16.36 Communication Systems Engineering
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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16.36: Comm. Sys. Engineering
Problem Set No. 4

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 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:

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

The carrier frequency allocated to this system is f_c = 900MHz. Frequency planning regulations require that the two-sided null-to-null bandwidth of g(t) does not exceed 6 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 modulater, 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: '000001010011100101110111'
      (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.