Contents

Piano Note Decoding: Lab P-14: 5 Lab Exercise

```
clc
clear
close all
```

5

```
idx = 1:5;  % 5 filters
```

5.1a

lower normalized radial frequency of the octave

```
lowRad = ones(length(idx), 1);
% the lowest octave starts at key 16
% Key 49 is 440 Hz, so 440*2^((16-49)/12) is the frequency of key 16
lowRad(1) = 440*2^((16-49)/12) / 8000 * 2 * pi;
for k = 2:5
    % each octave is double the previous
    lowRad(k) = lowRad(k-1) * 2;
end
% the high end of the octave is double the low
highRad = 2.*lowRad;
% low end frequencies in Hertz
lowHertz = lowRad / 2 / pi;
% high end frequencies in Hertz
highHertz = highRad / 2 / pi;
```

5.1b

the center point of the octave

```
centerRad  = sqrt(lowRad .* highRad);
% the center in Hertz
centerHertz = centerRad / 2 / pi;

fprintf("Octave\t\tLower Edge(Hz)\t\tHigh Edge(Hz)\t\tCenter(Hz) \n");
for i = 1:5
fprintf("%d\t\t%f\t\t%f\t\t%f\n", i+1, lowHertz(i), highHertz(i), centerHertz(i));
end
fprintf("\n");
fprintf("Octave\t\tLower Edge(rad)\t\tHigh Edge(rad)\t\tCenter(rad) \n");
for i = 1:5
fprintf("%d\t\t%f\t\t%f\t\t%f\n", i+1, lowRad(i), highRad(i), centerRad(i));
end
```

```
Octave          Lower Edge(Hz)          High Edge(Hz)           Center(Hz)
2               0.008176                0.016352                0.011562
3               0.016352                0.032703                0.023125
4               0.032703                0.065406                0.046249
5               0.065406                0.130813                0.092499
6               0.130813                0.261626                0.184997

Octave          Lower Edge(rad)         High Edge(rad)          Center(rad)
2               0.051370                0.102740                0.072648
3               0.102740                0.205480                0.145296
4               0.205480                0.410960                0.290593
5               0.410960                0.821921                0.581186
6               0.821921                1.643842                1.162372
```

5.2

5.2a.a

the instructions say this is nearly impossible

5.2a.b

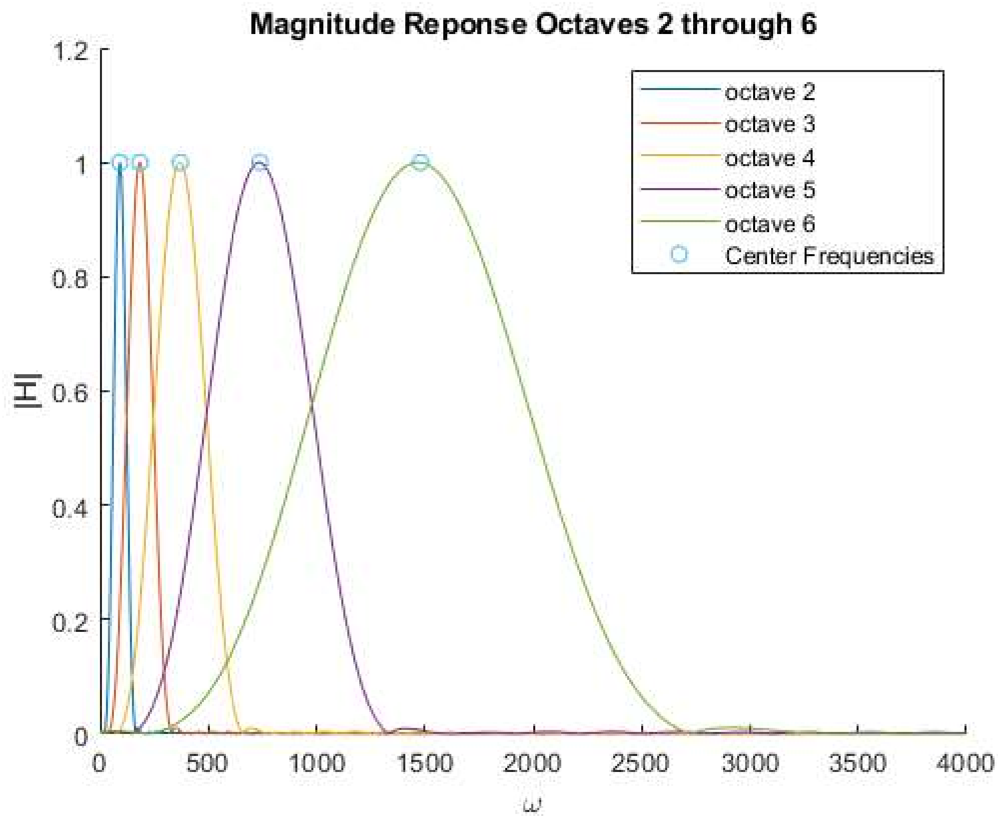
see the lines surrounding the HH variable for scaling of the filters

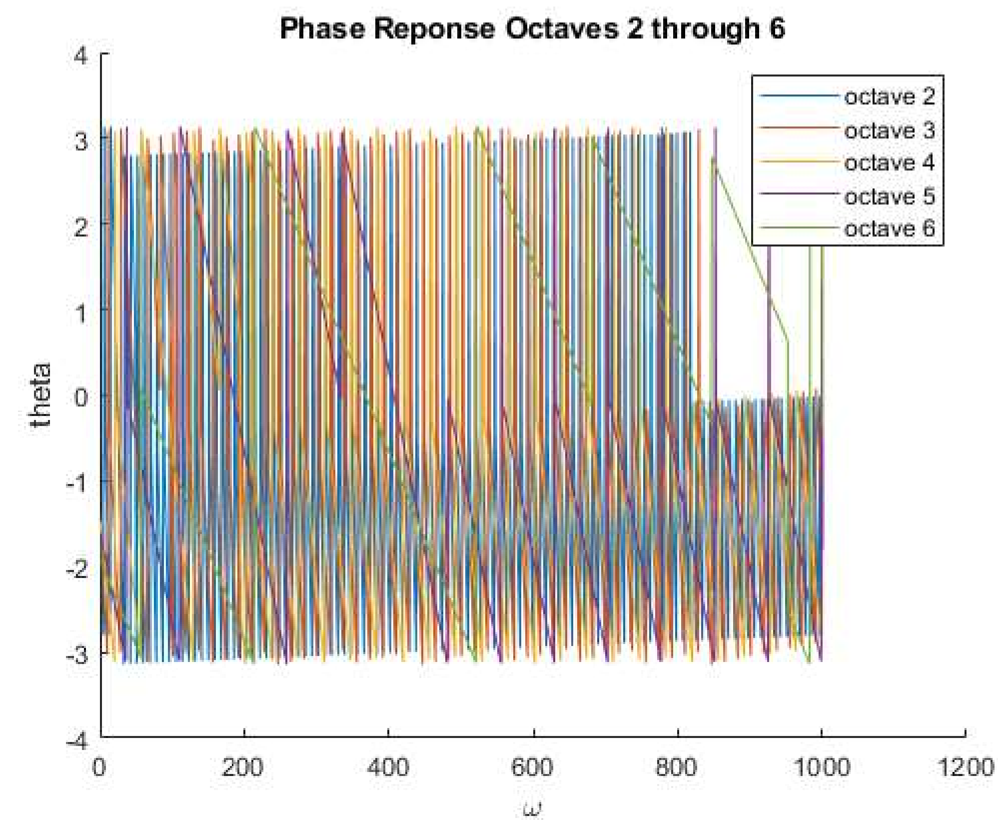
5.2b and 5.2c

The BWL ratio is used to calculate L according to L = BWL / Bandwidth

```
BWL = 0.141372 * 81;
% x axis in our plots
ww = 0:(pi/1000):pi;
% calculate L for filters
L = BWL ./ (highRad - lowRad);
% hamming windows, each will be of different lengths
windows = cell(length(idx),1);


figure
title("Magnitude Reponse Octaves 2 through 6");
xlabel("\omega");
ylabel("|H|");
hold on;
for i = idx
```

```
    % calculate the window using wc and L
    windows{i} = gen_hamming(centerRad(i),round(L(i)));
    % calculate magnitude and phase response of h
    HH = freqz(windows{i}, 1, ww);
    % normalize the coefficients such that the max is 1
    windows{i} = windows{i} ./ max(HH);
    % recalculate HH using normalized coefficients
    HH = freqz(windows{i}, 1, ww);
    % plot magnitude, use ww / 2 / pi * 8000 for frequency on x axis
    plot(ww / 2 / pi * 8000, abs(HH));
end
plot(centerHertz * 8000, ones(i, 1), 'o');
legend('octave 2', 'octave 3', 'octave 4', 'octave 5', 'octave 6', 'Center Frequencies');
hold off

WW = 0:pi/1000:pi;      % frequency range
figure
title("Phase Reponse Octaves 2 through 6");
xlabel("\omega");
ylabel("theta");
hold on;
for i = idx
    % calculate the window using wc and L
    windows{i} = gen_hamming(centerRad(i),round(L(i)));
    % calculate magnitude and phase response of h
    HH = freqz(windows{i}, 1, ww);
    % normalize the coefficients such that the max is 1
    windows{i} = windows{i} ./ max(HH);
    % recalculate HH using normalized coefficients
    HH = freqz(windows{i}, 1, ww);
    % plot magnitude, use ww / 2 / pi * 8000 for frequency on x axis
    %plot(ww / 2 / pi * 8000, abs(HH));
    plot(angle(HH));
end
%plot(centerHertz * 8000, ones(i, 1), 'o');
legend('octave 2', 'octave 3', 'octave 4', 'octave 5', 'octave 6');
hold off
```





5.2d

yes the filter's passbands are narrow enough however, there is non-zero area where the magnitude response is below 0.5 yet above 0

5.3

5.3a

number of points in xx

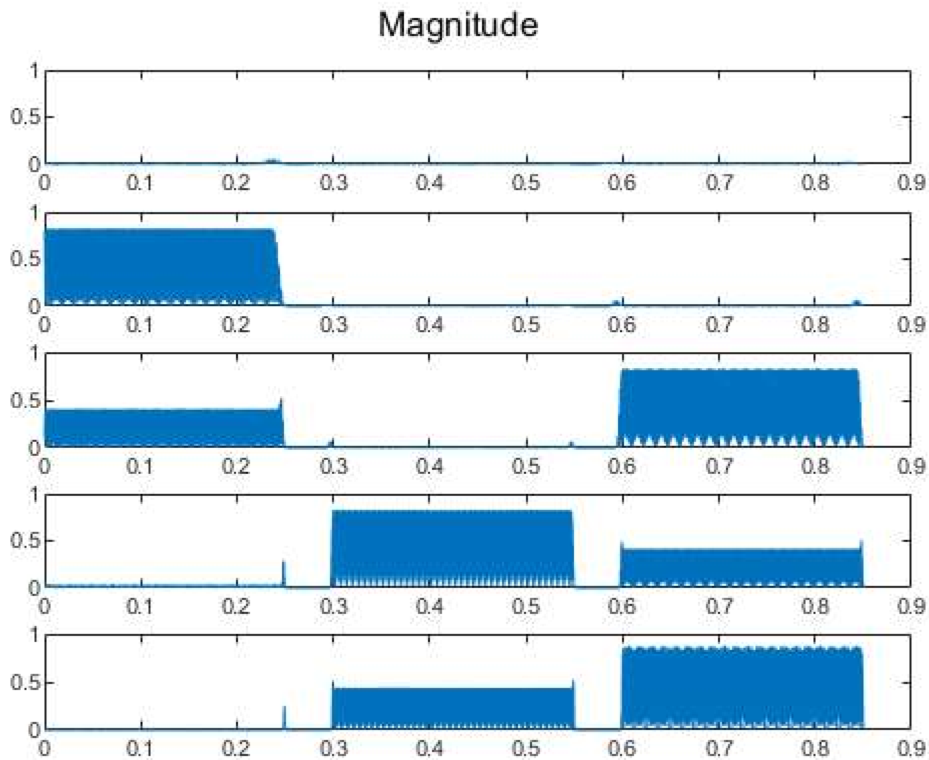
```
N = 0.85*8000;
% x(t)
xx = zeros(N,1);
% t
t = zeros(N,1);
for i = 1:N
    t(i) = i/8000;
end
% first segment goes to 0.25 seconds
for i = 1:round(0.25*8000)
    % formula for first segment
    xx(i) = cos(2*pi*220*i / 8000);
end
% zero in between
for i = round(0.25*8000) + 1:round(0.30*8000)
    xx(i) = 0;
end
% second segment goes from 0.30 to 0.55
for i = round(0.30*8000) + 1:round(0.55*8000)
    % formula for second segment
    xx(i) = cos(2*pi*880*i / 8000);
end
% zero in between
for i = round(0.55*8000) + 1:round(0.60*8000)
    xx(i) = 0;
end
% third segment goes from 0.60 to 0.85
for i = round(0.60*8000) + 1:round(0.85*8000)
    % formula for third segment
    xx(i) = cos(2*pi*440*i / 8000) + cos(2*pi*1760*i / 8000);
end
```

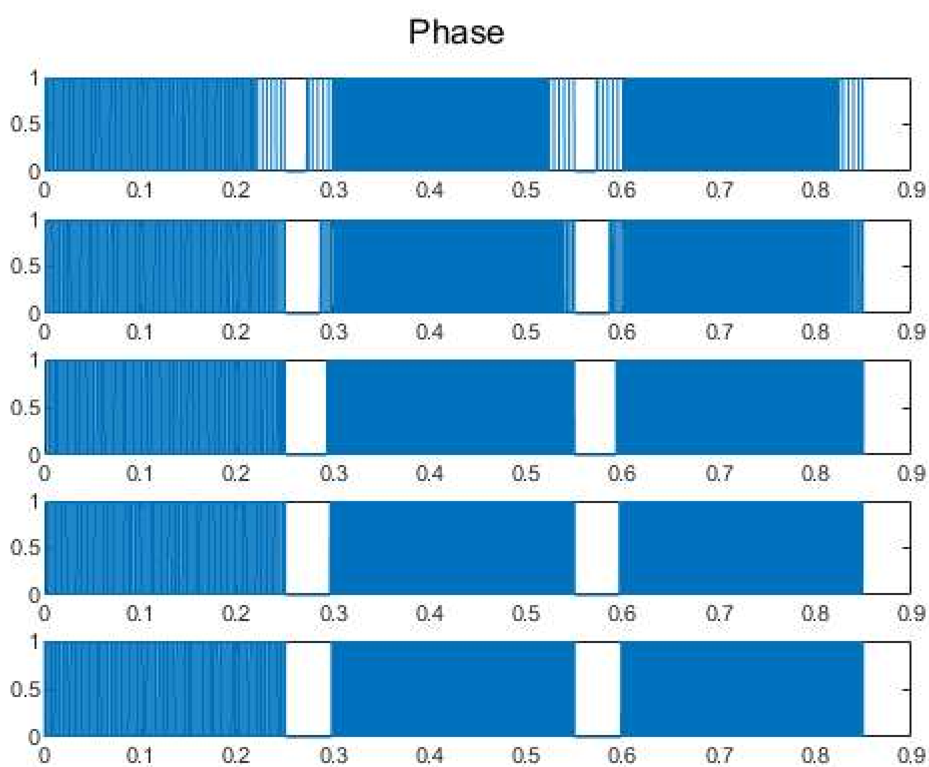
5.3b and 5.3c

matrix of outputs

```
output = zeros(length(xx), length(windows));
figure

for i = idx
    % calculate output using convolution
    yy = conv(windows{i}, xx);
    % cut off the first L elements of the convolution
    output(:, i) = yy(round(L(i)):end);
    subplot(length(idx),1,i);
    % plot the output
    plot(t, abs(output(:,i)));
    ylim([0,1])
end
sgtitle('Magnitude')

% matrix of outputs
output = zeros(length(xx), length(windows));
```

```
figure

for i = idx
    % calculate output using convolution
    yy = conv(windows{i}, xx);
    % cut off the first L elements of the convolution
    output(:, i) = yy(round(L(i)):end);
    subplot(length(idx),1,i);
    % plot the output
    plot(t, angle(output(:,i)));
    ylim([0,1])
end
sgtitle('Phase')
```





5.3d

Yes, the output signals have the correct magnitude and phase

5.3e

The transient time for the second lowest filter is 0.0142s The transient time for the third lowest filter is 0.006s The transient time for the fourth lowest filter is 0.004s The transient time for the fifth lowest filter is 0.0015s

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