GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING
Final Examination - Spring 2010
EE 4601: Communication Systems

Aids Allowed: Course textbook
one $8\frac{1}{2} \times 11$ two-side crib sheet
Attempt all questions
All questions are of equal value

DATE: Thursday May 6, 2010.

TIME: 8:00am - 10:50am
INSTRUCTOR: Professor G.L. Stüber

1) Random Processes: A random process is defined as

$$Y(t) = X(t) + X(t - 2T)$$

where $X(t)$ is a wide-sense stationary random process with autocorrelation function $\phi_{XX}(\tau)$ and power spectral density $\Phi_{XX}(f)$.

a) 4 marks: Find the autocorrelation function $\phi_{YY}(\tau)$.

b) 3 marks: Find the power spectral density $\Phi_{YY}(f)$, and simplify your expression to a single term.

c) 3 marks: Suppose that $X(t) = A\cos(2\pi f_c t + \Phi)$, where A is a constant and Φ is a uniformly distributed random phase on the interval $[-\pi, \pi)$. For what values of f_c will the power spectral density $\Phi_{YY}(f)$ goto zero?

2) Intersymbol Interference: Suppose that the discrete impulse response of a channel is

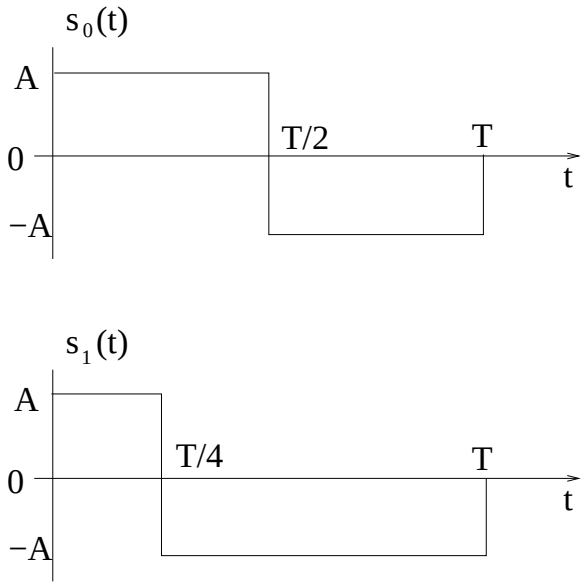
$$\mathbf{p} = \{0.1, 0.4, 3.1, -0.7, 0.2, 0, \ldots, 0, \ldots\}$$

a)6 marks: Design a 3-tap zero forcing equalizer.

b)2 marks: Compute the overall pulse $\mathbf{q}$.

c)2 marks: Compute distortion before D_p and after D equalization.

3) Signal Space: Consider the pair of waveforms $s_0(t)$ and $s_1(t)$ shown in the figure below



a) 4 marks: Using the Gram-Schmidt orthonormalization procedure, find a complete set of orthonormal basis functions.

b) 2 marks: Find the signal vectors $\mathbf{s}_0$ and $\mathbf{s}_1$ and plot them.

c) 3 marks: Find the Euclidean distance $d_{12} = \|\mathbf{s}_0 - \mathbf{s}_1\|$.

c) 3 marks: If the pair of waveforms is used for binary modulation on an AWGN channel, write down an expression for the probability of bit error in terms of the bit energy-to-noise ratio E_b/N_o.

4) Signal Constellations: Consider the set of signals $\{s_i(t)\}_{i=1}^{M}$, where the $s_i(t)$ have duration T. The signals have vector representations

$$\mathbf{s}_i = [s_{i1},\ s_{i2},\ \ldots,\ s_{iN}], \quad i = 1,\ 2,\ \ldots, M$$

where

$$s_{ij} = \begin{cases} +d \\ \text{or} \\ -d \end{cases} \quad \text{for all } i, j$$

a) 4 marks: Sketch this signal set in two ($N = 2$) and three ($N = 3$) dimensions.

b) 3 marks: How many distinct signal vectors are there in N dimensions?

c) 3 marks: Can you specify a set of time-domain waveforms that correspond to these signal vectors?

5) Coding: A rate 1/3 convolutional code has the generator sequences

$$\begin{aligned} \mathbf{g}^{(1)} &= (1,1,0) \\ \mathbf{g}^{(1)} &= (1,1,1) \\ \mathbf{g}^{(1)} &= (1,0,1) \end{aligned}$$

a) 2 marks: Draw the shift register convolutional encoder.

b) 3 marks: Draw the state transition diagram

b) 3 marks: Draw the modified state diagram

b) 2 marks: What is the minimum distance d_{free} (or d_{min}) of the code?