16.36 Communication Systems Engineering
Spring 2009

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Problem 1: Text problem 7.42

Hint: For the M=8 constellation you will need your trigonometric laws of sins and cosines. For the probability of error just consider the power required to keep adjacent symbols at the same distance under both constellations.

Problem 2: Text problem 7.48 (except part 3)

Problem 3:

A source signal, represented by a binary sequence with information rate $R_b = 9 \text{ kbps}$, is to be digitally modulated and transmitted over a channel. The modulation method is M-ary PAM (Pulse Amplitude Modulation). The basic pulse is a rectangular function of time:

$$g(t) = \begin{cases} A & t \in [0, T] \\ 0 & \text{otherwise} \end{cases}$$

The carrier frequency allocated to this system is $f_c = 900\text{MHz}$. Frequency planning regulations require that the two-sided null-to-null bandwidth of $g(t)$ does not exceed $6 \text{ kHz}$.

A) Determine the lowest modulation level $M$ for which the bandwidth requirements are met.

B) Propose a scheme for mapping the input bits into modulation waveforms. Make sure that waveforms with adjacent amplitude levels differ by one bit only.

C) Sketch the equivalent baseband signal if the input bit sequence is 011000111010.
Problem 4: Matlab Exercise
In this exercise, you will construct an M-ary symmetric PAM bandpass modulator function.
(This is not nearly as long as it looks)

A) Your function should look like the following:
   a. Inputs to your function will be a bit string to modulate, modulation level M, distance
      between the levels, carrier frequency, and sampling frequency. Output should be a vector
      containing the modulated waveform.
   b. The textbook (and notes) gives an equation for the different amplitude levels as \( A_m = (2m-1-M) \). A modification to this equation to reflect the input distance between levels, \( d \),
      would be \( A_m = (d/2) * (2m-1-M) \). You can verify that this will produce the desired
      amplitude levels.
   c. The pulse shaping function, \( g(t) \), should be a rectangular function with amplitude A. You
      can set A = 1 for this assignment.
   d. The symbol rate must be an integer multiple, n, of the carrier frequency. You can set n=1.
   e. As seen in the lecture notes, for a bandpass modulator, the transmitted waveform can be
      represented by \( A_m g(t) \cos(2\pi f_c t) \). You can recall from HW 1, that Matlab only works with
      discrete waveforms. Your carrier waveform needs to be constructed by sampling it at the
      input sampling frequency.
   f. Take one symbol’s worth of bits at a time to modulate, and construct an entire modulated
      waveform.

B) Use the following as inputs:
   a. Carrier frequency of 1 Hz.
   b. Sampling frequency must be at least at the Nyquist rate. But to produce nicer plots,
      choose the sampling frequency to be 100 Hz.
   c. Distance between the different signaling levels is 2.
   d. Two different M’s with respective input bit strings
      i. M = 4, input: ‘00011011’
      ii. M = 8, input: ‘00001010011100101110111’
         (You should notice that these are simply all of the symbols in order)

C) Please produce as output a clearly labeled plot of the modulated waveform for M=4 and
   M=8. Make sure to comment all of your code.