Example 6-13: Resonator Trumpet Filter.

Purpose:

Design a resonator filter to remove the noise from the noisy trumpet signal. Generate plots of the filter's frequency and impulse responses for $\alpha = 25$, and compare the filtered signal with the original noise-free trumpet signal.

Inputs:

Signal of an actual trumpet playing note B from the file `trumpet.mat`.
aa=α=minus real part of poles.
n=order (#poles) of resonator.
f=frequency in Hz of note to be eliminated.
fs=sampling rate in samples per s used.

Outputs:

Plot and sound of noiseless trumpet signal.
Plot and sound of noisy trumpet signal.
Plot and sound of filtered noisy trumpet.
Spectrum of noisy trumpet signal.
Frequency response H of resonator.
Impulse response of resonator.

Comments:

- The first sound is the noisy trumpet signal. Hit any key to hear the filtered signal.
- The trumpet signal is an actual trumpet playing note B, which has a fundamental frequency of 494 Hz and period $\frac{1}{494} \approx 2$ ms. This is apparent in its waveform plot.
- $\mathbf{H}_{\text{resonator}}(s) = 1 - \mathbf{H}_{\text{comb}}(s)$.
- The resonator impulse response $h(t)$ is $h(t) = \delta(t) - g(t)$, where $g(t)$ is the impulse response of the comb filter. The comb filter impulse response has an additive impulse: $g(t) = \delta(t) + \tilde{g}(t)$. So $h(t) = \delta(t) - [\delta(t) + \tilde{g}(t)] = -\tilde{g}(t)$ and $y(t) = h(t) * x(t) = -\tilde{g}(t) * x(t)$. The resonator impulse response does not have an additive impulse in it.
- The sampling rate used is the standard CD sampling rate of 44100 samples per s. Time is discretized to integer multiples of 1/44100
- **The noise level is ten times as large as the noise level used for the Butterworth filter in Section 6-9.3 above.** Yet the noise is almost eliminated. **Listen** to Z.

Program:

```
clear;load 'trumpet.mat'
aa=25;n=9;f=491;fs=44100;
L=length(X);dt=1/fs;t=[0:L-1]*dt;
Y=X+randn(1,L);%GOAL: Find X from Y.
%Design comb filter:
N=poly(j*2*pi*f*[-n:n]);
D=poly(-aa+j*2*pi*f*[-n:n]);
%Compute impulse response.
%Excludes additive impulse.
%Then resonator=delta-comb
%resonator=delta-(delta+h)=-h.
[R P K]=residue(N,D);
h=-real(R.'*exp(P*t));%note the -.
figure,subplot(211),plot(t,h)
%Convolve signal and filter
%using Fourier transforms.
Fh=fft(h)*dt;FY=fft(Y);
Z=real(ifft(FY.*Fh));
%Spectrum of noisy trumpet signal:
%See Chapter 8 for details.
If=[1:4000];F=(If-1)*fs/L;
FhI=abs(Fh(If));FYI=2*abs(FY(If))/L;
figure,subplot(211),
plot(F,FhI,'r',F,FYI,'b')
%Plot time waveforms:
I=[4601:4900];%Display interval.
figure,subplot(211),plot(t(I),X(I))
figure,subplot(211),plot(t(I),Y(I))
figure,subplot(211),plot(t(I),Z(I))
soundsc(Y,fs),pause,soundsc(Z,fs)
```

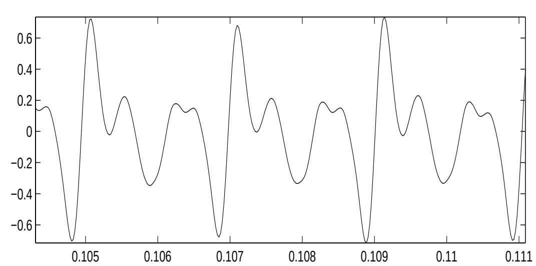

Figure 1: Noiseless trumpet.

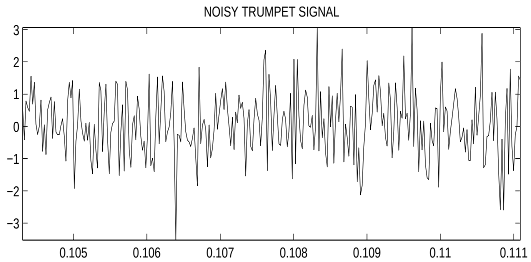

Figure 2: Noisy trumpet signal.

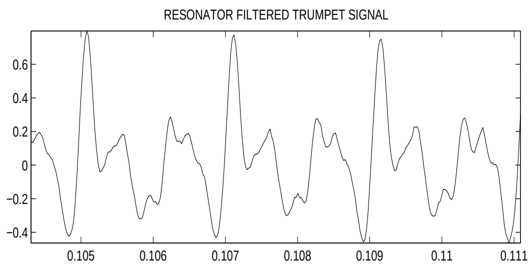

Figure 3: Resonator-filtered trumpet.

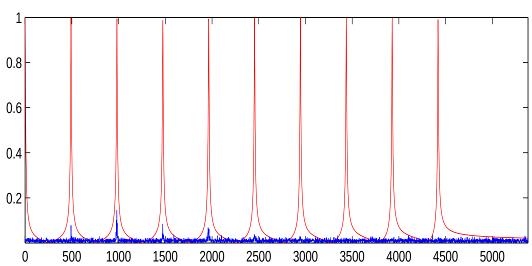

Figure 4: Spectrum of noisy trumpet (blue) and frequency response of resonator (red).

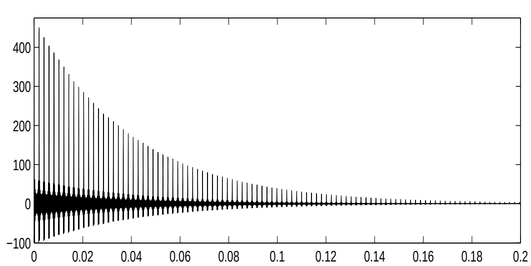

Figure 5: Impulse response of resonator.