ECE 454/554 HW04 FIR Filter Design

Assignment is due Wednesday, November 16 at Noon

This assignment will take a fair amount of time to do well, so it would be to your benefit to start it very soon.

To begin this assignment, please review the following online documents:

https://www.mathworks.com/help/signal/ug/filter-design-gallery.html

https://www.mathworks.com/help/signal/ref/designfilt.html?searchHighlight=designfilt&s_tid=srchtitle_designfilt_1

You will likely find additional Mathworks documentation and help files to be very useful.

This exercise involves the design of several lowpass and bandpass FIR filters. It will use the MATLAB `designfilt` function. For both filter types you should not specify the filter order – let the function determine the minimum order that will achieve your other specifications. It begins with the design of lowpass filters that have the following operational characteristics and requirements:

- Passband frequency: 20 kHz
- Stopband frequency: 24 kHz
- Passband ripple 1 dB
- Stopband attenuation: 65 dB
- Sampling rate: 60 kSamples/second

There is also a need for the design of a bandpass filter that has the following operational characteristics and requirements:

- Passband: 10 kHz to 20 kHz
- Lower stopband frequencies <= 8 kHz
- Upper stopband frequencies >= 22 kHz
- Stopband attenuation (both upper and lower stopbands) >= 65 dB
- Passband Ripple 1 dB
- Sampling rate: 60 kSamples/second

For both the lowpass and bandpass filters, the FIR design methods should include the equiripple method which is based on the Parks-McClellan Algorithm) and the kaiser window method. The result of this effort will be four filter designs. You might find a “for” loop to be somewhat useful in your code to reduce the amount of coding.

When each is complete, you should use the fvtool to create five results for each:

- The ‘freq’ option, which shows both magnitude and phase
- The ‘impulse’ option which shows the impulse response
- The ‘grpdelay option which shows group delay of the output
- The ‘polezero’ option which of couse shows the location of poles and zeros
- The ‘info’ option which provides a summary of the results

There are numerous other fvtool options you may wish to explore. You should analyze the results for each case and determine which method seems to provide a better result. An important consideration is cost, which is related to the number of elements needed in the FIR filter. But you may also examine the related factor of group delay along with any other performance characteristics you observe. Does the magnitude response meet the requirements? Is the phase linear within the passband? Is it linear outside the passband and does that matter?

What is the "Type" of this filter according to the Filter Information page? Is that consistent with the properties of the impulse response? Consider whether the impulse response is symmetric and whether the order (length) is even or odd. Any observations about the pole-zero constellation could also be insightful.

Examine the relationship between filter length, group delay, and phase response. Does the group delay predict the slope of the phase response. Hint: convert the phase response slope over a chosen frequency range to $\frac{d\emptyset}{d\omega}$ where $\emptyset$ is the change in phase (radians) and ω is the change in frequency (radians/second) yielding a result with unit seconds. Compare that with the group delay, τ_g when converted from samples to seconds via the sample rate. You may find the use of a spreadsheet to be very helpful for this portion of the homework.

Now that you have everything configured to provide the desired results, it is time to do a bit of exploration. See what happens if, for example, you reduce the spacing between the passband frequencies and the stopband frequencies. Or what happens if you change the ripple requirements. Does changing the sample rate impact the number of elements? As you explore these options, are there results that are surprising?

To submit for this assignment:

A MATLAB .m file that contains the code for the original filter designs followed by the code for at least one variation that you found to be most interesting. It should be well commented and should create the appropriate fvtool results for each case.

A document file that describes your observations for each of the results in these cases. These observations should include any performance differences you observe as well as the implementation cost based on the number of elements (Filter Length) for each implementation. You may also include any tools you may have used like spreadsheets to provide some background for your observations.

50% of the grade for this assignment is based on the code and generation of appropriate results and the remaining 50% is based on your observations and analysis of the data.

Hopefully this assignment ties together a variety of the concepts you have been exposed to this semester. Please prepare any questions you may have to discuss in class.