The University of Calgary
Department of Electrical & Computer Engineering

ENEL 471 Introduction to Communications Systems & Networks (Winter 2020)
PreLab – Exercises

Lab Day & Date: B04: Tuesday, January 21, 2020; B02: Wednesday, January 22, 2020
B03: Tuesday, January 28, 2020; B01: Wednesday, January 29, 2020

No Lab Report is Required.

1. Objective

The objective of this Lab is to:

Perform several exercises to become familiar with the MATLAB concepts required for ENEL 471.

2. Pre-Requisites

It is very strongly recommended that you complete the ENEL 471 MATLAB Self-learning Tutorial prior to doing the Pre-Lab Exercises. This document assumes that you have worked through the ENEL 471 MATLAB Self-learning Tutorial.

3. Procedure

3.1 Exercise #1: Generation and plotting of a sine wave.

a) Generate 1024 samples of a sine wave with 50 samples per cycle. Plot the vector generated versus the sample index, numbered 0, 1, …, 1023. Switch the grid on. Add the x-label: “Sample Number”, y-label: “Amplitude”, and the title: “Sine wave with period = 50”. Your result should appear as shown in Fig.1 on the next page. ***Hint:*** To set the limits of the scale along the x-axis and y-axis, the MATLAB syntax is: axis([x_ll, x_ul, y_ll, y_ul]) where (x_ll = 0) and (x_ul =1023) are respectively the lower limit and upper limit along the x-axis. Similarly, (y_ll = -1) and (y_ul = 1) are the corresponding limits on the y-axis.

Q1: How many cycles of the sine wave are shown in the plot?
Hint: Number of cycles = Total number of samples plotted / Number of samples per cycle.

b) Plot the vector generated in a) versus time, in seconds. Assume a cycle is 50 milliseconds long and 50 samples per cycle. Switch the grid on. Add the x-label: “Time in seconds”, y-label: “Amplitude”, and the title: “Sine wave with period = 0.05 seconds”. Your result should appear as shown in Figure 2.

Q2: What is the sampling interval in seconds?
Hint: Sampling interval = Cycle length in seconds / Number of samples per cycle

Q3: What is the sampling rate in samples per second?
Hint: Sampling rate = Number of samples per cycle / Cycle length in seconds.

Q4: Based on your answers to Q2 and Q3, what is the relationship between sampling interval and sampling rate?

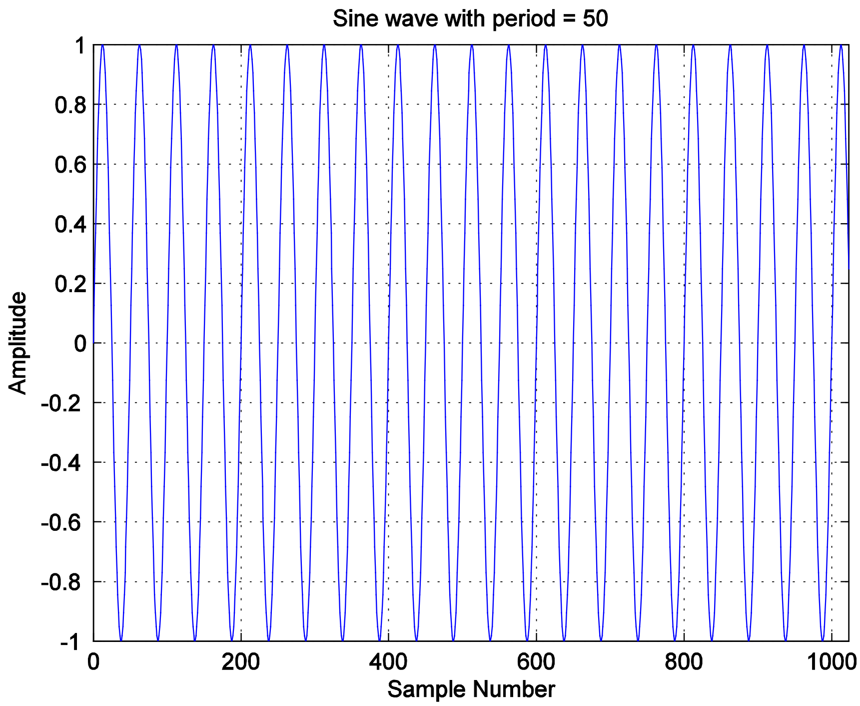

Figure 1 Plot of Sine wave amplitude vs. sample number.

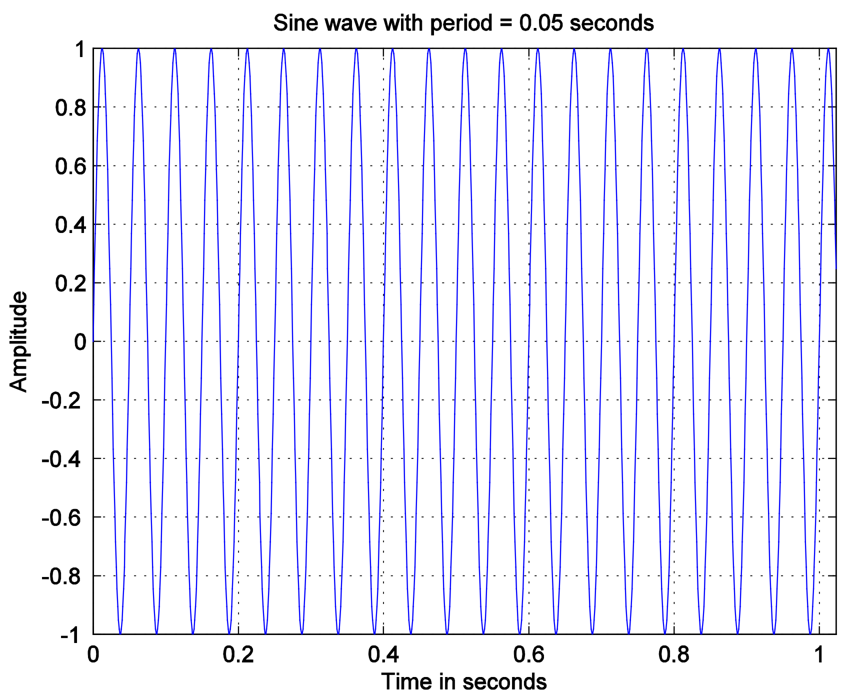

Figure 2 Plot of Sine wave vs. time in seconds.

3.2 Exercise #2: Simulation of samples of a Gaussian distributed random variable.

a) Generate 100 samples (i.e., total # of samples = 100) of a Gaussian random variable having a mean = 0 mean and variance = 2.

Hints:

1) variance = standard deviation squared.

2) In MATLAB, samples of a Gaussian distributed random variable can be generated using the built-in "*normrnd()*" function. For example, to generate a vector called "data" of length "*total_number_of_samples*" having a Gaussian distribution with mean "*mean_value*" and standard deviation "*sigma_value*", the MATLAB syntax is:

data = *normrnd(mean_value, sigma_value,* 1, *total_number_of_samples*);

Q5: Using the MATLAB built-in functions "mean()" and "std()", calculate the mean and standard deviation of vector "data", denoted by "mean_sim" and "sigma_sim", respectively.

Q6: What is the percent error between "sigma_sim" and "sigma_value"?

Q7: How can the percent error obtained in Q6 be decreased?

Q8: Determine the maximum and minimum value of vector "data" using the MATLAB built- in "max()" and "min()" functions, respectively.

b) Plot the vector generated in part a) versus the sample index, numbered 0, 1, …, 99. Switch the grid on. Add the x-label: "Sample Number", y-label: "Amplitude", and the title: "Gaussian Variates, mean = 0, variance = 2". Your result should be appear as shown in Fig. 3. (Note: your result will NOT be identical to that shown in Figure 3 because the variates are driven by random numbers.)

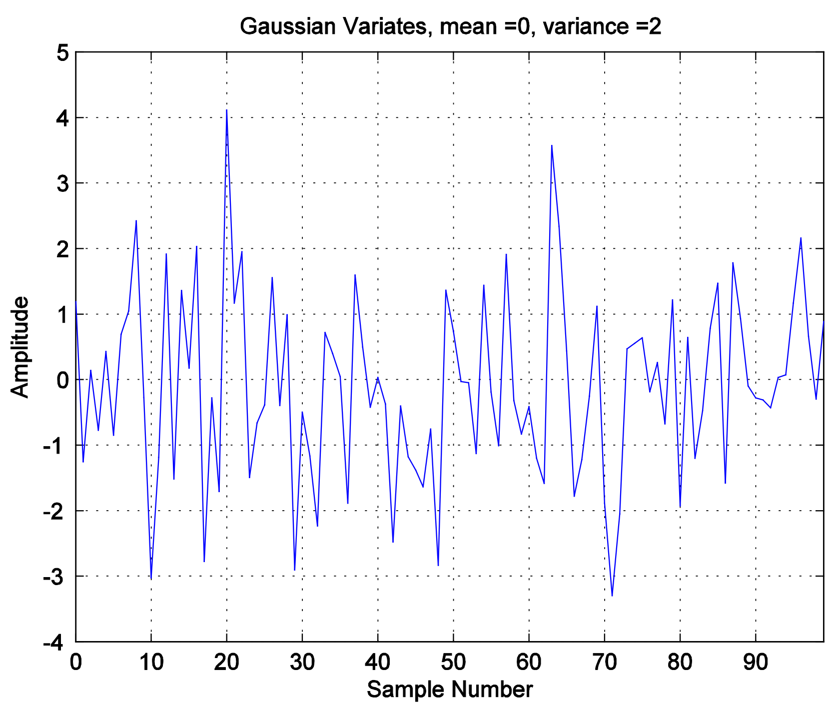

Figure 3 Gaussian variates vs. sample number.

3.3 Exercise #3: Study the effect of channel noise on the transmitted signal.

A binary information source generates a data bit “1” and forwards to a transmitter which converts the bit to a transmitted signal of the form:

$$s(t) = 1 \cdot \cos(2\pi \cdot f_c t) \tag{1}$$

where $s(t)$ is the value of the transmitted signal at time t, “1” is the information, and f_c is the frequency of the carrier (i.e., information bearing) signal. The transmitted signal passes through a channel modeled by the Gaussian distribution with a mean = 0 and a specified variance. The channel variation is modeled by changing the variance parameter. The objective is to observe the received signal as the channel changes (i.e., as the value of variance is changed).

To do Exercise #3 in MATLAB, proceed as follows:

Step 0: Preambles:

Step 0.1: Assume the carrier signal frequency $f_c = 10\ KHz$.

Step 0.2: Assume the data bit is of duration Tb seconds. Take $T_b = 0.125$ milliseconds.

Step 0.3: Let N denote the number of samples in one bit duration. Assume N = 31 samples so that the sampling interval $T_s = T_b / N = 4.032$ microseconds.

Step 1: Generate N samples of the transmitted signal during data bit duration T_b:

$$n = 0 : \mathrm{N} - 1$$
$$\mathrm{s} = 1 \cdot \cos(2\pi \cdot f_c \cdot n \cdot T_s) \tag{2}$$

where n is a vector of N time indices, s is a vector of N samples of the transmitted signal for data bit “1”. Let $s(\mathrm{nT}_s)$ denote the transmitted signal at time index n, $n = 0, \cdots, N-1$. A sample plot of $s(\mathrm{nT}_s)$ is shown in Figure 4.

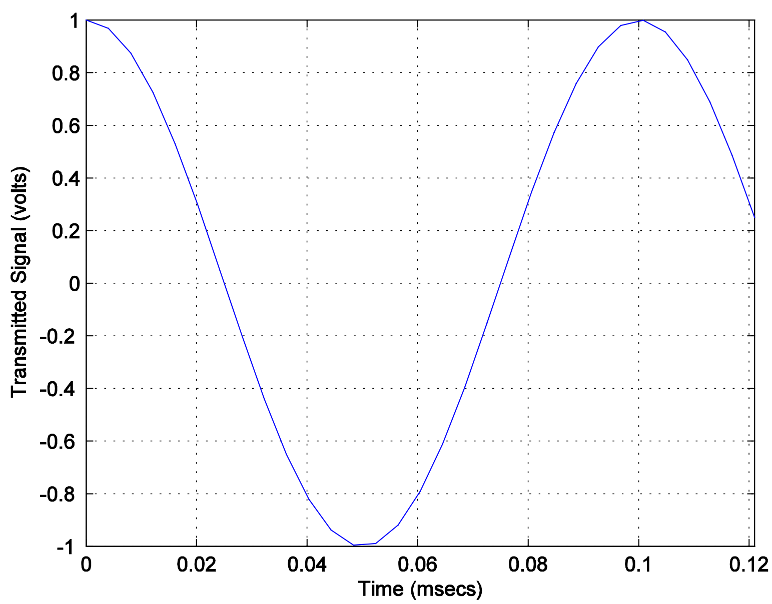

Figure 4 Transmitted signal vs. time

Step 2: Generate N samples of the Gaussian distributed channel:

$$channel\_noise = normrnd(mean\_value, sigma\_value, 1, N) \tag{3}$$

where $channel\_noise$ is a vector of N samples, determined by the MATLAB built-in function $normrnd(mean\_value, sigma\_value, 1, N)$.

Assume that: $mean\_value = 0$ and $sigma\_value = 0.1$. Let $channel\_noise(nT_s)$ denotes the channel noise variate at time index n, $n = 0, \cdots, N-1$. A sample plot of $channel\_noise(nT_s)$ is shown in Figure 5. (<u>Note:</u> your result will NOT be identical to that shown in Figure 5 because the variates are driven by random numbers).

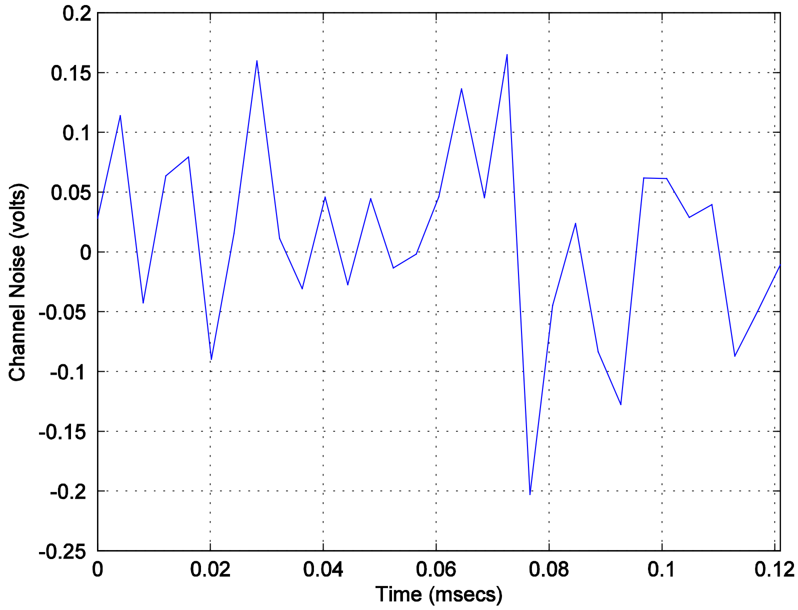

Figure 5 Channel noise vs. time.

<u>Step 3:</u> Calculate the received signal at the input of the receiver:

$$r = s + channel\_noise \tag{4}$$

where r is a vector of N samples. The vectors s and $channel\_noise$ are determined by eqns. (2) and (3), respectively. A sample plot of the received signal is shown in Figure 6. (<u>Note:</u> your result will NOT be identical to that shown in Figure 6 because the variates are driven by random numbers.)

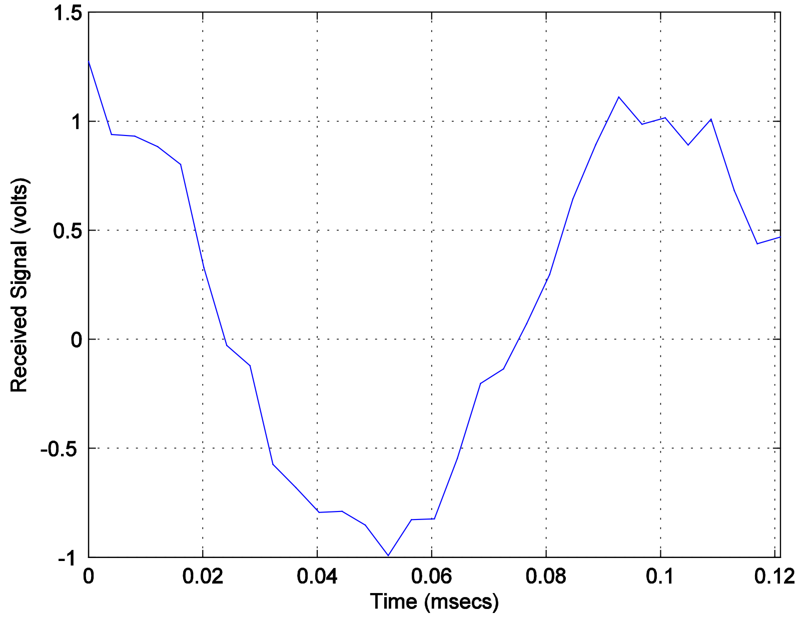

Figure 6 Received signal vs. time.