Example 6-7 Followup: Rejecting an Interfering Tone from Trumpet Signal

Purpose:

Design a notch filter to reject a 800 Hz interfering tone. Use this notch filter to eliminate the tone from the sum of the tone and an actual trumpet playing note B. The trumpet has a fundamental frequency of 494 Hz. Use $\alpha = 100$.

Inputs:

Signal of an actual trumpet playing note B from the file `trumpet.mat`.

aa=α=minus real part of poles.
f=frequency in Hz of note to be eliminated.
fs=sampling rate in samples per s used.
Trumpet fundamental frequency is not used.

Outputs:

Plot and sound of trumpet waveform.
Plot and sound of trumpet-plus-tone.
Plot and sound of filtered trumpet-plus-tone.
Spectrum of trumpet-plus-tone.
Frequency response H of notch filter.
Impulse response h of notch filter.

Comments:

- The first sound is the trumpet-plus-tone. Hit any key to hear the filtered signal.
- The trumpet signal is an actual trumpet playing note B. Its fundamental frequency is 494 Hz and period $\frac{1}{494} \approx 2$ ms. This is apparent in its waveform plot.
- The formulae are all given in the text.
- The notch filter impulse response has an additive impulse: $h(t) = \delta(t) + \tilde{h}(t)$. So we implement $y(t) = h(t) * x(t)$ $= [\delta(t) + \tilde{h}(t)] * x(t) = x(t) + \tilde{h}(t) * x(t)$.
- The sampling rate used is the standard CD sampling rate of 44100 samples per s. Time is discretized to integer multiples of 1/44100

Program:

```
clear;load 'trumpet.mat'
aa=100;f=800;fs=44100;L=length(X);
dt=1/fs;t=[0:L-1]*dt;
Y=X+cos(2*pi*f*t);
%GOAL: Recover X from Y.
%Design notch filter:
%Use formulae from the text.
aa2=aa*aa;wo=2*pi*f;
A=sqrt(4*aa2+aa2*aa2/wo/wo);
theta=atan(aa/wo/2);
h=-A*exp(-aa*t).*cos(wo*t+theta);
%Impulse response=delta+h.
%z=(delta+h)*y=y+h*y.
%Convolve signal and filter
%using Fourier transforms:
FY=fft(Y);Fh=fft(h)*dt;
Z=real(ifft(FY.*Fh));Z=Y+Z;
%Spectrum of trumpet+sinusoid.
%See Chapter 8 for details.
If=[1:4000];F=(If-1)*fs/L;
AY=2*abs(FY(If))/L;
AH=abs(1+Fh(If));
figure,subplot(211),plot(F,AY,F,AH,'r')
%Plot time waveforms:
It=[4601:4900];%display interval.
figure,subplot(211),plot(t(It),X(It))
figure,subplot(211),plot(t(It),Y(It))
figure,subplot(211),plot(t(It),Z(It))
figure,subplot(211),plot(t(If),h(If))
soundsc(Y,fs),pause,soundsc(Z,fs)
```

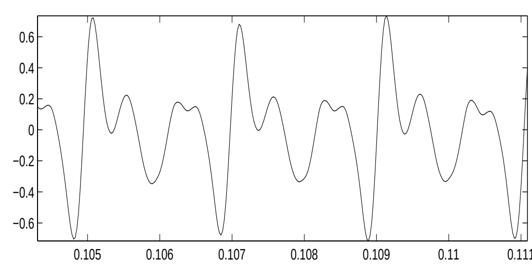

Figure 1: Trumpet waveform.

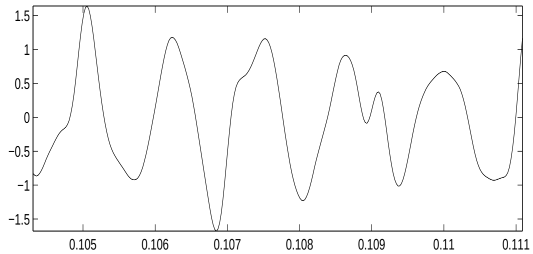

Figure 2: Trumpet-plus-tone.

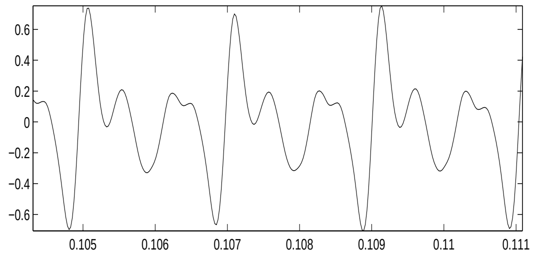

Figure 3: Filtered trumpet-plus-tone waveform.

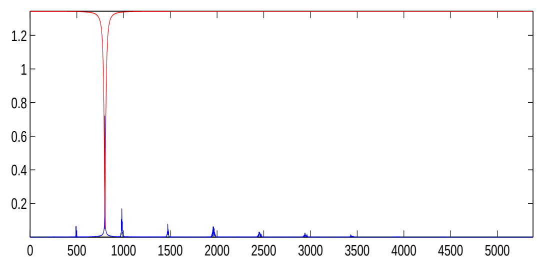

Figure 4: Frequency response of notch filter (red) and spectrum of trumpet-plus-tone signal (blue). Plotted vs. frequency in Hz.

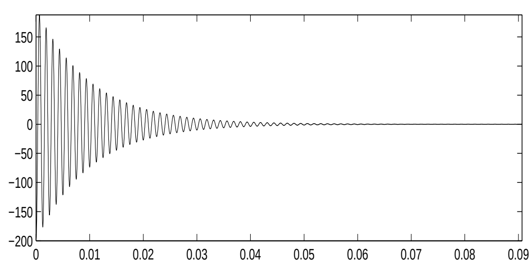

Figure 5: Impulse response of the notch filter. Excludes impulse.