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**AMERICAN INTERNATIONAL UNIVERSITY–BANGLADESH (AIUB)**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF COMPUTER ENGINEERING**

**DATA COMMUNICATION LABORATORY**

**Fall 2023-2024  
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 × 𝑏𝑎𝑛𝑑𝑤𝑖𝑑𝑡ℎ × 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 × 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,  
   
 SNR =

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)

**Results:**

Figure 1 : Nyquist bitrate Calculation Figure 2 : Calculation of SNR

Figure 3 : Shannon Capacity Calculation

|  |  |  |
| --- | --- | --- |
| **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)); |

**Performance Task:**

|  |  |
| --- | --- |
| 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) |  |

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) |  |

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))) |  |

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].

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**[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]