ECE 1473 - Digital Communication Systems
Homework Set 8

Due: Thursday, March 28, 2019

1. Schedule a meeting with the instructor. The agenda for the meeting will be:
   - Results of simulations for Homework Assignment 6.
   - Results of simulations for Homework Assignment 7.
   - Progress on simulations for Homework Assignment 8.
   - Progress on completion of the simulation project.

2. In this problem, you will simulate a BPSK system, including many of the elements that are required for the Design Project. The requirements are as follows:
   - Expand the simulation from Homework Assignment 6, Problem 1 to include BPSK modulation and demodulation followed by optimal detection.
   - It must be very easy to change certain parameters, such as the number of bits, the bit rate, the number of samples per bit, the carrier frequency, and the amplitudes of various pulses and signals.
   - Your simulation must also allow for the simulation of the PSD of the modulated signal, and comparison with the theoretical PSD for BPSK, by modifying the simulation from Homework Assignment 7, Problem 3.
   - Your simulation must compute the bit error rate for different values of E_b/N_0, and must compare this performance curve to the theoretical performance for BPSK with optimal detection.
   - Choose reasonable values for the bit rate, carrier frequency, etc., and consult with the other students to ensure that you use significantly different values. However, be careful to consider the memory requirements and execution time so that your simulations can be completed with reasonable speed.
   - Demonstrate your simulations to the class on March 28.

3. Consider the design of a binary bandpass communication system using either OOK or BPSK. The baseband signal is formed using root-RCRO pulses with rolloff factor $r = 0.5$, and with Unipolar NRZ signaling in the case of OOK and Polar NRZ signaling for BPSK. The root-RCRO pulse is defined in Homework Assignment 6, Problem 1, and in that definition T_b is the time per bit in seconds, and $R = 1/T_b$ is the bit rate. The Fourier transform of this pulse is given by

$$H(f) = T_b\sqrt{H_e(f)},$$

where $H_e(f)$ is the RCRO spectrum defined in Couch, equation (3-69).

The bandpass signal is formed by DSB-SC modulation, as described by Couch equation (5-13), where $m(t)$ is the baseband data signal, and A_c is the carrier amplitude that you will choose as part of the design. Assume that the data symbols are $a_k \in \{0, 1\}$ for the unipolar baseband signal, and $a_k \in \{-1, +1\}$ for the polar signal, respectively.

The channel specifications are:

- The theoretical PSD of the bandpass signal must have an absolute bandwidth of no more than 15 MHz, centered at 1.92 GHz.
- The average power of the bandpass signal, when connected to a load of 50Ω, must not exceed 0.5 W.

Assume that the bits to be transmitted by this system are equally likely to be 0 or 1, and are statistically independent from one another.

(a) Determine the PSD for the Polar NRZ signal. Show that the normalized average power in this signal is 1 W.

(b) Determine the PSD for the Unipolar NRZ signal, and the normalized average power in this signal.

(c) Determine the PSD for the OOK signal.

(d) Determine the PSD for the BPSK signal.

(e) Determine maximum values for R and A_c such that the channel specification will be met. Are the answers different for OOK and BPSK?

(f) Assume OOK signaling, and that the optimal coherent receiver is used. Determine the value of E_b/N_0 necessary to achieve bit error rates of $P_e = 10^{-5}$, 10^{-6}, and 10^{-7}. For each case, calculate the corresponding signal-to-noise ratio, and the value for N_0 assuming that the transmitted signal exactly meets the channel constraints from part (e). Summarize your results in a table, showing all values in dB units.

(g) Repeat part (d) for BPSK signaling, and compare your answers to part those from (d).