EEE 461 Communication Systems II

Lecture Presentation 16

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☞ *7.3 (Couch) Coherent Detection of Bandpass Binary Signals*

☞ On-Off Keying

The OOK signal is represented by

$$\begin{array}{lll} s_1(t) = A\cos(\omega_c t + \theta_c), & 0 < t \le T & \textit{binary}\ 1 \\ s_2(t) = 0, & 0 < t \le T & \textit{binary}\ 0 \end{array}$$

For coherent detection, a product detector is used.

The bandpass noise is represented by

$$n(t) = x(t)\cos(\omega_c t + \theta_n) - y(t)\sin(\omega_c t + \theta_n)$$

where the psd of $n(t)$ is $\mathcal{P}_n(f) = \frac{N_0}{2}$ and θ_n is uniformly distributed random variable which is independent of θ_c.

The noise power in the received signal is

$$E[x^2(t)] = \sigma_0^2 = E[n^2(t)] = 2(N_0/2)(2B) = 2N_0B$$

The optimum threshold is $V_T = A/2$.

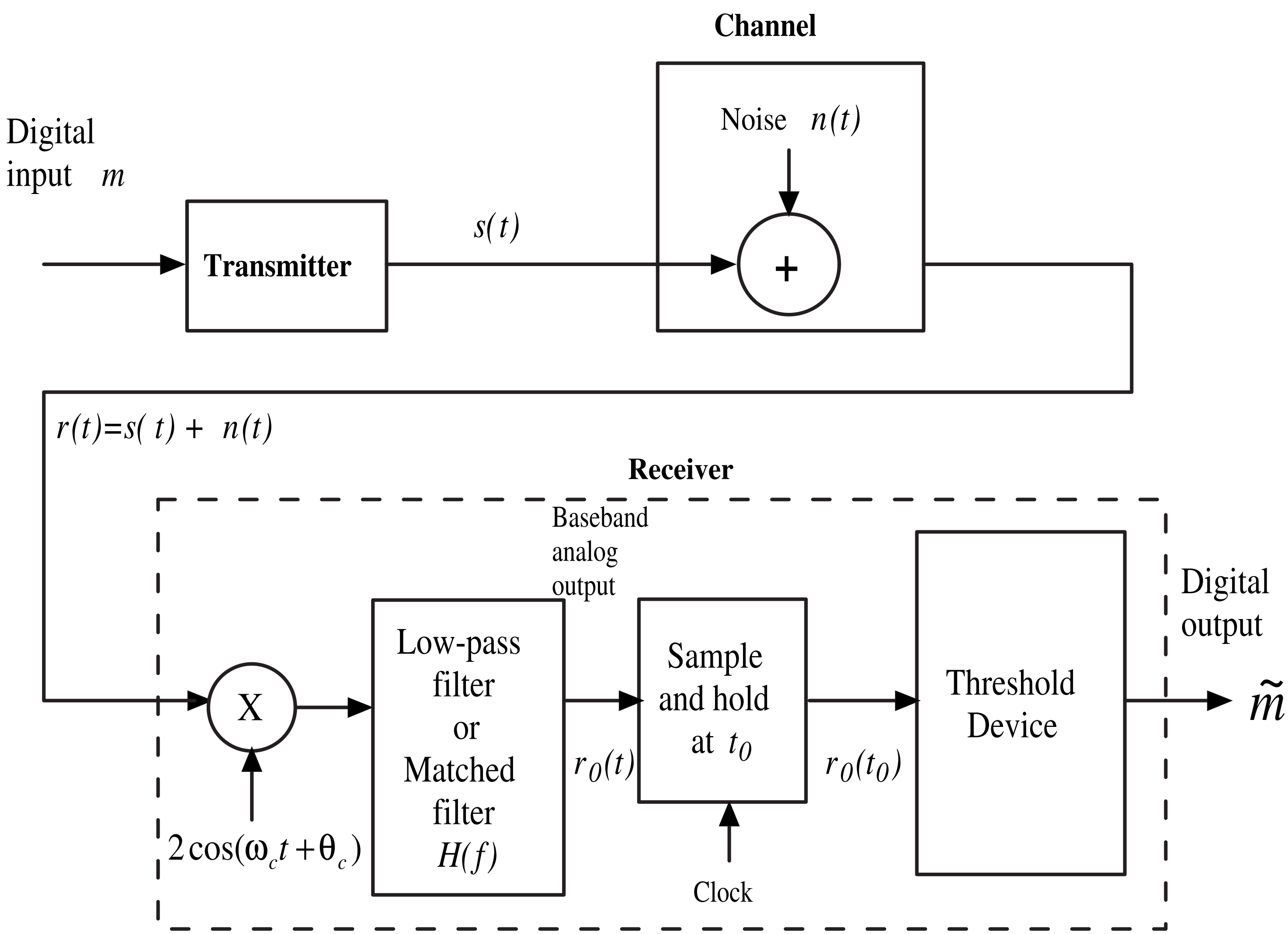


Figure 1: Coherent detection of OOK or BPSK signals.

$$P_e = Q\left(\sqrt{\frac{A^2}{8N_0B}}\right) \quad (narrowband\ filter) \tag{1}$$

where B is the bandwidth of the LPF.

The energy in the difference signal is

$$E_d = \int_0^T [A\cos(\omega_c t + \theta_c) - 0]^2 dt = \frac{A^2T}{2}$$

and the BER becomes

$$P_e = Q\left(\sqrt{\frac{A^2T}{4N_0}}\right) = Q\left(\sqrt{\frac{E_b}{N_0}}\right) \quad (matched\ filter) \tag{2}$$

☞ Binary-Phase-Shift Keying

The BPSK signal is represented by

$$
\begin{array}{ll}
s_1(t) = A\cos(\omega_c t + \theta_c), & 0 < t \le T \;\; binary\ 1 \\
s_2(t) = -A\cos(\omega_c t + \theta_c), & 0 < t \le T \;\; binary\ 0
\end{array}
$$

The noise power in the received signal is

$$E[x^2(t)] = \sigma_0^2 = E[n^2(t)] = 2(N_0/2)(2B) = 2N_0B$$

The optimum threshold is $V_T = 0$.

$$P_e = Q\left(\sqrt{\frac{A^2}{2N_0B}}\right) \quad (narrowband\ filter) \tag{3}$$

where B is the bandwidth of the LPF.

The energy in the difference signal is

$$E_d = \int_0^T [2A\cos(\omega_c t + \theta_c)]^2 dt = 2A^2T$$

and the BER becomes

$$P_e = Q\left(\sqrt{\frac{A^2T}{N_0}}\right) = Q\left(\sqrt{2\left(\frac{E_b}{N_0}\right)}\right) \quad (matched\ filter) \tag{4}$$

☞ Frequency-Shift Keying

The FSK signal is represented by

$$\begin{aligned} s_1(t) &= A\cos(\omega_1 t + \theta_c), \qquad 0 < t \le T \;\; binary\ 1 \\ s_2(t) &= -A\cos(\omega_2 t + \theta_c), \qquad 0 < t \le T \;\; binary\ 0 \end{aligned}$$

where the frequency shift is $2\Delta F = f_1 - f_2$.

The output noise power is

$$E[n_0^2(t)] = \sigma_0^2 = E[x_1^2(t)] + E[x_2^2(t)] = E[n_1^2(t)] + E[n_2^2(t)] = 4N_0B$$

The optimum threshold is $V_T = 0$.

$$P_e = Q\left(\sqrt{\frac{A^2}{4N_0B}}\right) \quad (bandpass\ filters) \tag{5}$$

The energy in the difference signal is

$$E_d = \int_0^T [A\cos(\omega_1 t + \theta_c) - A\cos(\omega_2 t + \theta_c)]^2 dt = A^2 T$$

when $s_1(t)$ is orthogonal to $s_2(t)$ or $(f_1 - f_2) \gg R$.

The BER becomes

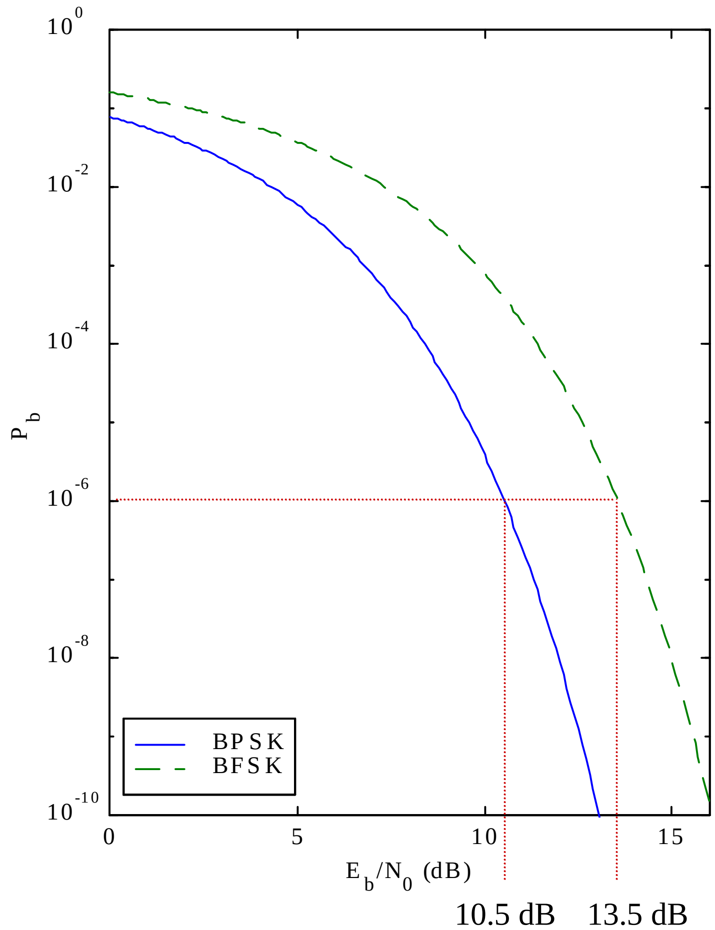
$$P_e = Q\left(\sqrt{\frac{A^2 T}{2N_0}}\right) = Q\left(\sqrt{\left(\frac{E_b}{N_0}\right)}\right) \quad (matched\ filter) \tag{6}$$

Comparing the Coherent Binary Detectors

To achieve $P_b = 10^{-6}$

BPSK requires $E_b/N_0 = 10.5$ dB

BFSK requires $E_b/N_0 = 13.5$ dB



For the same probability of bit error BPSK requires half the power.

BPSK is 3 dB better than coherent BFSK