Communication Systems
Lab – 1 Report

Name: Emre Nedim Hepsağ **Number:** 250206012
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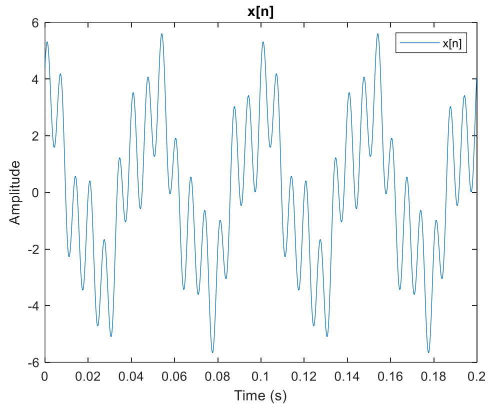
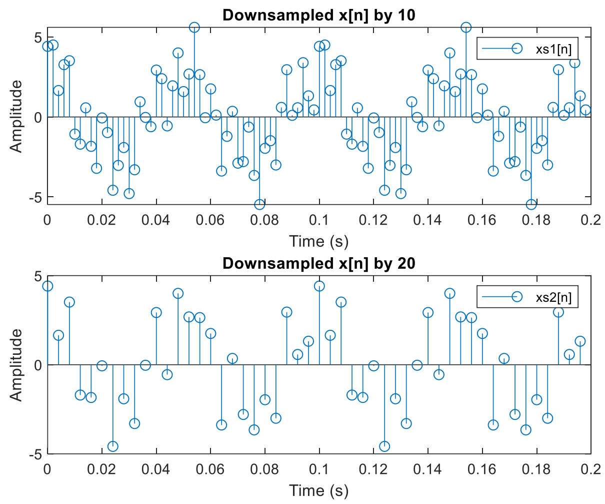
Figure 1



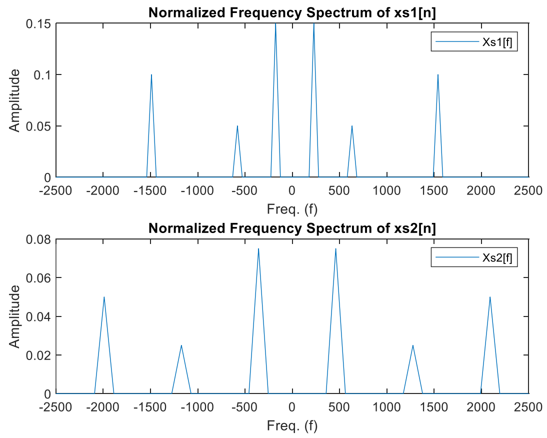
This figure shows us the addition of three sinusoidal signals with different amplitudes, phases, and frequencies.

Figure 2



Since we downsampled the signals, they have less points: first plot has $\frac{N}{10} = 100$, and the second one has $\frac{N}{20} = 50$ points. Furthermore, due to downsampling, some impulses are missing, and gap among frequency impulses are wider.

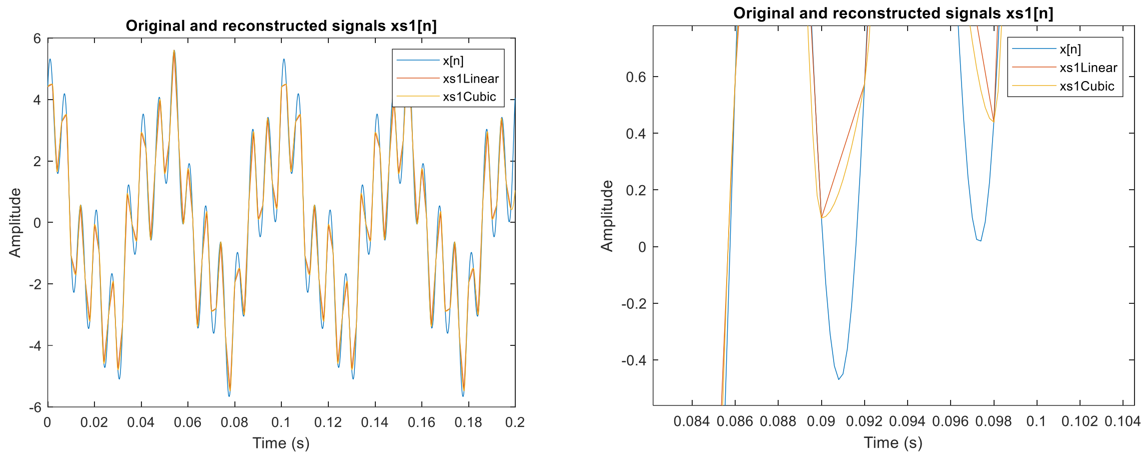
Figure 3



Because of three different sinusoidal signals, we see three double peaks. Additionally, frequency of first plot is as 10 times wider as original signal, and the second one is 20 times. Also, their amplitudes are inversely proportional to the sampling: xs1 = 1/10 and xs2 = 1/20. (Amplitudes were wrong in the sent code because while normalizing, I should have divided all signals by same $N = 1000$.)

Figure 4 and Figure 5

At the figure 4 and 5, we see reconstructed signals with linear and cubic interpolations. As seen, linear plot is like 1st degree polynomial, and the cubic is smoother like 3rd degree polynomial. Moreover, it is obvious that there are distortions in the reconstructed signals, but it is much more at xs2[n] (downsampled by 20). This phenomenon happens when new signal does not provide Nyquist criteria.



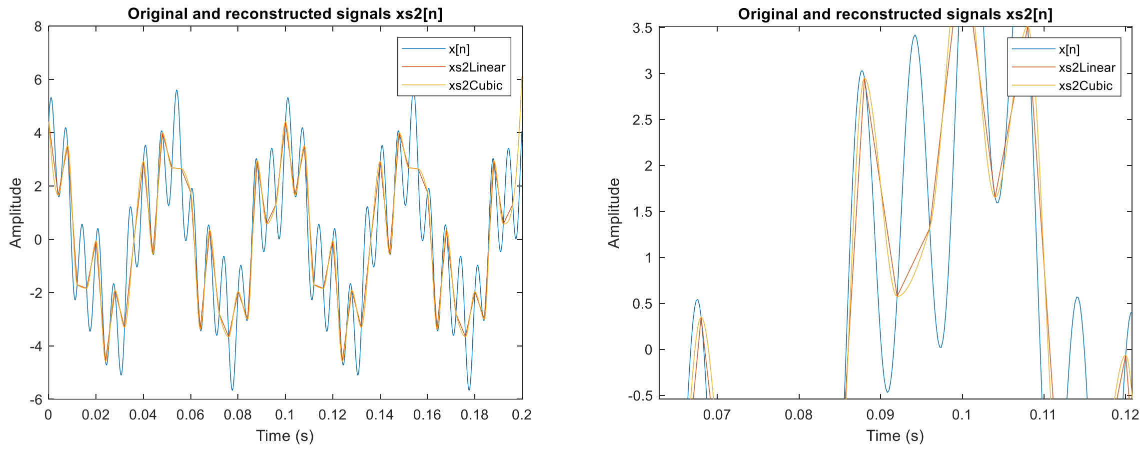
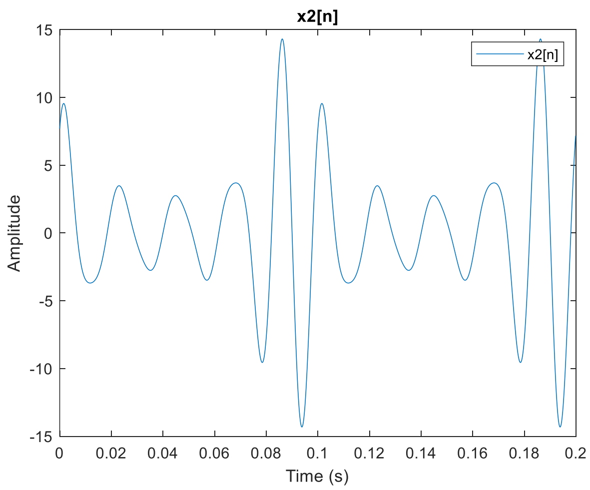


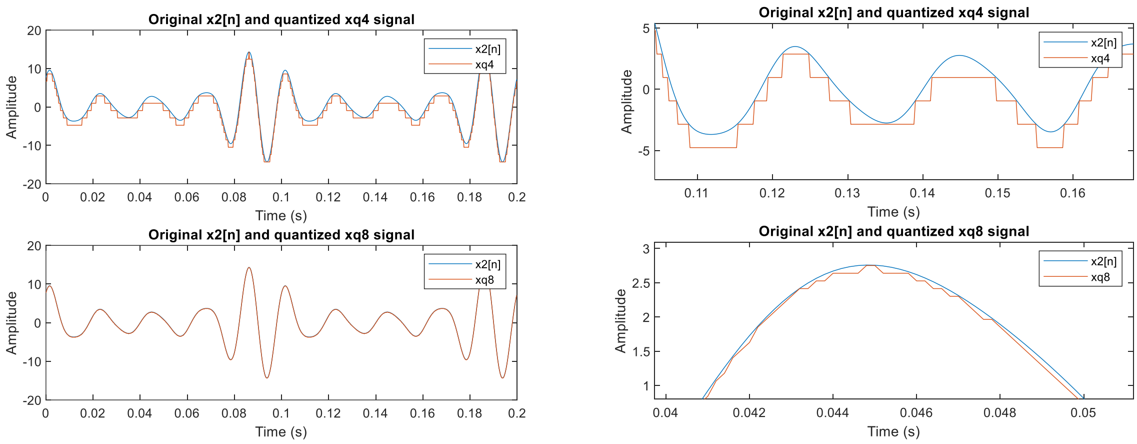
Figure 6



This figure is similar to figure 1, represents the addition of 5 sinusoidal signals with different parameters at time domain.

Figure 7

We see that 8-bit quantization is much more precise than 4-bit quantization because 4-bit has 32 levels, but 8-bit has 256 levels. Hence, it is xq8 has less error and more original like.



Questions

Report-Q1

Frequency resolution is $\frac{Sampling\ Frequency(F_s)}{FFT\ Size(N)}$, so if we increase the size as maintaining the sampling frequency constant would increase frequency resolution.

Report-Q2

This phenomenon happens because of undersampling. At x_{s2}, 150Hz is being pulled to 150*20= 3000, but it can be maximum 2500Hz due to the Nyquist frequency (Fs/2). Therefore, we observe it at 2500 – (3000 - 2500) = 2000Hz. In this way, 180Hz will be at 2500 – (180*20 - 2500) = 1400Hz.

Report-Q3

As seen in the figure 4 and 5, cubic interpolation gives better results because it connects the missing points with 3rd degree polynomial via curvy lines. However, since linear interpolation just puts straight line between dots, it is pretty basic and worse than cubic.

Report-Q4

We can implement linear interpolation without built in function by the formula of it which is $y = y_0 + (x - x_0)\frac{y_1 - y_0}{x_1 - x_0}$. While substituting the parameters of two points (x1, y1) and (x2, y2), y will be the linear interpolated result.

Report-Q5

Since 8-bit quantization is much more precise, we expect it to give less MSE. As seen in the figures, without zooming in, it is hard to recognize. After the calculation I obtained MSE values as:

MSE(4-bit) x_{q4} = 1.2138

MSE(8-bit) x_{q8} = 0.0041

As we know that the higher number of bits (N or R) result in better noise performance. Therefore, x_{q8} is expected to give higher values. Furthermore, in the decibel scale, every extra bit brings 6dB to SQNR. SQNR of x_{q4} is 13.5517, so SQNR of x_{q8} is expected to be 13.5517 + 4*6, and as we guessed it is 38.2465.