Assignment 5: Speech Scrambler

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Abstract

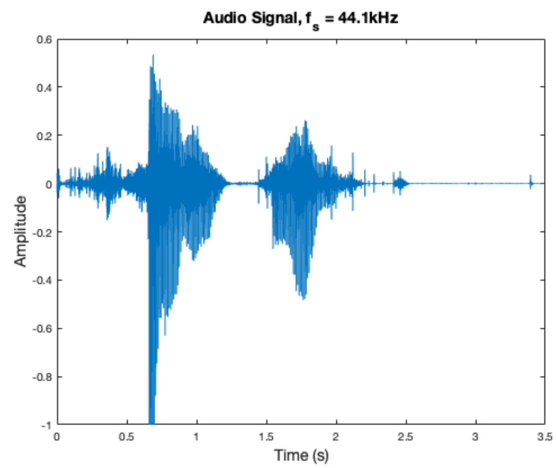
Speech signals are continuously becoming digital. Therefore, we will analyze how digital signals are scrambled and descrambled. In the report, we go through a method of scrambling and descrambling that are identical. We will see that using this method, we should get a perfectly reconstructed signal.

A. Introduction

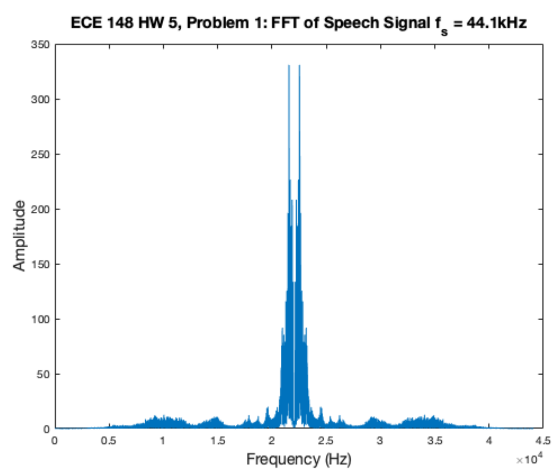
The communication of speech signals is now commonly conducted in the digital form. Thus, the speech scrambling procedure needs to be modified to accommodate. The objective of this exercise is to implement a simple digital speech scrambler. Using Audacity to record an audio signal, we read it through MATLAB and analyze it with scrambling.

B. Problem 1: Displaying FFT of original signal.

In my audio signal, I say a simple phrase, “Hello, there. How are you?” The spectrum of the audio signal can be seen in **Figure 1**



We then take the Fast Fourier Transform of our discrete signal after reading it in MATLAB. The frequency spectrum can be seen in **Figure 2**. The peak is around 22.05kHz, which is half of our sampling frequency of f_s = 44.1kHz. The whole spectrum is also held within f_s.



C. Problem 2: Applying Scrambling Procedure and Displaying its FFT Spectrum

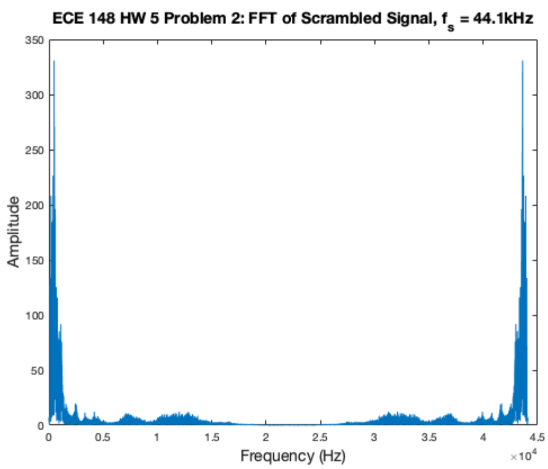
One way of scrambling is to modulate the speech sequence by

$$m(n) = e^{jn\pi}$$

Therefore, rotating DTFT spectrum by π. This one-step process achieves the same goal of the speech scrambling that the frequency index system is reversed and speech is no longer recognizable. The modulation sequence is also in the form

$$m(n) = e^{jn\pi} = (-1)^n$$
$$= \{\ldots -1, +1, -1, +1 \ldots\}$$

Therefore, for every odd instance in the audio signal, we multiply by -1. For every even n, we multiply by +1. We get the scrambled signal's FFT in **Figure 3**. It is still centered at $f_s/2$ and spans all of f_s



D. Problem 3: Checking if Scrambled Signal is Audible

In attempting to hear the scrambled signal, I found out that it is not audible.

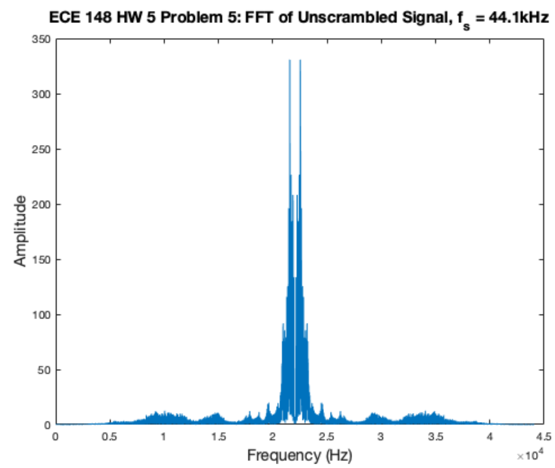
E. Problem 4: Descrambling the signal and checking if it is audible

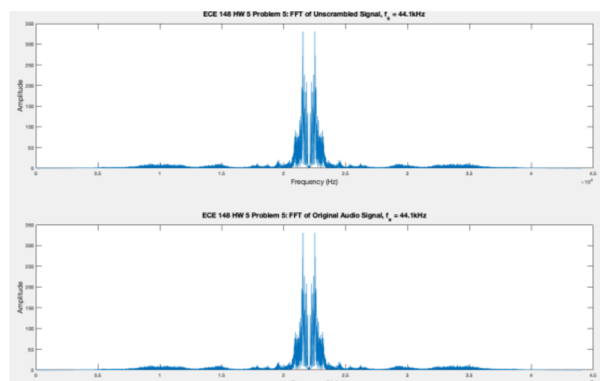
In the same process as scrambling, for every odd instance in the audio signal, we multiply by -1. For every even n, we multiply by +1. After testing the signal, I found that it *is* audible.

Therefore, I believe the signal has been successfully reconstructed.

F. Problem 5: Comparing FFT spectrum of the descrambled signal with the FFT spectrum of the original speech signal

After unscrambling, we see the frequency spectrum of the FFT of the unscrambled signal in **Figure 4**. The comparison with the original is seen in **Figure 5**. They look very identical.





G. Problem 6: Checking for distortions

One way to check for distortions is to find the mean square error between the original audio signal and the unscrambled signal. After computing on MATLAB, we see that the error is 0. This is to be expected through our simple -1_n multiplication.

H. Summary

We have taken an audio signal from Audacity and learned one method of speech scrambling. By making this signal into digital, we can implement a method to scramble the signal. We see that using the scrambling, the audio is not audible. After applying the descrambling procedure, we see that the audio can be heard correctly. Looking at the FFT spectrums, we see that the unscrambled and original spectrums are identical, which is what we expect from our scrambling method.