HACETTEPE UNIVERSITY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
ELE 409: DIGITAL SIGNAL PROCESSING LABORATORY

EXPERIMENT 5 - WINDOWING AND FIR FILTERS

I. PURPOSE

The are two main purposes of this experiment. The first is to study the concept of 'windowing', along with its effects on spectrum analysis. The second is the design of Finite-Impulse Response (FIR) filters, where the windowing method is employed.

- Learn how to use the following built-in functions and the reason why do we use:
  fir1, fdatool.
- Frequency range should be $[-1, 1]$ in your frequency domain figures.

II. PRELIMINARY WORK

1. Write MATLAB functions to generate the following windows:

   Rectangular window (**w**=rec(M))

   Bartlett window (**w**=bart(M))

   Blackman window (**w**=bla(M))

   where $M + 1$ is the window length.

   Note: To test the operation of your codes, you may use the MATLAB built-in functions boxcar, bartlett and blackman. Don't forget that your windows have a length of $M + 1$, therefore, you have to take this into account while using MATLAB built-in functions.

2. Using $M = 40$ generate the windows above, and plot their magnitude spectra in dB by taking a 100-point FFT. Repeat the procedure for $M = 80$. Compare all spectra (in terms of main lobe width and side lobe level) and state explicitly the effect of the window length.

3. Generate the signals below

   $$\mathbf{x}_1[n] = \cos(2\pi \times 0.242 \times n) + \cos(2\pi \times 0.258 \times n), \quad n = 0, \ldots, 255$$
   $$\mathbf{x}_2[n] = 2\cos(2\pi \times 0.25 \times n) + \cos(2\pi \times 0.008 \times n), \quad n = 0, \ldots, 255$$
   $$\mathbf{x}_3[n] = \cos(2\pi \times 0.29 \times n), \quad n = 0, \ldots, 255$$

   Compare $\mathbf{x}_1[n]$ and $\mathbf{x}_2[n]$, in terms of time waveform and magnitude spectrum.

4. Window the signal $\mathbf{x}_1[n]$ using rectangular windows of length M=40 and M=80, respectively. Then compute the magnitude spectra of the windowed signals. Compare the spectra of original signal with the windowed signals and comment on the results.

5. The signal $\mathbf{x}_3[n]$ can be thought to be obtained by windowing a sinusoid with a rectangular window. Compute the signal that would have been obtained if the window used were a bartlett window. Plot the magnitude spectra for both windowed signals and comment on the effect of using different types of windows.

6. Write down the advantages of FIR filters. What is a 'linear-phase filter'? Give an example of what happens if the filter is not linear-phase.

7. Compute the impulse response of a linear-phase, 30th order, lowpass filter with cut-off frequency $\omega_c = 0.2\pi$. Assume a bartlett window is used. Plot the magnitude and phase response of this filter. In order to implement your filter, you may use either MATLAB function fir1() or filter design and analysis tool (fdatool $\rightarrow$ fir $\rightarrow$ window).

8. Repeat part 7. for a bandpass filter that is created using a blackman window with passband limits $0.4\pi \leq \omega \leq 0.6\pi$.