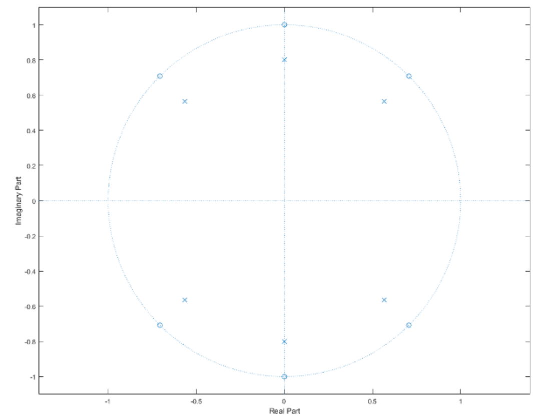
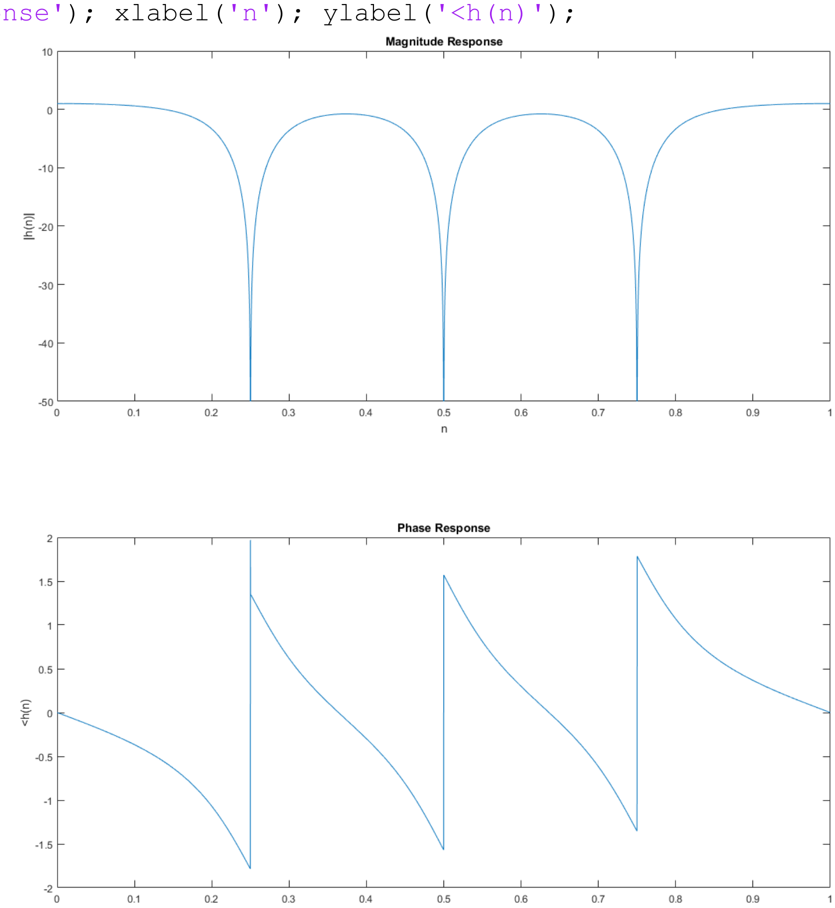
Jake Garrison 2/10/16 EE 442 HW 5

CODE AND PLOTS

%% Question 1

```
fs = 8000;                  % sampling rate
f0 = (1:3).*1000;         % notch frequency
fr = f0/fs;                 % ratio of notch freq. to Nyquist freq.
nw = 0.2;                   % width of the notch

zeros = [exp( 2*1i*pi*fr ), exp( -2*1i*pi*fr )]; % Compute zeros
poles = (1- nw) * zeros; % Compute poles

b = poly(zeros); % average filter coefficients
a = poly(poles); % autoregressive filter coefficients

[H, w] =  freqz(b,a,fs);
mag = abs(H);
db = 20*log10((mag+eps)/max(mag))+1;
pha = angle(H);
max(db)

%% Plot Zeros and Magnitude and Phase
figure; % zero plot
zplane(zeros.', poles.');
figure; % mag, phase plot
subplot(211); plot(w/pi,db)
title('Magnitude Response'); xlabel('n'); ylabel('|h(n)|');
ylim([-50, 10])
subplot(212); plot(w/pi, pha)
title('Phase Response'); xlabel('n'); ylabel('<h(n)');
```





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```
%% Filter Signal
load handel
%load splat
%load laughter
%load train
%load gong
% load chirp

% Add Spectral Noise
t= (1:1:length(y));
spectral = sum(cos(2*pi*fr(:)*t));
y_noise = y + spectral.';
filtered = filter(b,a,y_noise);

figure
subplot(311); plot(y)
title('Original'); xlabel('hz'); ylabel('h(n)'); ylim([-1, 1]);
subplot(312); plot(y_noise)
title('Added Noise'); xlabel('hz'); ylabel('h(n)');
subplot(313); plot(filtered)
title('Filtered'); xlabel('hz'); ylabel('h(n)'); ylim([-1, 1]);

%% Play Sound
% soundsc(y, Fs); pause() % original
soundsc(y_noise, Fs); pause()   % dirty
soundsc(filtered, Fs);  % clean

%% Spectral Plot
nwin = 512; % samples
noverlap = 256; %samples
nfft = 512; %samples

figure
subplot(311); spectrogram(y, nwin, noverlap, nfft); colormap(cool);
title('Original'); xlabel('hz'); ylabel('h(n)');
subplot(312); spectrogram(y_noise, nwin, noverlap, nfft); colormap(cool);
title('Added Noise'); xlabel('hz'); ylabel('h(n)');
subplot(313); spectrogram(filtered, nwin, noverlap, nfft); colormap(cool);
title('After Filtering'); xlabel('hz'); ylabel('h(n)');
```

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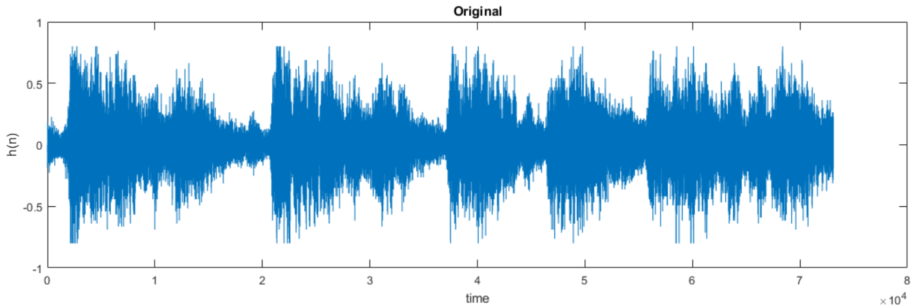

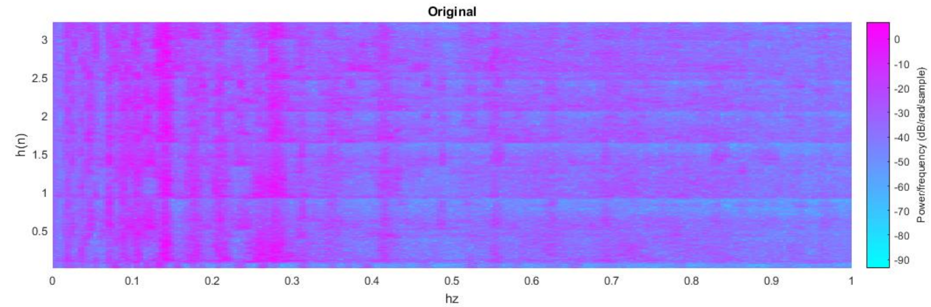

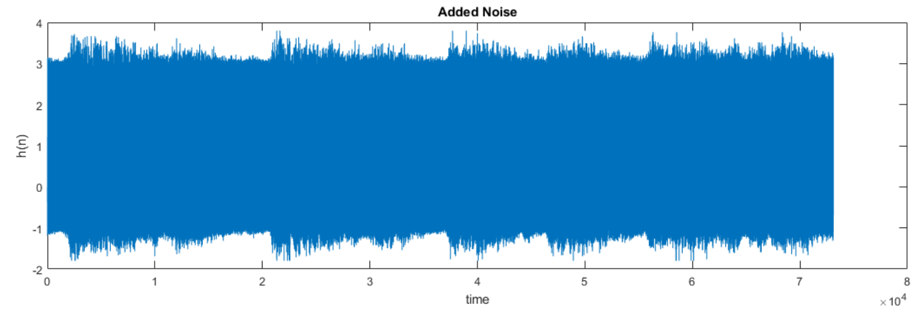

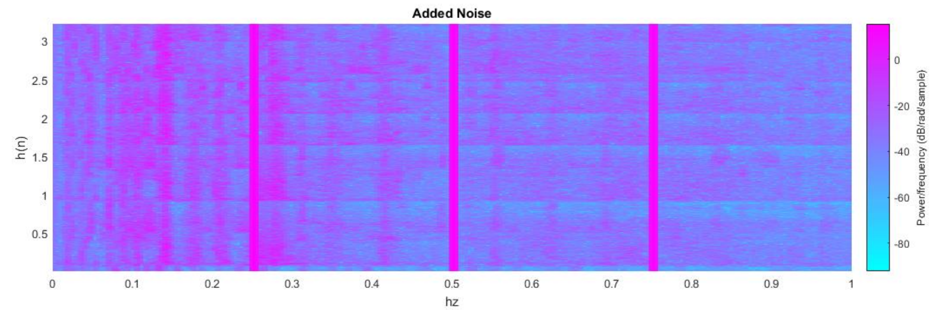

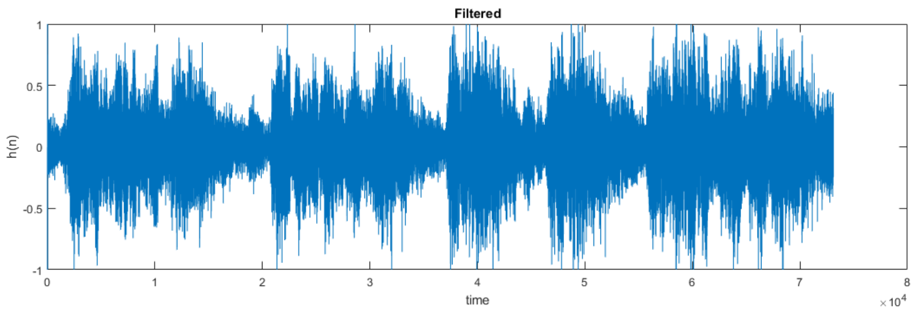

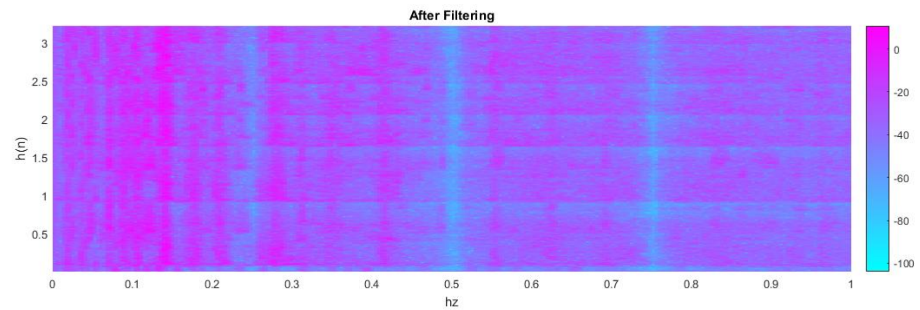

Adding the sines with amplitude 1 completely overtakes the signal. Removing these spectral peaks with the notch filter restores the original sound, although it is slightly quieter and missing the narrow bands that are filtered. At equal amplitude, The original and filtered signals sound the same.

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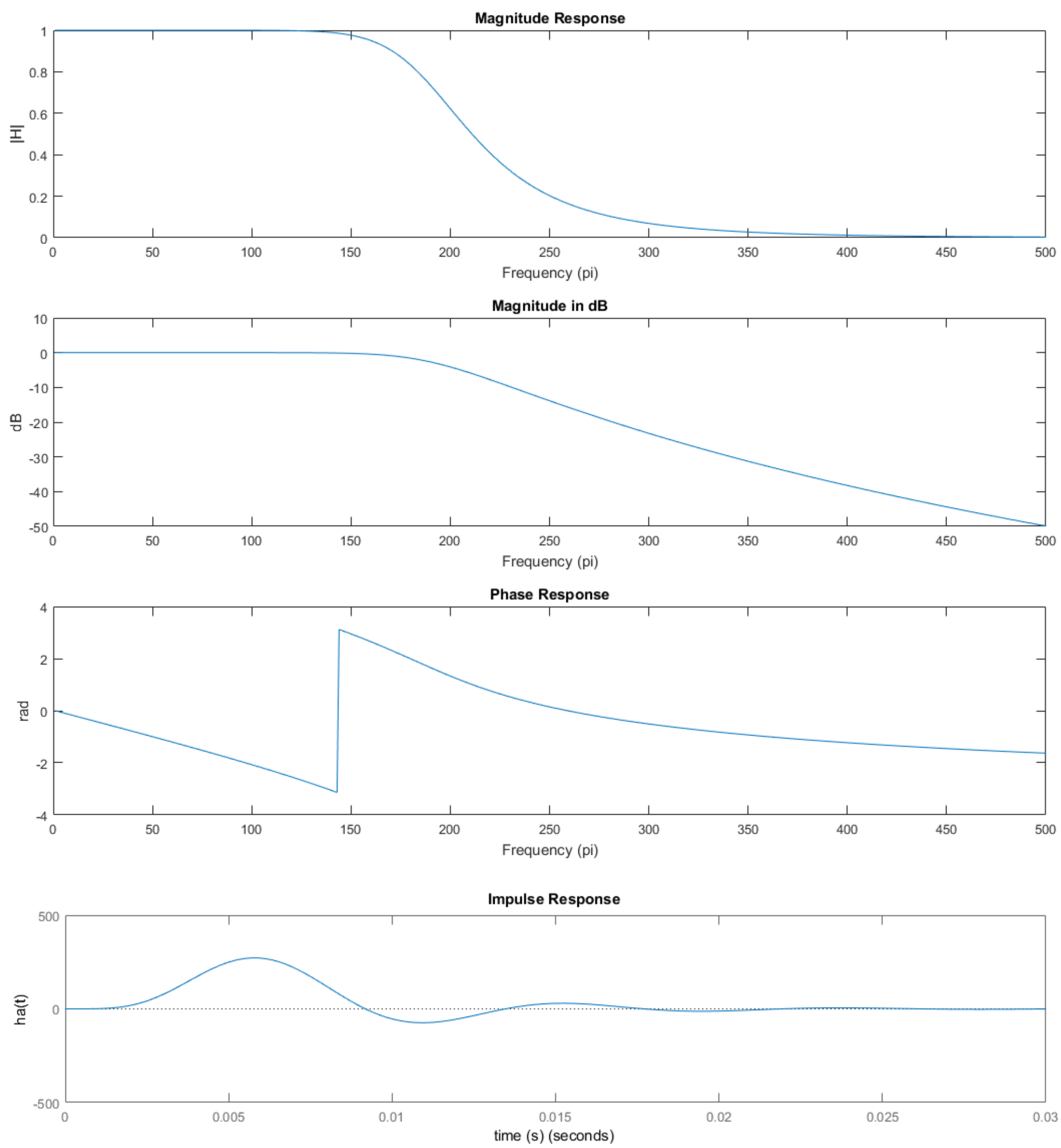
```
%% Question 2

Os = 2000; Op = 500; As = 50; Rp = 0.25;
[N, Om_c] = buttord(Op, Os, Rp, As, 's')
[b, a] = u_buttap(N, Om_c);
% Calculation of Frequency Response:
[db,mag,pha,w] = freqs_m(b,a, Os);

%% Plots
subplot(4,1,1); plot(mag);title('Magnitude Response')
xlabel('Frequency (pi)'); ylabel('|H|'); xlim([0, 500])
subplot(4,1,2); plot(db);title('Magnitude in dB')
xlabel('Frequency (pi)'); ylabel('dB'); ; xlim([0, 500])
subplot(4,1,3); plot(pha); title('Phase Response')
xlabel('Frequency (pi)'); ylabel('rad'); ; xlim([0, 500])
subplot(4,1,4); impulse(b,a); title('Impulse Response')
xlabel('time (s)'); ylabel('ha(t)');
```

Rational form:

```
Numerator: 1.0e+17 * [ 0.0000 -2.0239 ]
Denominator: 1.0e+64 * [ 0.0000 -0.0000  0.0000 -0.0000 0.0000 -0.0010  2.8364  -2.8355 ]
```



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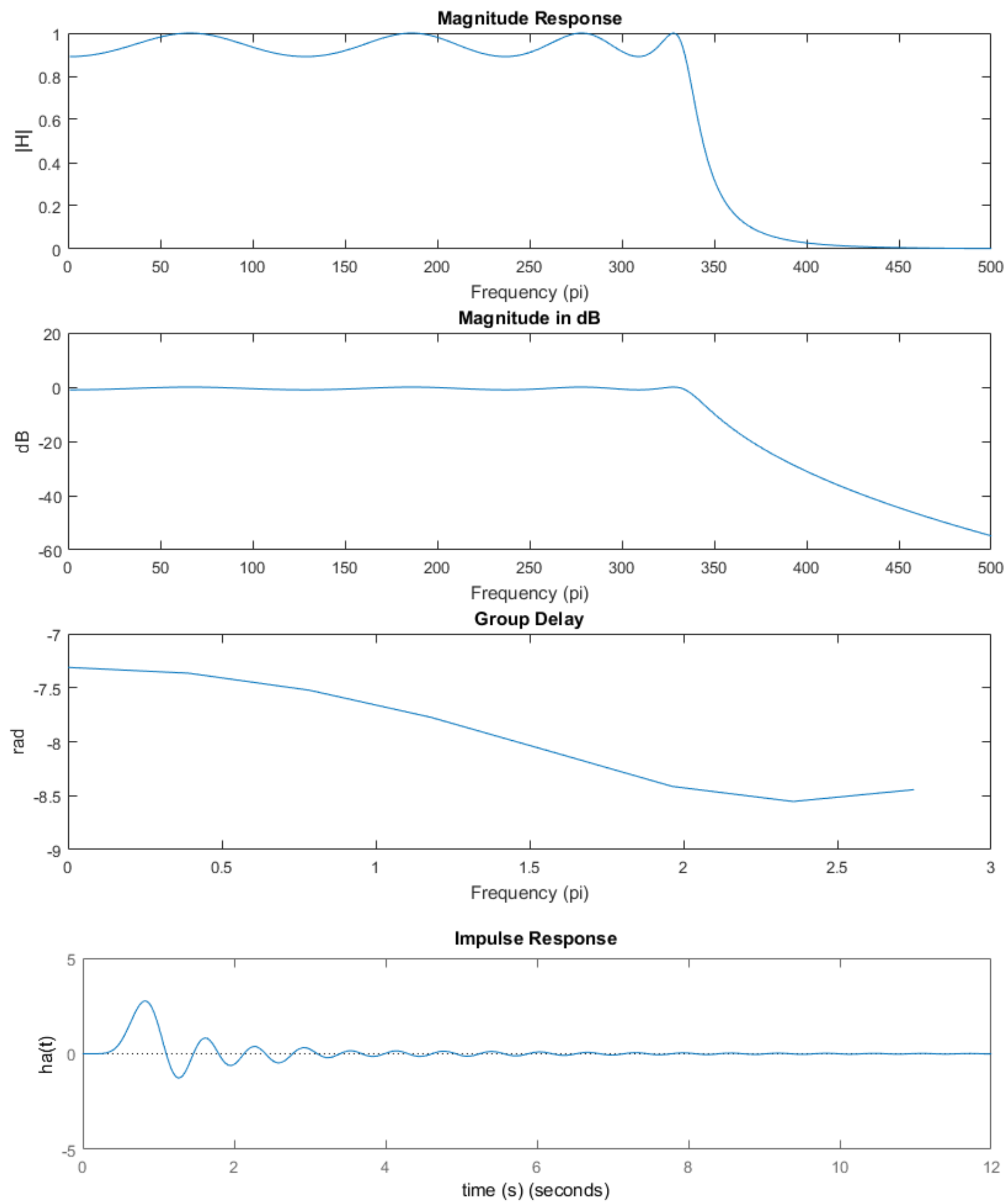
%% Question 3

```
Rp = 1; As = 50; Op = 10; Os = 15;
e = sqrt((10^0.1*Rp)-1); A = 10 ^ (As/20);
Or = Os/Op; g = sqrt((A^2 - 1)/(e^2));
N = ceil(log10(g + sqrt((g^2) - 1))/log10(Or + sqrt((Or^2) -1)));
[b, a]=u_chb1ap(N,Rp, Op);
[db,mag,pha,w] = freqs_m(b,a, Os);
[gd, wd] = grpdelay(b, a, N);
%% Plots
subplot(4,1,1); plot(mag);title('Magnitude Response')
xlabel('Frequency (pi)'); ylabel('|H|'); xlim([0, 500])
subplot(4,1,2); plot(db);title('Magnitude in dB')
xlabel('Frequency (pi)'); ylabel('dB'); xlim([0, 500])
subplot(4,1,3); plot(wd, gd); title('Group Delay')
xlabel('Frequency (pi)'); ylabel('rad');
subplot(4,1,4); impulse(b,a); title('Impulse Response')
xlabel('time (s)'); ylabel('ha(t)');
```

Rational form:

```
Numerator: 1.5353e+06
Denominator: 1.0e+64 * 1.0e+06
* [0 0 0.0002 0.0017 0.0184
0.0847 0.4478 1.0734  1.7227]
```



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```matlab
%% Question 4
Op = 4000*pi; Os = 6000*pi; Rp = 0.8; As = 25;
e = sqrt((10^(0.1*Rp))-1); A = 10 ^ (As/20);
Or = Os/Op; g = sqrt((A^2 - 1)/(e^2));
N = ceil(log10(g + sqrt((g^2) - 1))/log10(Or + sqrt((Or^2) -1)));
al = 1/e + (1 + 1/e^2)^(1/2)
min = 1/2*(al^(1/N) - al^(-1/N));
maj = 1/2*(al^(1/N) + al^(-1/N));
k = (0:N-1)';
ok(:,1) = min*Op*cos((pi/2)+(2*k+1)*pi/(2*N))
ok(:,2) = maj*Op*sin((pi/2)+(2*k+1)*pi/(2*N))
p = ok(:,1) + 1i*ok(:,2)
zplane(0,p)
a = poly(p);
b = prod(p); % N is odd so K = product of poles
[db,mag,pha,w] = freqs_m(b, a, Os);

% Plot results
figure;
subplot(2,1,1);plot(db); grid; axis([0, 500, -30, 2]);
title('Log Magnitude Response'); xlabel('frequency (pi)');
ylabel('Decibels');
subplot(2,1,2); plot(pha/pi); axis([0, 500, -pi, pi]);
title('Phase Response'); grid
xlabel('frequency (pi)'); ylabel('Radians')
```