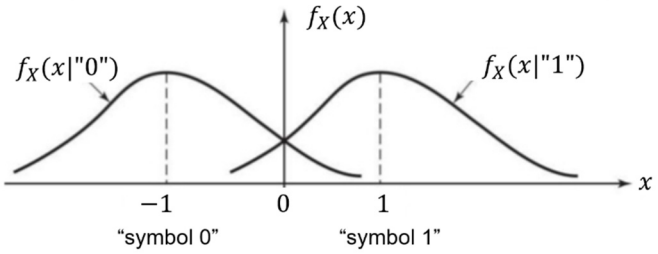
ECE3522 Practicum 2 : Error Rates in Digital Communications

Penalty will be imposed after 3/22/20 10:00 pm (1 point each hour; fraction rounds up)

In a digital communication system, when "symbol 1" is transmitted, the actual signal level is $s = 1$. When "symbol 0" is transmitted, the actual signal level is $s = -1$ (see the plot below).



At the receiver, the signal s is received together with additive noise w, which follows a normal (Gaussian) distribution (0, σ). That is, the expected value of the noise is 0, and its standard deviation is σ. In this case, the noise power is given as σ^2, and the input signal-to-noise ratio (SNR) is defined as the ratio between the signal power (which is 1) and the noise power (which is σ^2) and is given as $1/\sigma^2$. The input SNR is often described in dB levels, defined as $\mathrm{SNR}_{\mathrm{dB}} = 10\log_{10}(\mathrm{SNR}) = -20\log_{10}(\sigma)$. Therefore, when the input SNR is α dB, the value of σ can be obtained as $\sigma = 10^{-\alpha/20}$.

At the receiver, if the received signal ($x = s + w$) corresponding to a bit is higher than 0, the bit is decided as "symbol 1". Otherwise, the bit is decided as "symbol 0". The detected bit stream is compared with the transmitted bit stream. For any bit that the detected bit result and the transmitted bit information are different, that bit is said to be erroneously detected.

The sample Matlab codes in the appendix plot the relative frequency of the received signal x for $x \in [-4{:}\,0.1{:}\,4]$ and compute the number of erroneously detected bits when a binary bit stream of "symbol 1" is transmitted. The input SNR is 5 dB and the total number of transmitted bits is *N*=1,000,000. The red vertical line shows the detection threshold ($x = 0$).

This practicum requires the following results to be computed and reported:

1. When "symbol 1" is transmitted (s=1) and the input SNR is 5 dB, analytically find the expected value and standard derivation of $x = s + w$. Plot the probability density function (PDF) curve of the received signal x for $x \in [-4{:}\,0.1{:}\,4]$. Compute the probability $P[x < 0]$, which represents the bit error rate (BER) when "symbol 1" is transmitted (s=1).

2. When "symbol 1" is transmitted (s=1) and the input SNR is 5 dB, develop Matlab codes that plot the relative frequency (similar to PDF) of the received signal level x for $x \in [-4{:}\,0.1{:}\,4]$ using $N = 1{,}000{,}000$ samples. Experimentally find the expected value and the standard deviation from the simulated results of x. Compute the simulated BER by transmitting $N = 1{,}000{,}000$ "symbol 1" and computing the ratio N_{err}/N between the number of erroneously detected bits, N_{err}, and the total number of transmitted bits, N. Are they respectively close to the analytical results obtained in Part 1? Comment any discrepancies if there are.

3. Repeat Part 1 for input SNR = 10 dB. Comment how the following results are changed (or unchanged) as compared to Part 1 and explain why: (a) the expected value of x, (b) the standard deviation of x, (c) the shape of the PDF curve, and (d) BER.

4. Repeat Part 2 for input SNR = 10 dB. Do you observe the same changes (or no changes) as described in Part 3 (a) through (d)? Comment any discrepancies if there are.

Submit by e-mail to ece3522.temple@gmail.com

(a) A single Word or pdf file containing materials in the following order:

- Your name, TUid
- All the required values, figures, and observations. All plots must be properly labelled.
- Key references (website, book, paper, or name of collaborated students) if any
- Matlab codes

(b) All Matlab codes in .m format

Important: The Matlab code must be included in the Word or pdf file report, AND as a separate attachment. The name of the Word of pdf file must be in the following format with a proper file extension: Lastname_Firstname _practicum2_ECE3522 .

Requirements

Each student should complete the practicum separately. No group work is allowed.

A student can seek help, but the report must be his/her work and thus he/she must understand every word and every line of Matlab code reported. Copy and paste the Matlab codes from others work or from online resources are not permitted.

Appendix

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%% ========== Matlab code sample for Practicum 2 ===========
% Simulation: Error Rates in Digital Communications
%

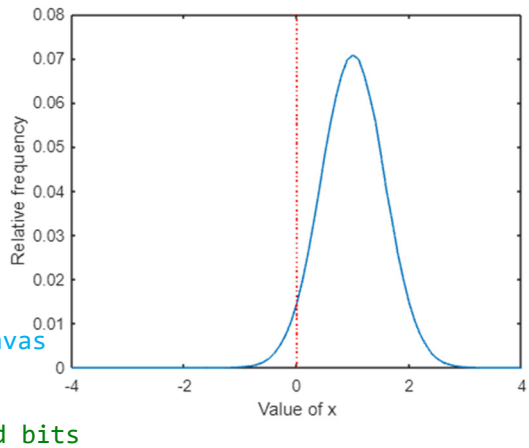
clear

N = 1e6;                          % number of bits transmitted
SNR_dB = 5;                       % signal-to-noise ratio in dB
sigma = 10^(-SNR_dB/20);          % noise standard deviation

signal = ones(N,1);               % bit stream with only 1's
noise = randn(N,1)* sigma;        % additive Gaussian noise
received = (signal*2-1) + noise; % received noisy signal

x_range = [-4:0.1:4];
hist_x = hist(received, [-4:0.1:4]);
plot(x_range, hist_x/N);
xlabel('Value of x')
ylabel('Relative frequency')
vline([0])                        % Matlab code posted in Canvas

detect = (received > 0);          % detected result
N_err = sum(abs(detect-signal)); % # of erroneously detected bits
fprintf('N = %d bits transmitted; N_err = %d error bits received \n', N, N_err)
```



Results:

N = 1000000 bits transmitted; N_err = 37752 error bits received

(The plot is shown at the right-hand side)