\pi t} \rightleftharpoons -j\,\mathrm{sgn}(f)$$

$$\mathrm{sgn}(f) = \begin{cases} 1, & f > 0 \\ 0, & f = 0 \\ -1, & f < 0 \end{cases}$$

$$\hat{G}(f) = -j\,\mathrm{sgn}(f) G(f)$$

Representations of Signals and Systems



1. A signal $g(t)$ and its Hilbert transform $\hat{g}(t)$ have the same magnitude spectrum.
2. If $\hat{g}(t)$ is the Hilbert transform of $g(t)$, then the Hilbert transform of $\hat{g}(t)$ is $-g(t)$.
3. A signal $g(t)$ and its Hilbert transform $\hat{g}(t)$ are orthogonal over the entire time interval $(-\infty, \infty)$, as shown by

$$\int_{-\infty}^{\infty} g(t)\hat{g}(t)dt = 0$$

Representations of Signals and Systems

Pre-envelope: g(t) is real valued--

$$g_+(t) = g(t) + j\hat{g}(t)$$

$$G_+(f) = G(f) + \text{sgn}(f)G(f)$$

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

Representations of Signals and Systems

$$g_-(t) = g(t) - j\hat{g}(t)$$

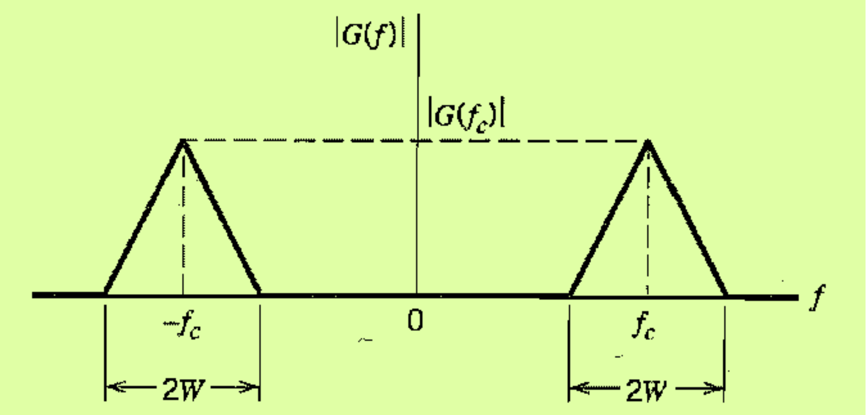
$$G_-(f) = \begin{cases} 0, & f > 0 \\ G(0), & f = 0 \\ 2G(f), & f < 0 \end{cases}$$

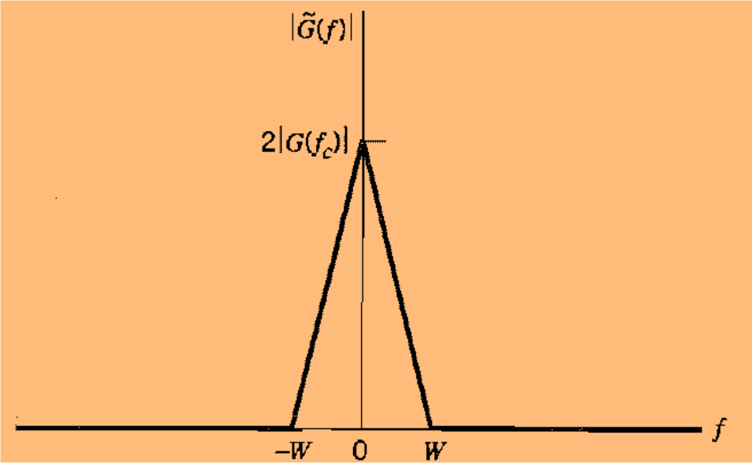
Thus the pre-envelopes $g_+(t)$ and $g_-(t)$ constitute a complementary pair of complex-valued signals. Note also that the sum of $g_+(t)$ and $g_-(t)$ is exactly twice the original signal $g(t)$.

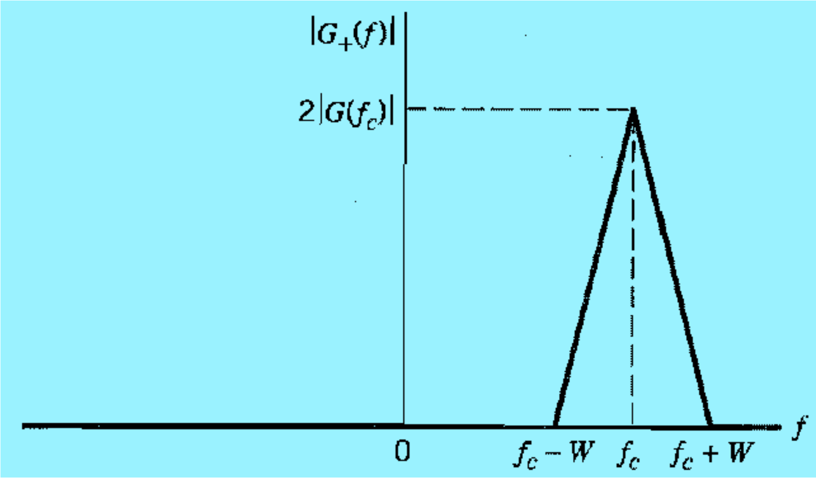
Representations of Signals and Systems

Canonical Representations of BP Signals

$$g_+(t) = \tilde{g}(t)\exp(j2\pi f_c t)$$







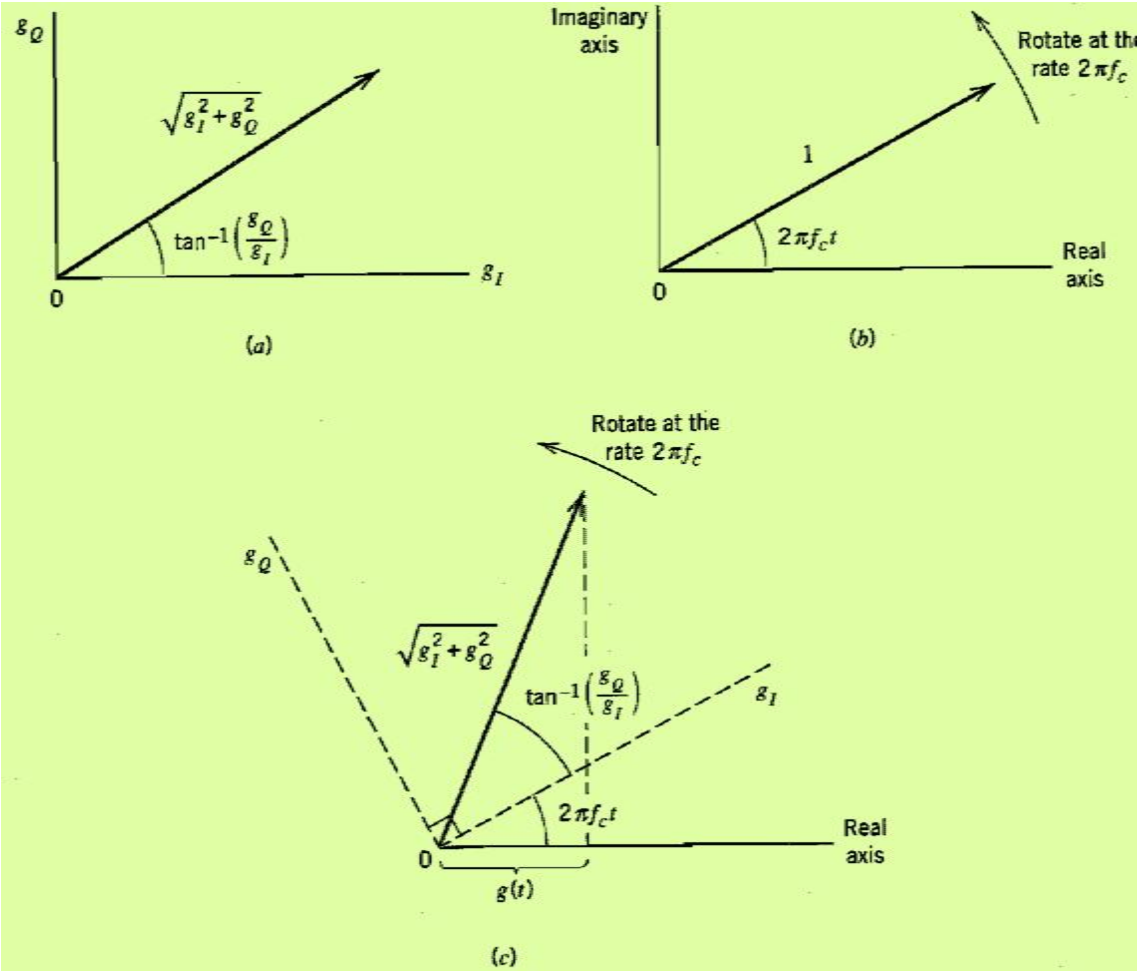
Representations of Signals and Systems

$$g(t) = \text{Re}[\tilde{g}(t)\exp(j2\pi f_c t)]$$

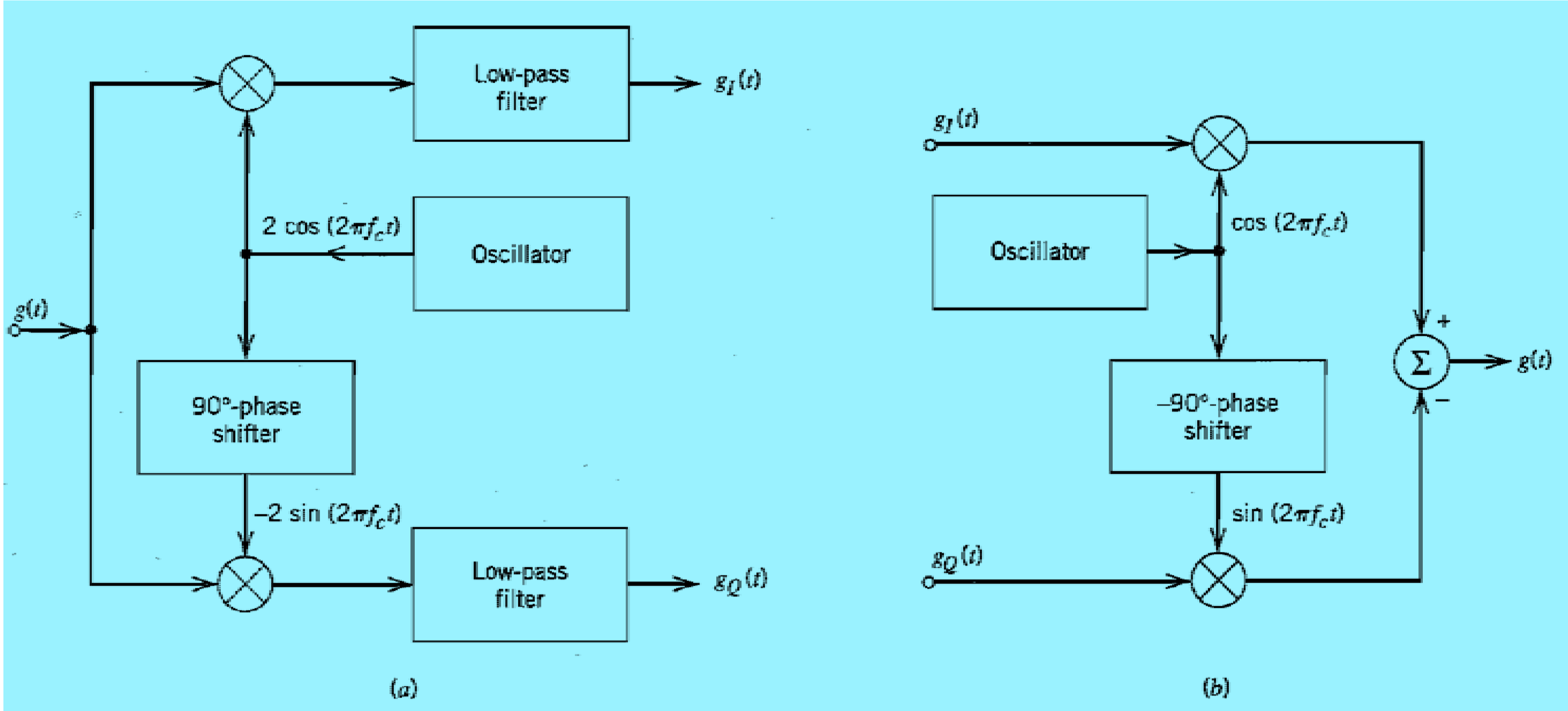
$$\tilde{g}(t) = g_I(t) + jg_Q(t)$$

$$g(t) = g_I(t)\cos(2\pi f_c t) - g_Q(t)\sin(2\pi f_c t)$$

Representations of Signals and Systems



Representations of Signals and Systems



Representations of Signals and Systems

$$\tilde{g}(t) = a(t)\exp[j\phi(t)]$$

$$g(t) = a(t)\cos[2\pi f_c t + \phi(t)]$$

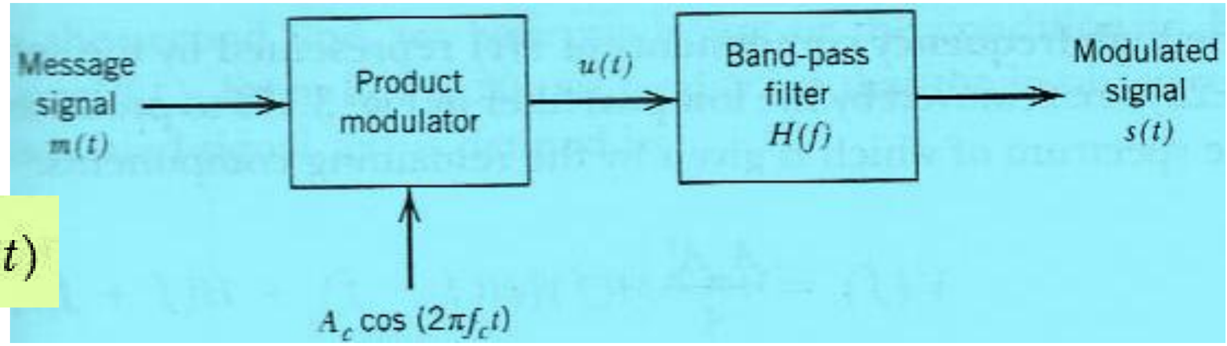
$$a(t) = \sqrt{g_I^2(t) + g_Q^2(t)}$$

$$\phi(t) = \tan^{-1}\left(\frac{g_Q(t)}{g_I(t)}\right)$$

$$g_I(t) = a(t)\cos[\phi(t)]$$

$$g_Q(t) = a(t)\sin[\phi(t)]$$

Filtering of Sidebands

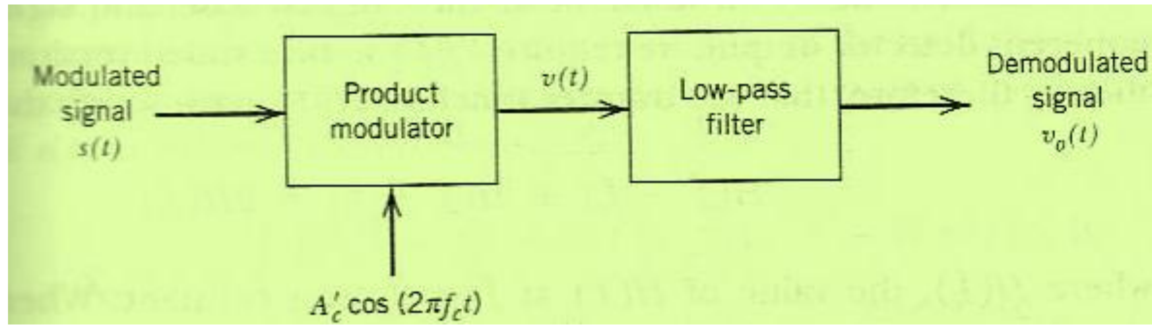


$$u(t) = A_c m(t) \cos(2\pi f_c t)$$

$$\begin{aligned} S(f) &= U(f)H(f) \\ &= \frac{A_c}{2}\left[M(f - f_c) + M(f + f_c)\right]H(f) \end{aligned}$$

Filtering of Sidebands

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



$$V(f) = \frac{A_c'}{2}[S(f - f_c) + S(f + f_c)]$$

$$V(f) = \frac{A_c A_c'}{4} M(f)[H(f - f_c) + H(f + f_c)]$$
$$+ \frac{A_c A_c'}{4}[M(f - 2f_c)H(f - f_c) + M(f + 2f_c)H(f + f_c)]$$

Filtering of Sidebands

$$V_o(f) = \frac{A_c A'_c}{4} M(f)[H(f - f_c) + H(f + f_c)]$$

$$H(f - f_c) + H(f + f_c) = 2H(f_c)$$

$$H(f - f_c) + H(f + f_c) = 1, \qquad -W \le f \le W$$

$$v_o(t) = \frac{A_c A'_c}{2} m(t)$$

Filtering of Sidebands

$$s(t) = s_I(t)\cos(2\pi f_c t) - s_Q(t)\sin(2\pi f_c t)$$

$$S_I(f) = \begin{cases} S(f - f_c) + S(f + f_c), & -W \le f \le W \\ 0, & \text{elsewhere} \end{cases}$$

$$\begin{aligned} S_I(f) &= \frac{1}{2}A_c M(f)[H(f - f_c) + H(f + f_c)] \\ &= \frac{1}{2}A_c M(f), \qquad -W \le f \le W \end{aligned}$$

$$s_I(t) = \frac{1}{2}A_c m(t)$$

Filtering of Sidebands

$$S_Q(f) = \begin{cases} j[S(f - f_c) - S(f + f_c)], & -W \le f \le W \\ 0, & \text{elsewhere} \end{cases}$$

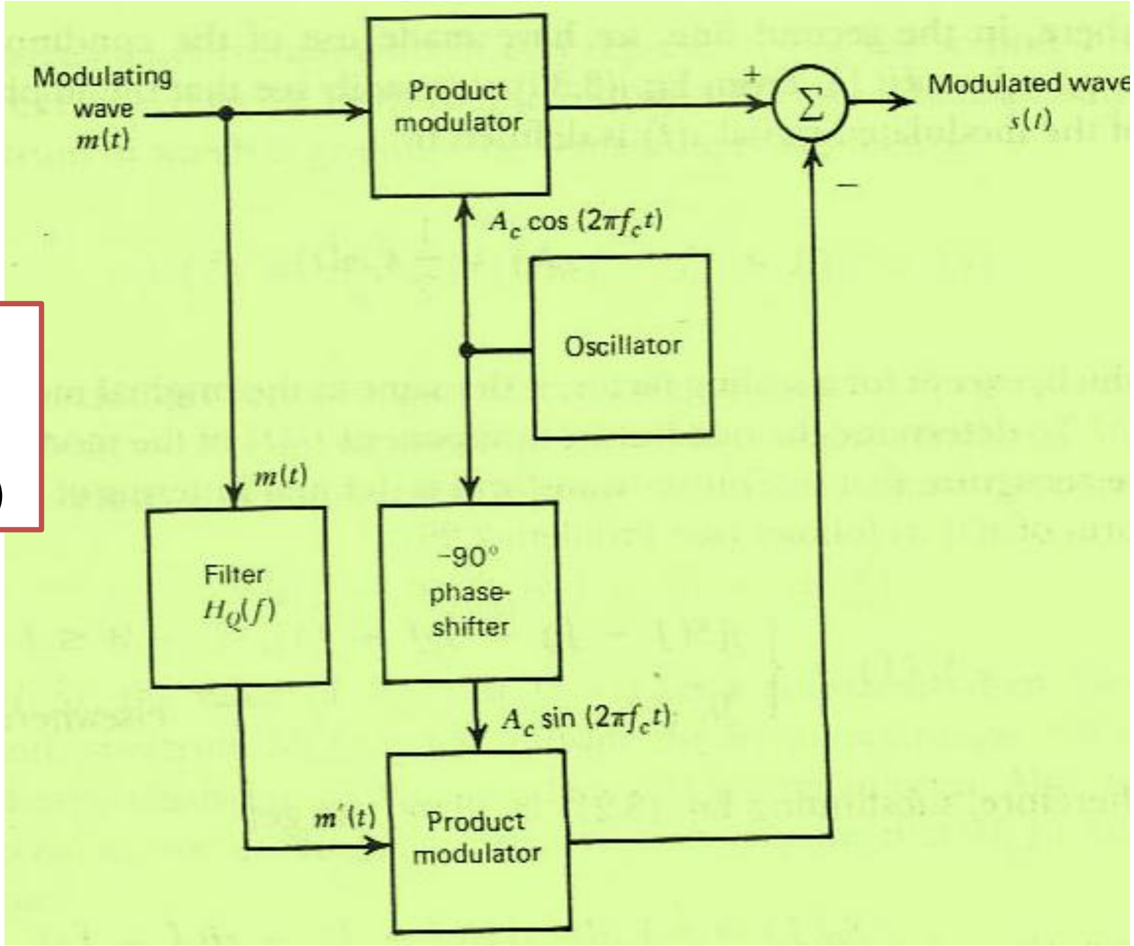
$$S_Q(f) = \frac{j}{2} A_c M(f) [H(f - f_c) - H(f + f_c)]$$

$$H_Q(f) = j[H(f - f_c) - H(f + f_c)], \quad -W \le f \le W$$

$$s_Q(t) = \frac{1}{2} A_c m'(t)$$

$$m(t) = \frac{1}{2} A_c m(t) \cos(2\pi f_c t) - \frac{1}{2} A_c m'(t) \sin(2\pi f_c t)$$

Filtering of Sidebands



1) $S_I(t)$ is completely independent of $H(f)$
2) Spectral modulation attributed to $H(f)$ is confined solely to the $S_Q(t)$

Q & A