% Tune-Up Tuesday #8 for October 30, 2018

% (a) Define impulse response *h40*[*n*] of a bandpass filter (BPF).

% It is a finite impulse response with 40 coefficients with

% center frequency of 600 Hz. Sampling rate is 8000 Hz.

fs = 8000;

fA = 600;

wA = 2\*pi\*fA/fs; % discrete-time frequency for 600 Hz

L = 40;

n = 0 : L-1; % vector of n values to consider

h40 = (2/L)\*cos(wA\*n);

% (b) Plot the magnitude response. What is the bandwidth?

freqz(h40); title('FIR BPF 40 points'); ylim( [-100 0] );

% **Answer**: The freqz command plots the magnitude in dB using *A*dB = 20 log10 |*A*|:

% |A| *A*dB |A| *A*dB |A| *A*dB

% 1.0 0dB 0.5 -6dB 0.0 -infinity

% Bandwidth is the extent in positive frequencies.

% For a bandpass filter, one way to measure bandwidth is to find the two frequencies

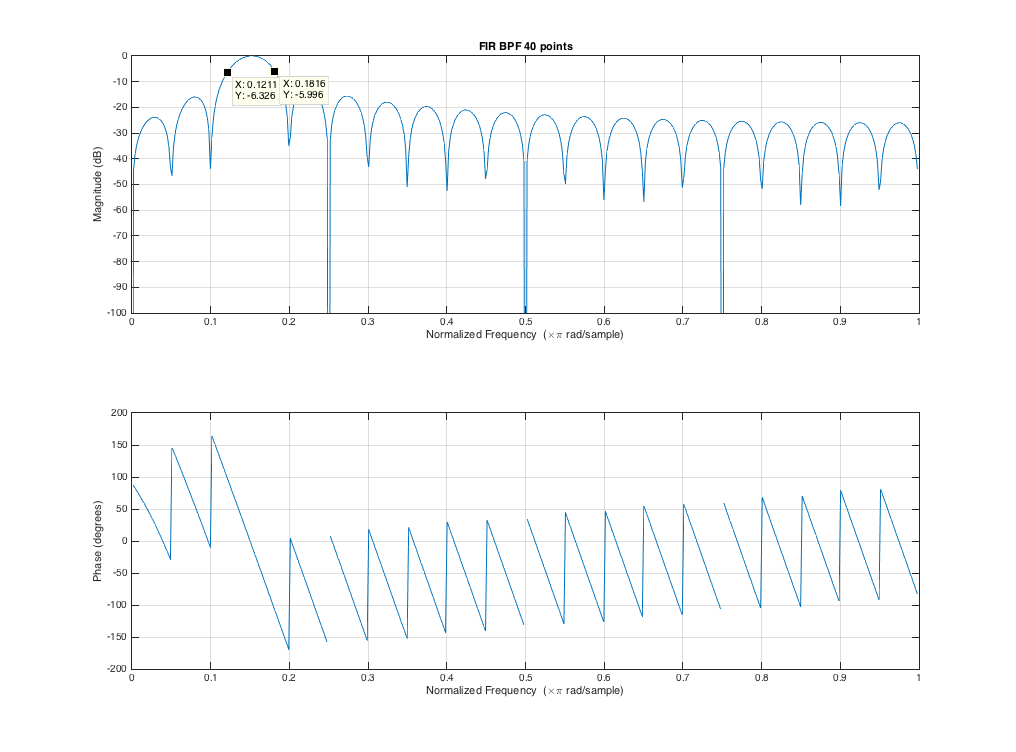
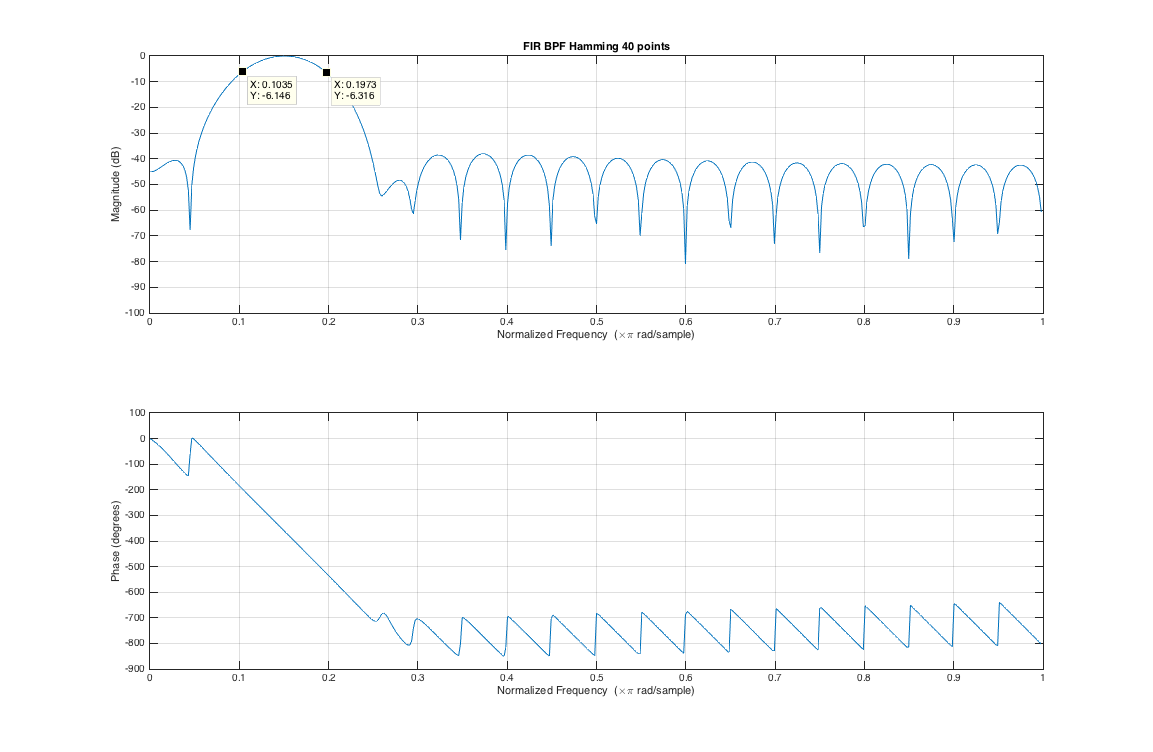
% with magnitude values that are 6 dB down from the maximum magnitude, or

% equivalently, 0.5 times full amplitude in linear units.

% By using the data cursor tool, discrete-time frequency values are 0.12\*pi and

% 0.18\*pi in rad/sample. Bandwidth = 0.06\*pi rad/sample. See left plot below.

% The frequencies correspond to 480 Hz and 720 Hz. Bandwidth = 240 Hz.



% (c) Plot the magnitude/phase response for the 40-point BPF

% based on the Hamming window. What is the bandwidth?

% How does it compare to part (b)?

hammingL = hamming(L)'; %% hamming(L) is Lx1

C = 3.78177 / L; %% normalize max mag to 1

h40hamming = C\*hammingL.\*cos(wA\*n);

figure; freqz(h40hamming);

title('FIR BPF Hamming 40 points'); ylim( [-100 0] );

% **Answer:** By using the method to compute the bandwidth in (b), the -6 dB down

% discrete-time frequencies are 0.103\*pi and 0.197\*pi in rad/sample.

% Bandwidth = 0.094\*pi rad/sample. See right plot on previous page

% The frequencies correspond to 412 Hz and 788 Hz. Bandwidth = 376 Hz.

% (d) Below *x*[*n*] contains a C major scale over two octaves.

% It might sound louder as the principal frequency increases.

C4 = 261.63;

D4 = 293.67;

E4 = 329.63;

F4 = 349.23;

G4 = 392.00;

A4 = 440.00;

B4 = 493.88;

C5 = 523.25;

D5 = 587.33;

E5 = 659.26;

F5 = 698.26;

G5 = 783.99;

A5 = 880.00;

B5 = 987.77;

C6 = 1046.50;

f = [C4,D4,E4,F4,G4,A4,B4,C5,D5,E5,F5,G5,A5,B5,C6];

bpm = 60;

beattime = 60/bpm;

fs = 8000;

Ts = 1/fs;

N = beattime/Ts;

t = 0 : Ts : (N-1)\*Ts;

Tmax = beattime\*length(f);

x = zeros(1, length(f)\*N);

for i = 1:length(f)

note = exp(-t/0.5).\*cos(2\*pi\*f(i)\*t);

x((i-1)\*N+1 : i\*N) = note;

end

sound(x, fs); pause(Tmax+1);

% (e) Filter *x*[*n*] with the 40-point Hamming BPF.

% How does the filter output sound compared to (d).

% Superimpose note frequencies on BPF magnitude response

[H, W] = freqz(h40hamming);

figure; hold on;

plot(W, abs(H));

H2 = freqz(h40hamming, 1, 2\*pi\*f/fs);

stem(2\*pi\*f/fs, abs(H2), 'r.');

xlabel('Normalized frequency (x \pi rad/sample)');

xlim( [0 1] ); hold off;

display 'hit any key for playback of filter output'

pause

y = filter(h40hamming, 1, x);

sound(y, fs);

% **Answer:** The amplitude of each note has been scaled by the magnitude response of

% the filter. The notes increase in amplitude, and then decrease in amplitude.