EE4402 Project

Instructions

1. This full mark of this project is 100, and its weightage in the final is 20%.
2. You are required to form a group of 4 students.
3. Every group are required to submit
    a. A softcopy **group report** of 10 pages at most in PDF format.
    b. Your simulation source code. Please include specifications on how to compile and run your code in your submission.
    c. A short video presenting your project in mp4 format. The video is at most 10 minutes. Please also include your presentation slides.
4. Submission deadline is 26th December. There will be a penalty for late submissions.

Project description

Digital communications have significant advantages compared to analogy communications. Digital communication signaling, detection, and error-correcting coding are the key factors. In this project, you are required to derive and simulate the PAM and QPSK in baseband vector channel modelled as $\boldsymbol{r} = \boldsymbol{s} + \boldsymbol{n}$, where $\boldsymbol{r}$ is the received signal in vector form, $\boldsymbol{s}$ is the transmitted symbol in vector form, and $\boldsymbol{n}$ is the AWGN noise vector projected to the signal space. The signal space here refers to the space spanned by the N-dimensional orthonormal basis $\{\phi_i(t): 1 \leq i \leq N\}$. They form a complete basis for signals in PAM and QPSK. Each element in $\boldsymbol{n}$ is a zero-mean Gaussian distributed random variable with variance $\frac{N_0}{2}$.

Task 1

Assume all symbols are equiprobable. Denote the average bit energy by E_b. Derive and simulate the bit error rate (BER) for PAM when the Gray mapping is applied.

a. If 2-PAM and 4-PAM have the same average bit energy E_b, indicate the symbols in vector form for 2-PAM and 4-PAM using E_b.

b. Derive the exact BER for 2-PAM and 4-PAM in terms of the signal-to-noise ratio (SNR) defined as $\frac{E_b}{N_0}$ when the Gray mapping is applied.

c. Simulate 2-PAM and 4-PAM modulation and detection in baseband with AWGN to find the experimental BER using Jupyter notebook or Matlab. Please simulate until the BER reaches 10^{-6} by varying the SNR. Plot the curve of BER vs. SNR. In this plot, the horizontal axis is SNR in dB-scale ($10\log_{10} SNR$), and the vertical axis is BER in log-scale ($\log_{10} BER$).

d. Plot the exact BER derived in step b in the same plot and comment on the result.

Task 2

Assume all symbols are equiprobable. Denote the average bit energy by E_b. Derive and simulate the bit error rate (BER) for QPSK (4PSK) when the Gray mapping is applied.

a. Sketch the constellation of the QPSK.

b. Mark the symbol vector forms (in terms of E_b) and the corresponding Gray coding.

c. Derive the exact BER and represent it using SNR defined as $\frac{E_b}{N_0}$ when the Gray mapping is applied. Derive a upper bound and a lower bound for the QPSK BER in terms of SNR.

d. Simulate QPSK modulation and detection in baseband with AWGN to obtain experimental BER using Jupyter notebook or Matlab. Please simulate until the BER reaches 10^{-6} by varying the SNR. Plot the curve of BER vs. SNR. In this plot, the horizontal axis is SNR in dB-scale, and the vertical axis is BER in log-scale.

e. Plot the exact BER vs. SNR, the upper bound, and the lower bound in the same plot and comment on the result.

f. Compare the simulation results in Task 1 and Task 2.

Hints:

1. You may need to use the python function random.gauss() to generate Gaussian distributed random variable. Please refer to the help to find how to use the functions.
2. To varying SNR value, you can fix $E_s = 1$ and adjust N_0 only.
3. To simulate the experimental BER in your program, you can count the number of bit errors and the number of bits transmitted. Their ratio will be the experimental BER. You may need to collect a sufficient number of bits in error, such as 100, before you can compute the BER.
4. Do not include code in your report. Describe your ideas with flow chart if needed.