Assigned: 11/17/10 Due: 12/01/10

FIR Filter Design

This project will investigate three methods for FIR filter design — windowing, frequency sampling, and the Parks-McClellan algorithm.

Exercises

1. Design a length-21 linear-phase FIR lowpass filter to approximate an ideal response with a passband edge of 0.25π. (Note that length-21 corresponds to a filter order of 20.) Design a filter using each of the following windows:

   - rectangular (`rectwin`)
   - triangular (`triang`)
   - Hanning (`hann`)
   - Hamming (`hamming`)
   - Blackman (`blackman`)

   Plot the impulse response, magnitude response, and zero-pole locations of the five filters. You may use `fir1` to do the designs. (Use `freqz` and `zplane` for magnitude response and pole-zero plots.) **Use subplot here and below to plot all three of these in the same row, and make them as small as you can without compromising legibility. Calculate frequency response with `[h,w] = freqz(b,a);` and then call `semilogy(w,abs(h))` to see the magnitude response. This is the best way to get it to display in a subplot. Also, be sure to calculate frequency response with `[h,w] = freqz(b,a);` and then call `semilogy(w,abs(h))` to see the magnitude response. This is the best way to get it to display in a subplot.** Compare the characteristics of the magnitude response. **NOTE: You will need to use a length-(21+2) window for Hann and Blackman windows and then pick out the middle 21 values, since these produce zeros on the end-points. Otherwise, your zero-pole locations will be in error.**

2. Design a length-21 linear-phase FIR lowpass filter using a Kaiser window with $\beta = 4$, 6, and 9. Plot the impulse response, magnitude response, and zero-pole locations. Compare the characteristics of the magnitude response with each other and with the filters from the first exercise. How does the trade-off of transition bandwidth and overshoot vary with β?

3. Use frequency sampling to design a length-21 FIR lowpass filter with cutoff 0.25π. (Do not use `fir2`.) Determine the desired DFT sample values from the specified cutoff (provide a listing or MATLAB command), and then take the inverse FFT (`ifft`). Keep in mind that the DFT coefficients must be symmetric to yield a real impulse response. For example, a cutoff of 0.5π and a length of 9 would yield a DFT coefficient vector [1 1 1 0 0 0 0 1 1] corresponding to the frequency values 2*pi*[0 1/9 2/9 3/9 4/9 5/9 6/9 7/9 8/9]. The k=0 value is the first entry in the vector. Note that the impulse response must be circularly shifted so the origin is in the middle instead of at 0. Plot the impulse response, magnitude response, and zero-pole locations. Compare the characteristics of the magnitude response to the other designs.

4. Design an optimal 21-point lowpass FIR filter using the Parks-McClellan algorithm (`firpm`). Use a passband cutoff of 0.23π and a stopband cutoff of 0.27π. Plot the impulse response,

magnitude response, and zero-pole locations. Compare the characteristics of the magnitude response to the other designs.

5. Design an 11th-order elliptic lowpass filter with a passband ripple of 1 dB, a passband cutoff of 0.24π, a stopband cutoff of 0.26π, and the largest possible stopband attenuation. (Use `ellipord` by trial and error to determine this.) Compare the magnitude response to the Parks-McClellan filter. Note that an 11th-order IIR filter requires approximately the same number of multiplies per output point as a length-21 FIR filter because it has both pole and zero coefficients.

6. **6410 and extra credit for 5410:** Read in the file `doorbell.au` using `auread`. Using the `fft` function, determine the frequencies of the upper and lower tone of the doorbell. Using trial-and-error, design a length-21 filter using any of the FIR techniques above such that the lower tone is attenuated no more than 3 dB while the upper tone is attenuated as much as possible. Describe how you designed your filter.

Write a **short** report describing your findings following my format instructions. The text should be no more than two pages of 12-point type with 1.5 line spacing, not including plots. The report should contain a concise description of your results. **Include all plots you were required to generate. Include the plots as small as possible *within* the text of the report, not at the end.** *Be sure to answer all questions.*

NOTE: All out-of-class work is to be done independently. Sharing of programming tips and discussing general concepts is ok. Collaborating on experiments or code-writing is not. Any such collaboration on these assignments will be considered an act of dishonesty and will be treated accordingly.
For further help:

- Matlab Primer
- Matlab Help Desk