Hacettepe University

Department of Electrical and Electronics Engineering

ELE 409 Digital Signal Proccessing Laboratory

EXPERIMENT 3 – QUANTIZATION

PRELIMINARY WORK

Ziya Tuna Bölükbaşı

21628166

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1)

Matlab Code

```
clc;
clear all;
close all;
[x,n]=SinSamples(3,2*pi,0,2,2*pi*50);
midtread_of_x=midtread(x,3,3);
midrise_of_x=midrise(x,3,3);
error_MtoX=midtread_of_x-x;% error of midtread of x
error_MroX=midrise_of_x-x;% error of midrise of x
sum_tread=sum(midtread_of_x.*conj(midtread_of_x))/sum(error_MtoX.*conj(error_MtoX))
sum_rise=sum(midrise_of_x.*conj(midrise_of_x))/sum(error_MroX.*conj(error_MroX))
snr_of_tread=10*log10(sum_tread);
snr_of_rise=10*log10(sum_rise);
figure;
grid on;
subplot(2,1,1),stem(n,x),title('Original Signal of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(n,midtread_of_x),title('Quantized Version of x[n]'),xlabel('Sample
Number'),ylabel('Amplitude')
figure;
grid on;
subplot(2,1,1),stem(n,error_MtoX),title('Quantization Error of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(n,x,'g'),title('Original Signal of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(n,midtread_of_x,'*'),title('Quantized Version of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(n,error_MtoX,'k'),title('Process of Quantization'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
figure;
grid on;
subplot(2,1,1),stem(n,x),title('Original Signal of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(n,midrise_of_x),title('Quantized Version of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
figure;
grid on;
subplot(2,1,1),stem(n,error_MroX),title('Quantization Error of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(n,x,'g'),title('Original Signal of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(n,midrise_of_x,'*'),title('Quantized Version of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(n,error_MroX,'k'),title('Process of Quantization'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
function [x,n]=SinSamples(A,w,teta,d,ws)
fs=ws/(2*pi); % sampling frequency
ts=(2*pi)/ws; % sampling period
n=0:1:d/ts-1; %number of sample
x=A*sin(w*n*ts+teta);
end
function [Xm]=midtread(x,max_x,n)
min_x=-max_x;
k=2^n;
t=(max_x-min_x)/k;
x(x>=max_x)=max_x;
x(x<min_x)=min_x;
l=floor((x-min_x)/t+1/2);
Xm=min_x+l*t;
end
function [Xm]=midrise(x,max_x,n)
min_x=-max_x;
k=2^n;
t=(max_x-min_x)/k;
x(x>=max_x)=max_x-t;
x(x<min_x)=min_x;
l=floor((x-min_x)/t);
Xm=min_x+l*t+t/2;
end
```

a)

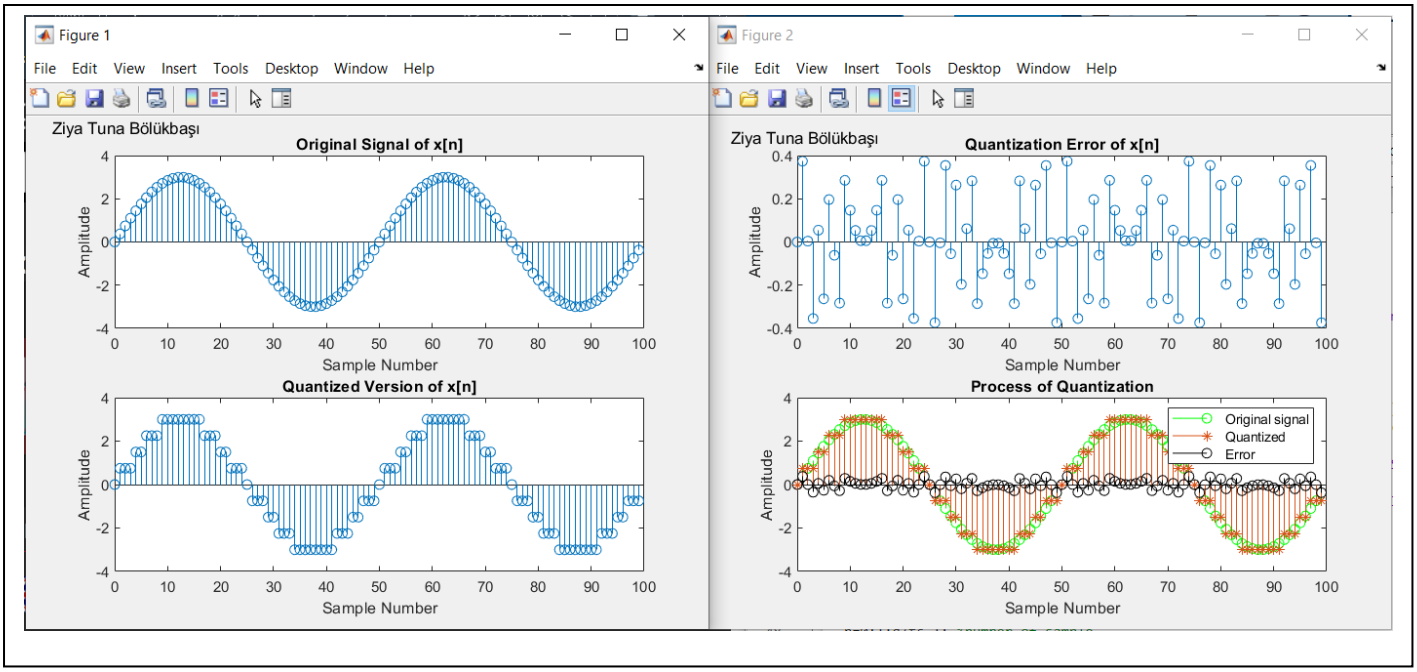


Figure 1
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Original Signal of x[n]
Amplitude
Sample Number
Quantized Version of x[n]
Amplitude
Sample Number
Figure 2
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Quantization Error of x[n]
Amplitude
Sample Number
Process of Quantization
Original signal
Quantized
Error
Amplitude
Sample Number

b)

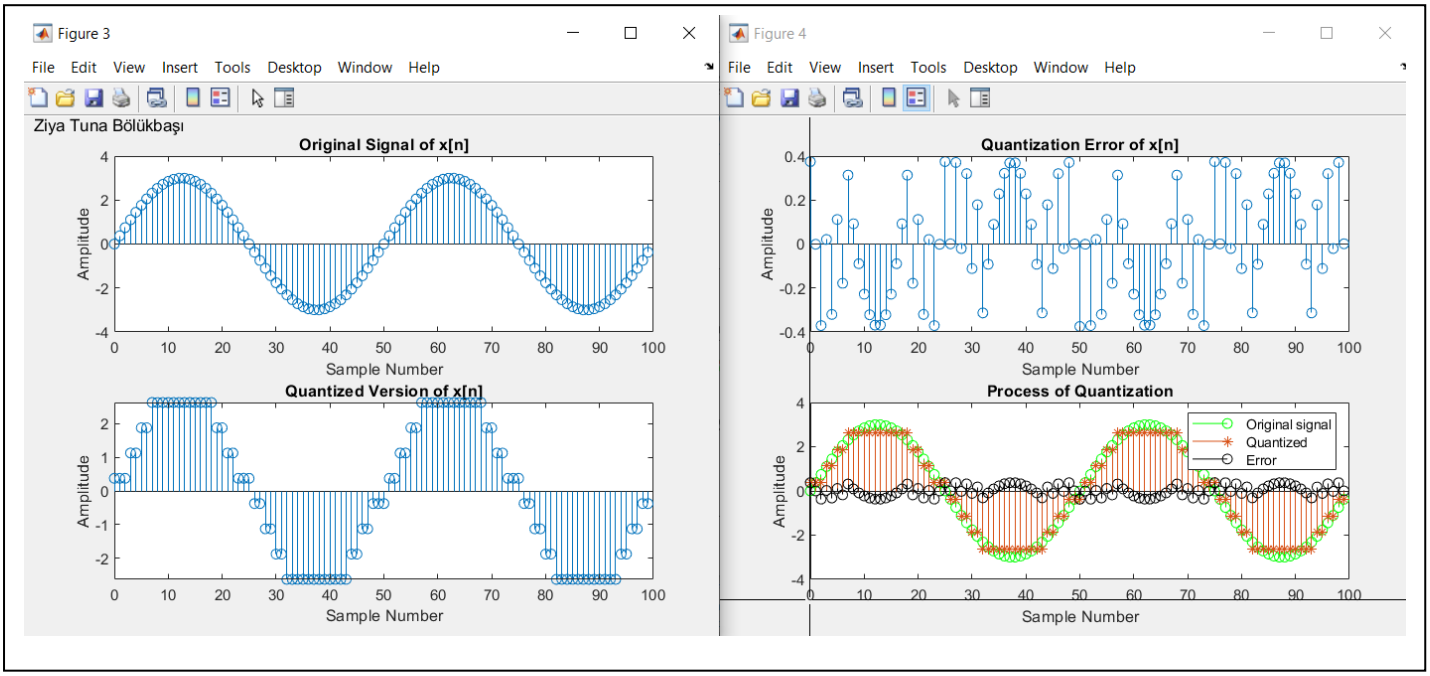
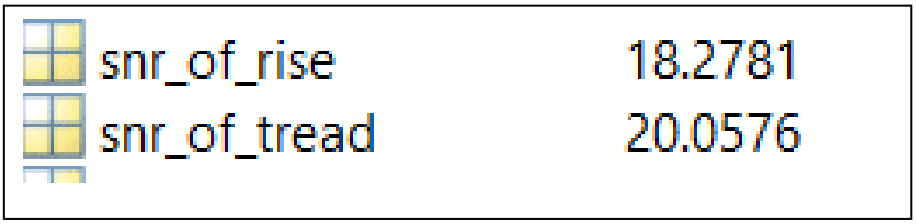


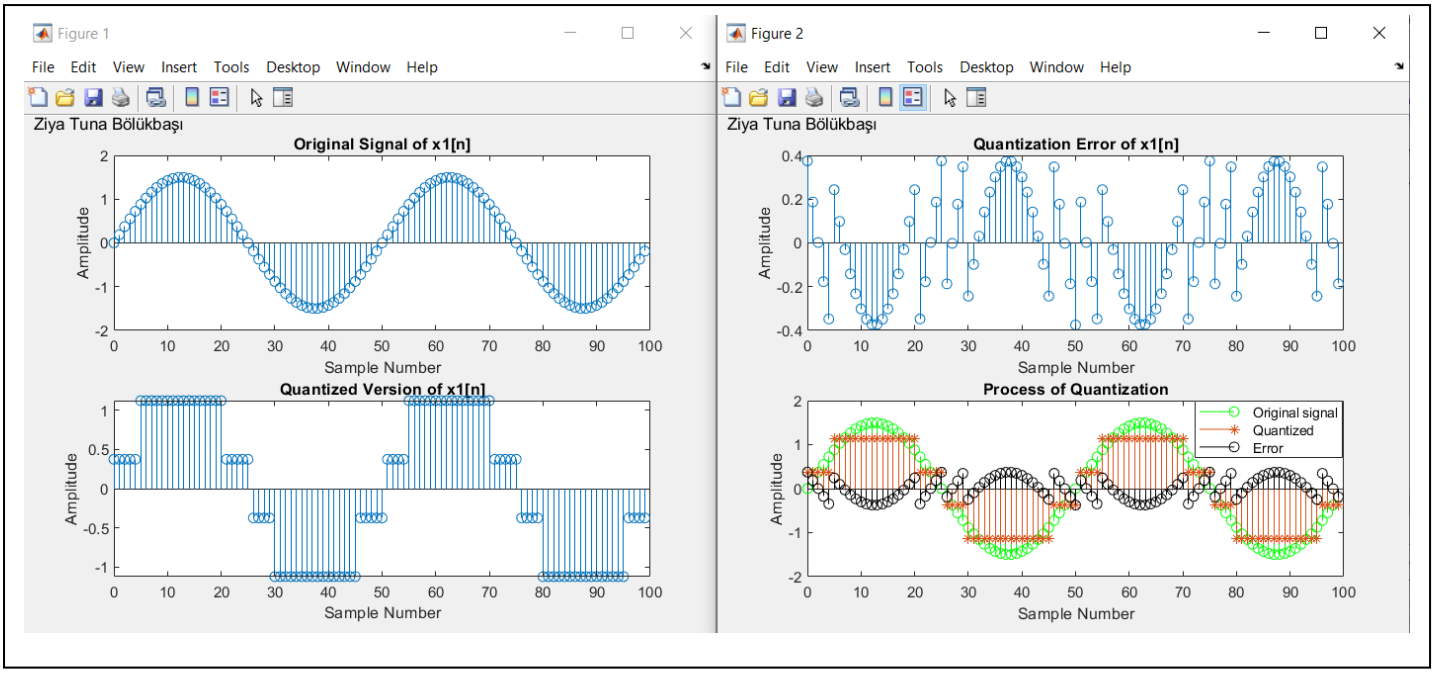
Figure 3
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Original Signal of x[n]
Amplitude
Sample Number
Quantized Version of x[n]
Amplitude
Sample Number
Figure 4
File Edit View Insert Tools Desktop Window Help
Quantization Error of x[n]
Amplitude
Sample Number
Process of Quantization
Original signal
Quantized
Error
Amplitude
Sample Number

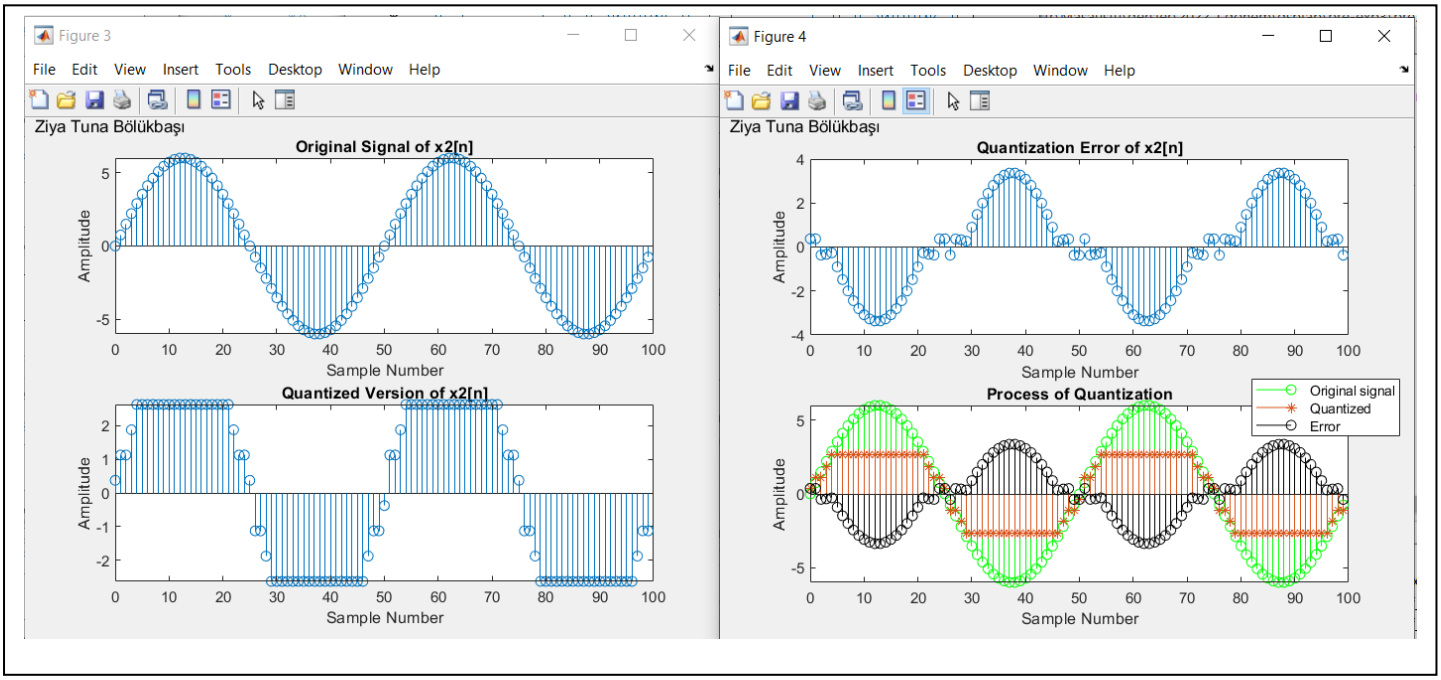

snr_of_rise
18.2781
snr_of_tread
20.0576

2)

Matlab Code

```
clc;
clear all;
close all;
[x,n]=SinSamples(3,2*pi,0,2,2*pi*50);
x1=0.5*x;
x2=2*x;
midrise_of_x1=midrise(x1,3,3);
midrise_of_x2=midrise(x2,3,3);
error_MroX1=midrise_of_x1-x1;% error of midrise of x
error_MroX2=midrise_of_x2-x2;% error of midrise of x
sum_rise_x1=sum(midrise_of_x1.*conj(midrise_of_x1))/sum(error_MroX1.*conj(error_MroX1))
sum_rise_x2=sum(midrise_of_x2.*conj(midrise_of_x2))/sum(error_MroX2.*conj(error_MroX2))
snr_of_rise_x1=10*log10(sum_rise_x1);
snr_of_rise_x2=10*log10(sum_rise_x2);
figure;
grid on;
subplot(2,1,1),stem(n,x1),title('Original Signal of x1[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(n,midrise_of_x1),title('Quantized Version of x1[n]'),xlabel('Sample
Number'),ylabel('Amplitude')
gtext('Ziya Tuna Bölükbaşı')
figure;
grid on;
subplot(2,1,1),stem(n,error_MroX1),title('Quantization Error of x1[n]'),xlabel('Sample
Number'),ylabel('Amplitude')
subplot(2,1,2),stem(n,x1,'g'),title('Original Signal of x1[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(n,midrise_of_x1,'*'),title('Quantized Version of x1[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(n,error_MroX1,'k'),title('Process of Quantization'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
gtext('Ziya Tuna Bölükbaşı')
figure;
grid on;
subplot(2,1,1),stem(n,x2),title('Original Signal of x2[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(n,midrise_of_x2),title('Quantized Version of x2[n]'),xlabel('Sample
Number'),ylabel('Amplitude')
gtext('Ziya Tuna Bölükbaşı')
figure;
grid on;
subplot(2,1,1),stem(n,error_MroX2),title('Quantization Error of x2[n]'),xlabel('Sample
Number'),ylabel('Amplitude')
subplot(2,1,2),stem(n,x2,'g'),title('Original Signal of x2[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(n,midrise_of_x2,'*'),title('Quantized Version of x2[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(n,error_MroX2,'k'),title('Process of Quantization'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
gtext('Ziya Tuna Bölükbaşı')
function [x,n]=SinSamples(A,w,teta,d,ws)
fs=ws/(2*pi); % sampling frequency
ts=(2*pi)/ws; % sampling period
n=0:1:d/ts-1; %number of sample
x=A*sin(w*n*ts+teta);
end
function [Xm]=midrise(x,max_x,n)
min_x=-max_x;
k=2^n;
t=(max_x-min_x)/k;
x(x>=max_x)=max_x-t;
x(x<min_x)=min_x;
l=floor((x-min_x)/t);
Xm=min_x+l*t+t/2;
end
```





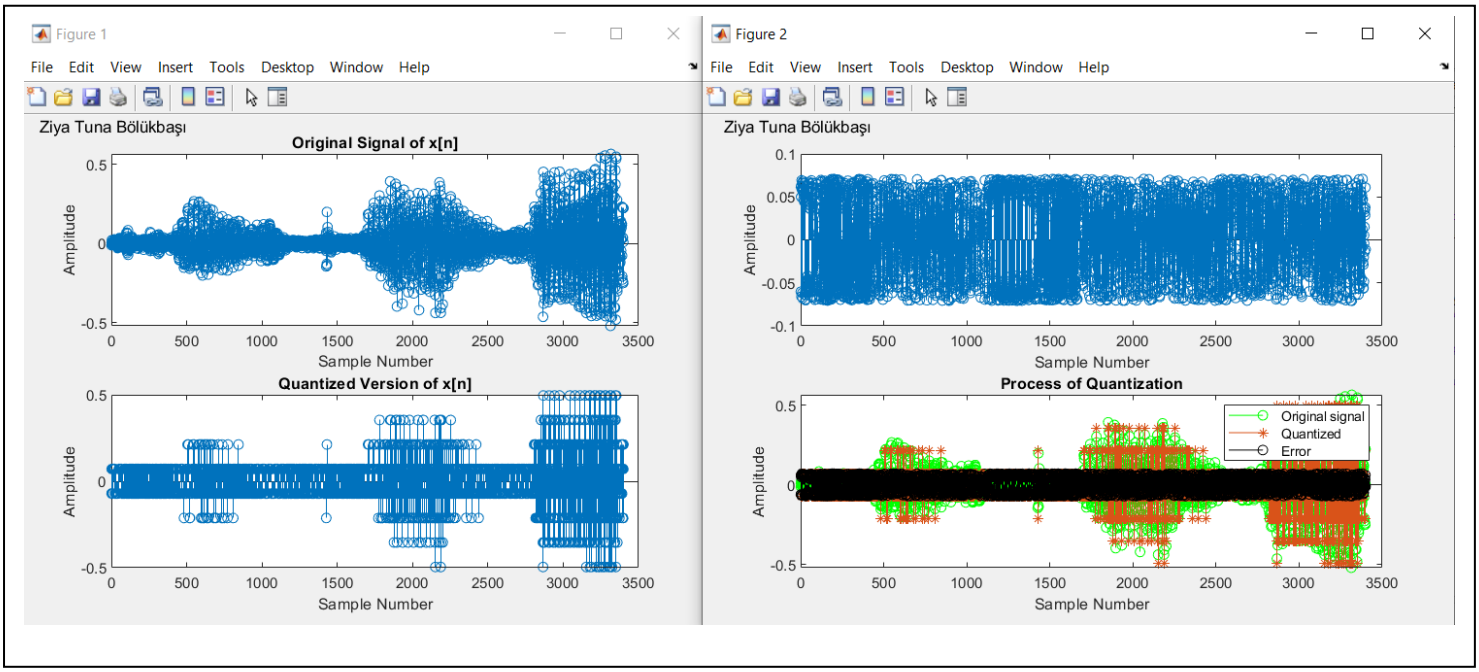
snr_of_rise_x1	11.5548
snr_of_rise_x2	1.1040

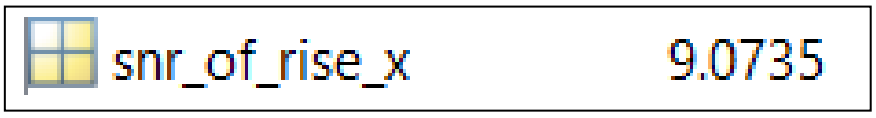
As the size of the signal increases, the number and size of the error increases and the snr value decreases. However, as the size of the signal decreases, the number and size of the error decreases and the snr value increases.

3)

Matlab Code

```
clc;
clear all;
close all;
[x,Fs]=audioread('C:\Users\Tuna\OneDrive - hacettepe.edu.tr\Masaüstü\sound3.wav');
max_x=max(x);
midrise_of_x=midrise(x,max_x,3);
error_MroX=midrise_of_x-x;
sum_rise_x=sum(midrise_of_x.*conj(midrise_of_x))/sum(error_MroX.*conj(error_MroX))
snr_of_rise_x1=10*log10(sum_rise_x);
figure;
grid on;
subplot(2,1,1),stem(x),title('Original Signal of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(midrise_of_x),title('Quantized Version of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
gtext('Ziya Tuna Bölükbaşı')
figure;
grid on;
subplot(2,1,1),stem(error_MroX),title('Quantization Error of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(x,'g'),title('Original Signal of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(midrise_of_x,'*'),title('Quantized Version of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(error_MroX,'k'),title('Process of Quantization'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
gtext('Ziya Tuna Bölükbaşı')
sound(midrise_of_x);
function [Xm]=midrise(x,max_x,n)
min_x=-max_x;
k=2^n;
t=(max_x-min_x)/k;
x(x>=max_x)=max_x-t;
x(x<min_x)=min_x;
l=floor((x-min_x)/t);
Xm=min_x+l*t+t/2;
end
```



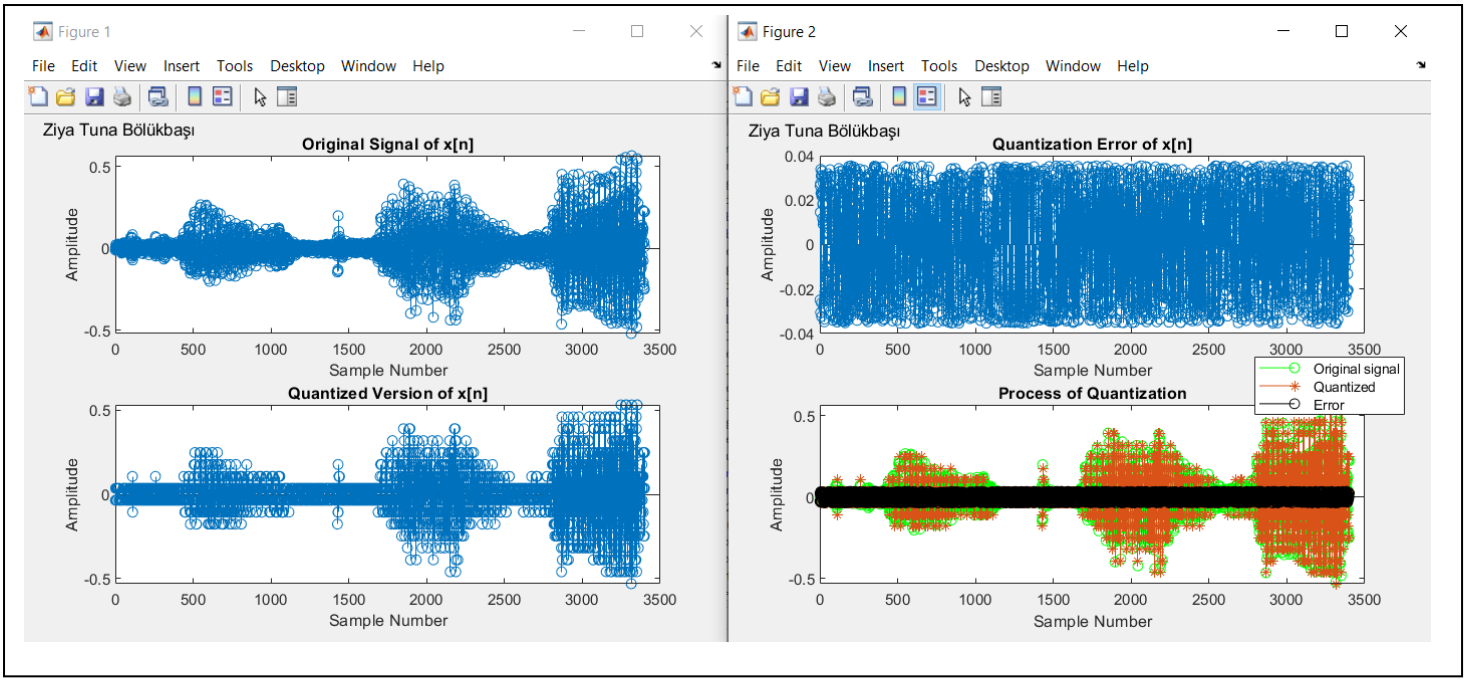


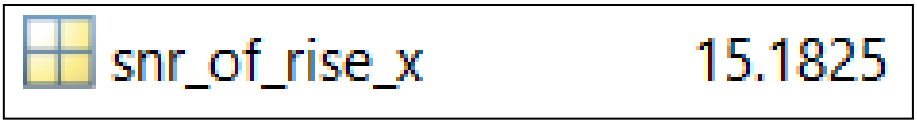
4)

Matlab Code

```
clc;

clear all;
close all;
[x,Fs]=audioread('C:\Users\Tuna\OneDrive - hacettepe.edu.tr\Masaüstü\sound3.wav');
max_x=max(x);
midrise_of_x=midrise(x,max_x,4);
error_MroX=midrise_of_x-x;
sum_rise_x=sum(midrise_of_x.*conj(midrise_of_x))/sum(error_MroX.*conj(error_MroX))
snr_of_rise_x1=10*log10(sum_rise_x);
figure;
grid on;
subplot(2,1,1),stem(x),title('Original Signal of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(midrise_of_x),title('Quantized Version of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
gtext('Ziya Tuna Bölükbaşı')
figure;
grid on;
subplot(2,1,1),stem(error_MroX),title('Quantization Error of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
subplot(2,1,2),stem(x,'g'),title('Original Signal of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(midrise_of_x,'*'),title('Quantized Version of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
stem(error_MroX,'k'),title('Process of Quantization'),xlabel('Sample Number'),ylabel('Amplitude')
hold on
gtext('Ziya Tuna Bölükbaşı')
sound(midrise_of_x);
function [Xm]=midrise(x,max_x,n)
min_x=-max_x;
k=2^n;
t=(max_x-min_x)/k;
x(x>=max_x)=max_x-t;
x(x<min_x)=min_x;
l=floor((x-min_x)/t);
Xm=min_x+l*t+t/2;
end
```



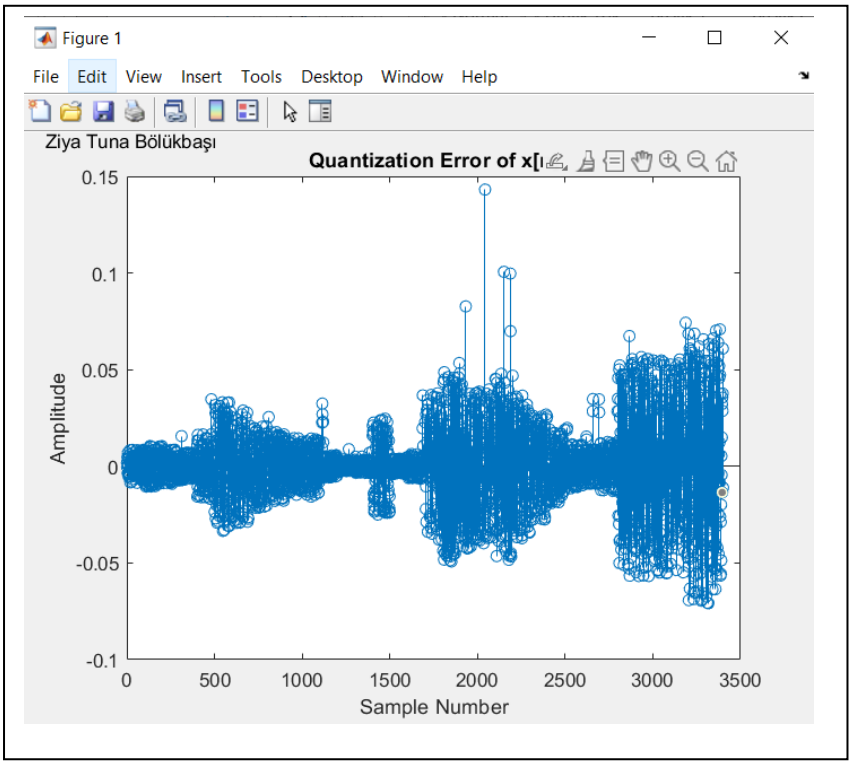


Looking at the graphs,we see that when we quantize 4-bit the error is less than 3-bit quantization.So when we do 4-bit quantization the sound is clearer.In 4-bit quantization SNR value has incrased.

5)

Matlab Code

```
clc;
clear all;
close all;
seg_samp=100;
[x,Fs]=audioread('C:\Users\Tuna\OneDrive - hacettepe.edu.tr\Masaüstü\sound3.wav');
length_of_x=length(x);
seg_num=ceil(length_of_x/seg_samp);
midrise_of_x=zeros(length_of_x,1);
for i=1:seg_num
    f_step=seg_samp*(i-1)+1;
    l_step=seg_samp*i;
    if(l_step>length_of_x)
      l_step=length_of_x
    end
    x_seg=x(f_step:l_step);
    max_x=max(x_seg);
    midrise_of_x_seg=midrise(x_seg,max_x,3);
    midrise_of_x(f_step:l_step)=midrise_of_x_seg;
end
error_MroX=midrise_of_x-x;
sum_rise_x=sum(midrise_of_x.*conj(midrise_of_x))/sum(error_MroX.*conj(error_MroX))
snr_of_rise_x=10*log10(sum_rise_x);
figure;
grid on;
stem(error_MroX),title('Quantization Error of x[n]'),xlabel('Sample Number'),ylabel('Amplitude')
gtext('Ziya Tuna Bölükbaşı')
function [Xm]=midrise(x,max_x,n)
min_x=-max_x;
k=2^n;
t=(max_x-min_x)/k;
x(x>=max_x)=max_x-t;
x(x<min_x)=min_x;
l=floor((x-min_x)/t);
Xm=min_x+l*t+t/2;
end
```



snr_of_rise_x	15.5082

With method we used in this question SNR value and quality of the output signal increase.