AMERICAN INTERNATIONAL UNIVERSITY–BANGLADESH (AIUB)

FACULTY OF ENGINEERING

DEPARTMENT OF COMPUTER ENGINEERING

DATA COMMUNICATION LABORATORY

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Section: I

Group: 4

EXPERIMENT NO : 3

Study of Nyquist bit rate and Shannon capacity using MATLAB

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Abstract:

This experiment aims to explore the application of MATLAB in solving communication engineering problems. Specifically, we seek to develop a practical understanding of Nyquist bit rate and Shannon capacity using MATLAB as our computational tool. Through hands-on exercises and simulations, we intend to bridge the gap between theory and application, enhancing our grasp of these critical communication concepts.

Theory:

I. Nyquist Bit Rate: The Nyquist bit rate formula defines the theoretical maximum bit rate for a noiseless channel.

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

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

II. Shannon capacity: Shannon capacity formula was introduced to determine the theoretical highest data rate for 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 is the capacity of the channel in bits per second.

III. Signal-to-noise ratio (SNR): To find the theoretical bit rate limit, we need to know the ratio of the signal power to the noise power. The signal-to-noise ratio is defined as,

$$\text{SNR} = \frac{Average\ Signal\ Power}{Average\ Noise\ Power}$$

We need to consider the average signal power and the average noise power because these may change with time. A high SNR means the signal is less corrupted by noise; a low SNR means the signal is more corrupted by noise.

Because SNR is the ratio of two powers, it is often described in decibel units, SNRdB, defined as

$$SNR_{dB} = 10log_{10}(SNR)$$

Results:

```
Command Window
>> fs = 8000; % Sampling frequency
>> t = 0:1/fs:1-1/fs; % Time duration
>> cx = 1.1*sin(2*pi*100*t) + 1.3*cos(2*pi*300*t) + 1.5*sin(2*pi*2000*t);
>> bandwidth = obw(cx,fs); % Bandwidth of the signal
>> L=2; % Level of the signal
>> BitRate = 2*bandwidth*log2(L)

BitRate =

   3.8019e+03

>>
```

Figure 1 : Nyquist bitrate Calculation

```
Command Window
>> fs = 8000; % Sampling frequency
>> f = 400; %Hz
>> t = 0:1/fs:1-1/fs;
>> A = 3.0;
>> powfund = A^2/2

powfund =

    4.5000

>> s = 0.1;
>> varnoise = s^2;
>> signal = A*sin(2*pi*f*t);
>> noise = s*randn(size(signal));
>> noisySignal = signal + noise;
>> SNR = snr(noisySignal) %Calculation of SNR using snr function

SNR =

   26.6065

>> defSNR = 10*log10(powfund/varnoise) %Calculation of SNR following the definition

defSNR =

   26.5321

>>
```

Figure 2 : Calculation of SNR

```
Command Window
>> fs = 8000; % Sampling frequency
>> f = 3; %Hz
>> t = 0:1/fs:1-1/fs;
>> A = 2;
>> s = 0.4;
>> x = A*sin(2*pi*f*t);
>> ns = s*randn(size(signal));
>> S_N_R = snr(x,ns);
>> bandwidth = obw(x,fs); % Bandwidth of the signal
>> C = bandwidth*log2(1+SNR) % Capacity of the channel

C =

    4.7391

>>
```

Figure 3 : Shannon Capacity Calculation

Performance Task:

ID = AB-CDEFG-H **ID** = 21-44998-2	C+D+H = 10 D+E+H = 15	x = A1*sin(2π(10*100)t) + A2*cos(2π(15*100)t) + s*randn(size(t));

a) A1 = A+B+H = 5
A2 = B+C+H = 7
s = C+D+H/30 = 0.33

b)

```
%Id:21-44998-2
A1=5;
A2=7;
s=0.33;
fs=40000;
t = 0:1/fs:1-1/fs;
powfund=(A1^2)/2+(A2^2)/2;
varnoise=s^2;
CDH=10;
DEH=15;
x =
A1*sin(2*pi*(CDH*100)*t)+A2*cos(2*pi*(DEH*100)*
t)+s*randn(size(t));
noise= s*randn(size(t));
SNR=powfund/varnoise
dfSNR=10*log10(powfund/varnoise)
```

Command Window

```
>> %Id:21-44998-2
A1=5;
A2=7;
s=0.33;
fs=40000;
t = 0:1/fs:1-1/fs;
powfund=(A1^2)/2+(A2^2)/2;
varnoise=s^2;
CDH=10;
DEH=15;
>> x = A1*sin(2*pi*(CDH*100)*t)+A2*cos(2*pi*(DEH*100)*t)+s*randn(size(t));
>> noise= s*randn(size(t));
>> SNR=powfund/varnoise
dfSNR=10*log10(powfund/varnoise)

SNR =

  339.7612


dfSNR =

   25.3117

>>
```

Figure 4 : SNR value calculation of the composite signal

c)

```
%Id:21-44998-2
A1=5;
A2=7;
s=0.33;
fs=40000;
t = 0:1/fs:1-1/fs;
powfund=(A1^2)/2+(A2^2)/2;
varnoise=s^2;
CDH=10;
DEH=15;
x =
A1*sin(2*pi*(CDH*100)*t)+A2*cos(2*pi*(DEH*100)*
t)+s*randn(size(t));
noise= s*randn(size(t));
SNR=powfund/varnoise;
dfSNR=10*log10(powfund/varnoise);
bandwidth = obw(x,fs)
capacity1=bandwidth*log2(1+SNR)
capacity2=bandwidth*log2(1+dfSNR)
```

Command Window

```
A1=5;
A2=7;
s=0.33;
fs=40000;
t = 0:1/fs:1-1/fs;
powfund=(A1^2)/2+(A2^2)/2;
varnoise=s^2;
CDH=10;
DEH=15;
>> x = A1*sin(2*pi*(CDH*100)*t)+A2*cos(2*pi*(DEH*100)*t)+s*randn(size(t));
>> noise= s*randn(size(t));
>> SNR=powfund/varnoise;
>> dfSNR=10*log10(powfund/varnoise);
>> bandwidth = obw(x,fs)
capacity1=bandwidth*log2(1+SNR)
capacity2=bandwidth*log2(1+dfSNR)

bandwidth =

  500.9821


capacity1 =

   4.2146e+03


capacity2 =

   2.3635e+03
```

Figure 5 : Bandwidth and maximum capacity Calculation

```
d) %Id:21-44998-2
A1=5;
A2=7;
s=0.33;
fs=40000;
t = 0:1/fs:1-1/fs;
powfund=(A1^2)/2+(A2^2)/2;
varnoise=s^2;
CDH=10;
DEH=15;
x =
A1*sin(2*pi*(CDH*100)*t)+A2*cos(2*pi*(DEH*100)*
t)+s*randn(size(t));
noise= s*randn(size(t));
SNR=powfund/varnoise;
dfSNR=10*log10(powfund/varnoise);
bandwidth = obw(x,fs);
DataRate1=floor(bandwidth*log2(1+SNR))
DataRate2=floor(bandwidth*log2(1+dfSNR))
level1=floor(2^(DataRate1/(2*bandwidth)))
level2=floor(2^(DataRate2/(2*bandwidth)))
```

```
Command Window
>> A1=5;
A2=7;
s=0.33;
fs=40000;
t = 0:1/fs:1-1/fs;
powfund=(A1^2)/2+(A2^2)/2;
varnoise=s^2;
CDH=10;
DEH=15;
>> x = A1*sin(2*pi*(CDH*100)*t)+A2*cos(2*pi*(DEH*100)*t)+s*randn(size(t));
>> SNR=powfund/varnoise;
dfSNR=10*log10(powfund/varnoise);
bandwidth = obw(x,fs);
>> DataRate1=floor(bandwidth*log2(1+SNR))
DataRate2=floor(bandwidth*log2(1+dfSNR))
level1=floor(2^(DataRate1/(2*bandwidth)))
level2=floor(2^(DataRate2/(2*bandwidth)))

DataRate1 =

        4214


DataRate2 =

        2363


level1 =

    18


level2 =

     5
```

Figure 6 : Signal levels to achieve the Data rate

Discussion & Conclusion:

In the Experiment, various functionalities of MATLAB were observed in hand. Various functions that were available on MATLAB were learned and observed. The Nyquist bitrate of a noiseless channel was calculated using MATLAB, followed by the determination of the SNR of the channel and the calculation of Shannon capacity for a noisy channel. Subsequently, for a composite signal, the SNR, bandwidth, and capacity of the signal were computed.

References:

[1] W. Stallings, Data and computer communications. 2000., Accessed: Oct. 3, 2023. [Online]. Available:https://www.portcity.edu.bd/files/636444710465881602_Dataandcomputercommunications.pdf [Online Copy]

[2] B. A. Forouzan, C. A. Coombs, and S. C. Fegan, Introduction to data communications and networking. McGraw-Hill Science, Engineering & Mathematics, 1998., Accessed: Oct. 3, 2023. [Online]. Available: https://archive.mu.ac.in/myweb_test/syllFybscit/dcn.pdf [Online Copy]