

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.

$$\text{BitRate} = 2 \times \text{bandwidth} \times \log_2 L$$

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:

$$\text{Capacity} = \text{bandwidth} \times \log_2(1 + \text{SNR})$$

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

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

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.

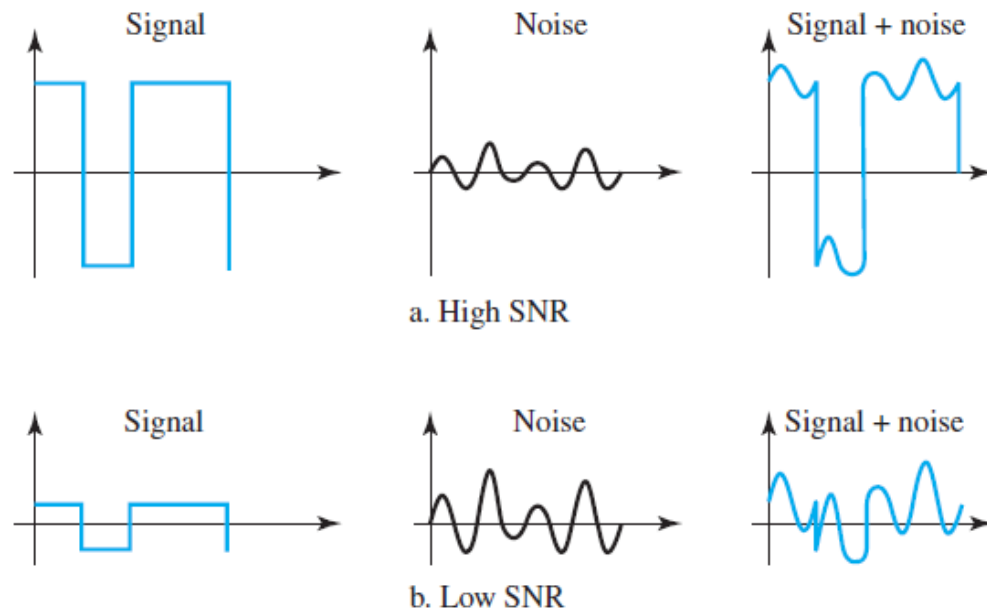


Fig: Two cases of SNR: a high SNR and a low SNR

Because SNR is the ratio of two powers, it is often described in decibel units, SNR_{dB} , defined as

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

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.**

Total harmonic distortion (THD): The total harmonic distortion (THD) is a measurement of the harmonic distortion present in a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

When a signal passes through a non-ideal, non-linear device, additional content is added at the harmonics of the original frequencies. THD is a measurement of the extent of that distortion.

Signal to noise and distortion ratio (SINAD): Signal-to-noise and distortion ratio (SINAD) is a measure of the quality of a signal from a communications device, often defined as

$$SINAD = \frac{P_{signal}}{P_{noise} + P_{distortion}}$$

Create a sinusoidal signal sampled at 48 kHz. The signal has a fundamental of frequency 1 kHz and unit amplitude. It additionally contains a 2 kHz harmonic with half the amplitude and additive noise with variance 0.1².

```
fs = 48e3;
t = 0:1/fs:1-1/fs;
A = 1.0;
powfund = A^2/2;
a = 0.4;
powharm = a^2/2;
s = 0.1;
varnoise = s^2;
x = A*cos(2*pi*1000*t) + a*sin(2*pi*2000*t) +
s*randn(size(t));

THD = thd(x); % Total harmonic distortion
defTHD = 10*log10(powharm/powfund);
TH = [THD defTHD]

SINAD = sinad(x); % Signal to noise and distortion
ratio
defSINAD = 10*log10(powfund/(powharm+varnoise));
SI = [SINAD defSINAD]
```

Output:

TH = 1×2

-7.9546 -7.9588

SI = 1×2

7.4571 7.4473

Example of Shannon capacity calculation for a noisy channel:

```
SNR = snr(x);
bandwidth = obw(x,fs); % Bandwidth of the signal

C = bandwidth*log2(1+SNR) % Capacity of the channel
```

C =

6.6576e+04

Software:

MATLAB2016a

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

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

$$x = A_1 \sin(2\pi(\text{C} \cdot 100)t) + A_2 \cos(2\pi(\text{G} \cdot 100)t) + s \cdot \text{randn}(\text{size}(t));$$

- (a) Select the value of the amplitudes as follows: let $A_1 = \text{AB}$, $A_2 = \text{AF}$ and $s = \text{AH}$
- (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?