Example 6-9: Separating Two Simultaneously Played Trumpet Notes.

Purpose:

Given signals $x_1(t)$ and $x_2(t)$ of two trumpets playing notes G and A simultaneously, design a comb filter that eliminates the trumpet playing note A, while keeping the trumpet playing note G. Compute and plot the comb filter's impulse and frequency responses. Choose $\alpha = 100\,s^{-1}$ and $n = 9$. Notes G and A have fundamental frequencies of 392 Hz and 440 Hz, respectively.

Inputs:

Signal of two actual trumpets playing notes G and A from the file `twotrumpetsGA.mat`.

aa=α=minus real part of poles.

n=order (#poles) of comb filter.

fs=sampling rate in samples per s used.

fr=frequency in Hz of the notes whose harmonics are to be eliminated.

Outputs:

Plot and sound of two-trumpets signal.
Plot and sound of filtered two-trumpets.
Spectrum of two-trumpets signal.
Frequency response H of comb filter.
Impulse response h of comb filter.

Comments:

- The first sound is the two-trumpets signal. Hit any key to hear the filtered signal.
- The input signal consists of two actual trumpets playing notes G and A. Their fundamental frequencies are 392 and 440 Hz, respectively. The period of the trumpet playing note G is $\frac{1}{392} \approx 2.5$ ms. This is apparent in the waveform plot of the filtered two-trumpets signal.
- The comb filter has poles and zeros:
  Zeros at $j2\pi 440k$ for integers $|k| \leq 9$.
  Poles at $-100 + j2\pi 440k$ for $|k| \leq 9$.
- The comb filter impulse response has an additive impulse: $h(t) = \delta(t) + \tilde{h}(t)$.
  So we implement $y(t) = h(t) * x(t)$
  $= [\delta(t) + \tilde{h}(t)] * x(t) = x(t) + \tilde{h}(t) * x(t)$.

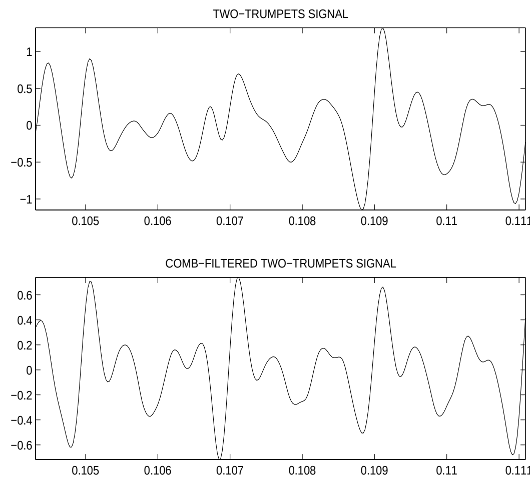

Figure 1: Top: Two-trumpets signal vs. time in s. Bottom: Filtered two-trumpets signal.

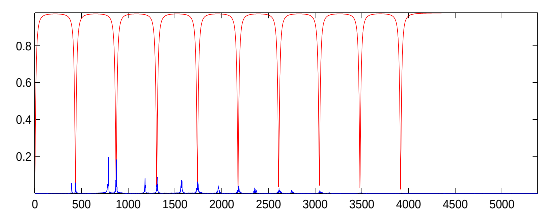

Figure 2: Frequency response of comb filter (red) and spectrum of two-trumpets signal (blue). Both plotted vs. frequency in Hz.

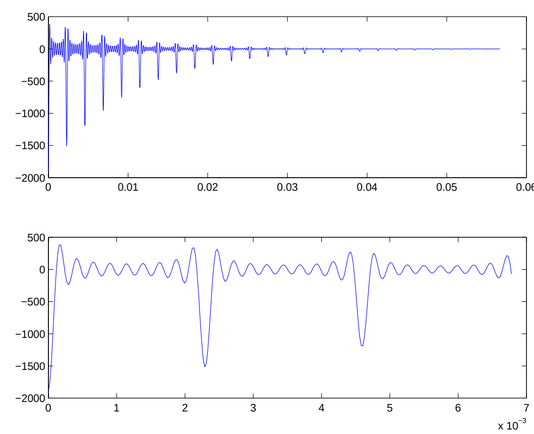

Figure 3: Top: Impulse response vs. time in s. Bottom: Zoom of initial part of impulse response.

Program:

```
clear;load 'twotrumpetsGA.mat'
aa=100;n=9;fr=435;fs=44100;
L=length(X);dt=1/fs;t=[0:L-1]*dt;
%Design comb filter:
N=poly(j*2*pi*fr*[-n:n]);
D=poly(-aa+j*2*pi*fr*[-n:n]);
%Compute impulse response:
%Excludes additive impulse.
[R P K]=residue(N,D);
h=real(R.'*exp(P*t));
Ih=[1:2500];%display interval
subplot(211),plot(t(Ih),h(Ih))
subplot(212),plot(t(1:300),h(1:300))
%Convolve signal and filter
%using Fourier transforms.
%Use y=(delta+h)*x=x+h*x.
Fh=fft(h)*dt;FX=fft(X);
Y=real(ifft(FX.*Fh));Y=X+Y;
%Spectrum of two-trumpet signal:
%See Chapter 8 for details.
If=[1:4000];F=(If-1)*fs/L;
FhI=abs(1+Fh(If));FXI=2*abs(FX(If))/L;
figure,subplot(211),
plot(F,FhI,'r',F,FXI,'b')
%Plot time waveforms:
figure,I=[4601:4900];%display interval
subplot(211),plot(t(I),X(I))
subplot(212),plot(t(I),Y(I))
soundsc(X,fs),pause,soundsc(Y,fs)
```