American International University- Bangladesh Department of Electrical and Electronic Engineering

COE 3201: Data Communication Laboratory

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

Abstract:

This experiment is designed to-

- 1.To understand the use of MATLAB for solving communication engineering problems.
- 2.To develop 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 noiseless channel.

$$BitRate = 2 \times bandwidth \times log_2L$$

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
$$\times log_2(1 + SNR)$$

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.

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

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

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.

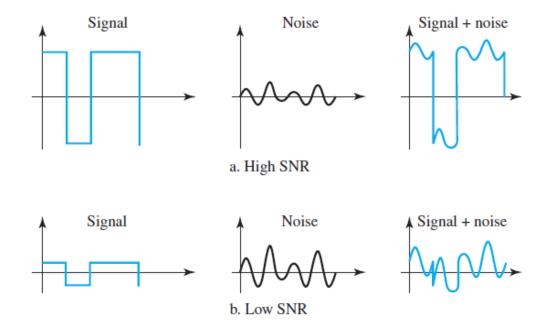


Fig: Two cases of SNR: a high SNR and a low SNR

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

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

Example of Nyquist bit rate calculation for a noiseless channel:

```
close all;
clc;
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)
```

Output:

BitRate =

3.8019e+03

Example: Calculation of SNR

```
close all;
clc;
%Define number of samples to take
fs = 8000; % Sampling frequency
f = 400; %HZ
%Define signal
t = 0:1/fs:1-1/fs;
A = 3.0;
powfund = A^2/2
s = 0.1;
varnoise = s^2;
signal = A*sin(2*pi*f*t);
%noise
noise = s*randn(size(signal));
%noisy signal
noisySignal = signal + noise;
SNR = snr(noisySignal) %Calculation of SNR using snr
function
defSNR = 10*log10(powfund/varnoise) %Calculation of
SNR following the definition
```

SNR =

26.2571

defSNR =

26.5321

Similar task can be done considering a noisy composite signal. Suppose our composite signal is, signal = 1.5*sin(2*pi*2*t)+0.9*cos(2*pi*10*t)+1.1*sin(2*pi*20*t)+0.13*randn(size(t));

*****Calculate the SNR value of the signal.

Example of Shannon capacity calculation for a noisy channel:

```
clc
close all
fs = 8000; % Sampling frequency
f = 3; %Hz
%Define signal
t = 0:1/fs:1-1/fs;
A = 2;
s = 0.4;
%signal
x = A*sin(2*pi*f*t);
%noise
ns = s*randn(size(signal));
S N R = snr(x, ns);
bandwidth = obw(x,fs); % Bandwidth of the signal
%capacity
C = bandwidth*log2(1+SNR) % Capacity of the channel
```

 $\mathbf{C} =$

6.6576e+04

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

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

```
x = A_1 \sin(2\pi((C+D+H)*100)t) + A_2 \cos(2\pi((D+E+H)*100)t) + s*randn(size(t));
```

- (a) Select the value of the amplitudes as follows: let $A_1 = (A+B+H)$, $A_2 = (B+C+H)$ 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?