#### Texas Tech University

#### Department of Electrical and Computer Engineering

#### ECE 4264 / 5364 Digital Signal Processing

#### Fall 2019 Group D1

# Homework 8

Due November 8 before midnight CDT.

Please submit to Blackboard exactly two files:

1. A single ZIP file with all your MATLAB programs, along with any data files necessary to run your programs.
2. A single report document in Word or PDF. Your report should include procedures and solutions to analytical problems, screenshots of results and graphs from programs, and discussions. Please do not include copies of your code in the report.

Submit your solutions to Blackboard by the date and time listed to avoid penalties. This homework is individual. You are welcome to discuss your approach with others, but your answers need to be unique. If your answers are found to be highly similar to others’ or to some material published, you may be subject to a review of academic integrity.

Undergraduate students only need to complete Part 1. Graduate students should complete both Part 1 and Part 2.

## Part 1 (Both ECE 4364 & 5364 students)

### Problem 1 (15 points)

The file “test\_signal.mat” contains a test signal that is buried in random noise. We want to identify the frequencies present in the signal, and their relative amplitudes. It is known that the test signal contains four sinusoids at different frequencies, but not all have the same amplitudes. The test signal is 5 seconds long and is sampled at 500 samples/second.

1. Load the test signal and plot it

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1. Compute the spectrum of the entire signal using a 2500-point DFT. Can you identify the four signal frequencies and their amplitudes? What are they?

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**I was able to identify the four signal frequencies and their amplitudes. I was able to isolate these frequencies further by taking the frequency spectrum in relation to power.**

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**I also centered the range around 0 to properly reflect periodicity. The four signals are at 100 Hz, 105 Hz, 200 Hz, and 210 Hz.**

1. From the spectrum in part b), compute the SNR of the signal, in dB. This is, the difference in dB between the lowest of the four signal frequencies, and the highest of the noise components.

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1. Estimate the power spectral density of the signal using Bartlett’s method. For this you need to divide the signal into windows of length N, compute the FFT of each, and average the resulting spectra. You may also use the periodogram() function in MATLAB, if you specify the window length and type. Modify N and observe the behavior.
2. What is the minimum window size N with which you can differentiate the four distinct signal frequencies?

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**I used a window size of 550 for the minimum to distinguish the four frequencies.**

1. What is the window size N that provides the highest SNR?

**I used a window size of 450 and that gave me the highest SNR value.**

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### Problem 2 (15 points)

Again, utilize the test signal in the file “test\_signal.mat” and estimate the power spectral density, but this time using Welch’s method.

1. Estimate the power spectral density using Welch’s method, with a rectangular window of N samples. Modify N and observe the behavior.

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**Starting point at a window size (N) of 1000.**

1. What is the minimum window size N with which you can differentiate the four distinct signal frequencies?

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**Using a rectangular window, I test window sizes between 250 and 270. A window size of 270 gave me the best results for differentiating between all 4 signal frequencies.**

1. What is the window size N that provides the highest SNR?

**A window size of 200 ended up giving me the best SNR.**

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1. Repeat the exercise using a Hanning window. What is the minimum window size N with which you can differentiate the four distinct signal frequencies? What is the window size N that provides the highest SNR?

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**The minimum window size N for the Hanning window is 500.**

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**Window size of 200 provides the maximum SNR.**

1. Comment on the effect of using windowing in this method.

**Windowing has definitely been a huge help in finding these frequencies in the PSD. From these problems, we’ve learned that each window has its own effect on how the magnitude response is viewed and that is has an interesting effect on how large the SNR is.**

1. Comment on the advantages and disadvantages of Welch’s method compared to Bartlett’s method.

**An advantage of Welch’s method over Bartlett’s is that Welch allows for the overlap of samples and allows for windowing to be applied. However, a disadvantage of Welch is that it is more computationally draining compared to Bartlett’s method. Overall, this problem proves that Welch is a superior approach to Bartlett due to the allowance of windowing.**

### Problem 3 (15 points)

An LTI digital system is implemented in the file “hidden\_system.p”. This is an obfuscated Matlab file that behaves like a regular .m function file, but you cannot observe the contents of it. The hidden system takes one argument that is a vector of digital samples, and produces a vector of digital samples after passing through the system:

y=hidden\_system(x) % x is the vector containing the input signal and y is vector containing the output signal

Your task is to estimate the transfer function of the hidden system and describe its behavior. We studied three different methods for system identification:

1. Direct application of an impulse signal, with repeated experiments
2. Application of a random input signal, using autocorrelation
3. Feeding a single frequency at a time, and sweeping
4. Select one of the three methods above

**I chose the frequency sweep method to analyze the transfer function.**

1. Using the method chosen, estimate the transfer function of the system, in the frequency domain (magnitude and phase). Modify the method parameters until the transfer function can be clearly observed.

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**Frequency Sweep of 100 frequencies**

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**Frequency Sweep of 250 frequencies**

1. Describe the behavior of the system (what it does to signals).

**The transfer function is similar to a bandpass filter. A bandpass filter takes in a specific range of frequencies and attenuates all other frequencies that are not in that specific range.**