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FUNDAMENTALS AND APPLICATIONS



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to $Q(x)$ by simpler functions can be found in Reference [7]. One such approximation, valid for $x > 3$, is

$$Q(x) = \frac{1}{x\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right) \quad (2.43)$$

We have optimized (in the sense of minimizing P_R) the threshold level, γ , but have not optimized the filter in block 1 of Figure 2.24; we next consider optimizing this filter by maximizing the argument of $Q(x)$ in Equation (2.41).

2.9.2 The Matched Filter

A matched filter is a linear filter designed to provide the maximum signal-to-noise power ratio at its output for a given transmitted symbol waveform. Consider that a known signal $s(t)$ plus AWGN, $n(t)$, is the input to a linear, time-invariant filter followed by a sampler, as shown in Figure 2.24. At time $t = T$, the receiver output, $z(T)$, consists of a signal component, a_i , and a noise component, n_o . The variance of the output noise (average noise power) is denoted by σ_o^2 , so that the ratio of the instantaneous signal power to average noise power, $(S/N)_T$, at time $t = T$, out of the receiver in block 1, is

$$\left(\frac{S}{N}\right)_T = \frac{a_i^2}{\sigma_o^2} \quad (2.44)$$

We wish to find the filter transfer function, $H_o(f)$, that *maximizes* Equation (2.44). We can express the signal, $a(t)$, at the filter output, in terms of the filter transfer function, $H(f)$ (before optimization), and the Fourier transform of the input signal, as follows:

$$a(t) = \int_{-\infty}^{\infty} H(f)S(f)e^{j2\pi ft} df \quad (2.45)$$

where $S(f)$ is the Fourier transform of the input signal, $s(t)$. If the two-sided power spectral density of the input noise is $N_o/2$ watts/hertz, then using Equations (1.19) and (1.53), we can express the output noise power, σ_o^2 , as

$$\sigma_o^2 = \frac{N_o}{2} \int_{-\infty}^{\infty} |H(f)|^2 df \quad (2.46)$$

We then combine Equations (2.44) to (2.46) to express $(S/N)_T$, as follows:

$$\left(\frac{S}{N}\right)_T = \frac{\left| \int_{-\infty}^{\infty} H(f)S(f)e^{j2\pi fT} df \right|^2}{N_o/2 \int_{-\infty}^{\infty} |H(f)|^2 df} \quad (2.47)$$