APECE-302: Radio & Television Engineering

Applied Physics, Electronics & Communication Engineering

Lecture # 11

University of Dhaka | APECE DU

Course Teacher: Dr. S.M. Riazul Islam

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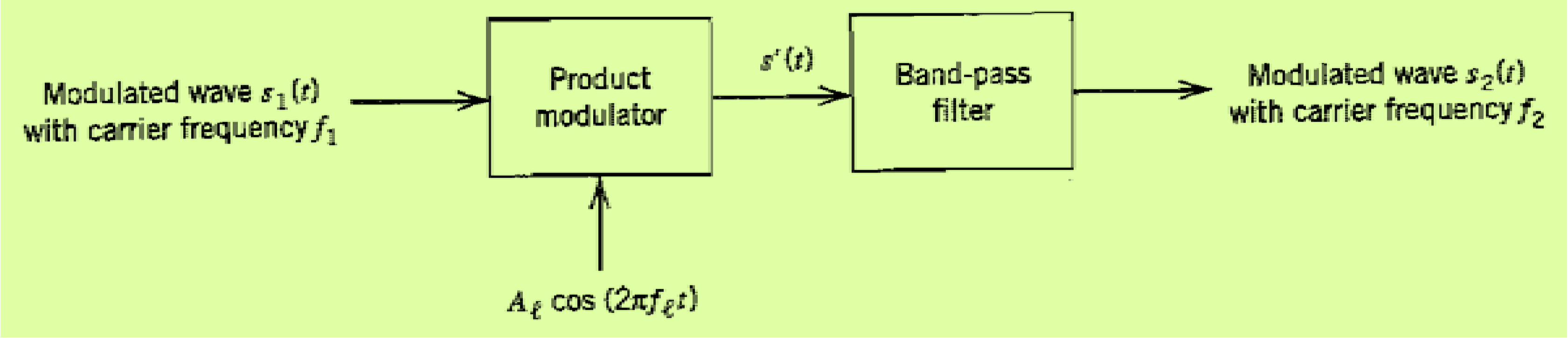
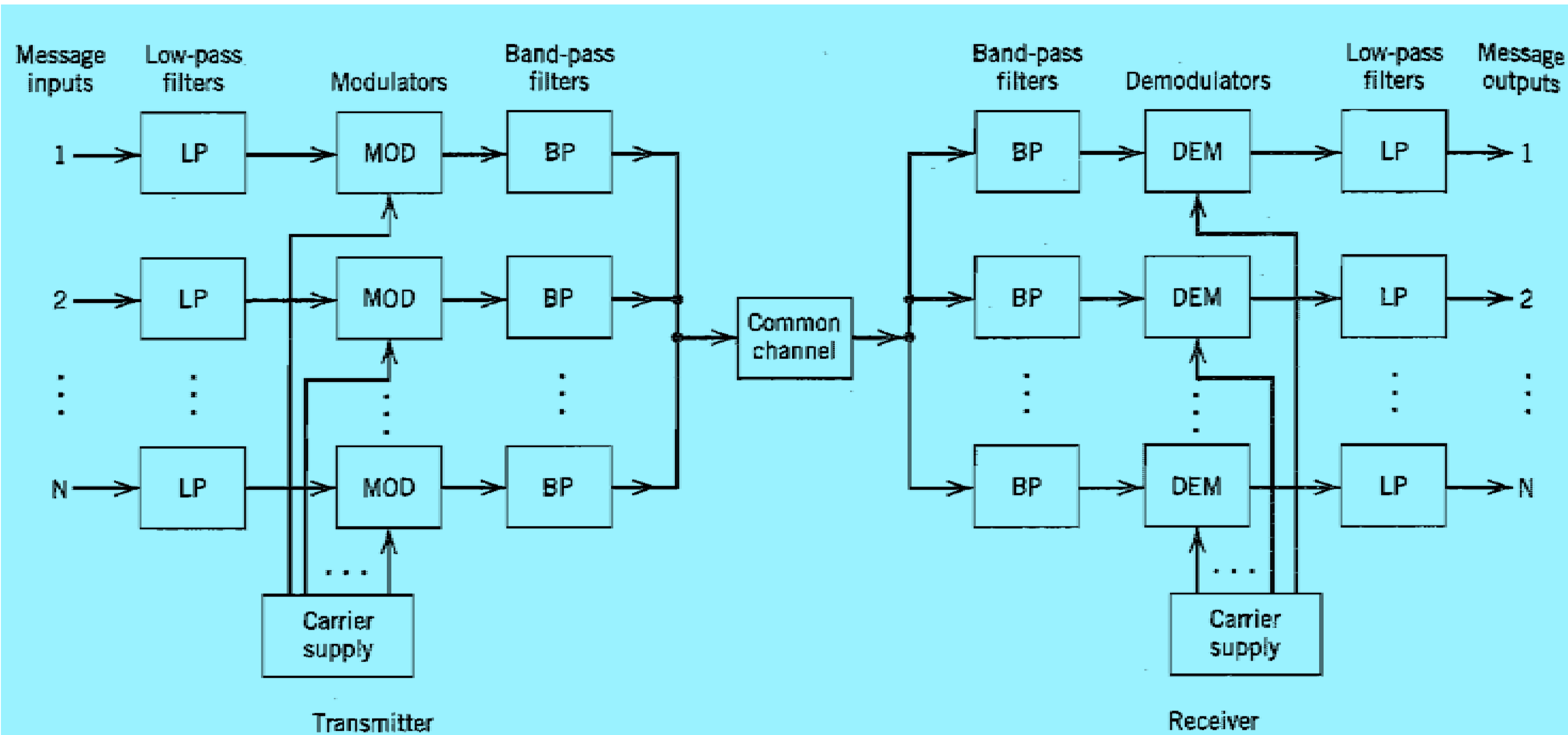
Frequency Translation and FDM



Frequency Translation and FDM



Angle Modulation

$$s(t) = A_c \cos[\theta_i(t)]$$

$$f_{\Delta t}(t) = \frac{\theta_i(t+\Delta t) - \theta_i(t)}{2\pi \, \Delta t}$$

$$f_i(t) = \lim_{\Delta t \to 0} f_{\Delta t}(t) = \lim_{\Delta t \to 0} \left[\frac{\theta_i(t+\Delta t) - \theta_i(t)}{2\pi \, \Delta t} \right] = \frac{1}{2\pi} \frac{d\theta_i(t)}{dt}$$

UM

$$\theta_i(t) = 2\pi f_c t + \phi_c$$

PM

$$\theta_i(t) = 2\pi f_c t + k_p m(t)$$

$$s(t) = A_c \cos[2\pi f_c t + k_p m(t)]$$

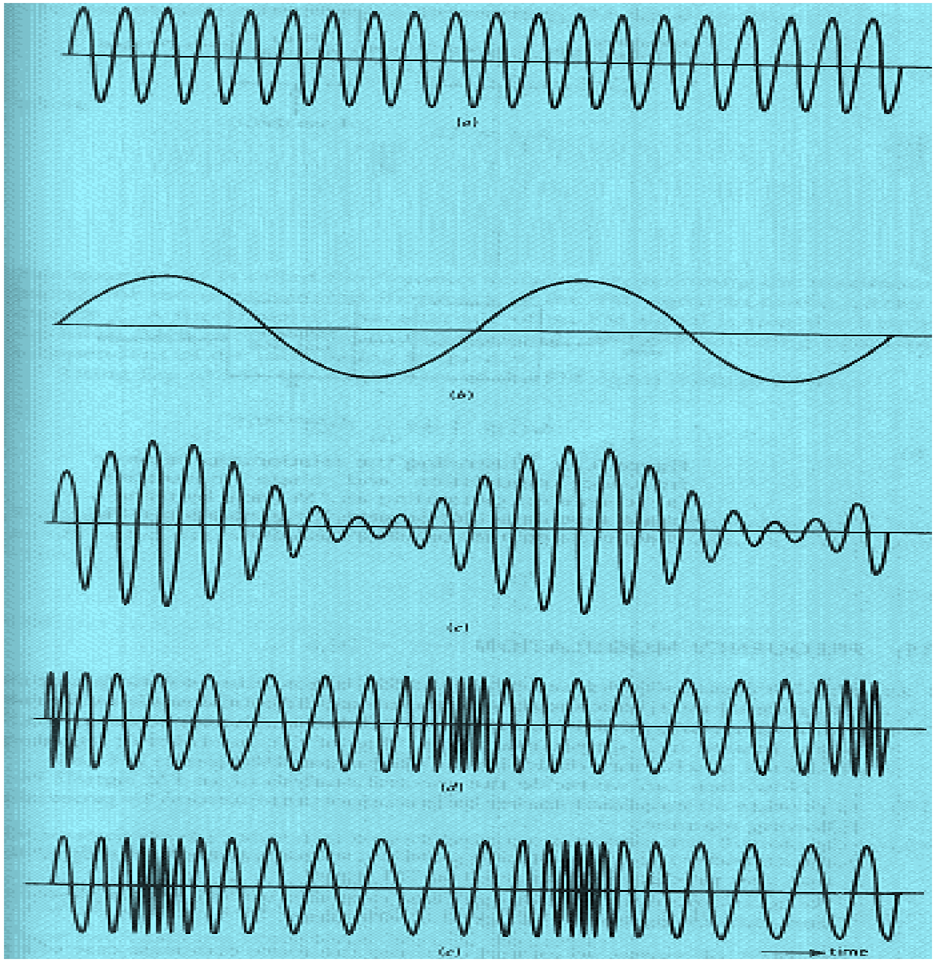
FM

$$f_i(t) = f_c + k_f m(t)$$

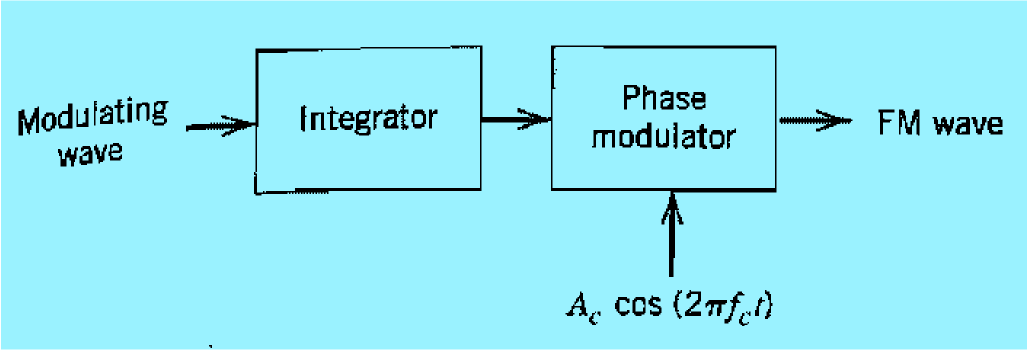
$$\theta_i(t) = 2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\, d\tau$$

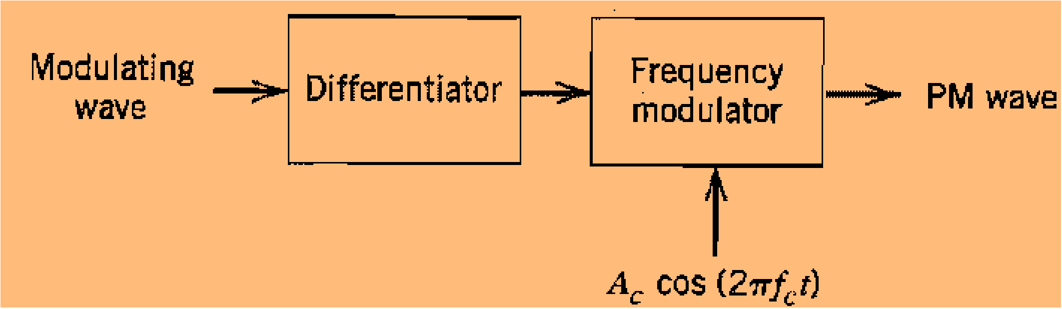
$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\, d\tau\right]$$

Angle Modulation



Angle Modulation





Frequency Modulation

Spectral Analysis: Difficult compared to simple AM

$$m(t) = A_m \cos(2\pi f_m t)$$

The instantaneous frequency of the resulting FM signal equals

$$f_i(t) = f_c + k_f A_m \cos(2\pi f_m t)$$
$$= f_c + \Delta f \cos(2\pi f_m t)$$

where

$$\Delta f = k_f A_m$$

Frequency deviation

Proportional to amplitude of m(t) and independent of f_m

Frequency Modulation

$$\theta_i(t) = 2\pi \int_0^t f_i(\tau)\, d\tau$$

$$= 2\pi f_c t + \frac{\Delta f}{f_m} \sin(2\pi f_m t)$$

Modulation index →

$$\beta = \frac{\Delta f}{f_m}$$

Phase deviation

$$\theta_i(t) = 2\pi f_c t + \beta \sin(2\pi f_m t)$$

$$s(t) = A_c \cos[2\pi f_c t + \beta \sin(2\pi f_m t)]$$

NB or WB

Frequency Modulation

NB Frequency Modulation

$$s(t) = A_c \cos(2\pi f_c t) \cos[\beta \sin(2\pi f_m t)] - A_c \sin(2\pi f_c t) \sin[\beta \sin(2\pi f_m t)]$$

$$\cos[\beta \sin(2\pi f_m t)] \simeq 1$$

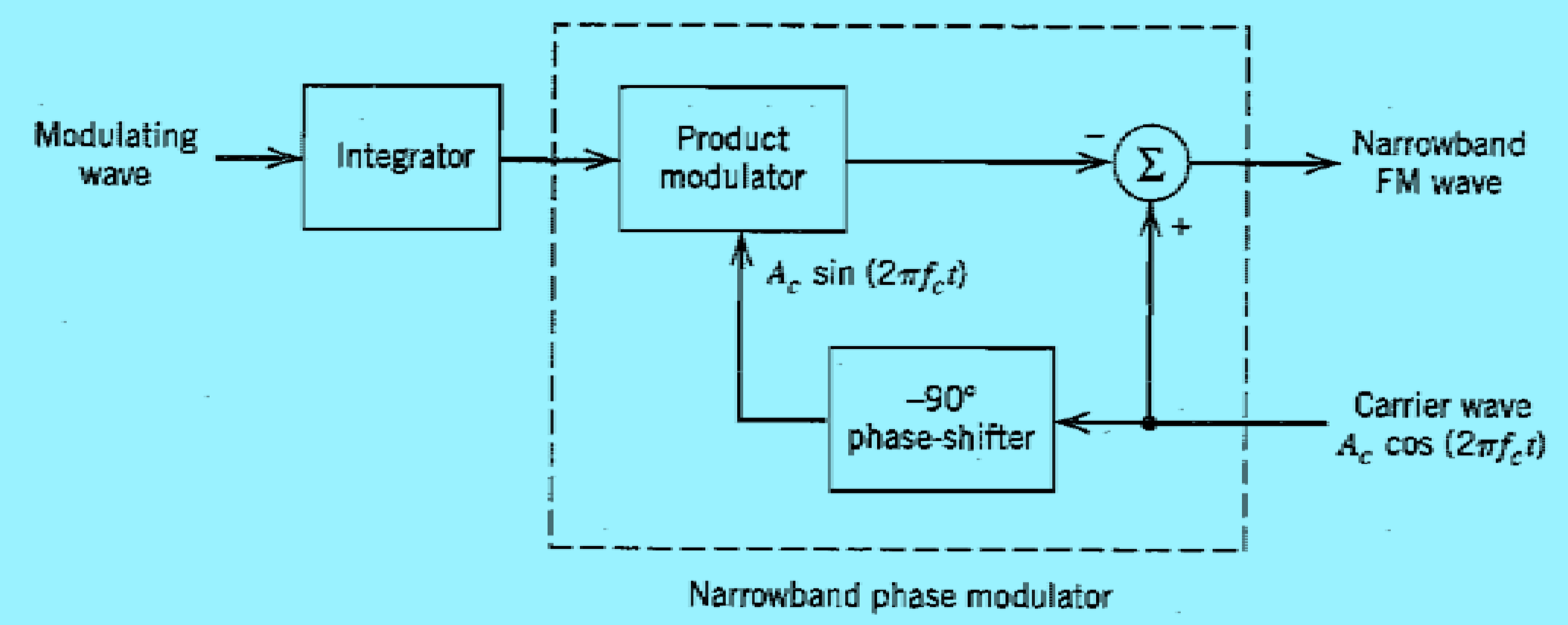
and

$$\sin[\beta \sin(2\pi f_m t)] \simeq \beta \sin(2\pi f_m t)$$

Hence, Equation (2.34) simplifies to

$$s(t) \simeq A_c \cos(2\pi f_c t) - \beta A_c \sin(2\pi f_c t) \sin(2\pi f_m t)$$

Frequency Modulation



1. The envelope contains a *residual* amplitude modulation and, therefore, varies with time.
2. For a sinusoidal modulating wave, the angle $\theta_i(t)$ contains *harmonic distortion* in the form of third- and higher-order harmonics of the modulation frequency f_m.

Modulation index < 0.3 rad

Frequency Modulation

$$s(t) \simeq A_c \cos(2\pi f_c t) + \frac{1}{2}\beta A_c\{\cos[2\pi(f_c + f_m)t] - \cos[2\pi(f_c - f_m)t]\}$$

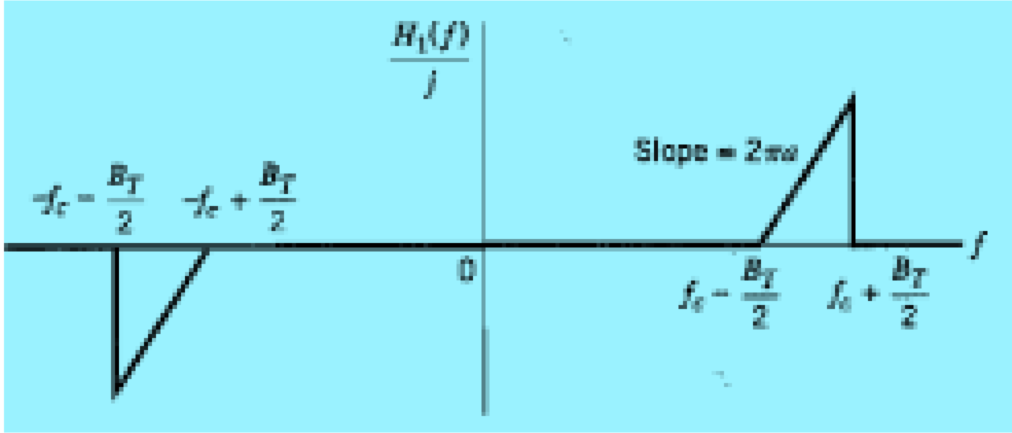
$$s_{AM}(t) = A_c \cos(2\pi f_c t) + \frac{1}{2}\mu A_c\{\cos[2\pi(f_c + f_m)t] + \cos[2\pi(f_c - f_m)t]\}$$

Difference is algebraic sign of LSB is reversed, so the Tx BW is the same as that if AM ($2f_m$)

FM Demodulation

Freq. discriminator: Slope circuit followed by envelope detector

$$H_1(f) = \begin{cases} j2\pi a\left(f - f_c + \frac{B_T}{2}\right), & f_c - \frac{B_T}{2} \le f \le f_c + \frac{B_T}{2} \\ j2\pi a\left(f + f_c - \frac{B_T}{2}\right), & -f_c - \frac{B_T}{2} \le f \le -f_c + \frac{B_T}{2} \\ 0, & \text{elsewhere} \end{cases}$$

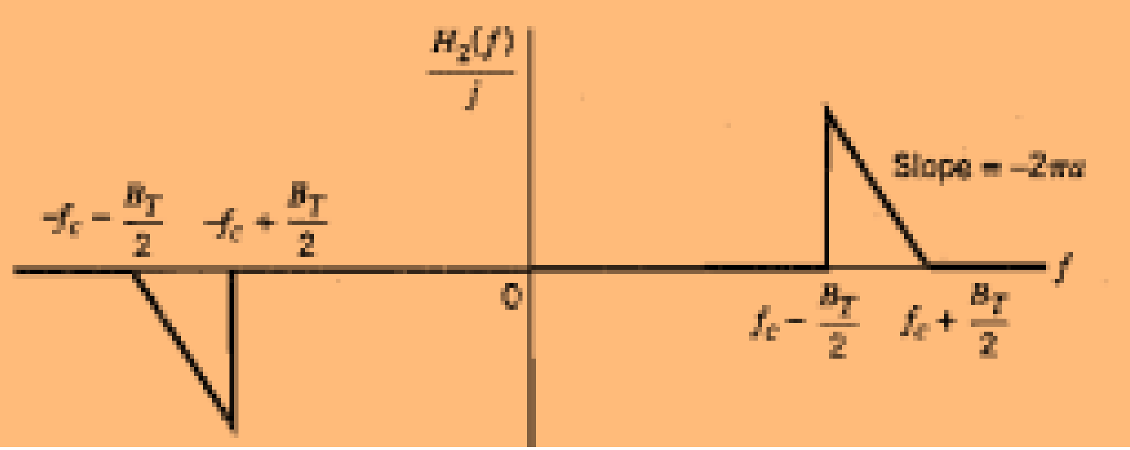


Thus for the problem at hand we get

$$\tilde{H}_1(f - f_c) = 2H_1(f), \qquad f > 0$$

Hence, using Equations (2.60) and (2.61), we get

$$\tilde{H}_1(f) = \begin{cases} j4\pi a\left(f + \frac{B_T}{2}\right), & -\frac{B_T}{2} \le f \le \frac{B_T}{2} \\ 0, & \text{elsewhere} \end{cases}$$



FM Demodulation

$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\, d\tau\right]$$

$$\tilde{s}(t) = A_c \exp\left[j2\pi k_f \int_0^t m(\tau)\, d\tau\right]$$

$$\tilde{S}_1(f) = \frac{1}{2}\tilde{H}_1(f)\tilde{S}(f) = \begin{cases} j2\pi a\left(f + \frac{B_T}{2}\right)\tilde{S}(f), & -\frac{B_T}{2} \le f \le \frac{B_T}{2} \\ 0, & \text{elsewhere} \end{cases}$$

$$\tilde{s}_1(t) = a\left[\frac{d\tilde{s}(t)}{dt} + j\pi B_T \tilde{s}(t)\right]$$

$$\tilde{s}_1(t) = j\pi B_T a A_c\left[1 + \frac{2k_f}{B_T} m(t)\right] \exp\left[j2\pi k_f \int_0^t m(\tau)\, d\tau\right]$$

$$|\tilde{s}_1(t)| = \pi B_T a A_c\left[1 + \frac{2k_f}{B_T} m(t)\right]$$

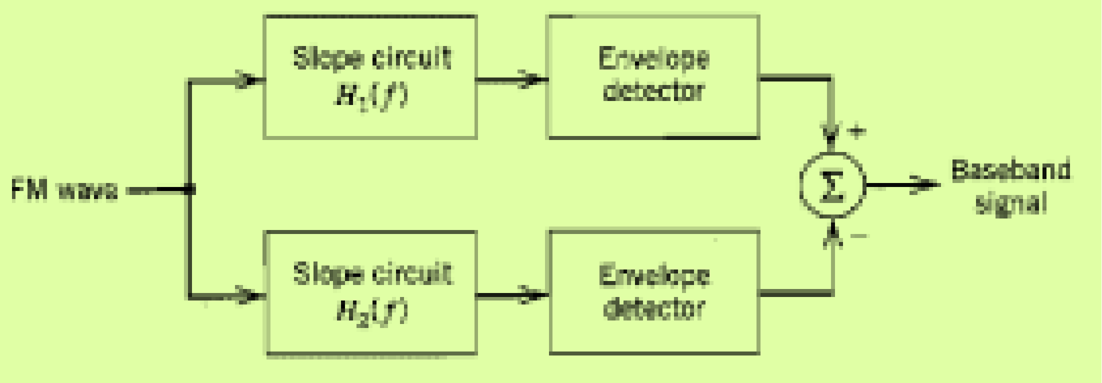
FM demodulation

$$\tilde{H}_2(f) = \tilde{H}_1(-f)$$

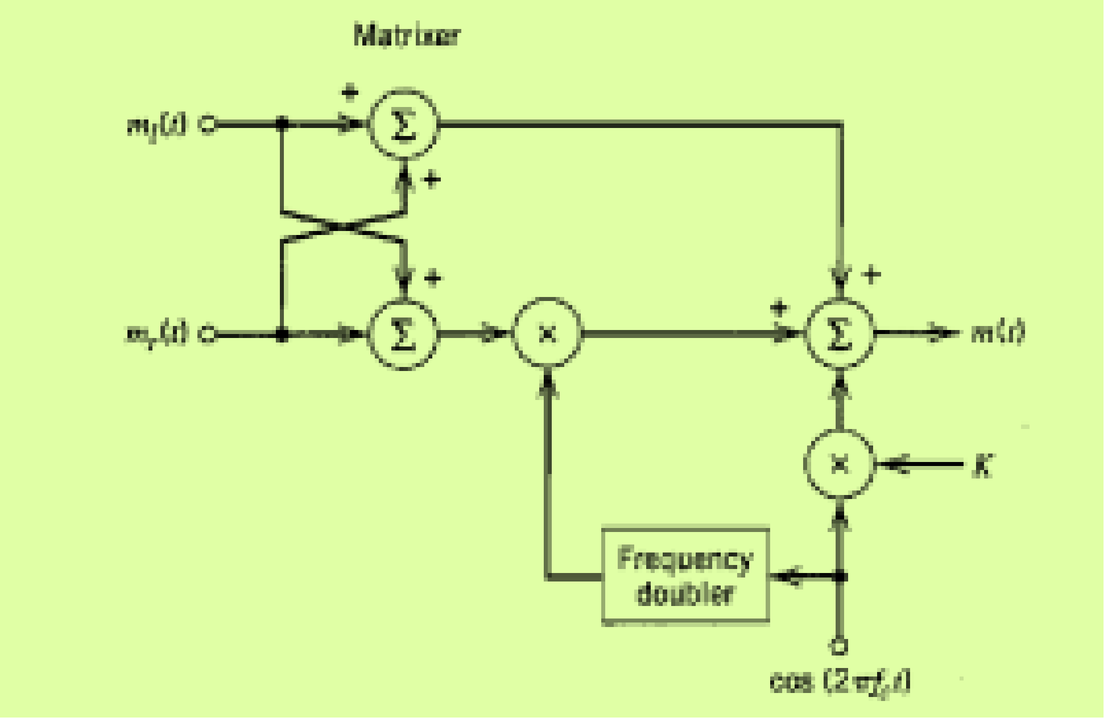
$$|\tilde{s}_2(t)| = \pi B_T a A_c \left[1 - \frac{2k_f}{B_T} m(t)\right]$$

$$s_o(t) = |\tilde{s}_1(t)| - |\tilde{s}_2(t)| = 4\pi k_f a A_c m(t)$$

Balanced Freq. Discriminator

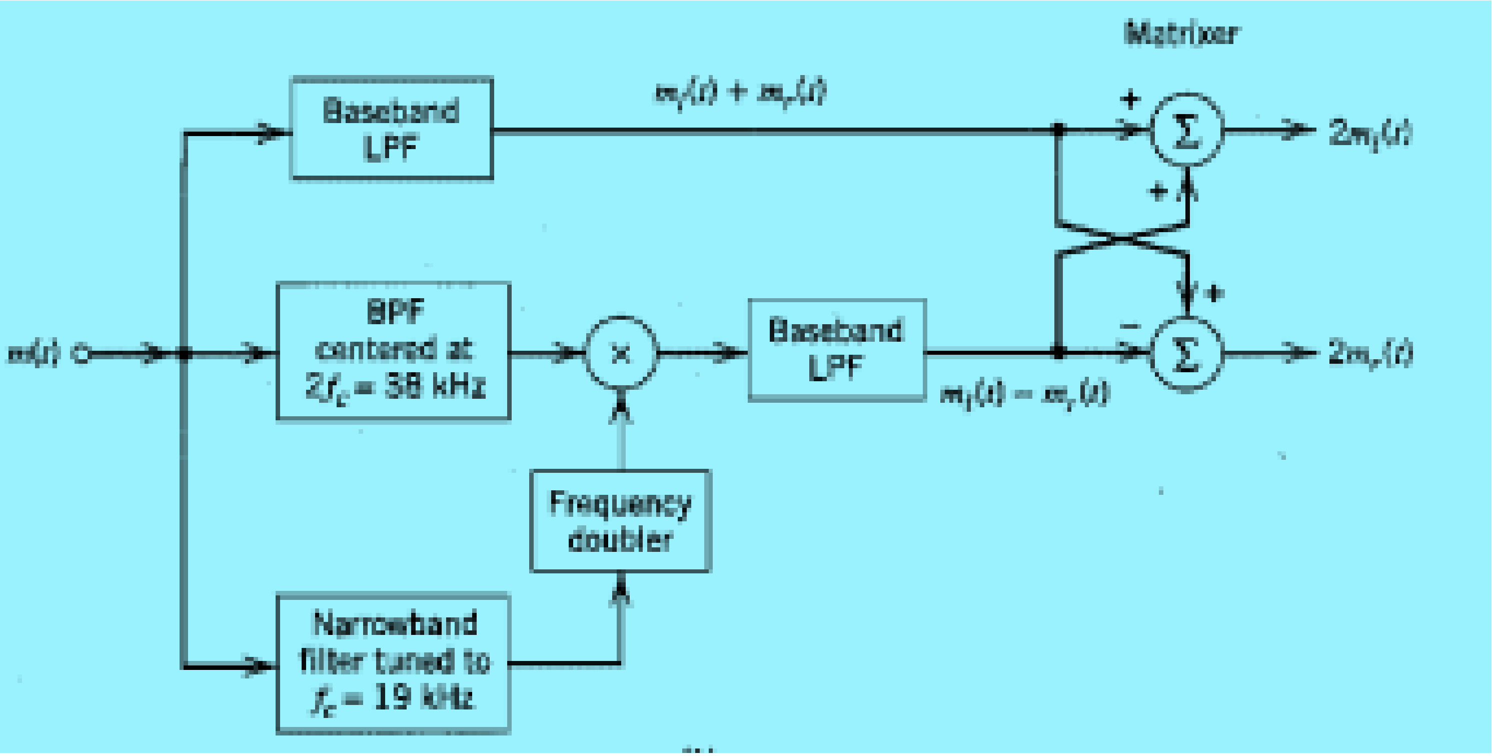


FM Stereo Multiplexing

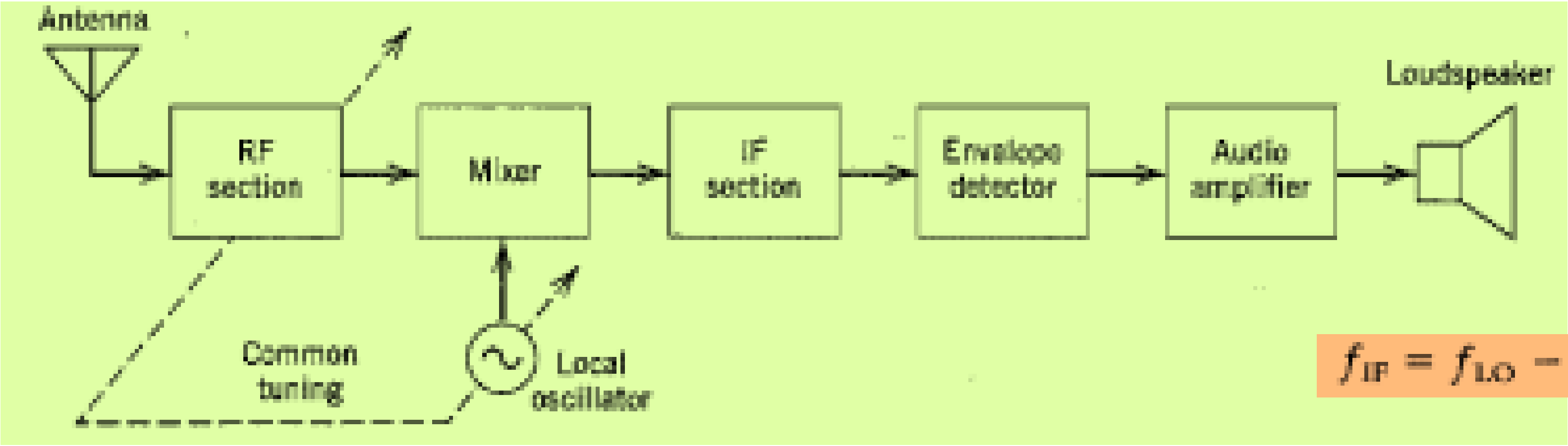


$$m(t) = [m_l(t) + m_r(t)] + [m_l - m_r(t)]\cos(4\pi f_c t) + K\cos(2\pi f_c t)$$

FM Stereo Multiplexing



Superhetrodyne Receiver



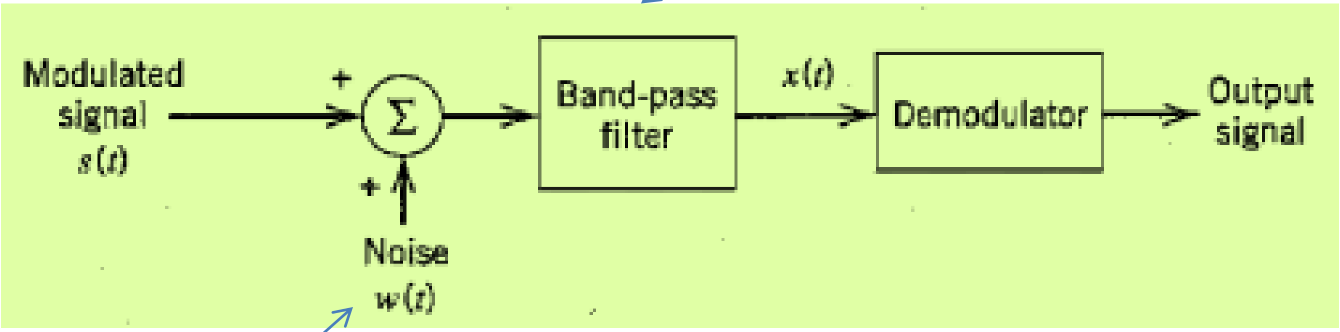
$$f_{IF} = f_{LO} - f_{RF}$$

Disadvantage: Image Frequency

Noise in CW Modulation Systems

Noisy Receiver Model

B_T w. f_c

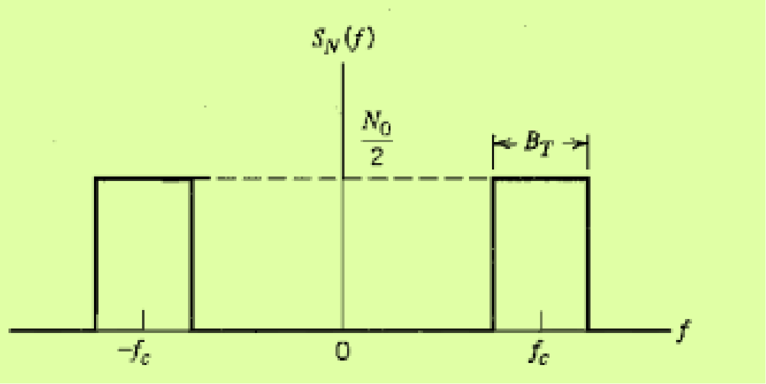


AWGN= Additive White Gaussian Noise

Channel Model followed by Rx Model

Noise in CW Modulation Systems

More about SNR



$f_c >> B_T$, So, filtered noise is NB

$$n(t) = n_I(t)\cos(2\pi f_c t) - n_Q(t)\sin(2\pi f_c t)$$

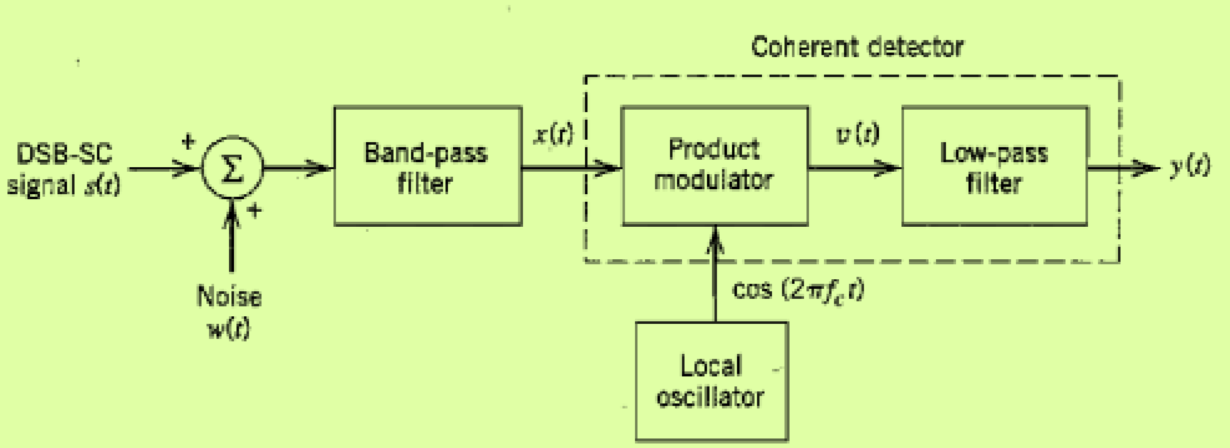
$$\text{Figure of merit} = \frac{(\text{SNR})_O}{(\text{SNR})_C}$$

$$x(t) = s(t) + n(t)$$

Noise power at the deomod I/P, N_0B_T. Therefore, $(\text{SNR})_I$?. $(\text{SNR})_O$
O/P SNR depends on modulation/demod scheme ➔ same signal s(t) and noise w(t) power. ➔ $(\text{SNR})_C$

Noise in CW Modulation Systems

Noise in DSB-SC Rx:



The DSB-SC component of the filtered signal $x(t)$ is expressed as

$$s(t) = CA_c \cos(2\pi f_c t) m(t)$$

Sample function of a ZMSP whose PSD is limitted To a max freq. W

$$P = \int_{-W}^{W} S_M(f)\, df$$

The avg. pow of DSB-SC signal $C^2A^2\_CP/2$

Noise in CW Modulation Systems

Noise pow in the msg BW= WN_O

$$(\text{SNR})_{C,\text{DSB}} = \frac{C^2A_c^2P}{2WN_0}$$

$$\begin{aligned} x(t) &= s(t) + n(t) \\ &= CA_c\cos(2\pi f_c t)m(t) + n_I(t)\cos(2\pi f_c t) - n_Q(t)\sin(2\pi f_c t) \end{aligned}$$

$$\begin{aligned} v(t) &= x(t)\cos(2\pi f_c t) \\ &= \tfrac{1}{2}CA_c m(t) + \tfrac{1}{2}n_I(t) \\ &\quad + \tfrac{1}{2}[CA_c m(t) + n_I(t)]\cos(4\pi f_c t) - \tfrac{1}{2}n_Q(t)\sin(4\pi f_c t) \end{aligned}$$

$$y(t) = \tfrac{1}{2}CA_c m(t) + \tfrac{1}{2}n_I(t)$$

$$\frac{(\text{SNR})_O}{(\text{SNR})_C}\bigg|_{\text{AM}} \simeq \frac{k_a^2P}{1 + k_a^2P}$$

$$\begin{aligned} (\text{SNR})_{O,\ \text{DSB-SC}} &= \frac{C^2A_c^2P/4}{WN_0/2} \\ &= \frac{C^2A_c^2P}{2WN_0} \end{aligned}$$

$(\tfrac{1}{2})^2 2WN_0 = \tfrac{1}{2}WN_0$

$$\frac{(\text{SNR})_O}{(\text{SNR})_C}\bigg|_{\text{DSB-SC}} = 1$$

SSB also

$$\frac{(\text{SNR})_O}{(\text{SNR})_C}\bigg|_{\text{FM}} = \frac{3k_f^2P}{W^2}$$

Q & A