AMERICAN INTERNATIONAL UNIVERSITY BANGLADESH

Faculty of Engineering

Laboratory Report Cover Sheet

Students must complete all details except the faculty use part.

Please submit all reports to your subject supervisor or the office of the concerned faculty.

Lab Title: **Study of signal frequency, spectrum, bandwidth, and quantization using MATLAB**

Experiment Number: **02** Due Date: **20 /02/2024** Semester: **Spring 2023-2024**

Subject Code: **COE3103** Subject Name: **DATA COMMUNICATION** Section: **E**

Course Instructor: **NOWSHIN ALAM** Degree Program: **B.Sc. CSE**

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Group Number (if applicable): 08 Individual Submission ☐ Group Submission ☐

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Introduction:

In the dynamic world of communication engineering, understanding a signal's characteristics like frequency, its unique spectrum, its range of bandwith, and how it transitions from continuous to quantization is crucial. Fortunately, we have MATLAB as a powrful ally, a software designed to analyze and solve complex problems in this field. This experiment bridges the gap between theory and practice, offering a hands-on exploration of MATLAB'S capabilities. Not only will we search into the fasinating concepts of frequency, spetrum, bandwith, and quantization, but we'll also master the commands and syntax necessary to interact with them directly within the MATLAB environment. This immersive journey equips us to not only unlock the secrects hidden within signals but also develop a deeper appreciation for the power of combining theoretical knowledge with practical application.

Theory:

Frequency: Frequency characterizes the rate of oscillation of a wave and is measured in Hertz (Hz). It signifies how many wave cycle pass through a point per seconds. The relationship between frequency (f), velocity of the wave (v), and wavelength(λ) is define by the formula,

$$v = f\lambda$$

Higher frequencies indicate rapid changes over short time spans while lower frequencies signify slower variation over longer durations.

Spectrum: Signals, typically represented in the time domain, can also be analyzed in the frequency domain, where they are referred to as spectra. This representation provides insights into signal's frequency components and their magnitudes.

Bandwith: Bandwith denotes the range of frequencies encomposed within a signal. For instance, if a composite signal comprises sinosoidal at 100, 250 and 400 Hz, its bandwith is calculated as the difference between the highest and lowest frequency components, i.e., (400-100) = 300 Hz.

Quantization: Quantization involves the process of converting ~~ato~~ analog signals into digital format by discretizing signal amplitudes into a finite set of levels. This process, esential for analog-to-digital conversion, involves sampling the analog signal and rounding off values to the nearest quantization level. The quality of quantization output depends on the number of quantization levels utilized. A simplified method of quantization is given below:

$\Delta = (xmax - xmin)/(L-1)$; Δ = step size

$L = 2m$; m = number of bit

$i = round\{(x - xmin)/\Delta\}$

$xq = xmin + i * \Delta$; $i = 0, 1, \ldots, L-1$

where x_{max} and x_{min} are the maximum and minimum values, respetively, of the analog input signal x. The symbol L denotes the number of quantization levels, where m is the number of bits used in ADC. The symbol Δ is the step size of the quantizer or the ADC resolution. Finally, x_q indicates the quantization level, and i is an index corresponding to the binary code.

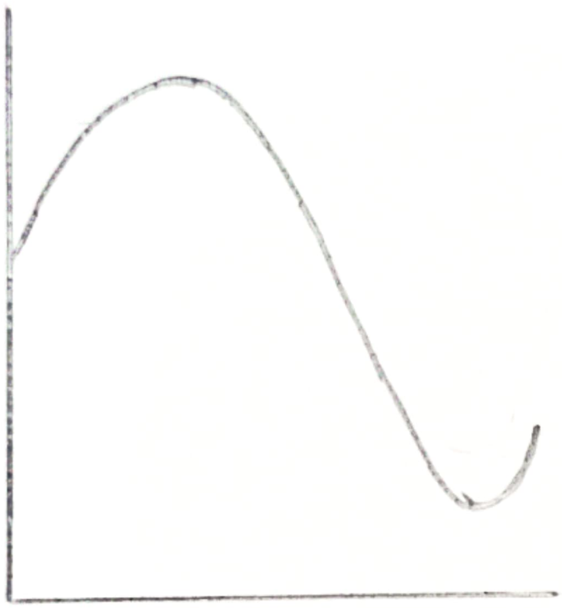


Figure: An analog Signal

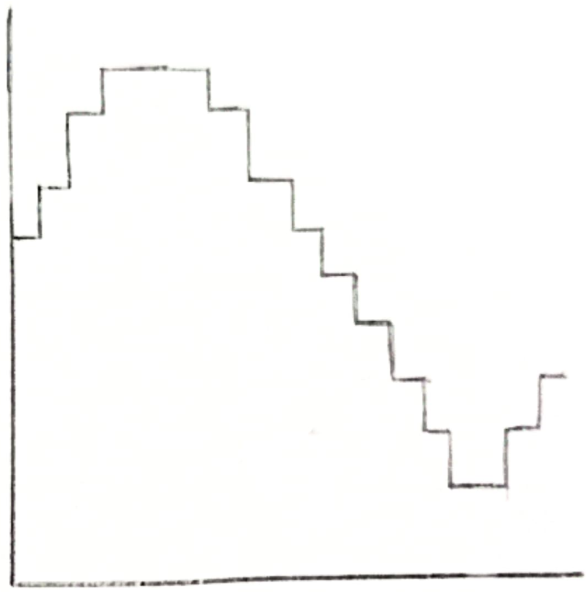


Figure: A quantized signal

In summary, this theoretical framework lays the groundwork for understanding signal properties and the quantization process, essential for communication engineering applications. Through MATLAB, these concept can be perfectly explored, analyzed, and applied to the real-world senarios.

Simulated Results:

ID = AB-CDEFG-H

ID = 22 - 46013 – 1

x1 = a1*cos(2*pi*f1*t)

x2 = a2*sin(2*pi*f2*t)

x3 = a3*cos(2*pi*f3*t)

signal_x = x1 + x2 + x3

The values of the amplitude and frequency are as follows: a1 = G + 1, a2 = F + 2, a3 = E + 3, f1 = E + 1, f2 = F + 2, f3 = G + 3.

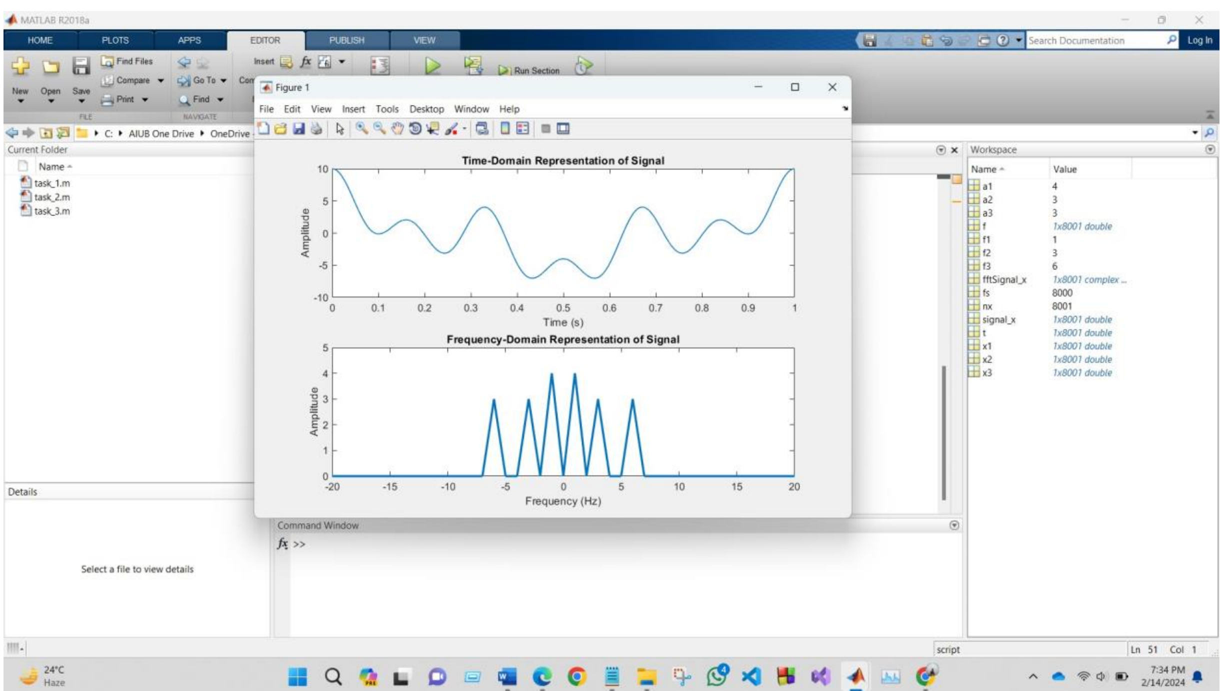
(a)

Show time domain and frequency domain representations of **signal_x** in a single figure window using subplot. Use **axis**, or **xlim**, or **ylim** to appropriately represent the signal.

Code & Simulation:

```
clc
close all
clear all

% x1 = a1*cos(2*pi*f1*t), x2 = a2*sin(2*pi*f2*t), x3 =
a3*cos(2*pi*f3*t)
% signal_x = x1 + x2 + x3
% a1 = G + 1, a2 = F + 2, a3 = E + 3, f1 = E + 1, f2 = F + 2, f3 = G
+ 3.

% ID = 22-46013-1
% ID = AB-CDEFG-H

a1 = 4;
a2 = 3;
a3 = 3;

f1 = 1;
f2 = 3;
f3 = 6;

%Define number of samples to take
fs = 8000;

%Define signal
t = 0: 1/fs: 1;
```

```
x1 = a1*cos(2*pi*f1*t);
x2 = a2*cos(2*pi*f2*t);
x3 = a3*cos(2*pi*f3*t);
signal_x = x1 + x2 + x3;
nx = length(t);

subplot(2,1,1);
plot(t, signal_x,'linewidth',1);
title('Time-Domain Representation of Signal');
xlabel('Time (s)');
ylabel('Amplitude');

fftSignal_x = fft(signal_x);

fftSignal_x = fftshift(fftSignal_x)/(nx/2);

f = linspace(-fs/2,fs/2,nx);

subplot(2, 1, 2)
plot(f, abs(fftSignal_x),'linewidth',2);
title('Frequency-Domain Representation of Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
xlim([-20 20])
```



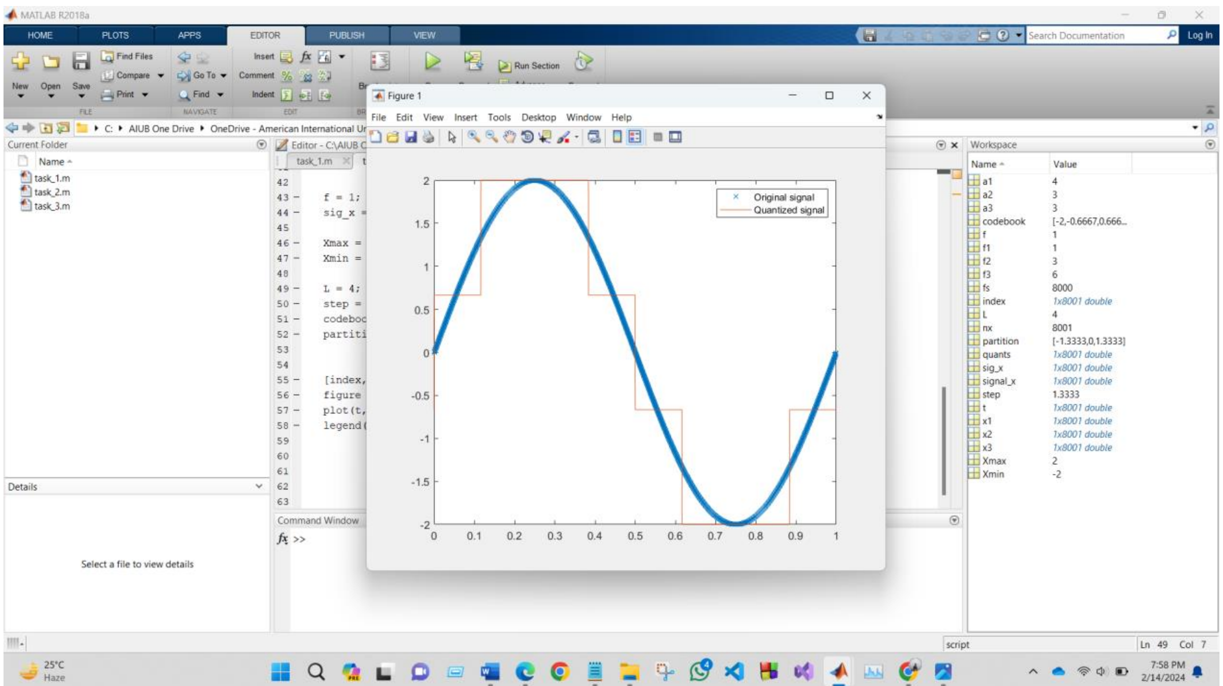
(b)

Quantize **signal_x** in 4 equally distributed levels and provide image for one cycle of the original signal and quantized signal. Use **axis**, or **xlim**, or **ylim** to appropriately represent the signal. [Use **quantiz()** function]

Code & Simulation:

```
clc
close all
clear all

% x1 = a1*cos(2*pi*f1*t), x2 = a2*sin(2*pi*f2*t), x3 =
a3*cos(2*pi*f3*t)
% signal_x = x1 + x2 + x3
% a1 = G + 1, a2 = F + 2, a3 = E + 3, f1 = E + 1, f2 = F + 2, f3 = G
+ 3.

% ID = 22-46013-1
% ID = AB-CDEFG-H

a1 = 4;
a2 = 3;
a3 = 3;

f1 = 1;
f2 = 3;
f3 = 6;


%Define number of samples to take
fs = 8000;

%Define signal
t = 0: 1/fs: 1;

x1 = a1*cos(2*pi*f1*t);
x2 = a2*cos(2*pi*f2*t);
x3 = a3*cos(2*pi*f3*t);
signal_x = x1 + x2 + x3;

f = 1;
sig_x = 2*sin(2*pi*f*t);

Xmax = max(sig_x);
Xmin = min(sig_x);

L = 4;
step = (Xmax - Xmin)/(L-1);
codebook = Xmin : step : Xmax;
partition = (Xmin + step/2) : step : (Xmax - step/2);
```

```
[index,quants] = quantiz(sig_x,partition,codebook); % Quantize.
figure
plot(t,sig_x,'x',t,quants)
legend('Original signal','Quantized signal');
```



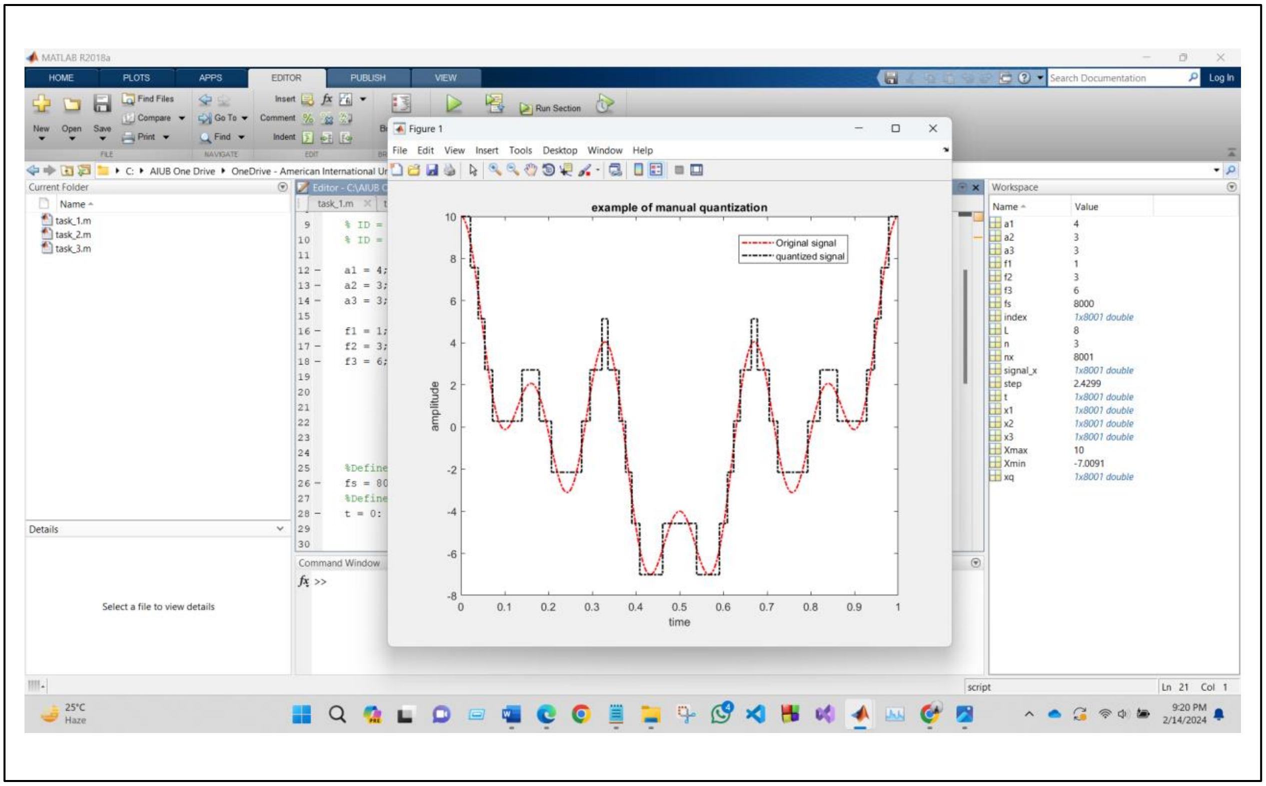
(c)

Quantize **signal_x** in 8 equally distributed levels and provide image for one cycle of the original signal and quantized signal. Use **axis**, or **xlim**, or **ylim** to appropriately represent the signal. [Do not use **quantiz()** function]

Code & Simulation:

```
clc
close all
clear all

% x1 = a1*cos(2*pi*f1*t), x2 = a2*sin(2*pi*f2*t), x3 =
a3*cos(2*pi*f3*t)
% signal_x = x1 + x2 + x3
% a1 = G + 1, a2 = F + 2, a3 = E + 3, f1 = E + 1, f2 = F + 2, f3 = G
+ 3.
```

```
% ID = 22-46013-1
% ID = AB-CDEFG-H

a1 = 4;
a2 = 3;
a3 = 3;

f1 = 1;
f2 = 3;
f3 = 6;

%Define number of samples to take
fs = 8000;
%Define signal
t = 0: 1/fs: 1;

x1 = a1*cos(2*pi*f1*t);
x2 = a2*cos(2*pi*f2*t);
x3 = a3*cos(2*pi*f3*t);
signal_x = x1 + x2 + x3;
nx = length(t);

n = 3;
L =(2^n);
Xmax = max(signal_x);
Xmin = min(signal_x);

step = (Xmax-Xmin)/(L-1);
index = round((signal_x - Xmin)/step);
xq = Xmin + index * step;


plot(t,signal_x,'r-.', 'linewidth',1.5);
hold on;
plot(t,xq,'k-.', 'linewidth',1.5);
xlabel('time')
ylabel('amplitude')
title('example of manual quantization')
legend('Original signal','quantized signal')
```



Conclusion:

Through hands-on simulations, exploring various MATLAB functions, the experiment successfully achived its objectives. We used MATLAB to plot frequency, spectrum, bandwith, and even visualize the effects of quantization on an analog signal. Beyond the theenical analysis, we also gained valuable experiance in formatting and presenting the results effectively. Overall, the experiment provide a comprehensive understanding of these functionalities within MATLAB.