ENEE 425

Section 0101 Fall 2004

Homework #9

You must attach a printed version of Matlab code (a Matlab file is preferable to copying and pasting a session, if possible). You may put several problems into a single printout, if the start of each problem is made obvious. Don't forget to answer the verbal questions too.

1) For each of the following generalized linear phase FIR filters, answer the subsequent questions

   a) $h[n] = -(\delta[n] + 3\delta[n-1] + 3\delta[n-2] + \delta[n-3])/8$

   b) $h[n] = \frac{1}{2}\delta[n] + \frac{1}{2}\delta[n-4]$

   c) $h[n] = \delta[n-3]$

      i) Decompose $H(\mathrm{e}^{j\omega})$ into $A(\mathrm{e}^{j\omega})\mathrm{e}^{-j\omega\alpha}\,\mathrm{e}^{j\beta}$

      ii) What type is it (I, II, III, IV)? Where does this mean it must have zeros?

      iii) Plot the magnitude $\left|H(\mathrm{e}^{j\omega})\right|$ for ω in the range $[0, 2\pi]$.

      iv) Where does $H(\mathrm{e}^{j\omega})$ actually have zeros?

      v) Describe $H(\mathrm{e}^{j\omega})$ in terms of its frequency selectivity.

2) Create lowpass filters in Matlab according to the following specifications:

   `rp = 1.0` dB [maximum gain distortion allowed in passband]

   `wp = 0.2` [passband upper limit, in Matlab normalized frequency (multiply by π to get radians)]

   `rs = 20.0` dB [minimum attenuation in stopband]

   `ws = 0.3` [stopband lower limit, in Matlab normalized frequency (multiply by π to get radians)]

   a) Use a Butterworth filter and the bilinear transformation.

      i) What is the minimum filter order needed? Use `buttord(wp, ws, rp, rs)`.

      ii) Create the discrete filter directly using `butter()` (which uses `bilinear()` implicitly and automatically). What are the numerator and denominator polynomials (that is, what are `b` and `a`)?

      iii) Plot this discrete filter in magnitude and phase. You may wish to use `freqz()`.

      iv) Evaluate the magnitude of this discrete filter at the two frequencies `wp` and `ws`, in both ordinary magnitude and in dB. How do those values compare to the specifications? If at least one of them doesn't match well, something is wrong and you need to fix it.

   b) Use a continuous Elliptical filter and the bilinear transformation.

i) What is the minimum filter order needed? Use `ellipord(wp, ws, rp, rs)`. How does this compare with the value in part (a)?

ii) Create the discrete filter directly using `ellip()` (which uses `bilinear()` implicitly and automatically).What are the numerator and denominator polynomials (that is, what are `b` and `a`)?

iii) Plot this discrete filter in magnitude and phase. You may wish to use `freqz()`. Describe qualitatively how this filter differs from the filter in part (a).

iv) Evaluate the magnitude of this discrete filter at the two frequencies `wp` and `ws`, in both ordinary magnitude and in dB. How do those values compare to the specifications? If at least one of them doesn't match well, something is wrong and you need to fix it.

v) Are there any phase jumps? How much does the phase jump each time? What is the magnitude doing at the same points? Explain what this phase jump/magnitude behavior means.

c) Which of these methods uses the lower order filter, and how many orders better is it than the worse?

d) Are either of these filters Generalized Linear Phase? Why or why not?

3) Repeat problem (2) for these specifications:

`rp = 0.1` dB [maximum gain distortion allowed in passband]

`wp = 0.6` [passband upper limit, in Matlab normalized frequency (multiply by π to get radians)]

`rs = 60.0` dB [minimum attenuation in stopband]

`ws = 0.75` [stopband lower limit, in Matlab normalized frequency (multiply by π to get radians)]

*This should be the **very last** time you ever use a Butterworth filter!*

4) Repeat problem (2b), e.g. elliptical filter only, for a high-pass filter with these specifications:

`rs = 40.0` dB [minimum attenuation in stopband]

`ws = 0.75` [stopband upper limit, in Matlab normalized frequency (multiply by π to get radians)]

`rp = 0.2` dB [maximum gain distortion allowed in passband]

`wp = 0.85` [passband lower limit, in Matlab normalized frequency (multiply by π to get radians)]

5) Repeat problem (2b), e.g. elliptical filter only, for a low-pass filter with these specifications:

`fs = 48` kHz [sampling frequency]

`rp = 0.1` dB [maximum gain distortion allowed in passband]

`wp = 14.4` kHz [passband upper limit]

`rs = 60.0` dB [minimum attenuation in stopband]

`ws = 18` kHz [passband upper limit]

In what way is this filter similar to the answer to (3b)?