THE UNIVERSITY OF TEXAS AT AUSTIN
Dept. of Electrical and Computer Engineering

EE345S Real-Time Digital Signal Processing Laboratory
Problem Set #4: Modulation, Carrier Recovery, Timing Recovery, and Equalization

Date assigned: April 13, 2006
Date due: April 20, 2006

Homework is due at the beginning of class. Late homework will not be accepted.

Reading: Johnson & Sethares, Sections 10.1–10.4, Ch. 11, Sections 12.1–12.4, Section 13.1–13.2, Appendix D

You may use any computer program to help you solve these problems, check answers, etc.

Homework is due at 5:00 PM sharp on Tuesday, December 6th, in class. Late homework will not be accepted.

As stated on the course descriptor, "Discussion of homework questions is encouraged. Please be sure to submit your own independent homework solution."

TAs may be reached during the lab hours for the course to answer questions about homework problems if they are not busy with lab duties. **Note the change in Prof. Evans' office hours. Prof. Evans will be out of town Nov. 28–30 at an IEEE conference.**

Problem 4.1 PAM vs. QAM.

For this problem, please make the following assumptions:

- The noise is additive white Gaussian noise with variance σ^2 in both the in-phase and quadrature components.
- 0's and 1's appear with equal probability.
- The symbol period T is equal to 1.
- The shortest distance between two constellation points is $2d$.

(a) Derive the symbol error probability formula for 16-QAM, also known as Quadrature Phase Shift Keying (QPSK).

(b) Calculate the average power of the 16-QAM signal.

(c) Write the probability of symbol error for 16-PAM and 16-QAM as functions of the signal-to-noise ratio (SNR). Superimposed on the same plot, plot the probability of symbol error for 16-PAM and 16-QAM as a function of SNR. For the horizontal axis, let the SNR take on values from 0 dB to 20 dB. Comment on the difference in the symbol error rate vs. SNR curves.

Problem 4.2 Carrier Phase Recovery via Phase Locked Loop
Johnson & Sethares, problem 10.14. See problem 10.12 for hints.

Problem 4.3 Carrier Phase Recovery via the Costas Loop
Johnson & Sethares, problem 10.17.

Problem 4.4 Timing Recovery Using Output Power Maximization
Johnson & Sethares, problem 12.9.

Problem 4.5 Linear Least-Squares Equalization
Johnson & Sethares, problem 13.1.