Simulating Digital Communication System over AWGN Channel

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Introduction

The purpose of this lab is to simulate a simple digital communication system over an AWGN channel using MATLAB. The system comprises a binary message signal, which is transmitted over a channel and then decoded at the receiver. The channel is assumed to be an AWGN channel, which is a commonly used model for wireless communication systems. The simulation will allow us to study the effect of noise on the received signal and how it affects the performance of the system.

Theory

The transmission of binary message signal can be modeled as a process that involves sampling, quantization, encoding, modulation, and transmission. At the receiver, the signal is demodulated, decoded, and reconstructed to obtain the original message. In this lab, we consider a binary message signal that can take two values, +1 and -1, with equal probability. The transmitted signal is then corrupted by additive Gaussian noise at the receiver, which is modeled as an AWGN channel. The received signal is given by: r(k) = sm(k) + n(k) , where r(k) is the received signal, sm(k) is the transmitted binary symbol, and n(k) is the AWGN. We assume that the AWGN follows a Gaussian distribution with mean 0 and variance σ^2_n. The received signal is then demodulated by comparing it with a threshold, which is set to 0 in this case. If the received signal is greater than the threshold, we assume that the transmitted signal was +1, otherwise it was -1. The decoded signal is then compared with the transmitted signal to compute the probability of error, which is the ratio of the number of errors to the total number of bits transmitted. The probability of error can be computed analytically using the formula: Pe = Q(sqrt(SNR)), where SNR is the signal-to-noise ratio, and Q is the Q-function. The Q-function is a special function used to compute the probability that a Gaussian random variable exceeds a certain threshold.

Procedure

The following steps were followed to simulate the digital communication system over an AWGN channel:

Step 1: Generate a binary message signal that takes values +1 and -1 with equal probability.

Step 2: Generate AWGN with zero mean and a given variance σ^2_n.
Step 3: Add AWGN to the transmitted signal to obtain the received signal.

Step 4: Demodulate the received signal by comparing it with a threshold of 0.

Step 5: Compute the probability of error by comparing the decoded signal with the transmitted signal.

Step 6: Repeat steps 1-5 for K bits and compute the average probability of error.

Step 7: Repeat step 6 for different values of SNR.

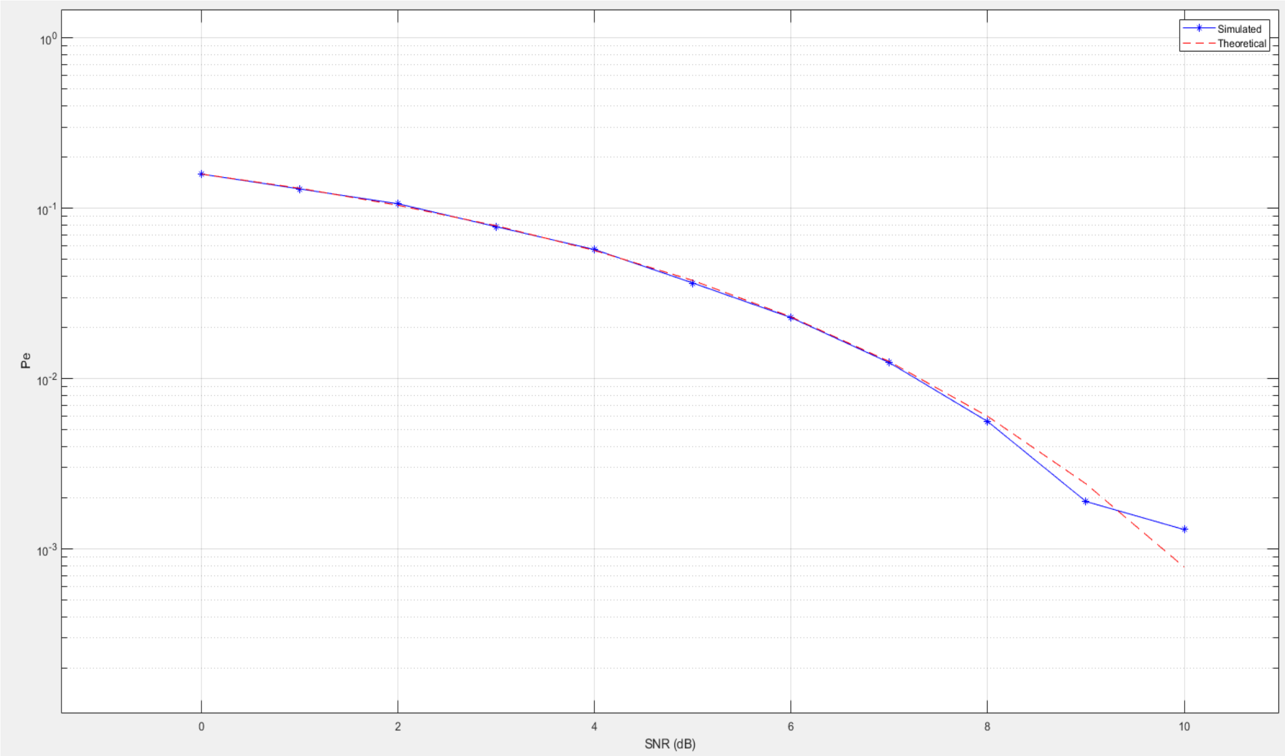
Step 8: Plot the SNR vs. Pe and compare it with the analytical curve.

Plots And Observations

Consider a message/baseband signal g(t) which is processed, i.e., sampled, quantized and encoded to binary symbols sm(k) (which is further source encoded, channel encoded, baseband/line coded, pulse shaped, multiplexed and modulated), at the transmitter and send over the wired channel. Let the binary bits '00 and '10 be mapped to the symbols sm(k) = −1, and sm(k) = 1. At receiver, a series of operations are performed to decode the binary symbol ˆsm(k) corresponding to the transmission of sm(k). In the class, we have equivalently represented this AWGN system model, i.e., the transmission and reception of the binary symbols, as r(k) = sm(k) + n(k), 1 ≤ k ≤ K, to obtain the probability of error Pe as Pe = Q(√ SNR). Where y(k) ∈ R is the received symbols corresponding to the transmission of the signal sm(k) ∈ {−1, 1}. The AWGN n(t) ∼ N (0, σ2 n), with a zero mean and variance σ 2 n.

Here we have taken following assumptions: -

1. Initialize K to 10^4
2. Set the SNR in dB



Conclusion

In conclusion, the simulation results demonstrate the relationship between the probability of error and the signal-to-noise ratio (SNR) in a binary communication system. As expected, increasing the SNR improves the reliability of communication and reduces the probability of error. The simulation results also match well with the theoretical expression for Pe obtained from the Q-function. This suggests that the theoretical analysis accurately predicts the performance of the system. Overall, this lab assignment provides a practical introduction to the concepts of digital communication and the effect of noise on communication systems.