Baseband Digital Transmission

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Preview

- There are several baseband digital modulation and demodulation techniques
- Noise : additive white Gaussian noise channel.
  - binary pulse modulation
  - non-binary modulation methods..

Binary Signal Transmission

- In a binary communication system, binary data consisting of a sequence of 0's and I's are
- transmitted by means of two signal waveforms, say,
  - s0(t) and s1 (t).
- Then each bit is mapped into a corresponding signal waveform according to the rule

$$
\begin{aligned}
0 &\rightarrow s_0(t), \qquad 0 \le t \le T_b \\
1 &\rightarrow s_1(t), \qquad 0 \le t \le T_b
\end{aligned}
$$

- bit time interval, $T_b = 1/R$, R data rate (bits per second)

Binary Signal Transmission

- the signal is transmitted through a channel and corrupted the addition of noise, denoted as n(t),
- This is a sample function of a white Gaussian process with power spectrum $N_0/2$ watts/hertz.
- such a channel is called an additive white Gaussian noise (AWGN) channel
- The received signal waveform is expressed as

$$r(t) = s_i(t) + n(t), \qquad i = 0, 1, \qquad 0 \le t \le T_b$$

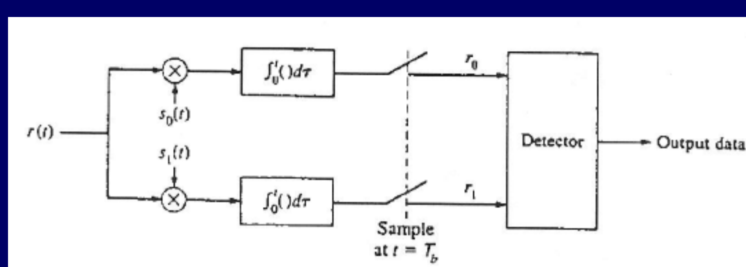
- The receiver must determine whether a 0 or a 1 was transmitted after observing the received signal r(t) in the interval o < r < T_b,.
- The receiver must minimize the probability of error (optimum receiver).

Optimum Receiver

- Optimum Receiver for the AWGN Channel consists of two building blocks.
  - Either signal correlator or matched filter
  - Detector

Signal Correlator

- The signal correlator correlates the received signal r(t) with the two possible transmitted signals so(t) and s1(t), [Figure 1.]



- The signsl correlator computes the two outputs

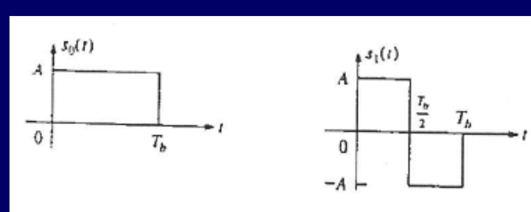
$$r_0(t) = \int_0^t r(\tau)s_0(\tau)\,d\tau$$

$$r_1(t) = \int_0^t r(\tau)s_1(\tau)\,d\tau$$

- in the interval $0 < t < T_b$

Illustrative-Problem 5.1 Determine the correlator outputs at the sampling instants.

- Suppose the signal waveforms s0(t) and s1(t) are the ones shown in Figure



- Let s0(t) be the transmitted signal, Then the received signal is

$$r(t) = s_0(t) + n(t), \qquad 0 \le t \le T_b$$

Determine the correlator outputs at the sampling instants.

- when the signal r(t) is processed by the two signal correlator shown in Figure 1., the outputs r0 and r1 at the sampling instant t=T_b are

$$r_0 = \int_0^{T_b} r(t)s_0(t)\,dt = \int_0^{T_b} s_0^2(t)\,dt + \underbrace{\int_0^{T_b} n(t)s_0(t)\,dt}_{n_0} = \mathcal{E} + n_0$$

$$r_1 = \int_0^{T_b} r(t)s_1(t)\,dt = \underbrace{\int_0^{T_b} s_0(t)s_1(t)\,dt}_{0} + \underbrace{\int_0^{T_b} n(t)s_1(t)\,dt}_{n_1} = n_1$$

where n0 and n1 are the noise components at the output of the signal correlators

- $\mathcal{E}$ = A^2T_b is the energy of the signals s0(t) and s1(t).
- Note that the two signal waveforms are orthogonal,

$$\int_0^{T_b} s_0(t)s_1(t)\,dt = 0$$

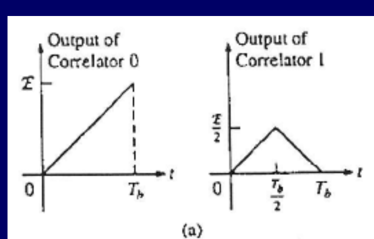
- when s1(t) is transmitted signal, the received signal must be

$$r(t) = s_1(t) + n(t), \qquad 0 \le t \le T_b$$

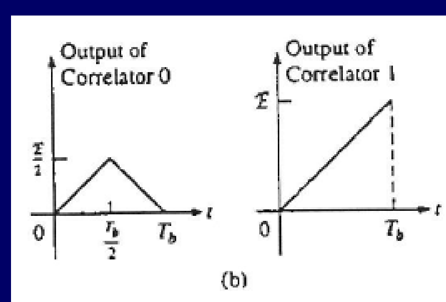
- in this case, the signal correlator output are

$$r_0 = n_0$$
$$r_1 = \mathcal{E} + n_1$$

- Figure 5.3 illustrates the two noise-free correlator output



s0(t) was transmitted.



s1(t) was transmitted.

Matched Filter

- The matched filter provides an alternative to the signal correlator for demodulating the received signal r(t).
- A filter that is matched to the signal waveform s(t), $0 < t < T_b$ has an impulse response

$$h(t) = s(T_b - t), \qquad 0 \le t \le T_b$$

Matched Filter

- y(t), output of the matched filter when the input waveform is s(t) is

$$y(t) = \int_0^t s(\tau)h(t-\tau)\,d\tau$$

$$y(t) = \int_0^t s(\tau)s(T_b - t + \tau)\,d\tau$$

$$y(T_b) = \int_0^{T_b} s^2(t)\,dt = \mathcal{E}$$

- $\mathcal{E}$ is the energy of the signal s(t).
- Therefore, the matched filter output at the sampling instant $t = T_b$ is identical to the output of the signal correlator.

Illustrative-Problem 5.1

- Consider the use of matched filters for the demodulation of the two signal waveforms shown in Figure 5.2
- Determine the outputs.

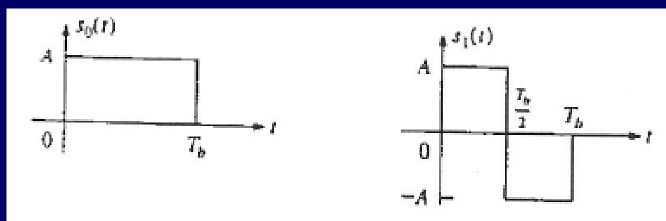
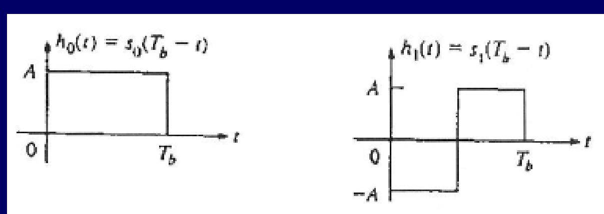


Figure 5.2

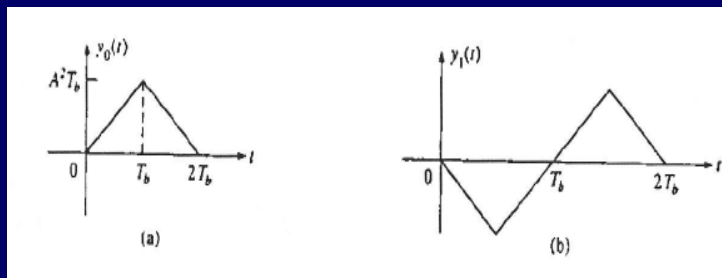
Illustrative-Problem 5.1

- The impulse responses of the two matched filters are

$$h_0(t) = s_0(T_b - t)$$
$$h_1(t) = s_1(T_b - t)$$



Illustrative-Problem 5.1



Signal outputs of matched filters when s0(t) is transmitted.

Detector

- The detector observes the correlator or matched filter outputs r0 and r1 and decides on whether the transmitted signal waveform is either s0(t) or s1(t), which correspond to tie
- transmission of either a 0 or a l, respectiveiy, The aprimumderccbr is defined as thederector
- That minimizes the probability of error