# Digital Communications
# Final Exam
May 10, 2004



I pledge that I have neither given nor received any assistance on this exam.

____________________________________________

(signed)

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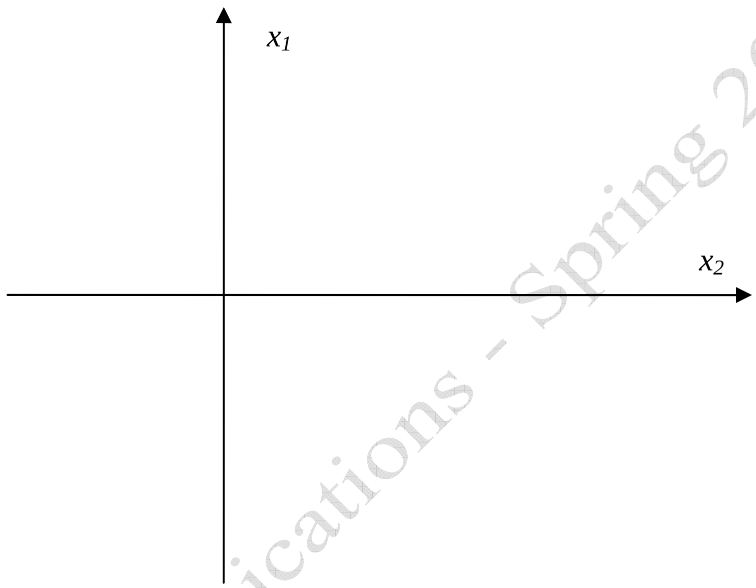
Name (print) Student Number

1. (20 points) Short answer. Please answer the following questions.

a. ( 5 points) Vector quantization: Consecutive samples of a memoryless source are to be quantized with a vector (of length 2) quanitzer with 1.5 bits per sample. The two-dimensional pdf of the source outputs is

$$p_{X_1X_2}(x_1, x_2) = e^{-(x_1+x_2)}$$

On the graph below, plot the *approximate* location of the quantization vectors to minimize MSE.




b. ( 5 points) Ricean fading: What type of fading is more severe: Ricean fading with $K = 0$, Ricean fading with $K$ = 10, or Rayleigh fading?

c. ( 5 points) Capacity: You see a presentation at a conference where a new coding/modulation scheme achieves an error rate of $10^{-8}$ at a spectral efficiency of 2bits/s/Hz with an SNR of 3dB. Does this seem reasonable? Why or why not?

d. (5 points) MSK: Which is the most energy efficient MSK, QPSK, or BFSK?

2. (20 points) Block coding: As a communications engineer for SpaceCom, Inc. you are designing a modulation and coding scheme for a satellite communications link. The system requires a 200kbps data rate in a 200kHz channel. The RF engineers inform you that based on filtering limitations, the system will use a root raised cosine pulse shaping scheme (i.e., to achieve an overall pulse shape which is raised cosine) with roll-off factor $\alpha = 0.5$ (r=0.5). The carrier frequency is 1.8GHz. A matched filter receiver is to be used. The following modulation and coding schemes are to be considered: QPSK, 8-PSK, (n=63, k=36, t=5) BCH code, (n=63, k=24, t=7) BCH code, (n=63, k=16, t=11) BCH code and no coding. The received power is -42dBm and the noise power spectral density is -105dBm/Hz. The desired bit error rate is $10^{-5}$. What modulation/coding scheme gives the best performance while meeting the specifications?

3. (25 points) Rayleigh Fading: A BPSK system is being deployed in a mobile environment. It is determined that the mobile has sufficient power to ensure that an $E_b/N_o$ value of 20dB is achieved over 90% of the coverage area.

(a - 5 points) What is the performance of the system in the 90% coverage area (i.e., at $E_b/N_o$ = 20dB) assuming perfect channel estimation?

(b – 10 points) It is determined that a BER of $10^{-4}$ is required for this application. A clever VT RF engineer has found a way to install additional antennas in the mobile unit to provide diversity against fading. How many antennas would be required to achieve the desired performance assuming maximal ratio combining?

(c – 10 points) A Turbo coding chip is found that will provide a coding gain of 7dB at a bit error rate of $10^{-4}$. The cost per handset is determined to be \$10 while the cost of RF electronics is \$5 per antenna. Is this a superior solution to (b) ?

(4) (35 points) Convolutional Codes: A rate 1/3 K=3 convolutional code (g = 577) is to be used in a BPSK modulated system.

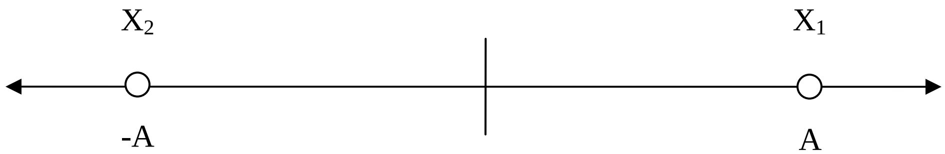
(a – 5 points) Draw the encoder.

(b – 5 points) Draw the state diagram.

(c – 5 points) Draw the trellis for 3 time intervals.

(d – 10 points) The sequence 2 1 1 0.25 2 2 -0.25 1 -0.25 is seen at the receiver. Decode the sequence using hard decision decoding (simply choose the lowest state metric for trellis termination) (e – 10 points) Repeat (d) for soft decision decoding.

5. (25 points) MAP and Maximum likihood detection: You are using the modulation scheme shown below in a non-AWGN channel. The channel noise is additive and uniformly distributed on [-*B*, *B*]. Assume that *B* > *A*.




(a – 10 points) Determine the MAP decision rule for this modulation scheme and noise.

(b – 5 points) Determine the ML decision rule.

(c – 10 points) Determine the probability of error for an SNR ($A^2/\sigma_n^2$) = 2 if the *apriori probabilities* are equal. (Note that $\sigma_n^2 = \frac{(b-a)^2}{12}$ for a uniform distribution.) Is this better or worse than Gaussian Noise?

# Appendix:  Q-function Plot