Tecnológico de Monterrey **Campus Ciudad de México** **School of Engineering and Sciences** **Department of Mechatronics**	**TE2019 Digital Signal Processing Laboratory** Student's 1 name and ID: Alfredo Zhu Chen - A01651980 Student's 2 name and ID: Luis Arturo Dan Fong - A016506720 Lab # 2 Sampling and Quantization Date: 26/02/2020

1 INTRODUCTION

This lab experiment consists of understanding the process of sampling and quantization in MATLAB as well as testing different bits for the quantization script in *WorkedExample2* and comparing the graphs and the SNR(Signal Noise Ratio) of each other while creating a table in which different bits would represent various SNR as a consequence.

OBJECTIVES

1. To implement sampling and quantization simulation in MATLAB.
2. To evaluate the impact of parameters involved in quantization on the signal-to-noise ratio.
3. To implement basic to medium complexity algorithms in MATLAB.

2 MATERIALS & METHODS

The materials used in this laboratory were:

- The word file with the instructions
- A computer with MATLAB software installed
- Zip File *Scripts+Data.zip* with the examples

After unzipping the files provided by the professor, we decided to first try the *WorkedExample1* and the *WorkedExample2* to understand their functioning. After that, we would modify them to work adequately for data in *speech.dat* and *siesmic.dat* so that we can analyze the results of sampling and quantization. We figured out where to insert the loop to obtain all SNR values for all bits for quantization, we tested our code and then graphed the results.

We made two copies of *WorkedExample2* and modified several values in order to adapt it for our final purposes, such as the file name of the data and sampling frequency. Likewise, the *biquant* command is used for the quantization process, which has parameters like number of bits for quantization, minimum value, maximum value and original data. We added a *for* loop to iterate over the numbers of bits for the quantization(3-15 for *speech.dat* and 13-31 for *seismic.dat*), this is useful for later comparisons.

```
%% Quantization process
snrValues=[]
for bits=3:15

    for i=1:N;
      [I(i), Xq(i)] = biquant(bits, -5, 5, X(i));   % Quantization index and level
    end

    eq = X-Xq;                                    % Calculates the quantization error

```

Figure 1. Quantization process

Inside the *for* loop which evaluates all numbers of bits for the quantization, we added an if condition to plot representative figures containing original signal plot, quantized signal plot and quantization error plot. We compare when bits are 3,8 and 15 for *speech.dat* ;13,18,25 and 31 for *seismic.dat*.

```
    %% Plotting for specific bits of quantization
    if bits==3||bits==8||bits==15;
        figure(bits);
        subplot(3,1,1);
        plot(t, X);     % Original signal
        xlabel('Time (s)')
        ylabel('x(t)')
        title('Original signal')
        grid on

        subplot(3,1,2);
        stairs(t, Xq); % Quantized signal
        xlabel('Time (s)')
        ylabel('x_{q}(t)')
        title("Quantized signal with "+bits+" bits")
        grid on

        subplot(3,1,3);
        stairs(t, eq); %Quantization error
        xlabel('Time (s)')
        ylabel('e_{q}(t)')
        title("Quantization error with "+bits+" bits")
    end
```

Figure 2. Generating representative figures with plots

The following part of the code computes SNR due to quantization and the values are stored in the array snrValues with the corresponding index.

```
    %% Computing SNR
    disp('Signal power to quantization error noise:');
    snrValues(bits-2)=snr(X,Xq);
```

Figure 3. Computing SNR

We used *sound* function to hear sound quality after quantization. The example below is used to test when there are 4 bits for quantization and it is only used for *speech.dat.*

```
68      %%
69      %%Produce quantized audio signal when using specifc bits of quantization
70 -    if bits==4
71 -        sound(Xq/max(abs(Xq)),8000);
72 -    end
```

Figure 4. Sound quality evaluation

3 RESULTS AND DISCUSSION

After analyzing the figure 5 given after the loop from 3 to 15 bits, it is clear that there is a direct proportion between the number of bits and the amount of SNR produced, although the graphs from the 3, 8, and 15 bits showed in the same relation(figure 6,7 and 8). When there are more bits of quantization the SNR is bigger and this indicates that the signal is much more high than the noise, thus preserving much information of the original signal.

Table1. Bits vs SNR(dB) - Speech

Bits	SNR (dB)
3	6.9400 dB
4	11.3159 dB
5	16.3573 dB
6	21.2231 dB
7	26.7621 dB
8	32.5606 dB
9	38.4213 dB
10	43.8753 dB
11	49.4182 dB
12	55.3042 dB
13	61.2876 dB
14	67.3104 dB
15	73.3009 dB

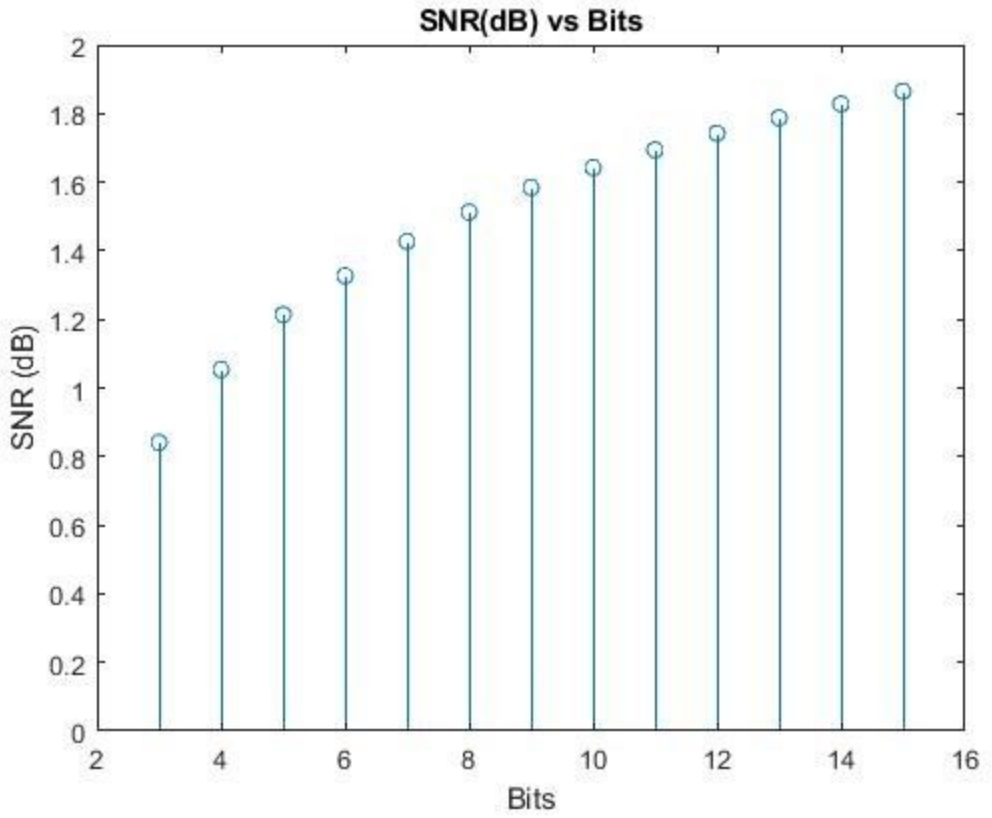

Figure 5. SNR(dB) vs Bits Graph - speech

By comparing the data quantized using 3,8 and 15 bits, we can see that using 15 bits has less error of quantization and the quantized signal is very identical to the original one. Using 8 bits we still see some similarities between the quantized signal and the original one, but the error is higher than when using 15 bits. Furthermore, using 3 bits has much higher error and the quantized signal is evidently different from the original one.

When more bits are used for quantization, the quality of the sound is more preserved rather than using less bits. This indicates that important information of the signal is lost when there are not enough bits for quantization.

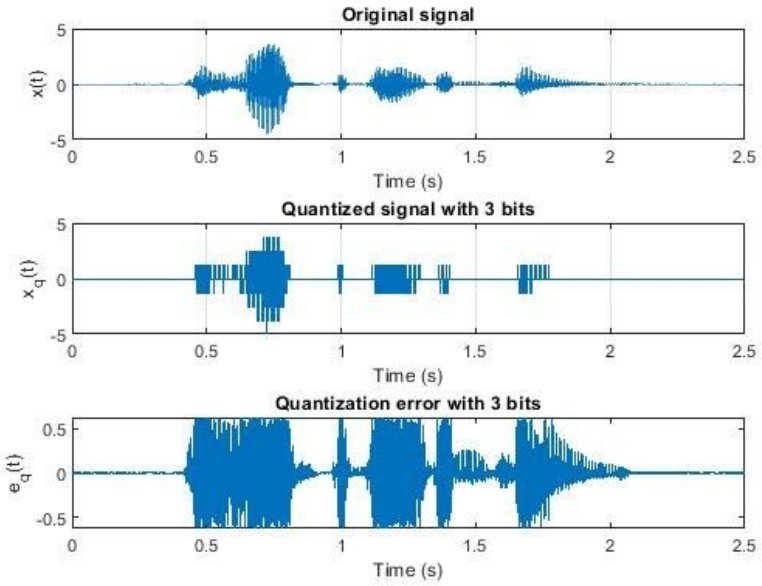

Figure 6. Original Speech and Quantized speech - 3 bits speech

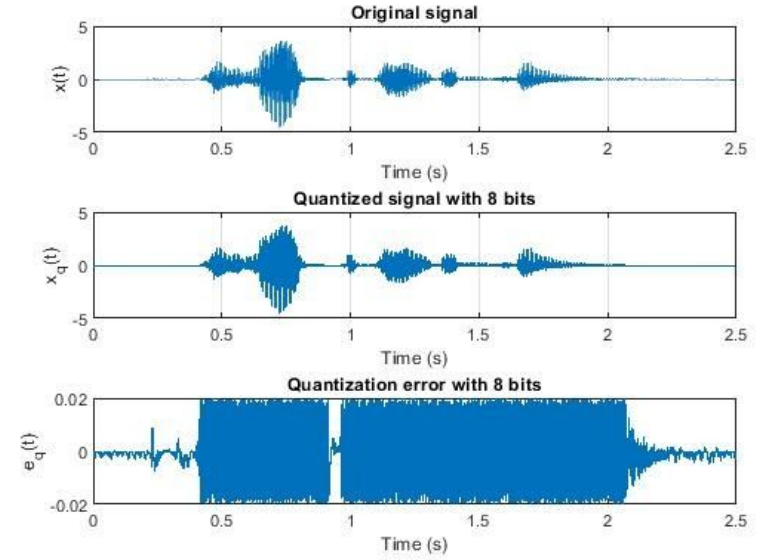

Figure 7. Original Speech and Quantized Speech - 8 bits specch

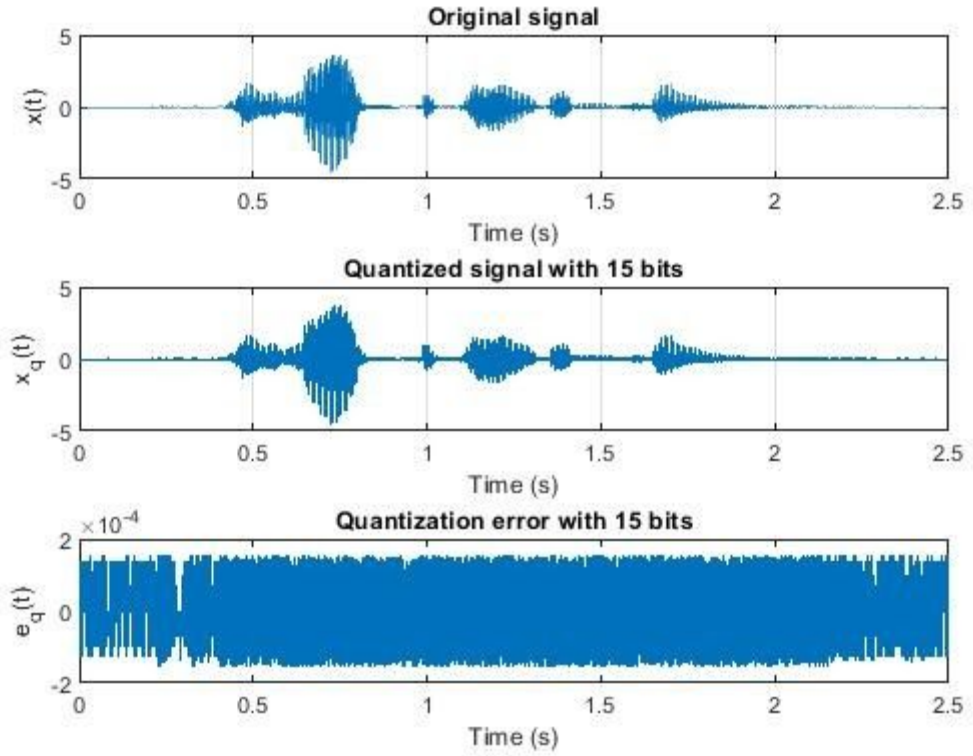

Figure 8. Original Speech vs Quantized Speech - 15 bits speech

The seismic data tends to have similar behavior to speech data, using more bits of quantization could provide less quantization error and maintain more properties of the original signal. Comparing 13,18,25 and31 bits of quantization, there wasn't a lot of difference between quantized signal and original signal, this is due to using enough bits of quantization in order to not lose much information.

Table 2. Bits vs SNR (dB) - Seismic

Bits	SNR (dB)
13	60.9191 dB
14	67.0418 dB
15	73.0109 dB
16	78.9328 dB
17	85.0823 dB
18	91.1005 dB
19	96.9778 dB
20	103.1416 dB
21	109.0905 dB

22	115.2497 dB
23	121.1201 dB
24	127.1505 dB
25	133.2452 dB
26	139.2358 dB
27	145.1943 dB
28	151.2604 dB
29	157.2679 dB
30	163.3505 dB
31	169.2519 dB

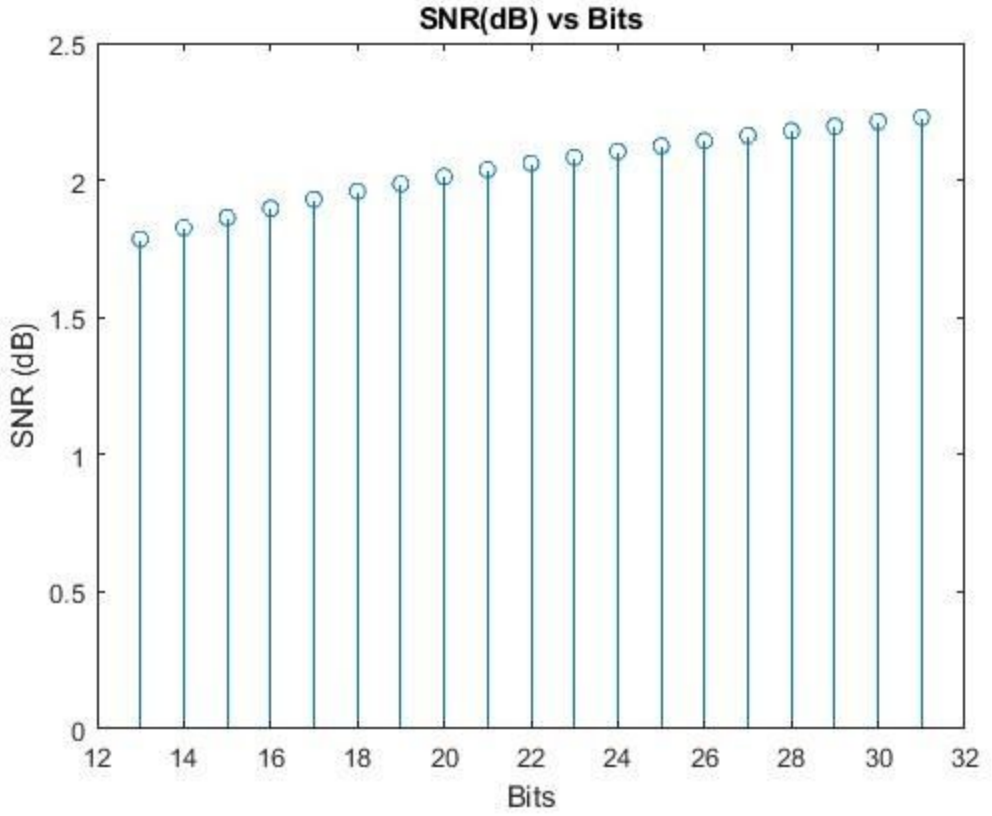

Figure 9. SNR(dB) vs Bits Graph - seismic

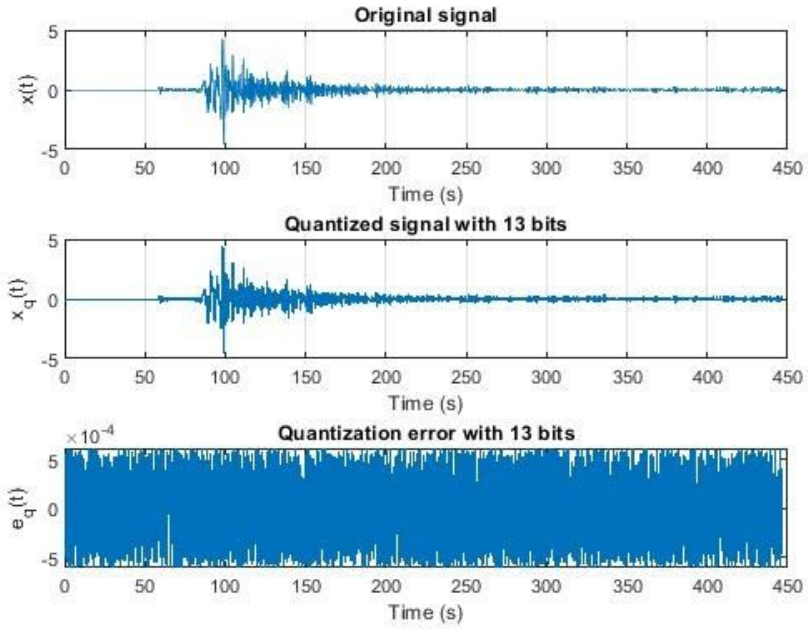

Figure 10. Original Speech vs Quantized Speech - 13 bits seismic

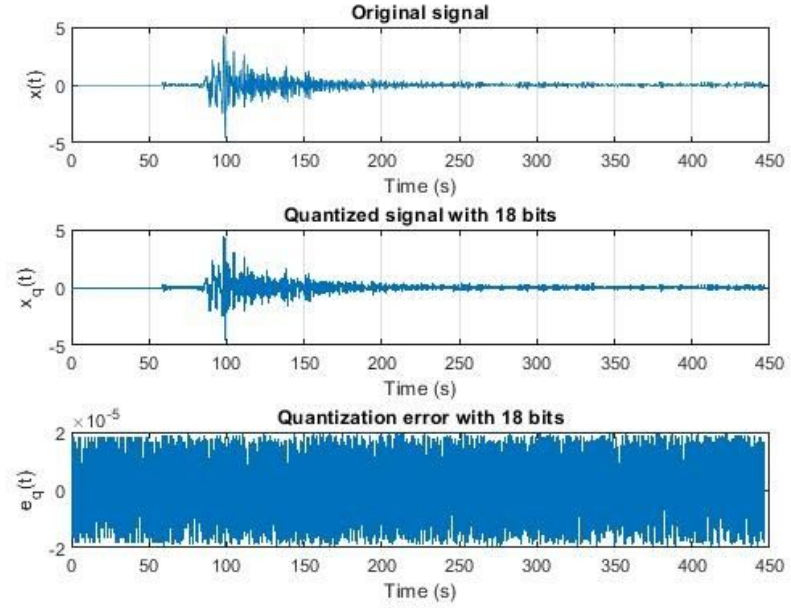

Figure 10. Original Speech vs Quantized Speech - 18 bits seismic

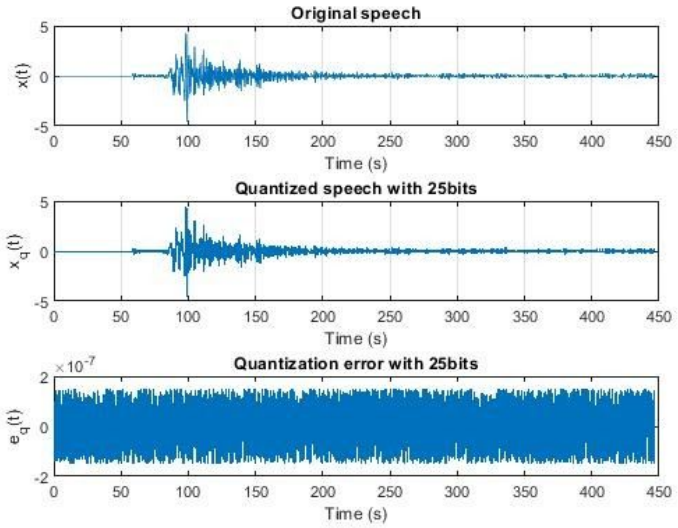

Figure 11. Original Speech vs Quantized Speech - 25 bits seismic

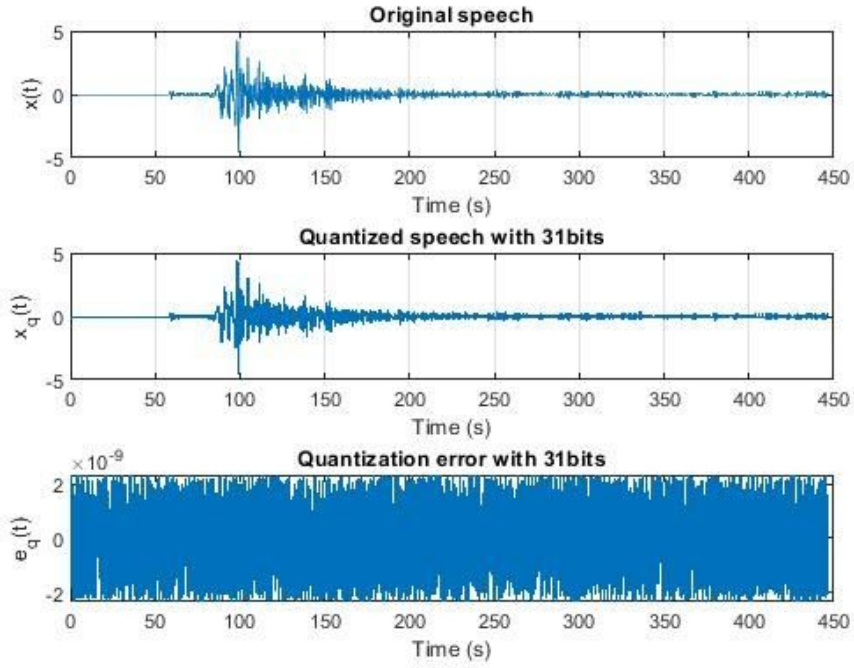

Figure 12. Original Speech vs Quantized Speech - 31 bits seismic

4 CONCLUSION

We can conclude that there is a direct relationship between the number of bits used for the quantization process and the resulting SNR. Likewise, the objectives planned for the experiment were achieved, by sampling and quantizing the data, as well as identifying the impact of the parameters in those processes; and finally modifying the script for creating a slightly more complex algorithm that allowed us to automatize graphing the data.