Elec4621 Lab3 - T1 2019

March 13, 2019

This lab is essentially a practice Matlab exercise as well as illustrating the concepts of signal representation, sampling and convolution. When you are done, you are required to upload your code and results (observations) as a zipped file to the submission box on Moodle. You are to name the file using your student number.

1. A third order filter has the transfer function:

$$H(z) = 1 + 0.33z^{-1} - 0.162z^{-2} - 0.3312z^{-3} - 0.1296z^{-4}$$

   (a) What is the DC gain of the filter?

   (b) Using Matlab, find the zeroes of the filter.

   (c) How many filters have the same magnitude response? List their transfer functions. Plot their magnitude responses in Matlab to confirm that they are identical. [Make sure the DC gains of all the filters are normalised to 1 and plot them on the same axes].

   (d) Plot the magnitude responses of the filters on the same axes. What do you observe?

   (e) Plot the phase response these filters (on the same axes). What do you observe?

   (f) Recalling that the group delay is the derivative of the phase response with respect to frequency (that is $\tau_g(\omega) = \frac{d\theta(\omega)}{d\omega}$), write a Matlab script that calculates the group delay of each of the filters. [Hint: the derivative can be approximated numerically as the first order difference (or higher order difference) and the approximation is good provided the frequency grid is fine)]. Plot the group delays on the same axes. Which filter has the smallest group delay? what are its zeros? What do you conclude?

(g) Repeat the above for the filter:

$$H(z) = 1 - 2.6949z^{-1} + 3.9307z^{-2} - 2.6949z^{-3} + z^{-4}$$

2. A filter has the impulse response

$$h[n] = \text{sinc}\left(\frac{n}{6}\right),$$

for $-\infty < n < \infty$. Here $\text{sinc}(x) = \frac{\sin(\pi x}{\pi x}$.

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(a) Is the filter linear? time invariant? causal?

(b) What is the transfer function of the filter?

(c) Plot the frequency response (both magnitude and phase) of the filter. What do you observe?

(d) The filter is to be approximated by an implementable filter. One method to achieve this is to truncate the filter to $2L$ samples, such that the filter impulse response is defined for $-L \leq n \leq L$. investigate the frequency response for various values of L.

i. Comment on the magnitude response of the filter. (what do you observe with respect to the response in 2c?)

ii. Comment on the phase response of the filter.

iii. What should the group delay be for the filter to be practically realisable?

(e) One way to improve the frequency response is to multiple the truncated impulse response by a suitable window. That is we put $h'[n] = w[n]h[n]$.

Plot the frequency response for the same values of L as above but with a Hanning window applied. Compare your results with those obtained without the application of the window. What do you observe?