ELEG5663 Project 2
Bit Error Rate of Binary Signaling

I. Objectives

1. Learn to perform simulation of baseband digital communication systems.
2. Understand the orthogonal representation of signal and noise.
3. Understand the operations of unipolar signaling and bipolar signaling.
4. Compare the BER performances of unipolar signaling and bipolar signaling.

II. Theories

The simulation of baseband digital communication system can be performed by using the orthogonal representation of signal and noise. For a two-dimensional orthonormal base, $\psi_1(t)$ and $\psi_2(t)$, the signals, $s_i(t)$, for $i=1,2$, and noise of interests, $n(t)$, can be represented as

$$s_i(t) = a_{i1}\psi_1(t) + a_{i2}\psi_2(t)$$
$$n(t) = n_1\psi_1(t) + n_2\psi_2(t)$$

Thus, the system equation of the communication system can be written as

$$y_1 = a_{i1} + n_1 \qquad (1)$$
$$y_2 = a_{i2} + n_2 \qquad (2)$$

Then the simulation can be performed by using the above equation(s) depend on the dimension of the signaling. Both bipolar and unipolar system are of one dimension, so only equation (1) will be used during simulation in this project.

The variance of the noise on each dimension is $E[n_1^2] = E[n_2^2] = \frac{N_0}{2}$. For binary modulation, the energy per bit is $E_b = [(a_{11}^2 + a_{i2}^2) + (a_{21}^2 + a_{22}^2)]/2$.

III. Procedures

A. Bipolar Signaling

1. In the simulation, the data are going to be transmitted and received in slots. Assume each slot has 200 modulated symbols. Generate a random binary sequence with length equal to the length of a slot. The '1's and '0's are equal probable. (Hint: A = (rand(1, 1) > 0.5) generates random variable with equal probability of '0' and '1').
2. Map the binary sequence to the orthogonal representation of bipolar signaling. That is, '1' mapped to $a_{11} = A$, and '0' mapped to $a_{21} = -A$ as shown in the following figure. For bipolar signaling as shown in Fig. 1, what are the values of a_{12} and a_{22}? For convenience, let $E_b = 1$, then what should be the value of A?

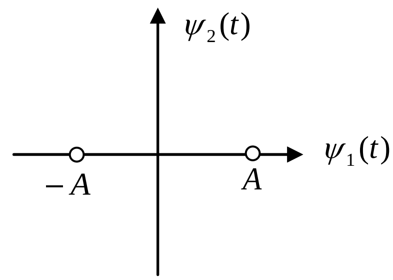


Fig. 1, Orthogonal representation of bipolar signaling

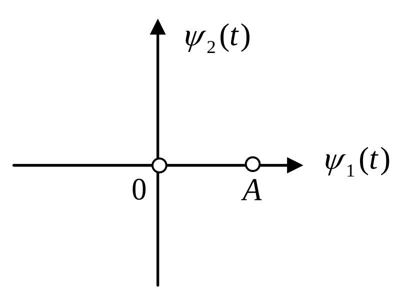
3. Generate zero-mean AWGN. Since bipolar signal has only one dimension, only n_1 in eqn. (1) needs to be generated. If $E_b = 1$, then what is the variance of n_1 at $E_b / N_0 = 0$ dB. Generate 200 uncorrelated zero-mean Gaussian random variables based on the calculated variance. (Uncorrelated Gaussian random variables with zero-mean and unit variance can be generated with the function randn(m, n).)
4. Pass the signal through AWGN channel, the received signals are:

$$y = a + n_1$$

   Where a is the orthogonal representation of the signal, and it's value depends on the binary information.
5. Perform maximum likelihood detection based on the value of y. For bipolar signaling, what should be the threshold? Detect the original transmitted sequence by using the noise distorted value y.
6. Compare the detected sequence with the original sequence, and count the number of errors.
7. Repeat the above procedures 1000 times. Count the total number of errors during the 1000 runs. Calculate the BER as BER = total # of bit errors/total # of bits transmitted.
8. Repeat Steps 1 – 7 for $E_b / N_0 = 2$ dB, 4 dB, 6 dB, and 8 dB, respectively.
9. Plot the BER obtained from simulation as a function of E_b / N_0 (dB). (Use logscale for the BER, e.g. semilogy).
10. In the same figure, plot the theoretical BER. You simulation results and theoretical value should agree very well.

B. Unipolar Signaling

11. The orthogonal representation of unipolar signal can be represented as follows.



‘1’ mapped to $a_{11} = A$, and ‘0’ mapped to $a_{21} = 0$. If $E_b = 1$, what is the value of A?

12. With the calculated value of A, perform simulation of unipolar signal at $E_b / N_0 = 0$ dB, 2dB, 4dB, 6dB, 8dB. Plot the simulated BER.
13. Plot in the same figure the theoretical BER. Compare the simulation results with theoretical results.
14. Compare the BER performance of unipolar signaling and bipolar signaling.