Question 1

a) In Matlab, read the following sentence and record your own voice for 4 seconds at a rate 40 kHz and generate a "message.wav" file.

"Use a pencil to write the first draft."

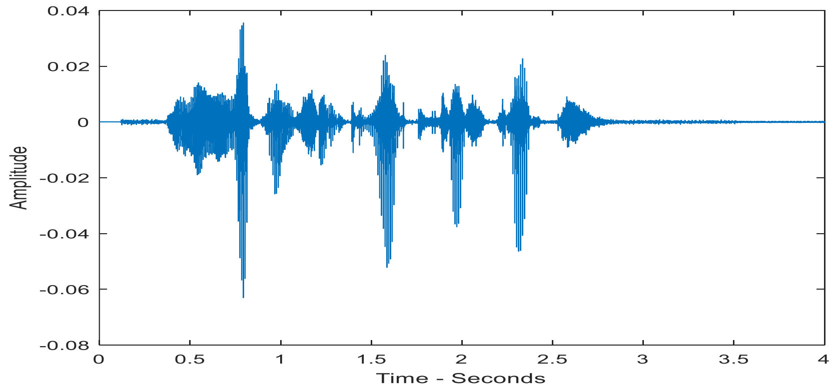

Figure 1 – Original Message Signal

Figure 1 shows the message signal I recorded with my own voice.

b) Downsample your message signal at a sampling rate 8 kHz, show the original signal and its discrete time samples for a very short period of time.

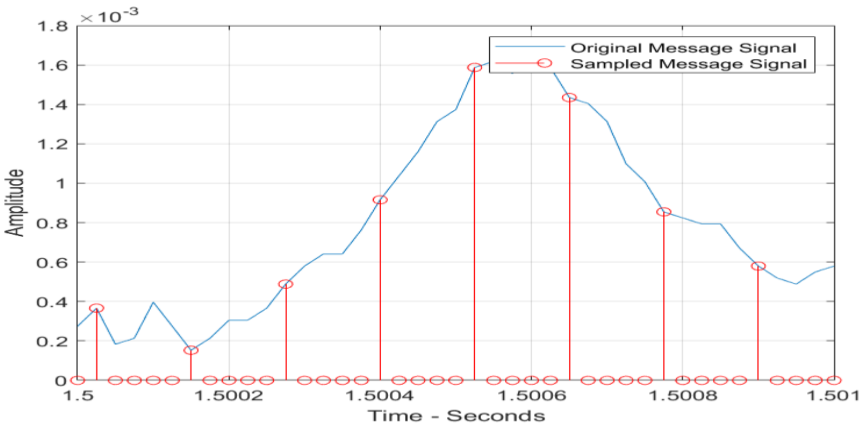

Figure 2 – Sampled signal with Original Signal

Figure 2 shows the sampled version of the original message signal at 8kHz.

c) Using Spectrum Analyzer, show the two sided spectrum of the original signal and the sampled signal

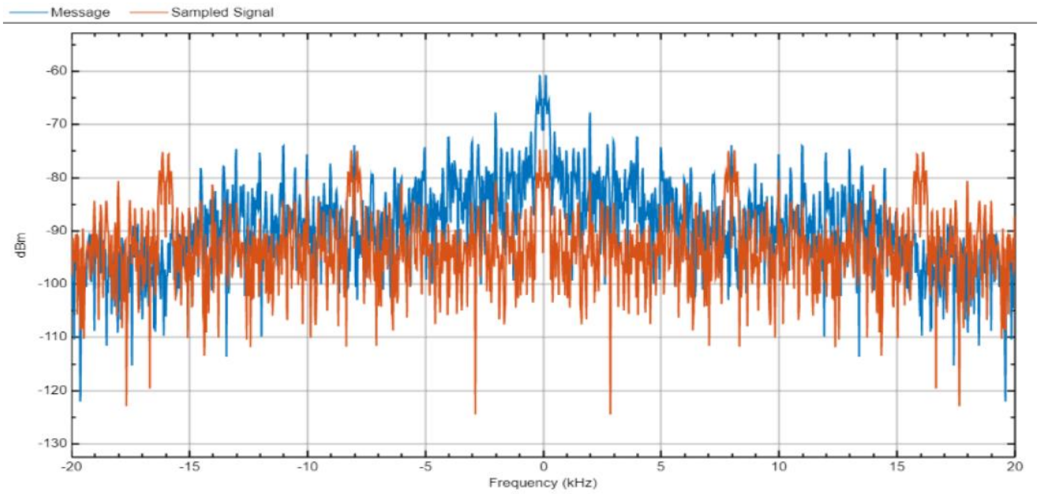

Figure 3 - Two Sided Spectrum of the Original Signal and the Sampled Signal

Figure 3 shows two-sided spectrum of the original signal and the sampled signal at 8kHz obtained using Spectrum Analyzer.

d) Define a low pass filter with suitable cutoff frequencies to recover the original low pass filter from its discrete time samples. Listen the original message signal and recovered message signal at 40 kHz and comment on your results.

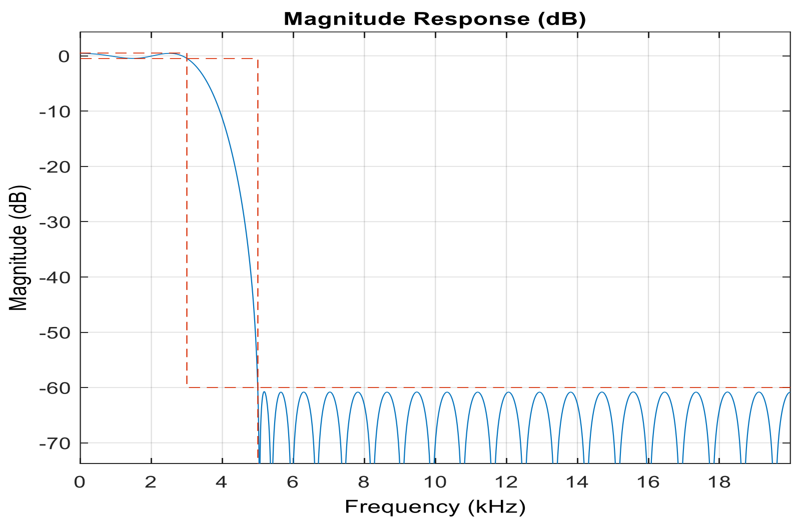

Figure 4 – Low – Pass Filter

Figure 4 shows the Low-Pass filter it should use to convert the signal back to our original signal. As seen in the figure, the cut-off frequency is 3kHz and the stop frequency is 5kHz.

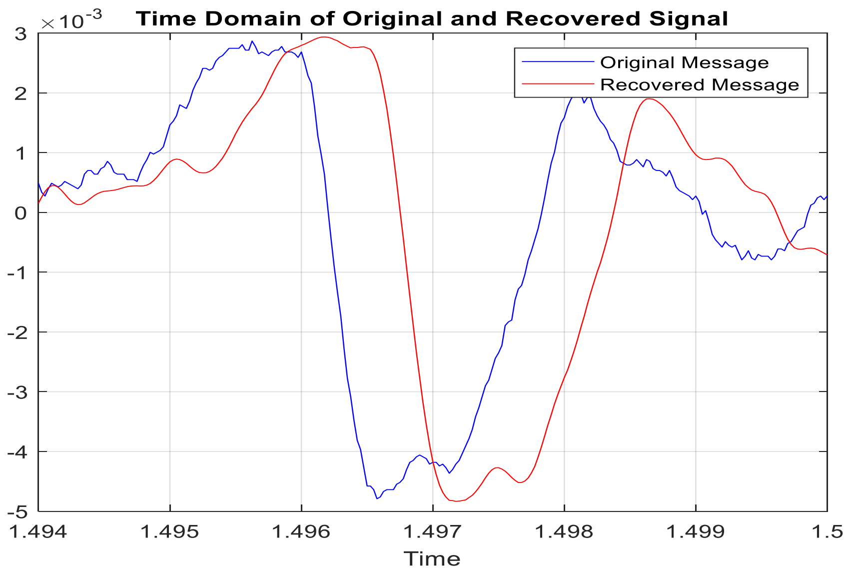

Figure 5 Recovered Message Signal with Original Message Signal

Figure 5 shows the recovered signal with the help of Low-Pass filter and the original signal at 8kHz. There is a phase difference between the original signal and the recovered signal, but this assumed difference is normal. When we listened to the sound after applying the low pass filter, there was some noise in the sound as expected.

e) Repeat the above steps for the new sampling rate 4 kHz. What happens at 4 kHz? Comment on your results.

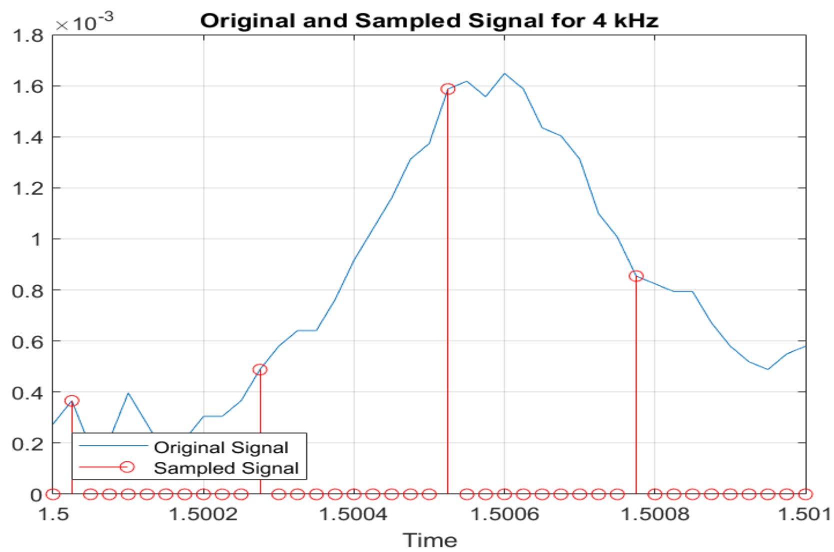

Figure 6 - Sampled Message signal with Original Message Signal

Figure 6 shows the sampled version of the original message signal at 4kHz.

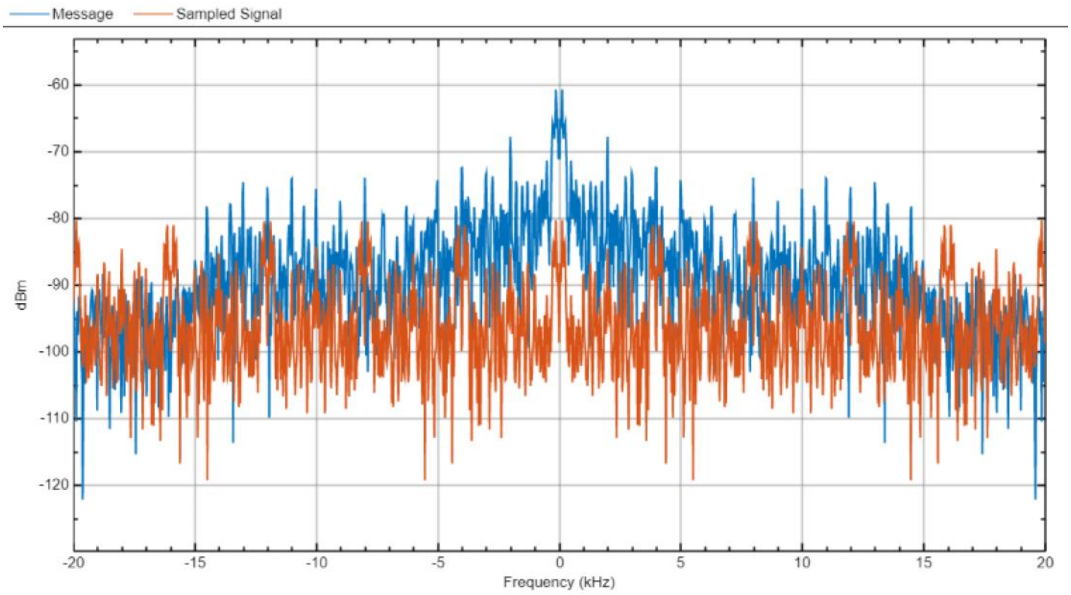

Figure 7 - Two Sided Spectrum of the Original Signal and the Sampled Signal

Figure 7 shows two-sided spectrum of the original signal and the sampled signal at 4kHz obtained using Spectrum Analyzer.

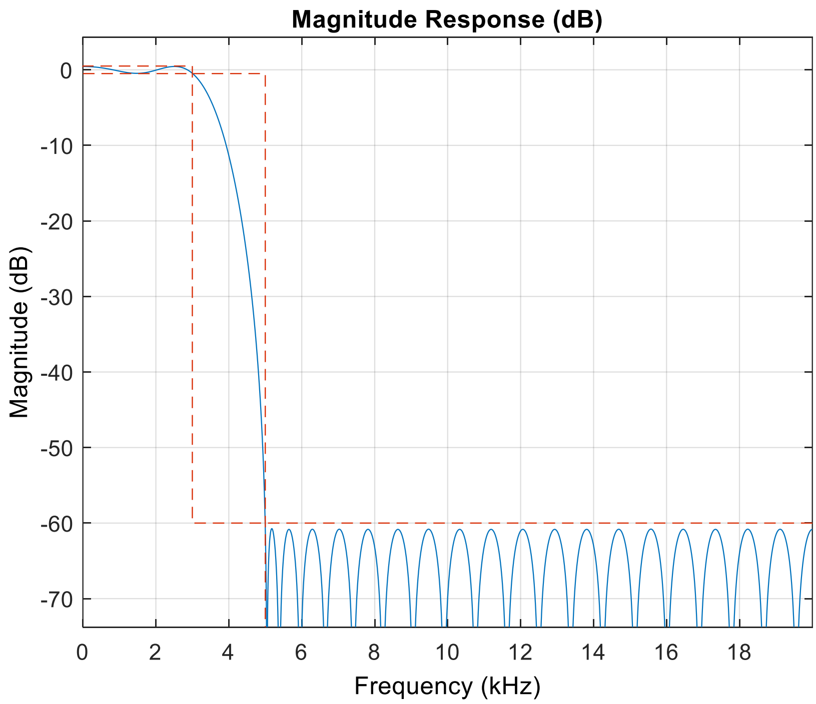

Figure 8 - Low – Pass Filter

Figure 8 shows the Low-Pass filter it should use to convert the signal back to our original signal. As seen in the figure, the cut-off frequency is 2kHz and the stop frequency is 4kHz.

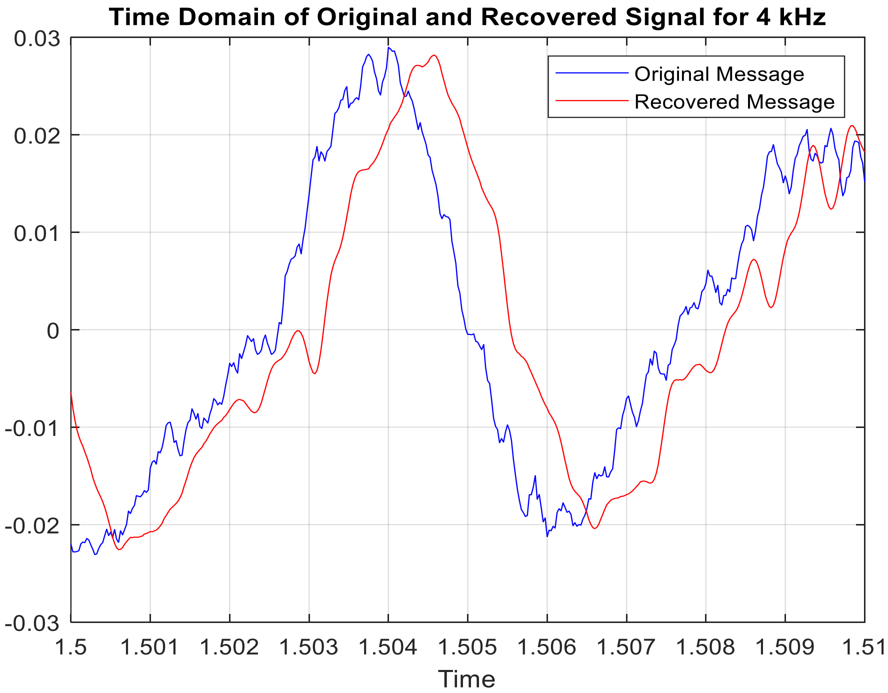

Figure 9 Recovered Message Signal with Original Message Signal

Figure 9 shows the recovered signal with the help of Low-Pass filter and the original signal at 4kHz.

Comment:

When we reduced our message signal from the original 40 kHz sampling rate to 8 kHz sampling rate, we observed that the sampling rate decreased by 5 times. But at the 4kHz sampling rate, we noticed that this ratio is 10 times (We can see this result by checking at *Figure 2 and Figure 6*) . We notice a significantly higher degree of information loss at 4 kHz compared to downsampling of the 8kHz sample rate signal. Also, when we ran the code in MATLAB, we realized that the sound quality was lower than before when we edited the sampling rate to 4kHz, as we expected.

Question 2

a) In Matlab, read the following sentences and record your own voice for 4 seconds at a rate 40 kHz and generate “message1.wav” and “message2.wav” files.

“The two met while playing on the sand.”

“This is a grand season for hikes on the road.”

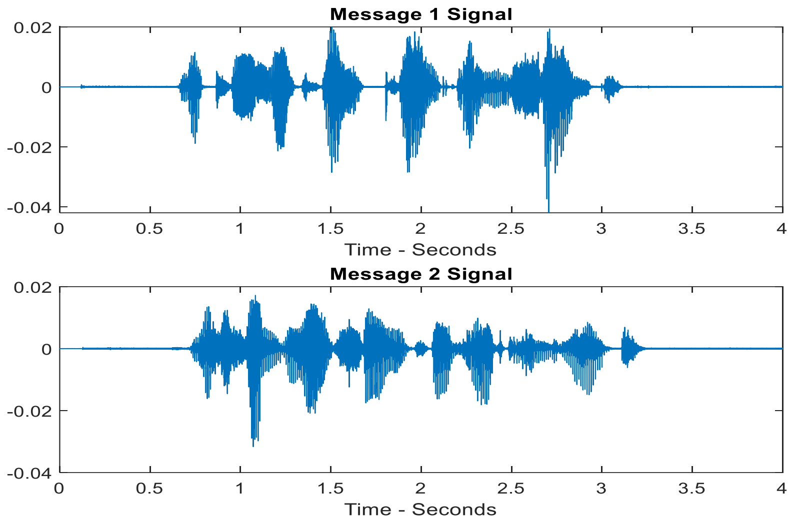

Figure 10 – Original Message Signal 1 and Message 2

Figure 10 shows the message1 and message2 signal I recorded with my own voice.

b) In Matlab, implement an analog QAM modulator with carrier frequency 8 kHz. Show the two sided QAM spectrum using Spectrum Analyzer.

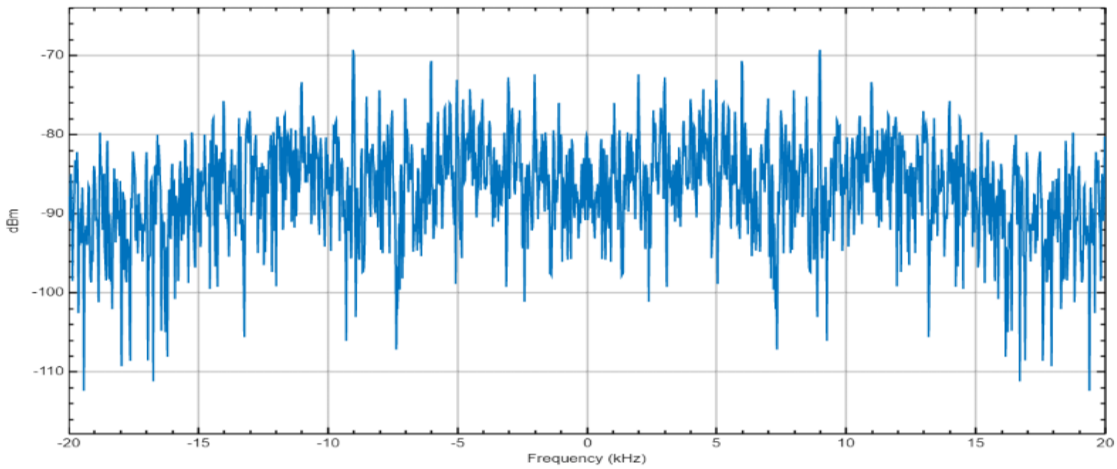

Figure 11 – Two Sided QAM Spectrum

Figure 11 shows the two sided QAM spectrum of the original signal with carrier frequency 8kHz using Spectrum Analyzer.

c) Add Gaussian channel noise whose power is 1 micro Watts

In *Figure 13 and Figure 14* we obtained recovered signal and effect of 1 micro Watts is observed.

d) Implement QAM demodulator and recover message 1 and message 2. Listen the original message signals and recovered message signals and comment on your results.

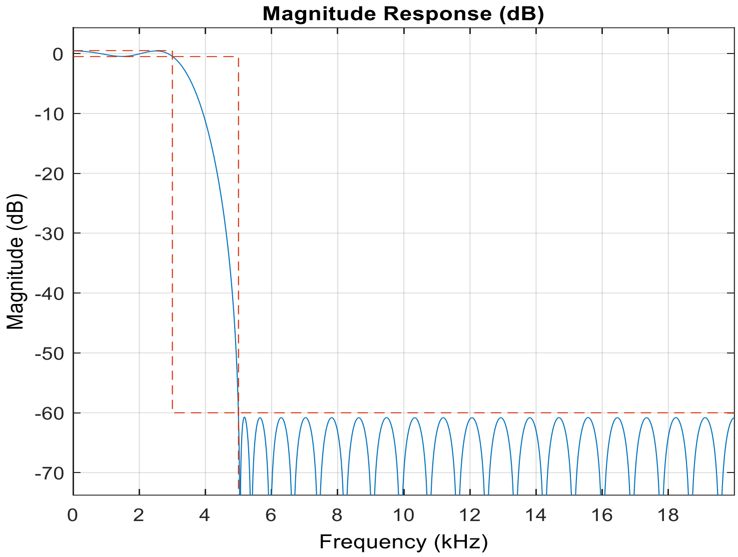

Figure 12 – Low – Pass Filter

Figure 12 shows the Low-Pass filter it should use to convert the signal back to our original signal. As seen in the figure, the cut-off frequency is 3kHz and the stop frequency is 5kHz.

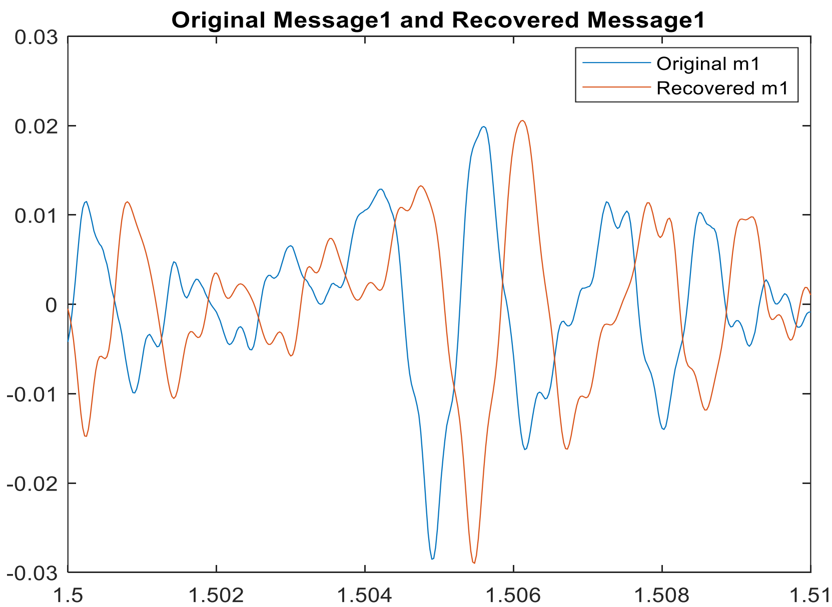

Figure 13 Recovered Message 1 Signal with Original Message 1 Signal

Figure 13 shows the recovered message 1 signal with the help of Low-Pass filter and the original signal. We observe a phase difference between the original and the recovered signal, however, this difference is considered normal.

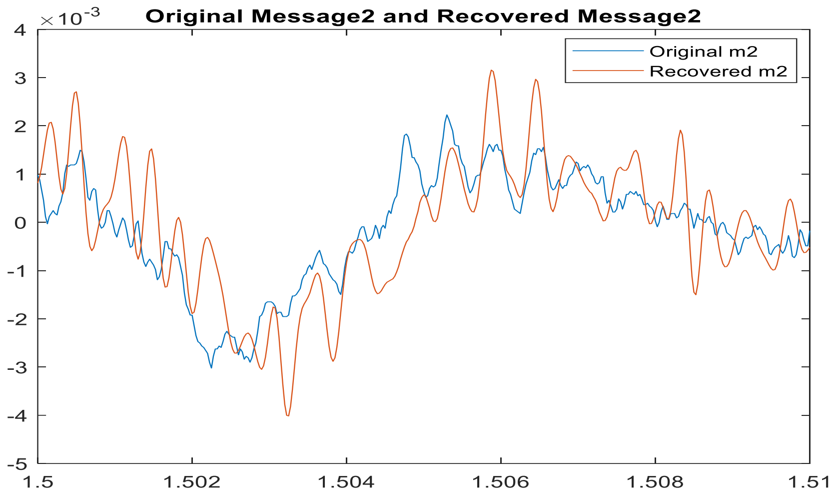

Figure 14 Recovered Message 2 Signal with Original Message 2 Signal

Figure 14 shows the recovered message 2 signal with the help of Low-Pass filter and the original signal. We observe a phase difference between the original and the recovered signal, however, this difference is considered normal.

e) Repeat the above steps with channel noise whose power is 1 milliWatts. Comment on your results.

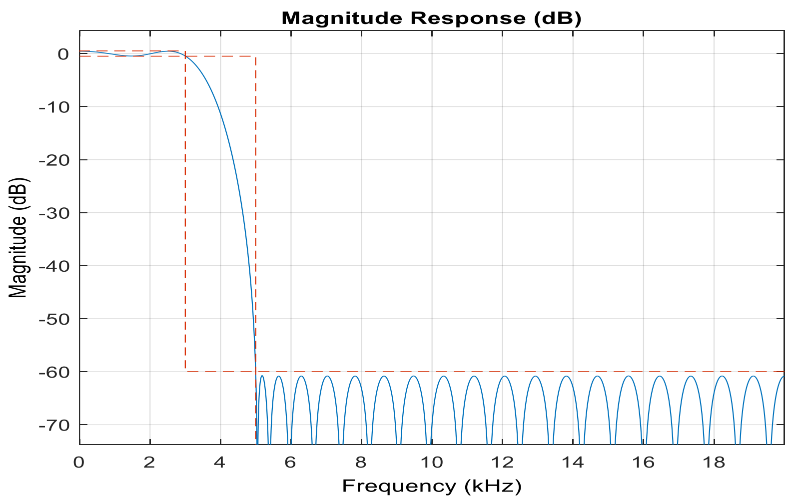

Figure 15 – Low – Pass Filter

Figure 15 shows the Low-Pass filter with channel noise whose power is 1 milliWatts. It should use to convert the signal back to our original signal. As seen in the figure, the cut-off frequency is 3kHz and the stop frequency is 5kHz.

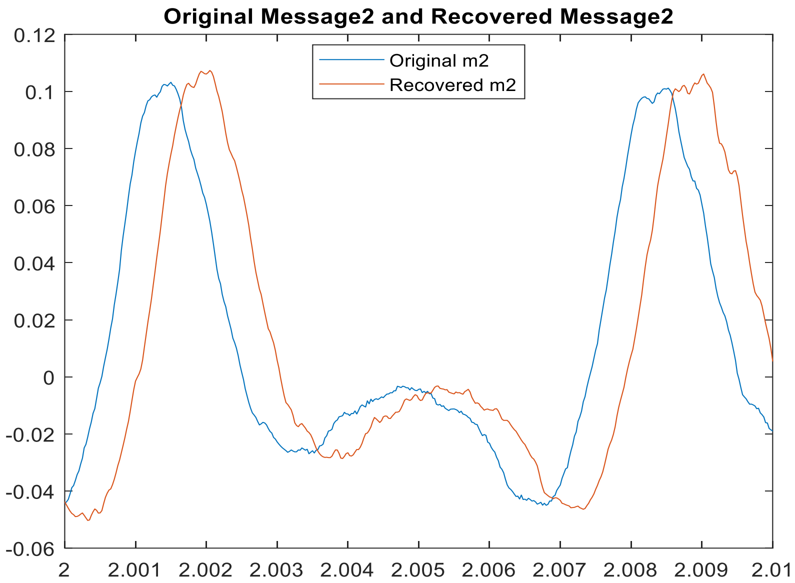

Figure 16 Recovered Message 1 Signal with Original Message 1 Signal

Figure 16 shows the recovered message 1 signal with the help of Low-Pass filter and the original signal with channel noise whose power is 1 milliWatts.

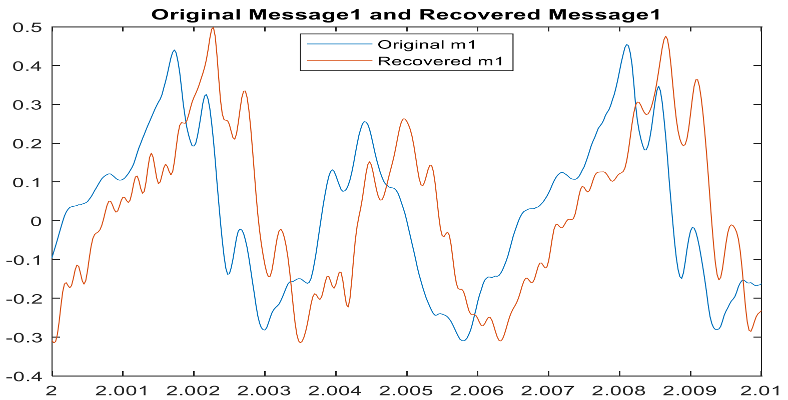

Figure 17 Recovered Message 1 Signal with Original Message 1 Signal

Figure 17 shows the recovered message 2 signal with the help of Low-Pass filter and the original signal with channel noise whose power is 1 milliWatts.

Comments:

When we applied 1 milliWatts of channel noise, we saw much more deviation than the previous graphs. Also, our voices more parasitic and delayed compared to previous audio recordings. This is because we used micro Watts channel noise power in the previous case. In this question, we have an idea about the Gaussian channel noise and make inferences by comparing two different values.

Question 3

a) In Matlab, read the following sentence and record your own voice for 4 seconds at a rate 40 kHz and generate "message.wav" file,

"We find joy in the simplest things. "

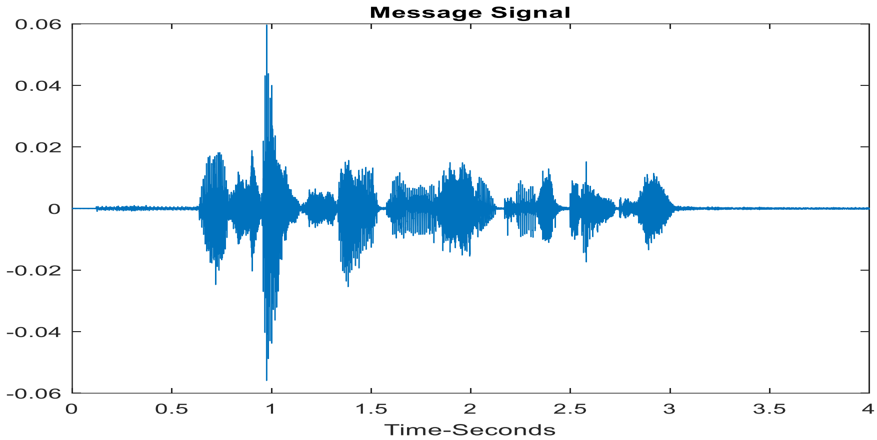

Figure 18 – Original Message Signal

Figure 18 shows the message3 signal I recorded with my own voice.

b) In Matlab, implement an USB modulator with carrier frequency 8 kHz. Show the two sided USB spectrum and DSB spectrum using Spectrum Analyzer

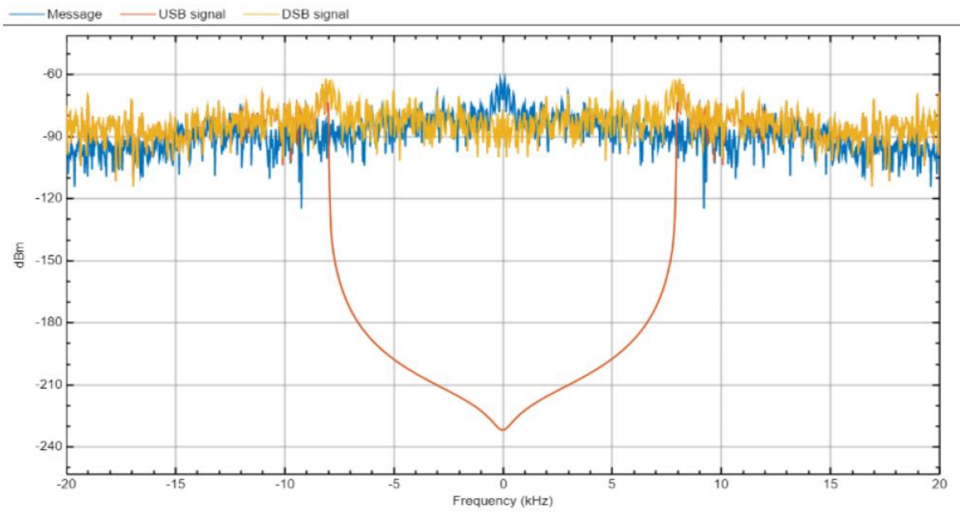

Figure 19 – Two Sided USB and DSB Spectrum

Figure 19 shows the two sided USB spectrum and DSB spectrum using Spectrum Analyzer.

c) Add Gaussian channel noise whose power is 1 micro Watts.

In *Figure 21* we obtained USB &DSB modulated signal and effect of 1 micro Watts is observed.

d) Implement USB/LSB demodulators and recover the message. Listen the original message signals and recovered message signals and comment on your results

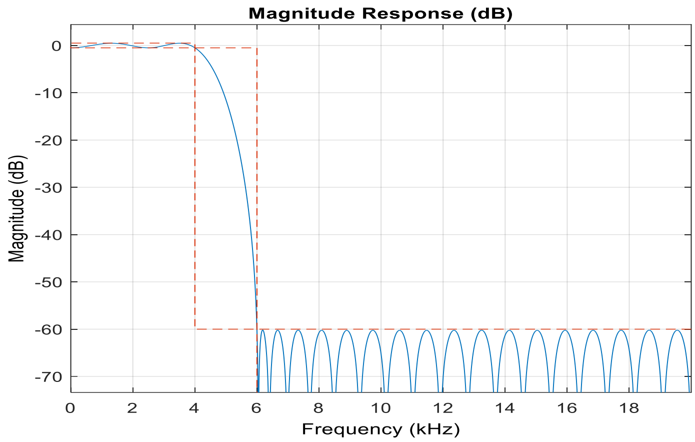

Figure 20 – Low – Pass Filter

Figure 20 shows the Low-Pass filter it should use to convert the signal back to our original signal. As seen in the figure, the cut-off frequency is 4kHz and the stop frequency is 6kHz.

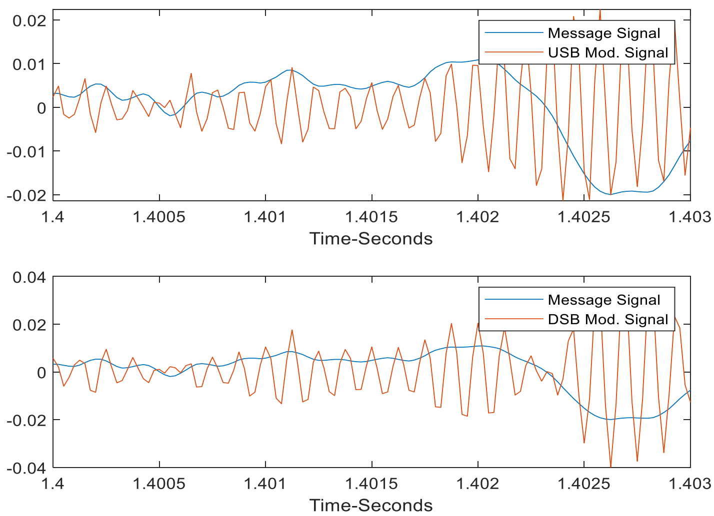

Figure 21 – USB & LSB demodulated Signals

Figure 21 shows the USB and LSB demodulated signals for 1 micro Watts channel noise power.

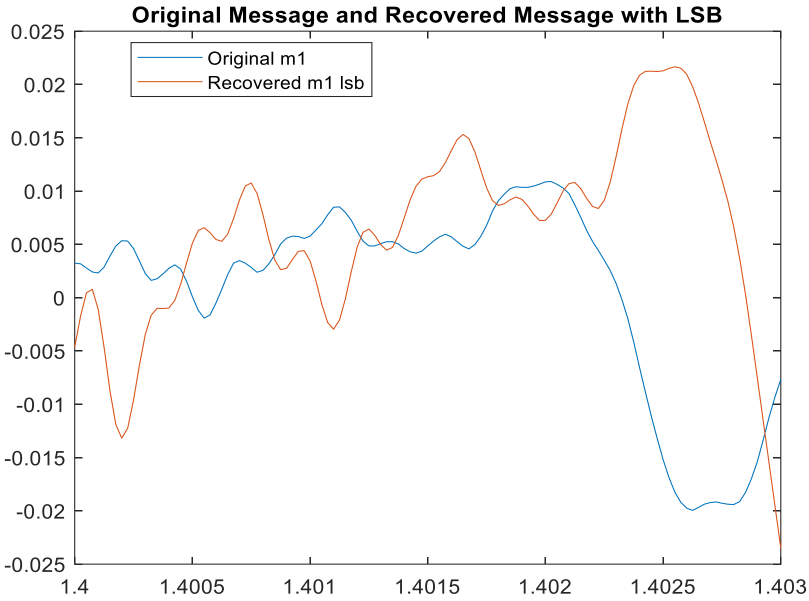

Figure 22 – Recovered LSB Message & Original Message

Figure 22 shows the recovered LSB signal using a low pass filter and the original message signal for 1 micro Watts channel noise power.

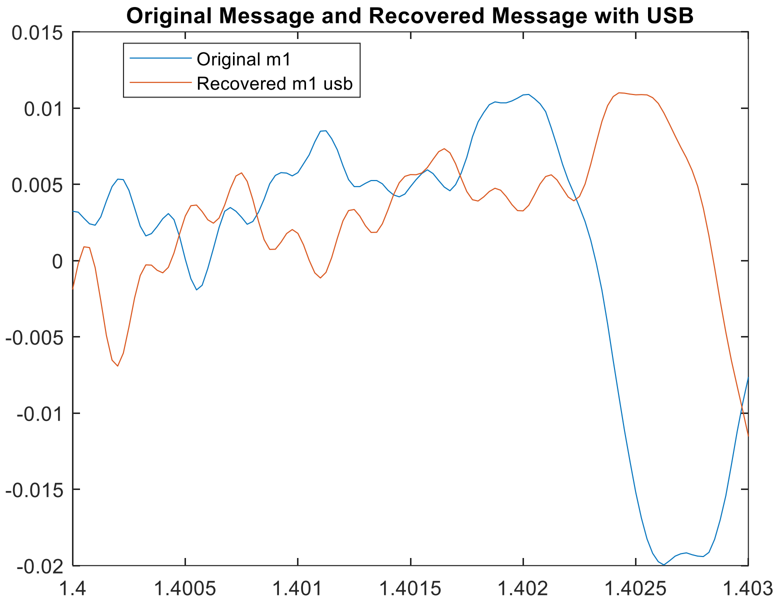

Figure 23 – Recovered USB Message & Original Message

Figure 23 shows the recovered USB signal using a low pass filter and the original message signal for 1 micro Watts channel noise power.

e) Repeat the above steps with channel noise whose power is 1 milliWatts. Comment on your results.

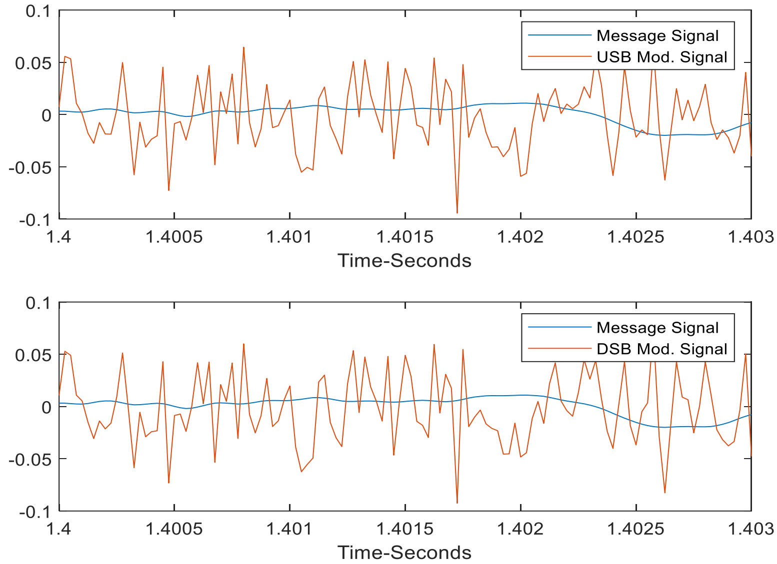

Figure 24 – USB & LSB demodulated Signals

Figure 24 shows the USB and LSB demodulated signals for 1 milliWatts channel noise power.

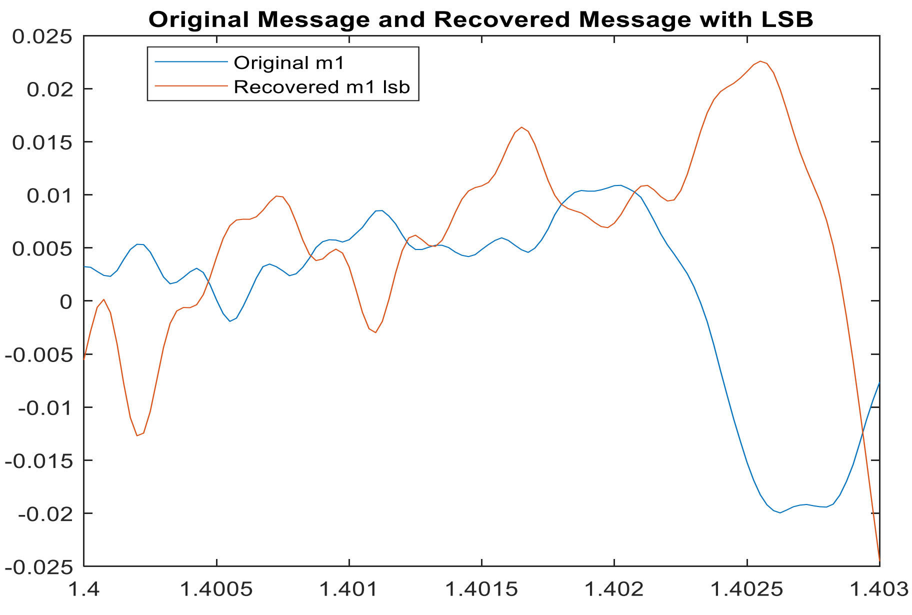

Figure 25 – Recovered LSB Message & Original Message

Figure 25 shows the recovered LSB signal using a low pass filter and the original message signal for 1 milliWatts channel noise power.

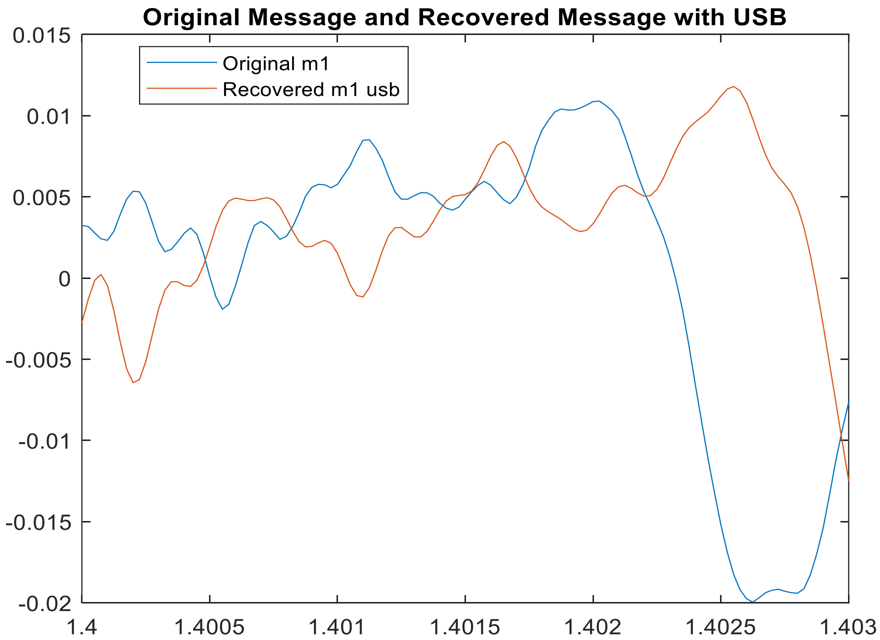

Figure 26 – Recovered USB Message & Original Message

Figure 26 shows the recovered LSB signal using a low pass filter and the original message signal for 1 milliWatts channel noise power.

Comments:

First of all, we transferred the formulas we learned in the lesson to the MATLAB code and obtained the USB and DSB spectrum in *Figure 19*. Then we got the DSB and USB modulations. Afterwards, we obtained recovered signals by putting these messages into the low pass filter in *Figure 25 and Figure 26.* Meanwhile, we added Gaussian channel noise and observed some changes in our signals. Also by listening to the audio recordings, we observed that the Gaussian channel noise is 1milliWatts with more distortion than when it is 1microwatts. Finally, as we have already learned, when we listen to sounds, it sounds louder on LSB than on USB because while we applied modulation according to DSB, we applied demodulation according to LSB.