Communications Engineering

Course No: 14:332:421 - (Fall 2005)

Final Exam

Instructions : *Answer all questions.* **Maximum Marks: 100**. *The points for each question are listed below in parentheses. You are allowed a total time of* **3 hours**.

1. Read the following statements and state if they are "true" or "false". State appropriate reasons to justify your answer. (**20**)

   (a) Samples (in time) taken from a white noise process are independent.

   (b) Raised cosine pulse shaping with a roll-off factor $\alpha = 0.2$ requires lesser transmisssion bandwidth than ideal Nyquist pulse shaping.

   (c) An ideal raised cosine pulse shape with $\alpha = 1$ has the property that the pulse width measured at half amplitude is exactly the bit duration.

   (d) A decision-feedback equalizer is an example of a linear equalizer.

   (e) QPSK modulation supports a higher data rate than BPSK modulation, but at a higher bit-error-rate.

   (f) Noncoherent modulation improves error performance over coherent modulation.

   (g) BPSK modulation with spreading improves the bit-error rate performance over BPSK modulation without spreading on an AWGN channel.

   (h) BPSK modulation with spreading improves the bit-error rate performance over BPSK modulation without spreading on a multipath channel

   (i) Pseudo-Noise (PN) sequences of length N can be closely approximated by random binary sequences for large values of N.

   (j) The period of a PN sequence produced by a linear feedback shift register with m flip-flops cannot exceed $2^m - 1$

2. Binary data are transmitted over a radio link using coherent binary phase shift keying (**15**) at a data rate of 10^6 bits per second. The power spectral density of the additive white Gaussian noise at the receiver is 10^{-10} Watts per Hertz.

   (a) Find the average carrier power required to maintain an average probability of error of 10^{-4}.

   Hint: You may assume that erfc(2.65) = 0.0002, where the complimentary error function erfc(x) which is given as

$$\text{erfc(x)} = \frac{2}{\sqrt{\pi}} \int_x^\infty \exp(-z^2) dz$$

(b) Repeat part (a) assuming that the BPSK signal is spread over a bandwidth of 2 MHz before transmitting.

(c) Repeat part (a) assuming non-coherent orthogonal frequency shift keying

3. Consider a binary communication system where a bit 1 is transmitted by sending a signal $s_1(t)$ and a bit 0 is transmitted by sending a signal $s_2(t)$. A modified correlator is designed as shown in Figure 1 to decide if a 0 or 1 was transmitted. The signals $s_1(t)$ and $s_2(t)$ are of of unit energy and their correlation coefficient is given as **(20)**

$$\rho = \int_0^T s_1(t)s_2(t)dt$$

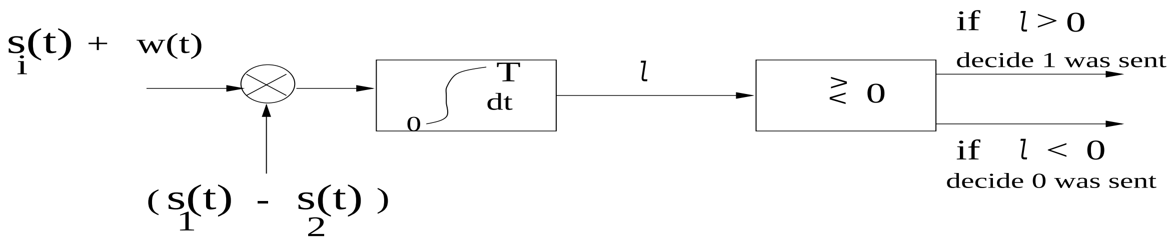

Figure 1: Modified Correlator

(a) Assuming equiprobable hypotheses and transmission over an AWGN channel ($w(t)$ is a Gaussian random process of zero mean and power spectral density 1/2), find the probability of error of the above receiver as a function of the correlation coefficient ρ.

Your answer should be in terms of the complimentary error function erfc(x) which is given as

$$\text{erfc(x)} = \frac{2}{\sqrt{\pi}} \int_x^\infty \exp(-z^2)dz$$

(b) Using the result in part (a), determine if orthogonal signaling ($s_1(t)$ and $s_2(t)$ are orthogonal to each other) is better than antipodal signaling ($s_1(t) = -s_2(t)$)

4. It is desired to transmit an analog signal with a maximum frequency of 5 KHz over a channel of bandwidth 2 MHz using direct-sequence spread spectrum modulation with spreading codes from an alphabet $\{+1, -1\}$. Assuming ideal sampling followed by using 2-bit quantization, answer the following questions: **(15)**

(a) What is the processing gain of the system ?

(b) What is the chip duration of the direct-sequence code ?

(c) How many synchronous users can be supported in the system if it is desired to obtain a bit-error performance similar to that in a single user system ? Justify your answer.

5. In a direct-sequence CDMA system with BPSK modulation, the feedback shift register used to generate the PN sequence has length $m = 7$. In the presence of an externally generated jamming signal, the system is required to have an average probability of bit error that does not exceed 10^{-4}. Calculate the following parameters: **(15)**

   (a) Processing gain

   (b) Antijam margin
   Hint: Use the *Hint* from question 2 (a)

6. Consider a fiber-optic communication system where a bit 1 is represented by transmitting a laser of intensity λ_1 and a bit 0 is represented by sending a laser of intensity λ_0 (usually $\lambda_1 > \lambda_0$). The optical signals that are transmitted over an optical fiber are detected using a photo-detector receiver as shown in Figure 2 to decide if a 0 or 1 was transmitted. **(15)**

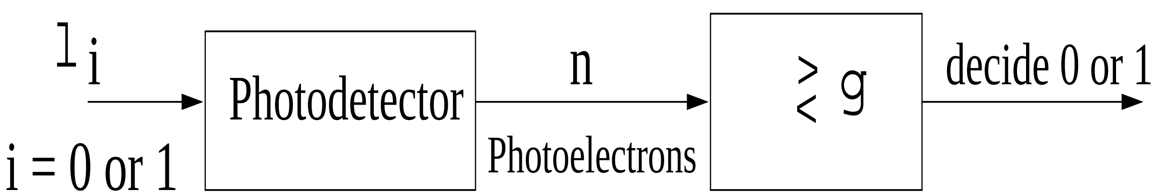

Figure 2: Receiver for an Optical Communication System

The transmitted laser excites the photodetector device to produce photoelectrons n at the output of the detector. The photoelectrons generated at the output are Poisson random variables distributed according to the intensity of the laser (either λ_1 or λ_0) as follows :

$$P(n = r) = \frac{\exp(-\lambda_i)\lambda_i^r}{r!}, \ i = 0, 1$$

The number of photoelectrons n at the output of the photodetector is compared to a threshold γ to to decide if a 1 or a 0 was transmitted. Determine the optimum threshold γ that minimizes the probability of making an error assuming equiprobable bit transmission.

Good luck and Happy Holidays!