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.

Laboratory Title: Study of Nyquist bit rate and Shannon capacity using MATLAB

Experiment Number: 03 Submission Date: 15/02/2023 Semester: Spring 2022 – 2023

Subject Code: COE 3201 Subject Name: Data Communication Section: K

Course Instructor: DR. SHUVRA MONDAL Degree Program: BSc CSE

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Group Number (if applicable): **01** ☐ Individual Submission ☒ Group Submission

No.	Student Name	Student ID	Contribution
1	SHEAKH, MOHAMMAD BIN AB. JALIL SHEAKH	20-42132-1	Performance Task (b)
2	AURTHY, MOST. LILUN NAHAR	20-43997-2	Performance Task (b)
3	NISHAT, TARIKUL ISLAM	21-44632-1	Abstract, Introduction, Performance Task (c)
4	MULLICK, IFTEKHAR UDDIN	21-44649-1	Discussion, Conclusion, Performance Task (d)
5	ULLAH, MD ISMAIL JOBI	21-44747-1	Performance Task (c)
6	ALANSAR, SADIAH	21-45612-3	Performance Task (d)

For faculty use only: **Total Marks:** 6 **Marks Obtained:** 6

Faculty comments Excellent!

Title:

Study of Nyquist bit rate and Shannon capacity using MATLAB

Abstract:

This experiment was designed to help understand the use of MATLAB for solving communication engineering problems. This experiment also helps us develop the understanding of Nyquist bit rate and Shannon capacity using MATLAB.

Introduction:

i. **Nyquist Bit Rate:** The Nyquist bit rate formula defines the theoretical maximum bit rate for a noiselesschannel.

$$BitRate=2 \times bandwidth \times log2L$$

In this formula, bandwidth is the bandwidth of the channel, L is the number of signal levels used to representdata, and BitRate is the bit rate in bits per second.

ii. **Shannon capacity:** Shannon capacity formula was introduced to determine the theoretical highest data ratefor a noisy channel:

$$Capacity= bandwidth \times log2\ (1+ SNR)$$

In this formula, bandwidth is the bandwidth of the channel, SNR is the signal-to-noise ratio, and capacity isthe capacity of the channel in bits per second.

Signal-to-noise ratio (SNR): To find the theoretical bit rate limit, we need to know the ratio of the signalpower to the noise power.

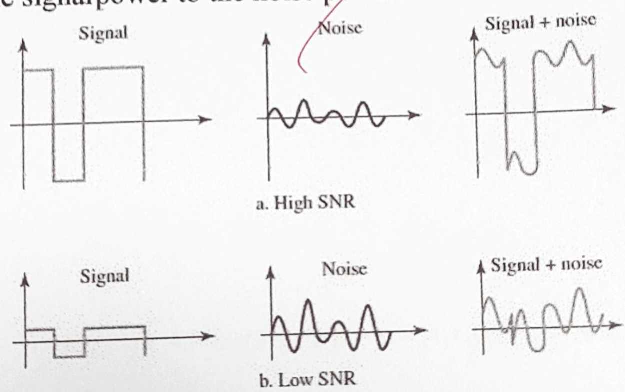

Fig: Two cases of SNR; One is high and the other is Low SNR

Because SNR is the ratio of two powers, it is often described in decibel units, SNRdB, defined as SNRdB = 10log10 (SNR)

Simulation:

Performance Task:

The selected ID is the following:

2	0	-	4	3	9	9	7	-	2
A	**B**		**C**	**D**	**E**	**F**	**G**		**H**

Performance Task for Lab Report: (your ID = AB-CDEFG-H)

*****Generate a composite signal using two simple signals as,***

x = A1 sin(2π((C+D+H)*100)t) + A2 cos(2π((D+E+H)*100)t) + s*randn(size(t));

(a) Select the value of the amplitudes as follows: let A1 = (A+B+H), A2 = (B+C+H) and s = (C+D+H)/30

(b) Calculate the SNR value of the composite signal.

(c) Find the bandwidth of the signal and calculate the maximum capacity of the channel.

(d) What will be the signal level to achieve the data rate?

Performance Task A:

A1 = 2 + 0 + 2 = 4

A2 = 0 + 4 + 2 + 6

s = (4 + 3 + 2) / 30 = 9 / 30

Performance Task B :

Code:

```
close all;
clc;
%Define number of samples to take
fs = 8000; % Sampling frequency
A = 2;
B = 0;
C = 4;
D = 3;
E = 9;
F = 9;
G = 7;
H = 2;
t = 0:1/fs:1-1/fs;
A1 = A + B + H;
A2 = B + C + H;
s = (C + D + H)/30;
X = A1*sin(2*pi*((C + D + H)*100)*t) + A2*cos(2*pi*((E + D + H)*100)*t) + s*randn(size(t));
%noise
noise = s*randn(size(X));
noisySignal = X + noise;
SNR = snr(noisySignal) %Calculation of SNR using snr function
```

Command Window

```
>> %Define number of samples to take
fs = 8000; % Sampling frequency
A = 2;
B = 0;
C = 4;
D = 3;
E = 9;
F = 9;
G = 7;
H = 2;
t = 0:1/fs:1-1/fs;
A1 = A + B + H;
A2 = B + C + H;
s = (C + D + H)/30;
X = A1*sin(2*pi*((C + D + H)*100)*t) + A2*cos(2*pi*((E + D + H)*100)*t) + s*randn(size(t));
%noise
noise = s*randn(size(X));
noisySignal = X + noise;
SNR = snr(noisySignal) %Calculation of SNR using snr function

SNR =

    3.3805

fx >>
```

Fig 1: SNR value of the composite signal

Performance Task C :

Code:

```
fs = 8000; % Sampling frequency
%Define signal
t = 0:1/fs:1-1/fs;
A = 2;
B = 0;
C = 4;
D = 3;
E = 9;
F = 9;
G = 7;
H = 2;
%signal
A1 = A + B + H;
A2 = B + C + H;
s = (C + D + H)/30;
X = A1*sin(2*pi*((C + D + H)*100)*t) + A2*cos(2*pi*((E + D + H)*100)*t) + s*randn(size(t));
%noise
ns = s*randn(size(X));
S_N_R = snr(X,ns);
bandwidth = obw(X,fs) % Bandwidth of the signal
%capacity
C = bandwidth*log2(1+S_N_R)
```

Command Window

```
>> fs = 8000; % Sampling frequency
%Define signal
t = 0:1/fs:1-1/fs;
A = 2;
B = 0;
C = 4;
D = 3;
E = 9;
F = 9;
G = 7;
H = 2;
%signal
A1 = A + B + H;
A2 = B + C + H;
s = (C + D + H)/30;
X = A1*sin(2*pi*((C + D + H)*100)*t) + A2*cos(2*pi*((E + D + H)*100)*t) + s*randn(size(t));
%noise
ns = s*randn(size(X));
S_N_R = snr(X,ns);
bandwidth = obw(X,fs) % Bandwidth of the signal
%capacity
C = bandwidth*log2(1+S_N_R)

bandwidth =

   500.9822


C =

   2.3448e+03

fx >>
```

Fig 2: Bandwidth of the signal and the maximum capacity of the channel

Performance Task D:

Code :

```
fs = 8000; % Sampling frequency
A = 2;
B = 0;
C = 4;
D = 3;
E = 9;
F = 9;
G = 7;
H = 2;
t = 0:1/fs:1-1/fs; % Time duration
A1 = A + B + H;
A2 = B + C + H;
s = (C + D + H)/30;
X = A1*sin(2*pi*((C + D + H)*100)*t) + A2*cos(2*pi*((E + D + H)*100)*t) + s*randn(size(t));
bandwidth = obw(X,fs) % Bandwidth of the signal
L=1.9;
BitRate = 2*bandwidth*log2(L)
L = 2.^(BitRate/(2*bandwidth)) %Signal level to achieve data rate
```

Command Window

```
>> fs = 8000; % Sampling frequency
A = 2;
B = 0;
C = 4;
D = 3;
E = 9;
F = 9;
G = 7;
H = 2;
t = 0:1/fs:1-1/fs; % Time duration
A1 = A + B + H;
A2 = B + C + H;
s = (C + D + H)/30;
X = A1*sin(2*pi*((C + D + H)*100)*t) + A2*cos(2*pi*((E + D + H)*100)*t) + s*randn(size(t));
bandwidth = obw(X,fs); % Bandwidth of the signal
L=1.9; % Level of the signal
BitRate = 2*bandwidth*log2(L)

BitRate =

  927.8188

>> L = 2.^(BitRate/(2*bandwidth))

L =

    1.9000

fx >>
```

Fig 3: The signal level to achieve the data rate

Discussion and Conclusion:

In the following experiment, the problem statement (b), the Signal-to-noise ratio (SNR) was determined. To determine the following value, two methods were implemented in MATLAB. In the MATLAB, there was a pre-determined function called 'snr' function. This function can determine the value of SNR by implementing the value signal. In the performance task, the noisy composite signal was implemented in the snr function and a value was obtained. Another way to determine the SNR value is using the definition of SNR. But using that formula can cause some errors in the calculation due to using approximation and manual input. Hence, the 'snr' function is used for the most accurate answer.

In the problem statement (c), bandwidth of the signal was determined using the built-in function - obw. The 'obw' function took the composite signal and the estimated sample frequency and provided the value of bandwidth. Using the SNR Value and Bandwidth, maximum capacity of the channel was calculated. This provided us with a value that tells us the highest theoretical data rate in the noisy channel in bits/sec.

In the problem statement (d), the level of the signal was determined at which the data rate could have been achieved. The signal level needed to be as low as possible as increasing level of signal reduces the reliability of the system. As the level of system matched with the preferred level of signal used on previous calculations, the signal level was appropriate for the data rate for the composite signal. Hence, all the objectives of the experiment were achieved.

References:

- Prakash C. Gupta, “Data communications”, Prentice Hall India Pvt.
- William Stallings, "Data and Computer Communications”, Pearson
- Forouzan, B. A. "Data Communication and Networking. Tata McGraw." (2005).
- AIUB Data Communication Engineering Lab Manual, Report 03