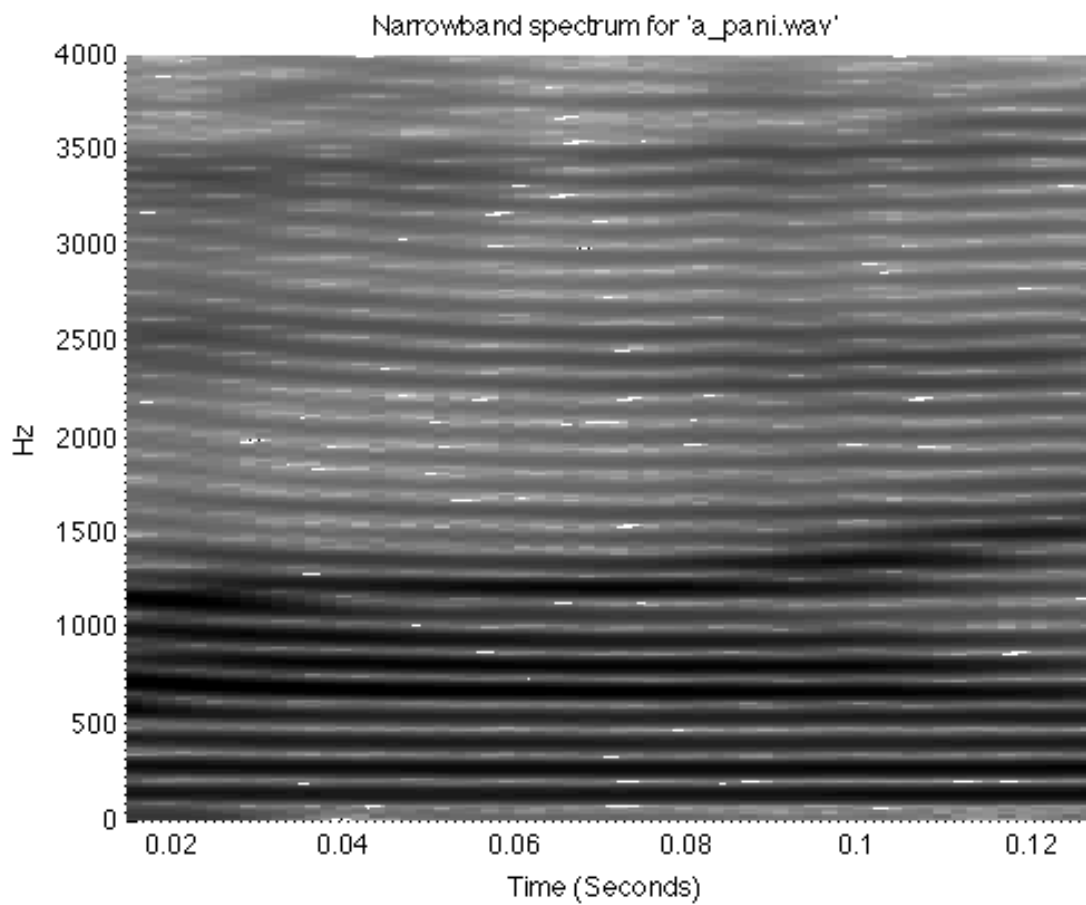# EE 679 Computing Assignment 3

Name: Swrangsar Basumatary Roll: 09d07040
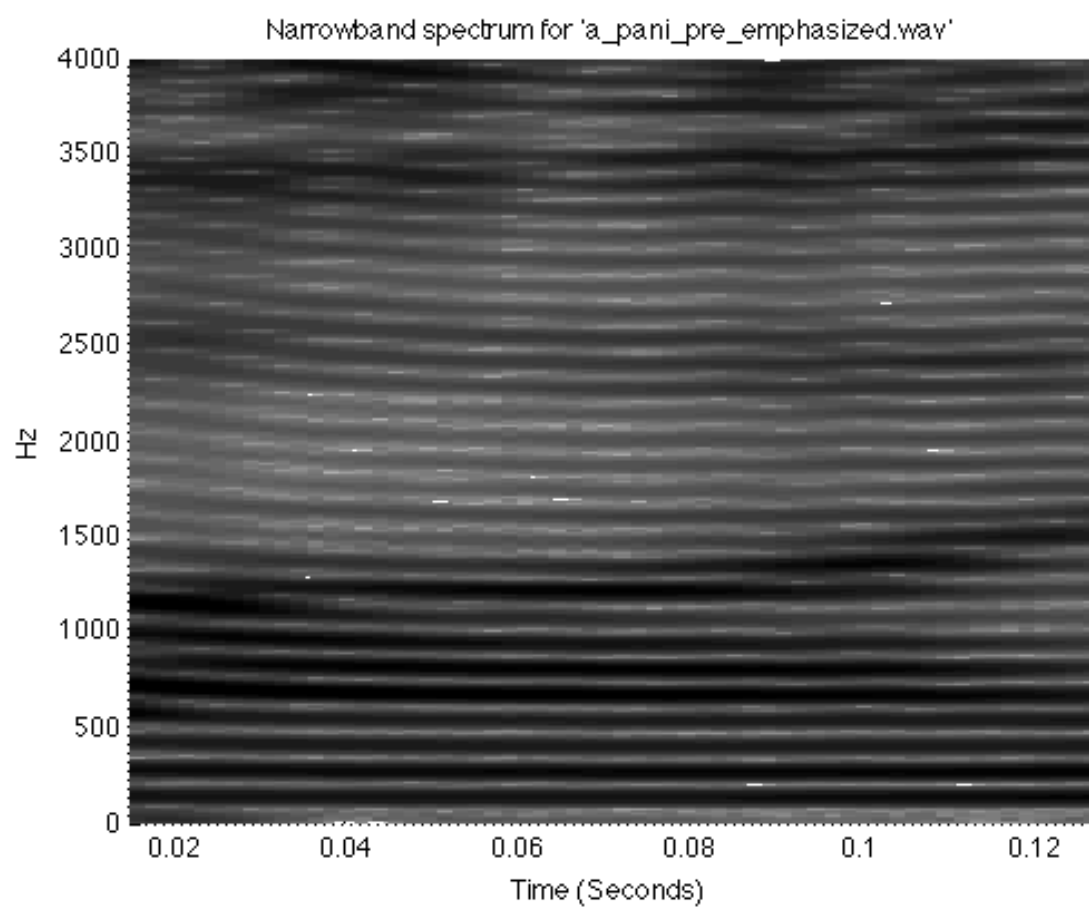
Question 1

Finding the narrowband spectrum of four syllables:
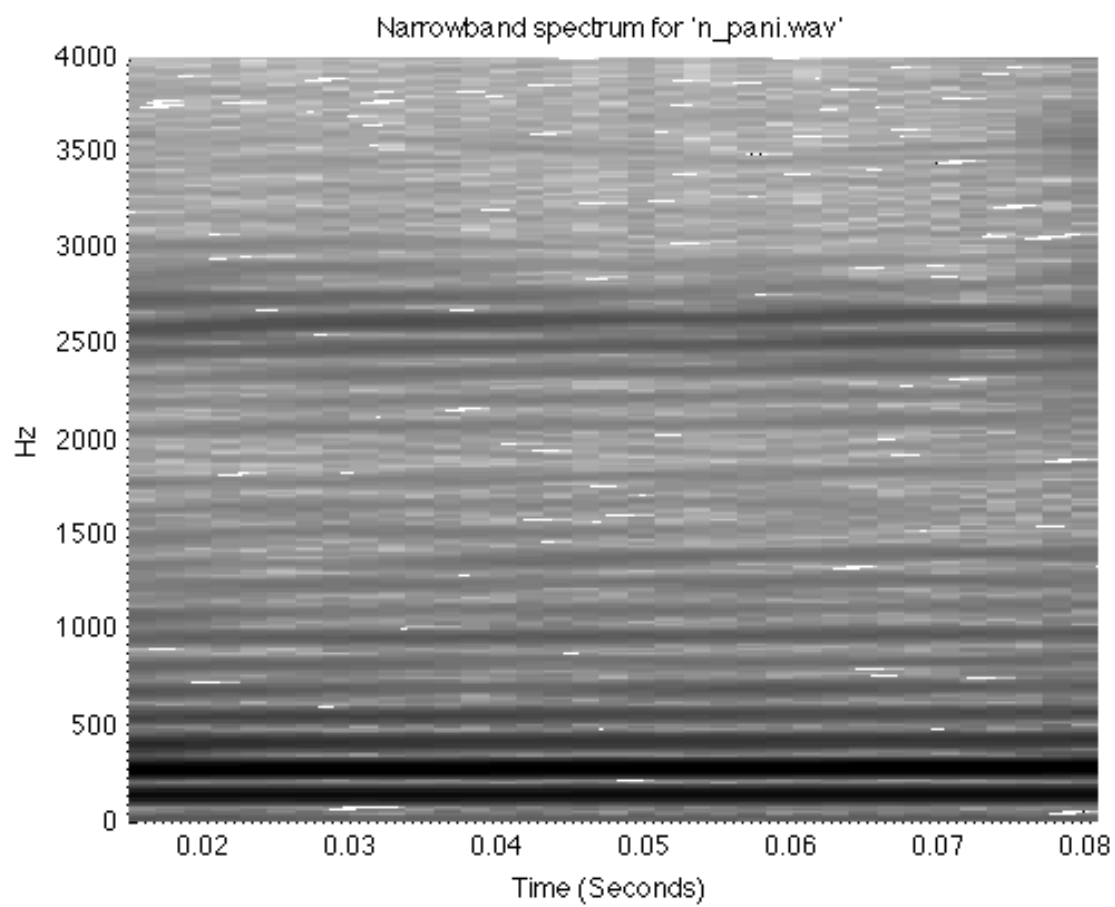
a) /a/ in 'pani'

Narrowband spectrum for 'a_pani.wav'

b) /a/ in 'pani' pre-emphasized

Narrowband spectrum for 'a_pani_pre_emphasized.wav'

c) /n/ in 'pani'

Narrowband spectrum for 'n_pani.wav'

d) /n/ in 'pani' pre-emphasized

Narrowband spectrum for 'n_pani_pre_emphasized.wav'

e) /I/ in 'pani'

Narrowband spectrum for 'i_pani.wav'

f) /I/ in 'pani' pre-emphasized

Narrowband spectrum for 'i_pani_pre_emphasized.wav'

g) /s/ in 'uska'

Narrowband spectrum for 's_uska.wav'
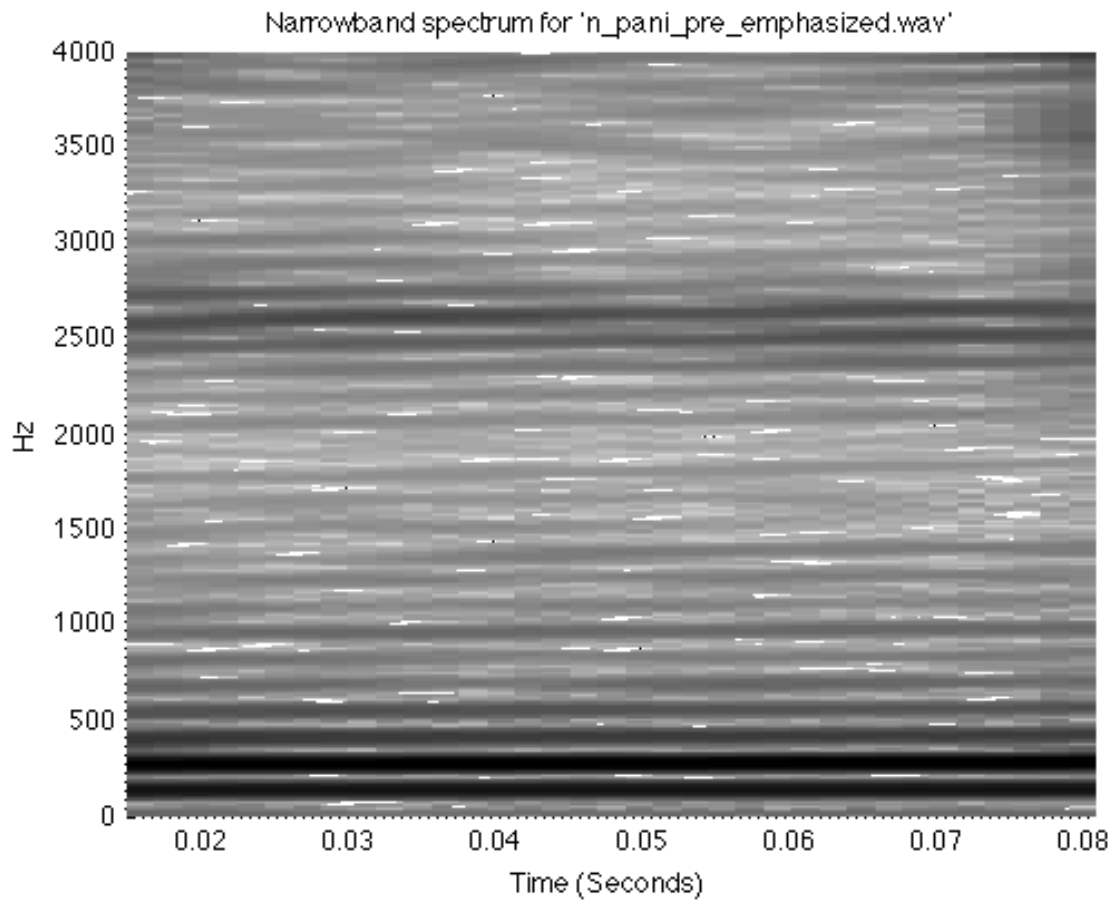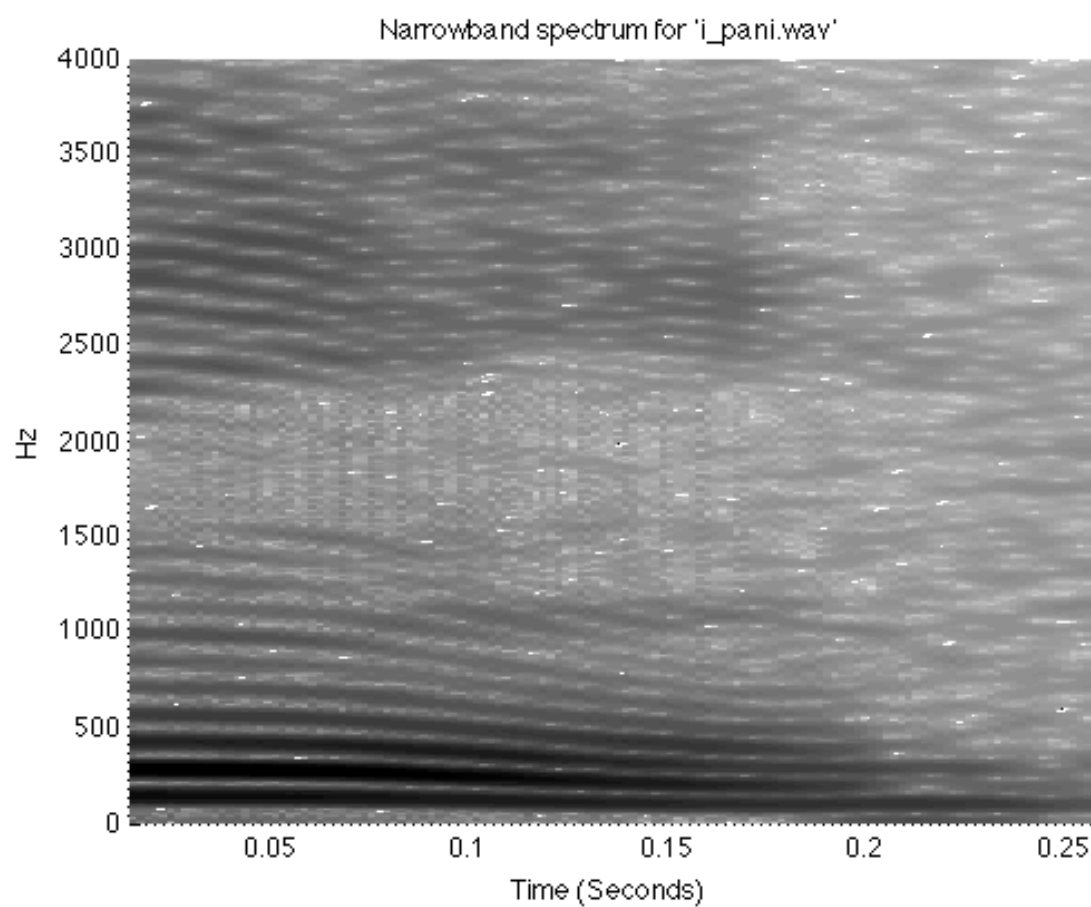
h) /s/ in 'uska' pre-emphasized
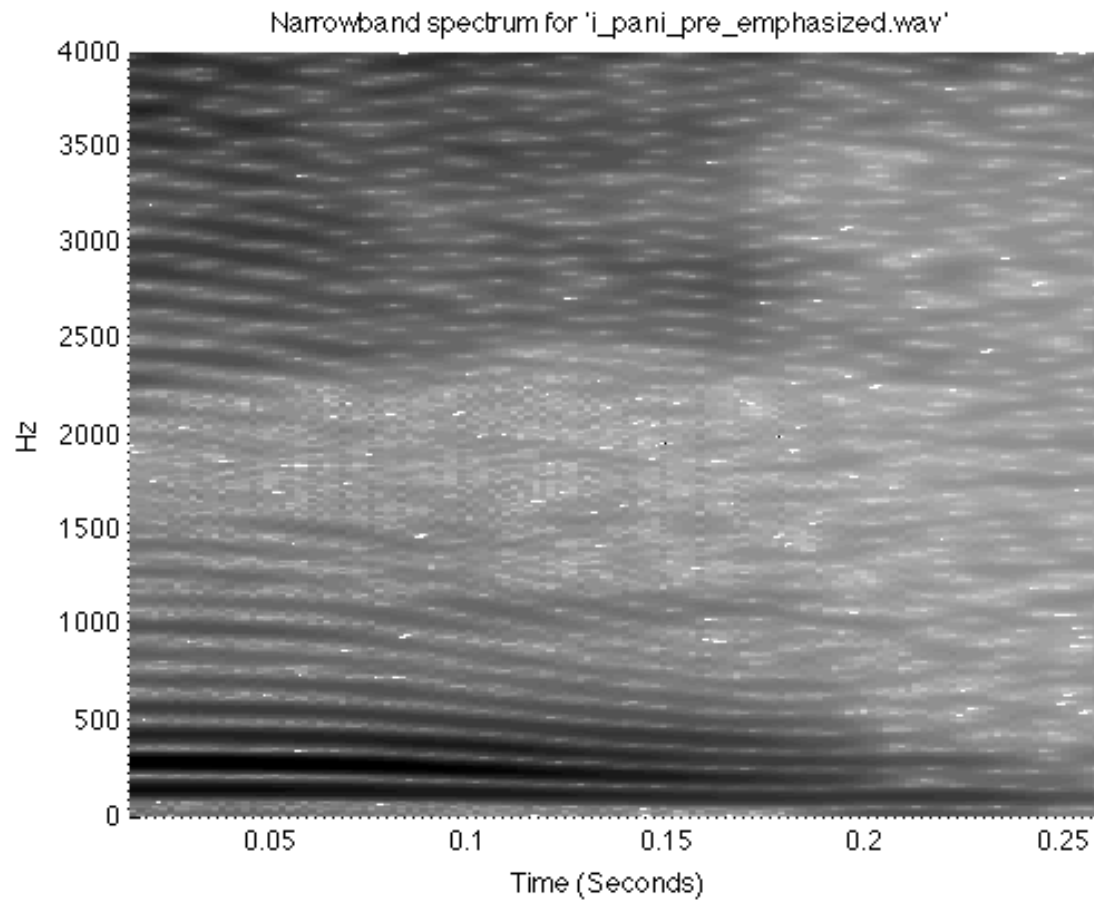
Narrowband spectrum for 's_uska_pre_emphasized.wav'
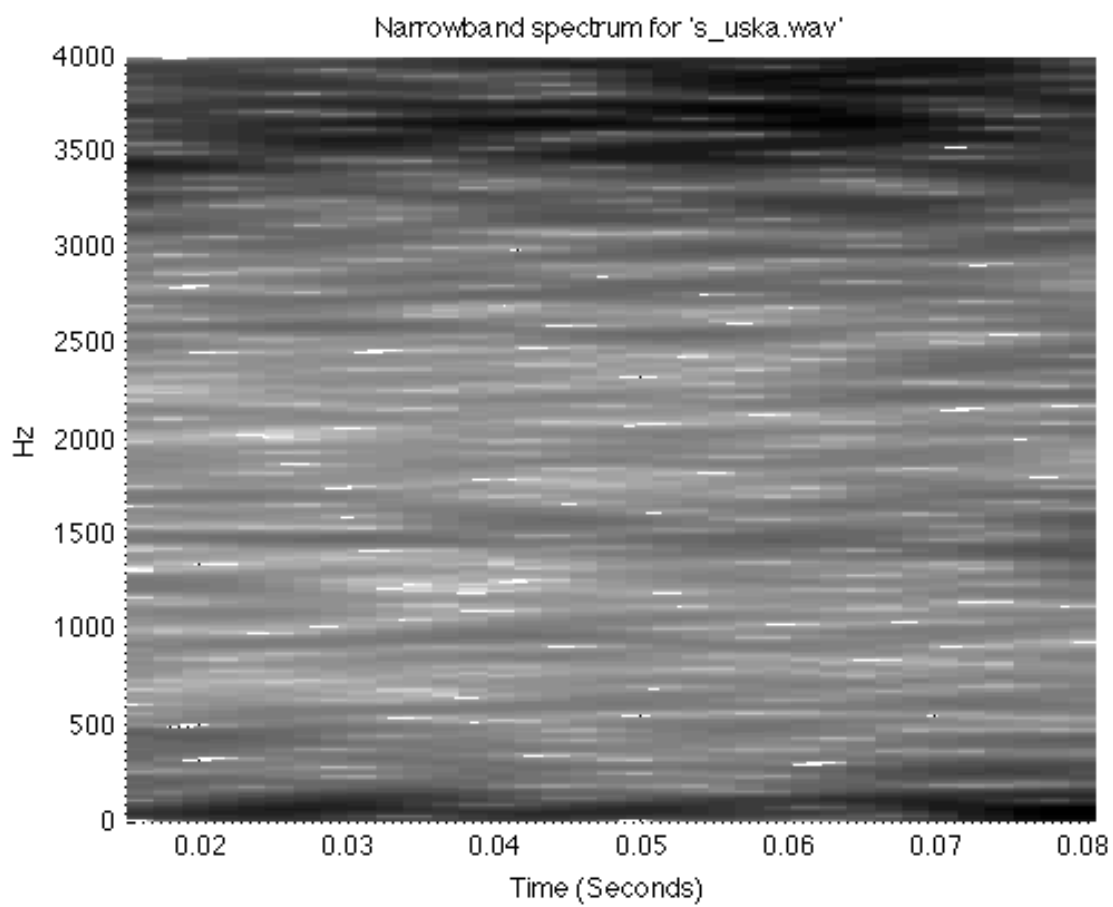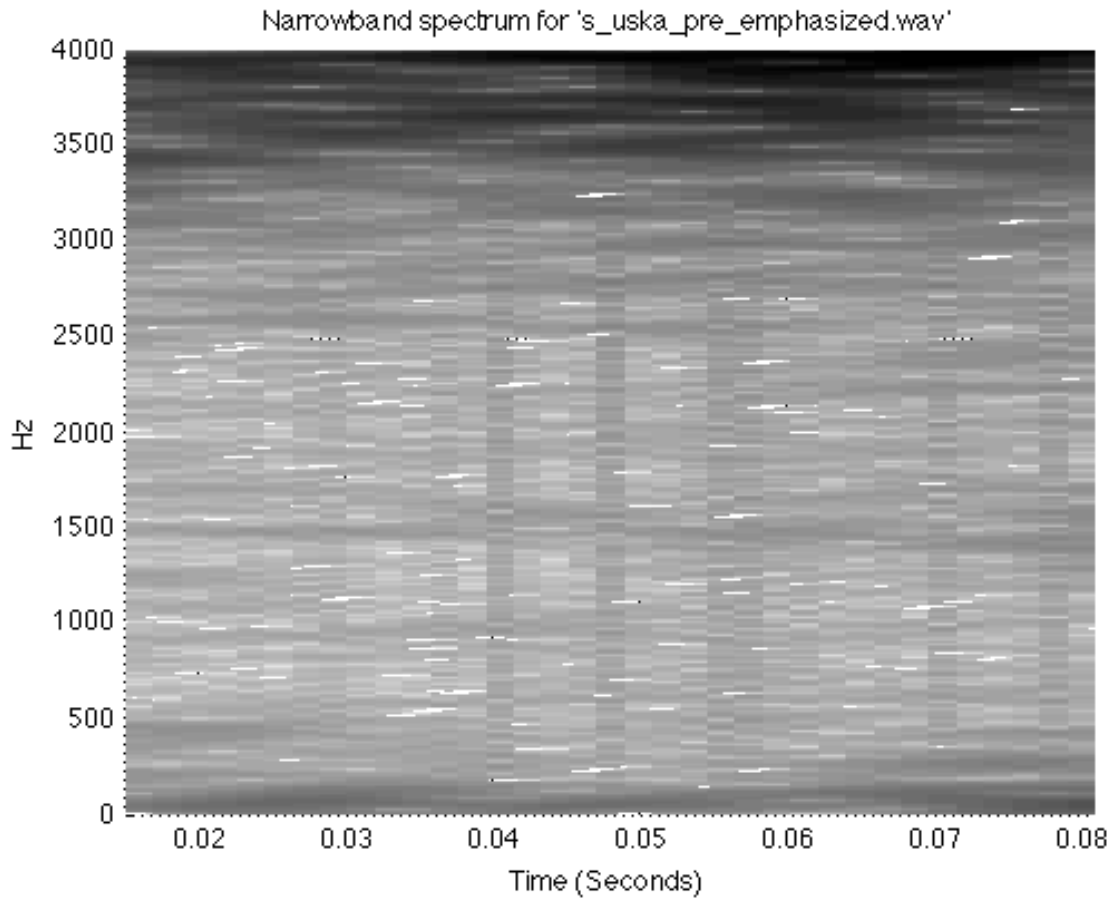
Script for finding the narrowband spectrum

```
close all; clear all;


figure(100); clf;
printNarrowbandSpectrum('a_pani.wav');
[y, fs] = preEmphasize('a_pani.wav');
wavwrite(y, fs, 32, 'a_pani_pre_emphasized.wav');
figure(200); clf;
printNarrowbandSpectrum('a_pani_pre_emphasized.wav');

figure(300); clf;
printNarrowbandSpectrum('n_pani.wav');
[y, fs] = preEmphasize('n_pani.wav');
wavwrite(y, fs, 32, 'n_pani_pre_emphasized.wav');
figure(400); clf;
printNarrowbandSpectrum('n_pani_pre_emphasized.wav');
```

```matlab
figure(500); clf;
printNarrowbandSpectrum('i_pani.wav');
[y, fs] = preEmphasize('i_pani.wav');
wavwrite(y, fs, 32, 'i_pani_pre_emphasized.wav');
figure(600); clf;
printNarrowbandSpectrum('i_pani_pre_emphasized.wav');

figure(700); clf;
printNarrowbandSpectrum('s_uska.wav');
[y, fs] = preEmphasize('s_uska.wav');
wavwrite(y, fs, 32, 's_uska_pre_emphasized.wav');
figure(800); clf;
printNarrowbandSpectrum('s_uska_pre_emphasized.wav');
```

Code for the functions used in finding the narrowband spectrum

```matlab
function [signal, fs] = preEmphasize(inputFile)

[y, fs] = wavread(inputFile);
siz = size(y);
length = siz(1);

for k = 1:length
    if k > 1
        y(k) = y(k) - (0.97*y(k-1));
    end
end

signal = y;
end


function printNarrowbandSpectrum(fileInput)

[y, fs] = wavread(fileInput);

colormap('gray');
map = colormap;
imap = flipud(map);
M = round(0.030*fs);   % 30 ms window
N = 2^nextpow2(4*M); % with zero padding
w = 0.54 - 0.46 * cos(2*pi*[0:M-1]/(M-1)); % w = hamming(M);
[~,F,T,P] = spectrogram(y, w, (M*(15/16)), N, fs);
```

```matlab
surf(T,F,10*log10(P),'edgecolor','none');
title(['Narrowband spectrum for ''', fileInput, ''''],
'interpreter', 'none');
axis tight;
colormap(imap);
view(0,90);
xlabel('Time (Seconds)'); ylabel('Hz');

end
```

Answer to Question 2(a)

The script:

```matlab
close all; clear all;

autocorrCoeffs1 = getAutoCorrCoefficients('a_pani', 6);
autocorrCoeffs2 = getAutoCorrCoefficients('a_pani', 8);
autocorrCoeffs3 = getAutoCorrCoefficients('a_pani', 10);
autocorrCoeffs4 = getAutoCorrCoefficients('a_pani', 12);
autocorrCoeffs5 = getAutoCorrCoefficients('a_pani', 16);

figure(100); clf;
subplot(3,2,1); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''a_pani'' for p = ''6''',
'interpreter', 'none');
subplot(3,2,2); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''a_pani'' for p = ''8''',
'interpreter', 'none');
subplot(3,2,3); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''a_pani'' for p = ''10''',
'interpreter', 'none');
subplot(3,2,4); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''a_pani'' for p = ''12''',
'interpreter', 'none');
subplot(3,2,5); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''a_pani'' for p = ''16''',
'interpreter', 'none');

LPCoeffs1 = getLPCoefficients('a_pani', 6);
LPCoeffs2 = getLPCoefficients('a_pani', 8);
LPCoeffs3 = getLPCoefficients('a_pani', 10);
```

```matlab
LPCoeffs4 = getLPCoefficients('a_pani', 12);
LPCoeffs5 = getLPCoefficients('a_pani', 16);

figure(200); clf;
subplot(3,2,1); stem(LPCoeffs1); axis tight;
title('LP coefficients of ''a_pani'' for p = ''6''', ...
'interpreter', 'none');
subplot(3,2,2); stem(LPCoeffs2); axis tight;
title('LP coefficients of ''a_pani'' for p = ''8''', ...
'interpreter', 'none');
subplot(3,2,3); stem(LPCoeffs3); axis tight;
title('LP coefficients of ''a_pani'' for p = ''10''', ...
'interpreter', 'none');
subplot(3,2,4); stem(LPCoeffs4); axis tight;
title('LP coefficients of ''a_pani'' for p = ''12''', ...
'interpreter', 'none');
subplot(3,2,5); stem(LPCoeffs5); axis tight;
title('LP coefficients of ''a_pani'' for p = ''16''', ...
'interpreter', 'none');


%% Now for n_pani

autocorrCoeffs1 = getAutoCorrCoefficients('n_pani', 6);
autocorrCoeffs2 = getAutoCorrCoefficients('n_pani', 8);
autocorrCoeffs3 = getAutoCorrCoefficients('n_pani', 10);
autocorrCoeffs4 = getAutoCorrCoefficients('n_pani', 12);
autocorrCoeffs5 = getAutoCorrCoefficients('n_pani', 16);

figure(300); clf;
subplot(3,2,1); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''n_pani'' for p = ''6''', ...
'interpreter', 'none');
subplot(3,2,2); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''n_pani'' for p = ''8''', ...
'interpreter', 'none');
subplot(3,2,3); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''n_pani'' for p = ''10''', ...
'interpreter', 'none');
subplot(3,2,4); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''n_pani'' for p = ''12''', ...
'interpreter', 'none');
subplot(3,2,5); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''n_pani'' for p = ''16''', ...
'interpreter', 'none');
```

```matlab
LPCoeffs1 = getLPCoefficients('n_pani', 6);
LPCoeffs2 = getLPCoefficients('n_pani', 8);
LPCoeffs3 = getLPCoefficients('n_pani', 10);
LPCoeffs4 = getLPCoefficients('n_pani', 12);
LPCoeffs5 = getLPCoefficients('n_pani', 16);

figure(400); clf;
subplot(3,2,1); stem(LPCoeffs1); axis tight;
title('LP coefficients of ''n_pani'' for p = ''6''',
'interpreter', 'none');
subplot(3,2,2); stem(LPCoeffs2); axis tight;
title('LP coefficients of ''n_pani'' for p = ''8''',
'interpreter', 'none');
subplot(3,2,3); stem(LPCoeffs3); axis tight;
title('LP coefficients of ''n_pani'' for p = ''10''',
'interpreter', 'none');
subplot(3,2,4); stem(LPCoeffs4); axis tight;
title('LP coefficients of ''n_pani'' for p = ''12''',
'interpreter', 'none');
subplot(3,2,5); stem(LPCoeffs5); axis tight;
title('LP coefficients of ''n_pani'' for p = ''16''',
'interpreter', 'none');


%% Now for i_pani

autocorrCoeffs1 = getAutoCorrCoefficients('i_pani', 6);
autocorrCoeffs2 = getAutoCorrCoefficients('i_pani', 8);
autocorrCoeffs3 = getAutoCorrCoefficients('i_pani', 10);
autocorrCoeffs4 = getAutoCorrCoefficients('i_pani', 12);
autocorrCoeffs5 = getAutoCorrCoefficients('i_pani', 16);

figure(500); clf;
subplot(3,2,1); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''i_pani'' for p = ''6''',
'interpreter', 'none');
subplot(3,2,2); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''i_pani'' for p = ''8''',
'interpreter', 'none');
subplot(3,2,3); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''i_pani'' for p = ''10''',
'interpreter', 'none');
subplot(3,2,4); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''i_pani'' for p = ''12''',
'interpreter', 'none');
subplot(3,2,5); stem(autocorrCoeffs1); axis tight;
```

```matlab
title('Autocorr coefficients of ''i_pani'' for p = ''16''', ...
'interpreter', 'none');

LPCoeffs1 = getLPCoefficients('i_pani', 6);
LPCoeffs2 = getLPCoefficients('i_pani', 8);
LPCoeffs3 = getLPCoefficients('i_pani', 10);
LPCoeffs4 = getLPCoefficients('i_pani', 12);
LPCoeffs5 = getLPCoefficients('i_pani', 16);

figure(600); clf;
subplot(3,2,1); stem(LPCoeffs1); axis tight;
title('LP coefficients of ''i_pani'' for p = ''6''', ...
'interpreter', 'none');
subplot(3,2,2); stem(LPCoeffs2); axis tight;
title('LP coefficients of ''i_pani'' for p = ''8''', ...
'interpreter', 'none');
subplot(3,2,3); stem(LPCoeffs3); axis tight;
title('LP coefficients of ''i_pani'' for p = ''10''', ...
'interpreter', 'none');
subplot(3,2,4); stem(LPCoeffs4); axis tight;
title('LP coefficients of ''i_pani'' for p = ''12''', ...
'interpreter', 'none');
subplot(3,2,5); stem(LPCoeffs5); axis tight;
title('LP coefficients of ''i_pani'' for p = ''16''', ...
'interpreter', 'none');


%% Now for s_uska

autocorrCoeffs1 = getAutoCorrCoefficients('s_uska', 6);
autocorrCoeffs2 = getAutoCorrCoefficients('s_uska', 8);
autocorrCoeffs3 = getAutoCorrCoefficients('s_uska', 10);
autocorrCoeffs4 = getAutoCorrCoefficients('s_uska', 12);
autocorrCoeffs5 = getAutoCorrCoefficients('s_uska', 16);

figure(700); clf;
subplot(3,2,1); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''s_uska'' for p = ''6''', ...
'interpreter', 'none');
subplot(3,2,2); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''s_uska'' for p = ''8''', ...
'interpreter', 'none');
subplot(3,2,3); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''s_uska'' for p = ''10''', ...
'interpreter', 'none');
subplot(3,2,4); stem(autocorrCoeffs1); axis tight;
```

```matlab
title('Autocorr coefficients of ''s_uska'' for p = ''12''', ...
'interpreter', 'none');
subplot(3,2,5); stem(autocorrCoeffs1); axis tight;
title('Autocorr coefficients of ''s_uska'' for p = ''16''', ...
'interpreter', 'none');

LPCoeffs1 = getLPCoefficients('s_uska', 6);
LPCoeffs2 = getLPCoefficients('s_uska', 8);
LPCoeffs3 = getLPCoefficients('s_uska', 10);
LPCoeffs4 = getLPCoefficients('s_uska', 12);
LPCoeffs5 = getLPCoefficients('s_uska', 16);

figure(800); clf;
subplot(3,2,1); stem(LPCoeffs1); axis tight;
title('LP coefficients of ''s_uska'' for p = ''6''', ...
'interpreter', 'none');
subplot(3,2,2); stem(LPCoeffs2); axis tight;
title('LP coefficients of ''s_uska'' for p = ''8''', ...
'interpreter', 'none');
subplot(3,2,3); stem(LPCoeffs3); axis tight;
title('LP coefficients of ''s_uska'' for p = ''10''', ...
'interpreter', 'none');
subplot(3,2,4); stem(LPCoeffs4); axis tight;
title('LP coefficients of ''s_uska'' for p = ''12''', ...
'interpreter', 'none');
subplot(3,2,5); stem(LPCoeffs5); axis tight;
title('LP coefficients of ''s_uska'' for p = ''16''', ...
'interpreter', 'none');
```

The functions:

```matlab
function LPCoeffs = getLPCoefficients(inputFile, poleOrder)


autocorrCoeffs = getAutoCorrCoefficients(inputFile, poleOrder);
LPCoeffs = levinsonDurbin(autocorrCoeffs);
end

function autocorrelationCoefficients = ...
getAutoCorrCoefficients(inputFile, poleOrder)
% poleOrder = 6 ;
% inputFile = 'a_pani.wav';
windowDuration = 0.030; % in ms

[y, fs] = preEmphasize(inputFile);
```

```matlab
siz = size(y);
length = siz(1);
centralIndex = round(length/2);
M = round(windowDuration * fs);
startIndex = round(centralIndex - M/2);

windowedSignal = y(startIndex:startIndex + M-1);
ACCoeff = zeros(poleOrder+1, 1);

for p = 0:poleOrder
    for k = 0:M-1
        valueToBeAdded = 0;
        if k-p >= 0
            valueToBeAdded = windowedSignal(k+1) .*
windowedSignal(k+1-p);
        end
        ACCoeff(p+1) = ACCoeff(p+1) + valueToBeAdded;
    end
end

autocorrelationCoefficients = ACCoeff;
% figure, stem(ACCoeff);
% title(['Autocorrelation coefficients of ''', inputFile, '''
for p = ''', num2str(poleOrder), '''], 'interpreter', 'none');

end


function [ coeff, b0 ] = levinsonDurbin(autocorrCoeffs)

siz = size(autocorrCoeffs(:));
poleOrder = siz(1) - 1;
p = poleOrder;
rx = autocorrCoeffs(:); % autocorr coefficients
a = zeros(p+1);
e = zeros(1, p+1);
G = zeros(1, p+1);
reflected = zeros(1, p+1);
a(1, 1) = 1; e(1) = rx(1);

for j = 0:p-1;
    G(j+1) = rx(j+2);
    sum = 0;
    if j > 0
        for i = 1:j;
```

```
                sum = sum + (a(j+1, i+1)*rx(j+2-i));
        end
    end
    G(j+1) = G(j+1) + sum;
    reflected(j + 2) = -G(j+1)/e(j+1);

    for i  = 1:j;
            a(j+2, i+1) = a(j+1, i+1) + (reflected(j+2)*a(j+1,
j-i+2));
    end

    a(j+2, j+2) = reflected(j+2);
    e(j+2) = e(j + 1) * (1-(abs(reflected(j+2))^2));

end
b0 = sqrt(e(p+1)); % the b(0) that we require in the numerator
of the transfer function
coeff = a(p+1, (2:end)); % coeff is the array of a(p)
coefficients
coeff = -1 * coeff;

end
```

The plots:

Autocorr coefficients of 'a_pani' for p = '6
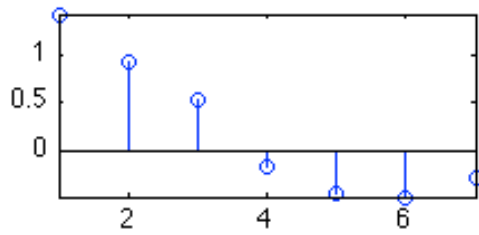
Autocorr coefficients of 'a_pani' for p = '8
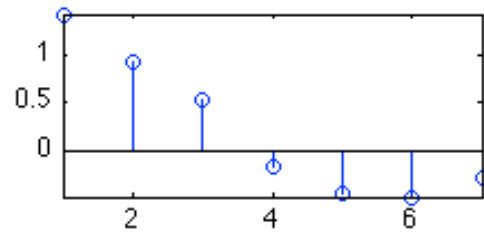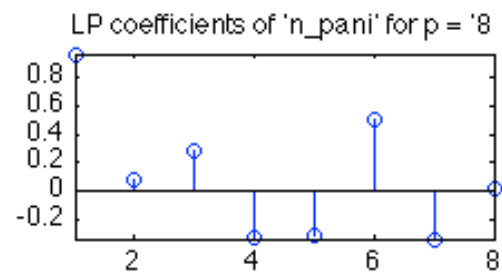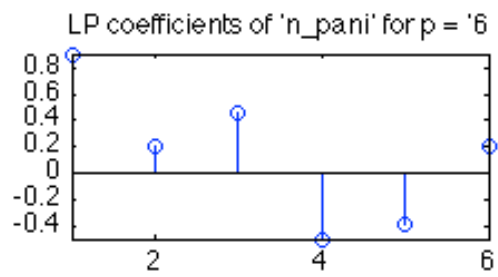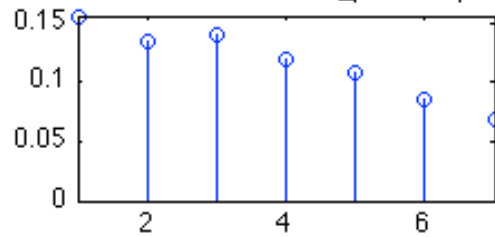
Autocorr coefficients of 'a_pani' for p = '10

Autocorr coefficients of 'a_pani' for p = '12
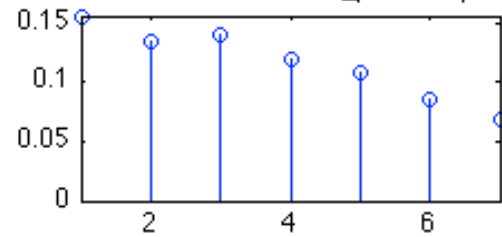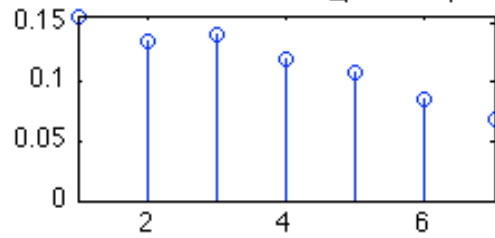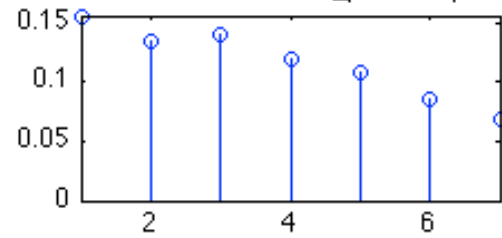
Autocorr coefficients of 'a_pani' for p = '16

LP coefficients of 'a_pani' for p = '6

LP coefficients of 'a_pani' for p = '8
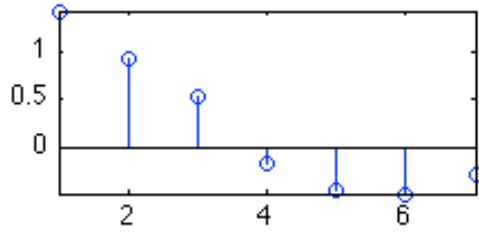
LP coefficients of 'a_pani' for p = '10

LP coefficients of 'a_pani' for p = '12
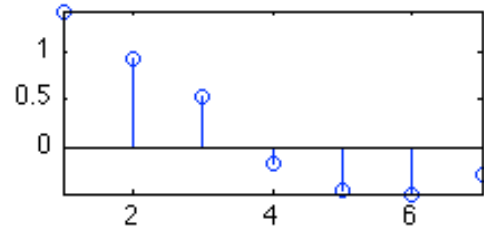
LP coefficients of 'a_pani' for p = '16
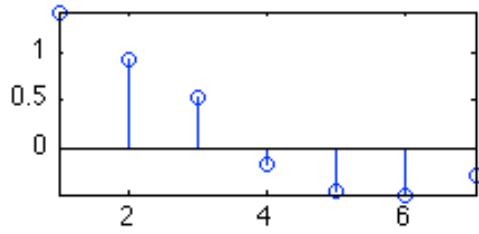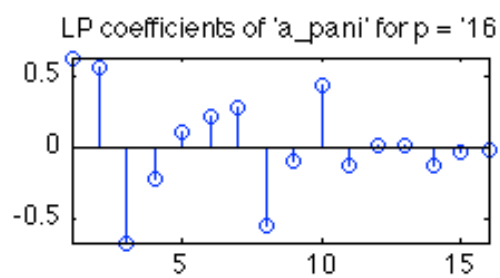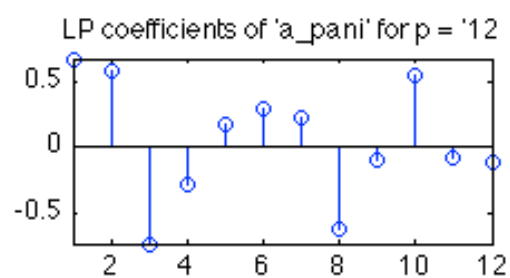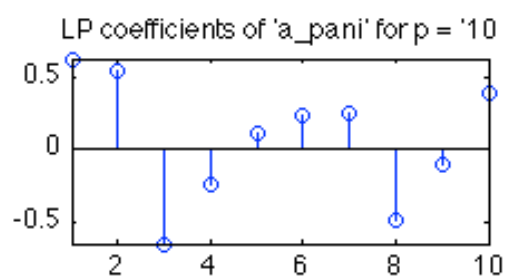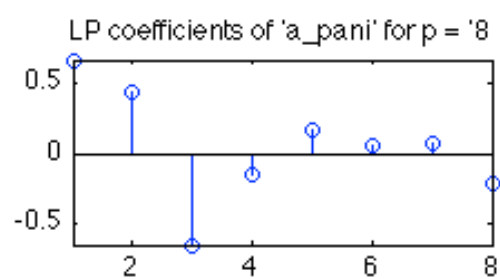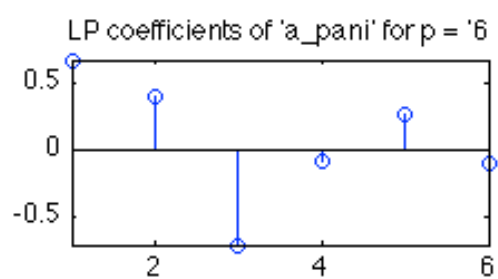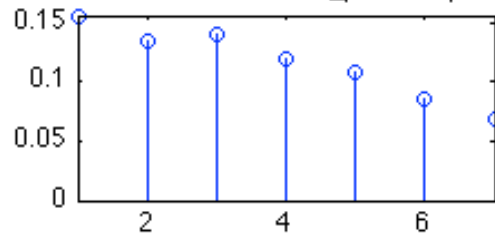
Autocorr coefficients of 'n_pani' for p = '6
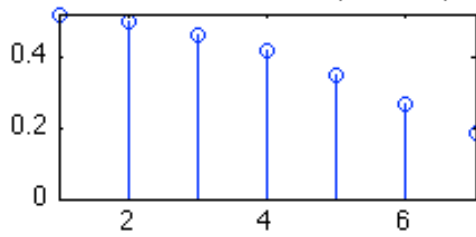
Autocorr coefficients of 'n_pani' for p = '8
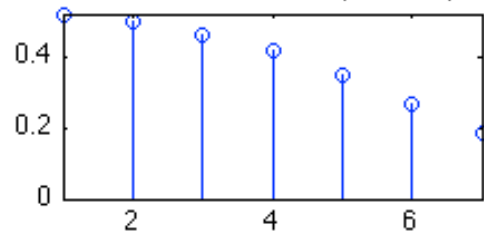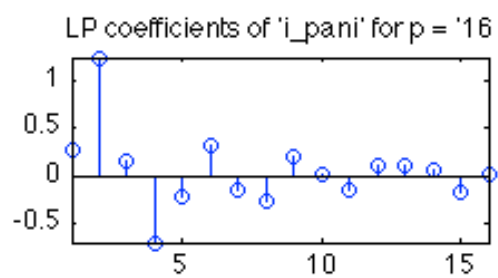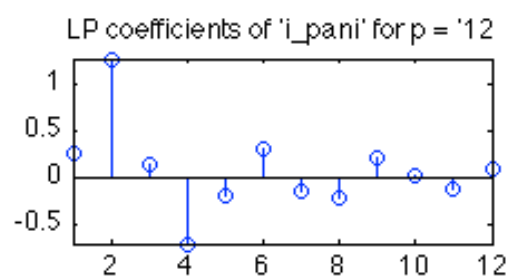
Autocorr coefficients of 'n_pani' for p = '10

Autocorr coefficients of 'n_pani' for p = '12

Autocorr coefficients of 'n_pani' for p = '16

LP coefficients of 'n_pani' for p = '6

LP coefficients of 'n_pani' for p = '8
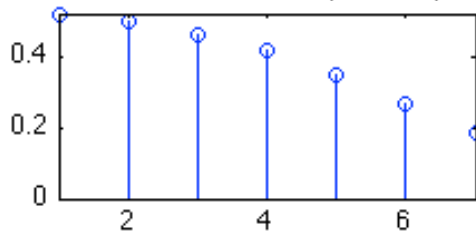
LP coefficients of 'n_pani' for p = '10

LP coefficients of 'n_pani' for p = '12
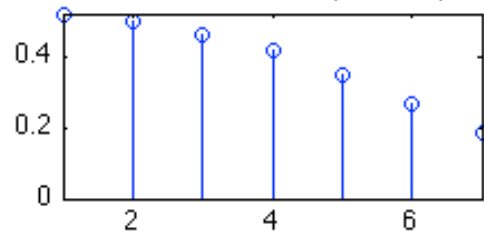
LP coefficients of 'n_pani' for p = '16
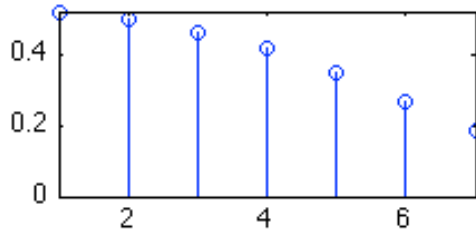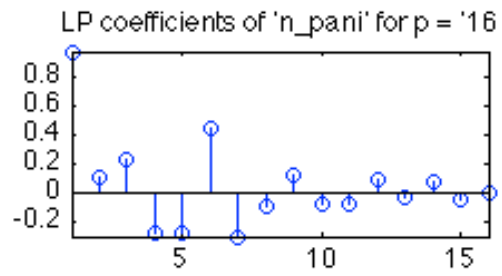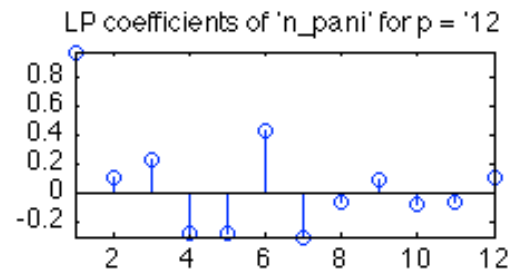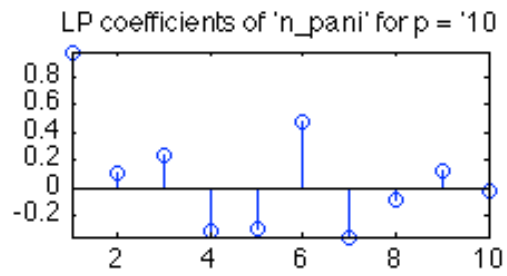
Autocorr coefficients of 'i_pani' for p = '6

Autocorr coefficients of 'i_pani' for p = '8
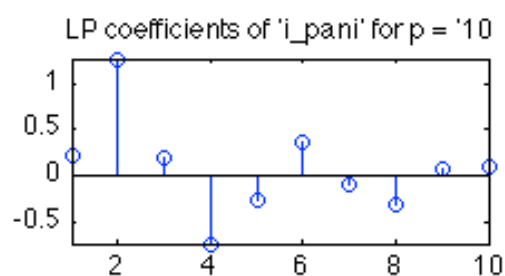
Autocorr coefficients of 'i_pani' for p = '10
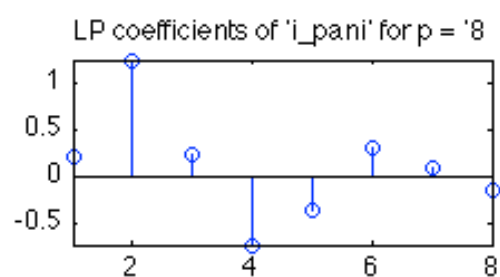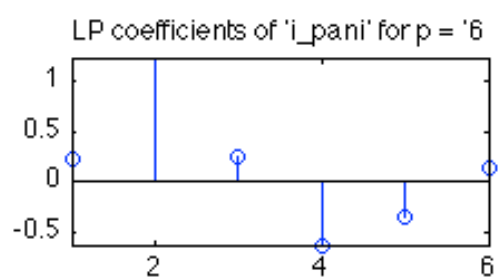
Autocorr coefficients of 'i_pani' for p = '12

Autocorr coefficients of 'i_pani' for p = '16

LP coefficients of 'i_pani' for p = '6

LP coefficients of 'i_pani' for p = '8

LP coefficients of 'i_pani' for p = '10

LP coefficients of 'i_pani' for p = '12

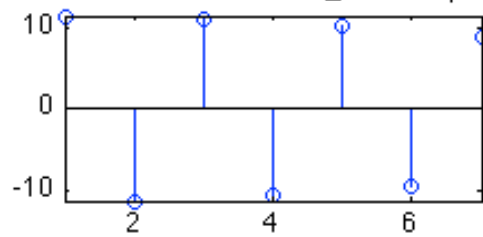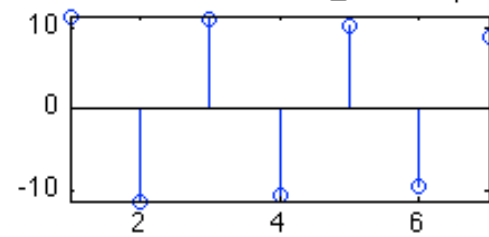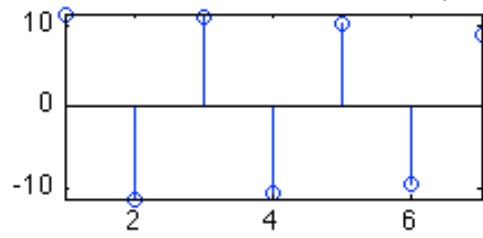LP coefficients of 'i_pani' for p = '16

Autocorr coefficients of 's_uska' for p = '6
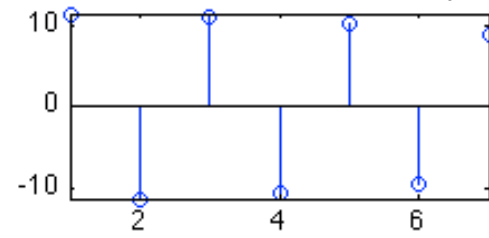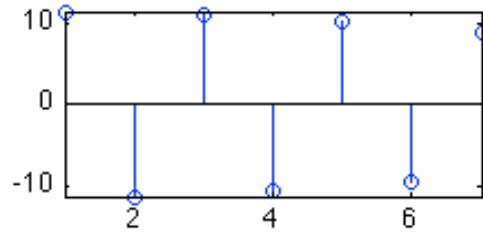
Autocorr coefficients of 's_uska' for p = '8
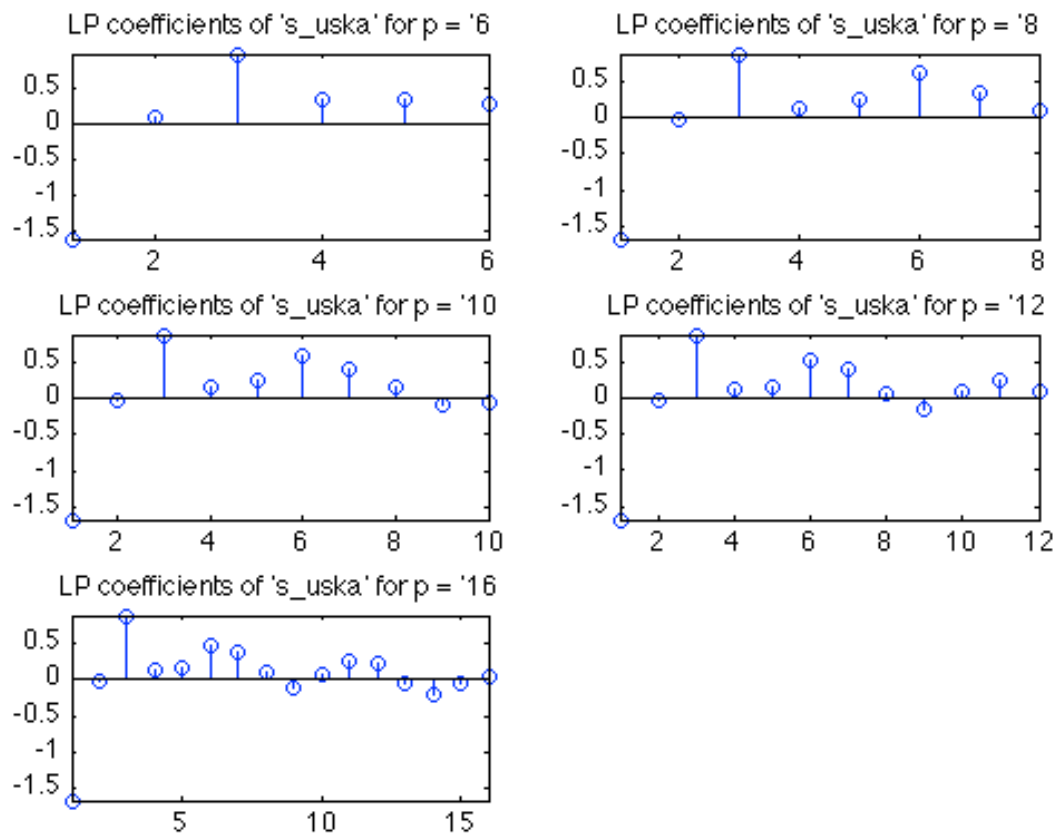
Autocorr coefficients of 's_uska' for p = '10

Autocorr coefficients of 's_uska' for p = '12

Autocorr coefficients of 's_uska' for p = '16

LP coefficients of 's_uska' for p = '6
LP coefficients of 's_uska' for p = '8
LP coefficients of 's_uska' for p = '10
LP coefficients of 's_uska' for p = '12
LP coefficients of 's_uska' for p = '16

The pole zero plots

The script:

```
close all; clear all;
%% for /a/ in 'pani'

inputFile = 'a_pani.wav';
poleOrder1 = 6;
poleOrder2 = 10;
num = (1);

LPCoeffs1 = -getLPCoefficients(inputFile, poleOrder1);
LPCoeffsFull1 = (cat(1, (1), LPCoeffs1(:)))'
LPCoeffs2 = -getLPCoefficients(inputFile, poleOrder2);
LPCoeffsFull2 = (cat(1, (1), LPCoeffs2(:)))';

figure(100); clf;
```

```matlab
subplot(2, 1, 1), zplane(num, LPCoeffsFull1);
title(['Pole-zero plot for all pole filter of order = ''',
num2str(poleOrder1), ''' in ''', inputFile, ''''],
'interpreter', 'none');
subplot(2, 1, 2), zplane(num, LPCoeffsFull2);
title(['Pole-zero plot for all pole filter of order = ''',
num2str(poleOrder2), ''' in ''', inputFile, ''''],
'interpreter', 'none');


%% for /n/ in 'pani'

inputFile = 'n_pani.wav';
poleOrder1 = 6;
poleOrder2 = 10;
num = (1);

LPCoeffs1 = -getLPCoefficients(inputFile, poleOrder1);
LPCoeffsFull1 = (cat(1, (1), LPCoeffs1(:)))'
LPCoeffs2 = -getLPCoefficients(inputFile, poleOrder2);
LPCoeffsFull2 = (cat(1, (1), LPCoeffs2(:)))';

figure(200); clf;
subplot(2, 1, 1), zplane(num, LPCoeffsFull1);
title(['Pole-zero plot for all pole filter of order = ''',
num2str(poleOrder1), ''' in ''', inputFile, ''''],
'interpreter', 'none');
subplot(2, 1, 2), zplane(num, LPCoeffsFull2);
title(['Pole-zero plot for all pole filter of order = ''',
num2str(poleOrder2), ''' in ''', inputFile, ''''],
'interpreter', 'none');

%% for /I/ in 'pani'

inputFile = 'i_pani.wav';
poleOrder1 = 6;
poleOrder2 = 10;
num = (1);

LPCoeffs1 = -getLPCoefficients(inputFile, poleOrder1);
LPCoeffsFull1 = (cat(1, (1), LPCoeffs1(:)))'
LPCoeffs2 = -getLPCoefficients(inputFile, poleOrder2);
LPCoeffsFull2 = (cat(1, (1), LPCoeffs2(:)))';

figure(300); clf;
subplot(2, 1, 1), zplane(num, LPCoeffsFull1);
```

```matlab
title(['Pole-zero plot for all pole filter of order = ''', ...
num2str(poleOrder1), ''' in ''', inputFile, ''''], ...
'interpreter', 'none');
subplot(2, 1, 2), zplane(num, LPCoeffsFull2);
title(['Pole-zero plot for all pole filter of order = ''', ...
num2str(poleOrder2), ''' in ''', inputFile, ''''], ...
'interpreter', 'none');

%% for /s/ in 'uska'

inputFile = 's_uska.wav';
poleOrder1 = 6;
poleOrder2 = 10;
num = (1);

LPCoeffs1 = -getLPCoefficients(inputFile, poleOrder1);
LPCoeffsFull1 = (cat(1, (1), LPCoeffs1(:)))'
LPCoeffs2 = -getLPCoefficients(inputFile, poleOrder2);
LPCoeffsFull2 = (cat(1, (1), LPCoeffs2(:)))';

figure(400); clf;
subplot(2, 1, 1), zplane(num, LPCoeffsFull1);
title(['Pole-zero plot for all pole filter of order = ''', ...
num2str(poleOrder1), ''' in ''', inputFile, ''''], ...
'interpreter', 'none');
subplot(2, 1, 2), zplane(num, LPCoeffsFull2);
title(['Pole-zero plot for all pole filter of order = ''', ...
num2str(poleOrder2), ''' in ''', inputFile, ''''], ...
'interpreter', 'none');
```
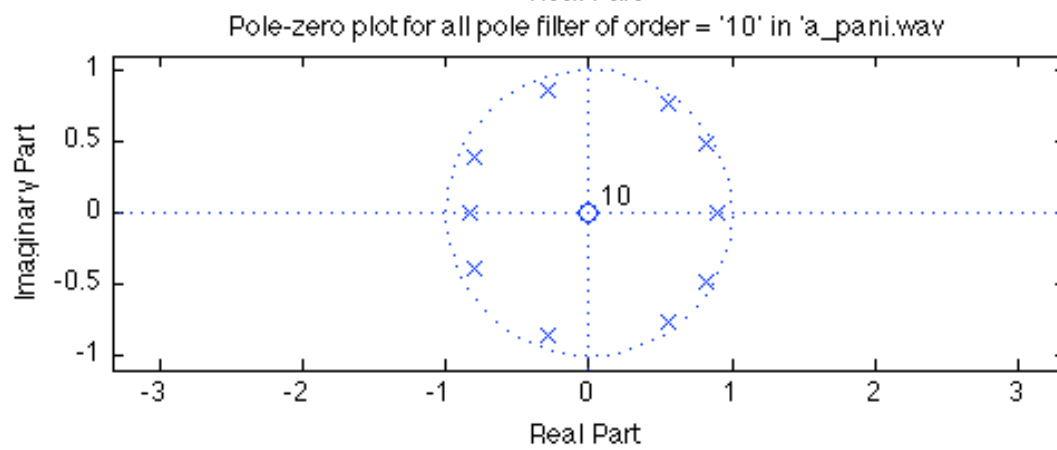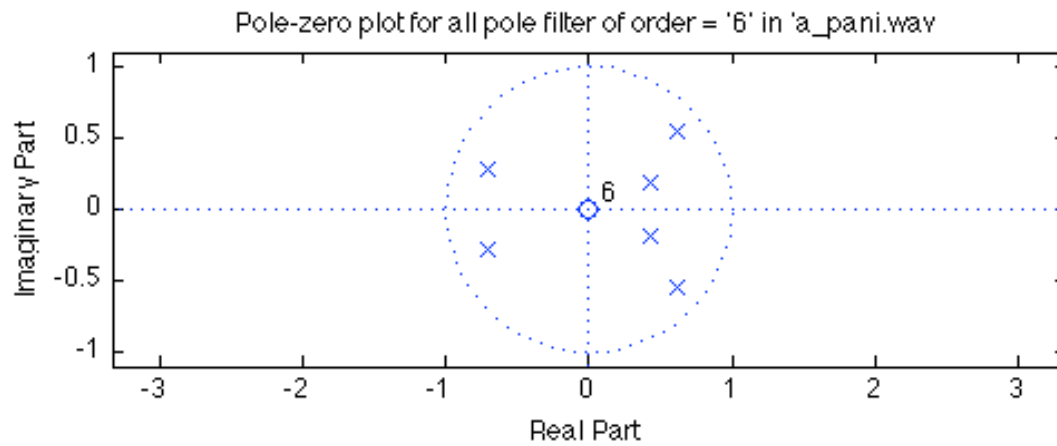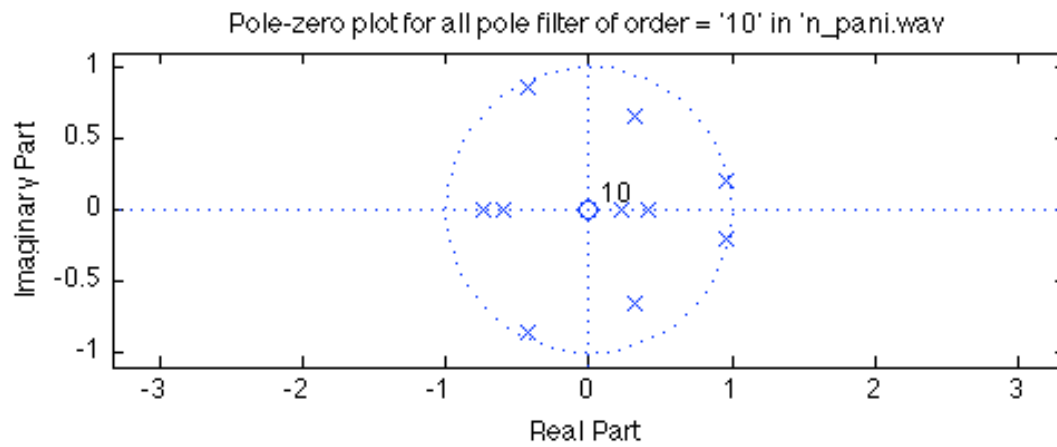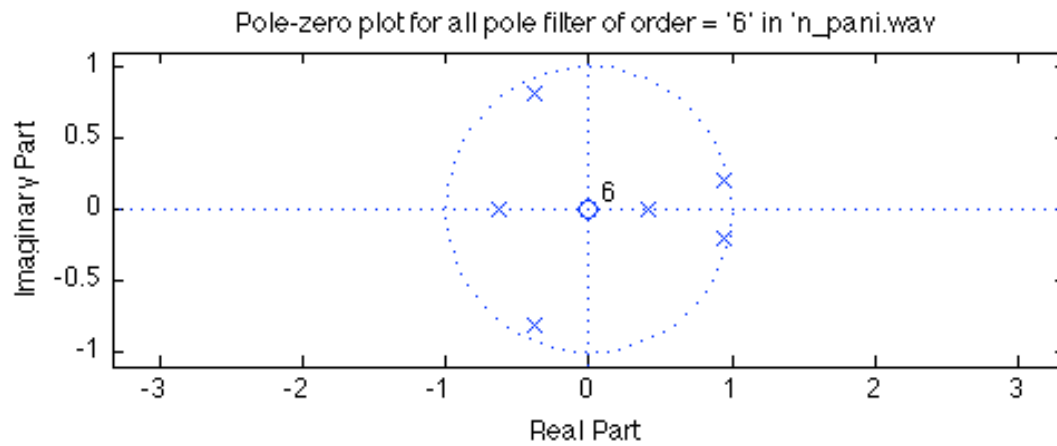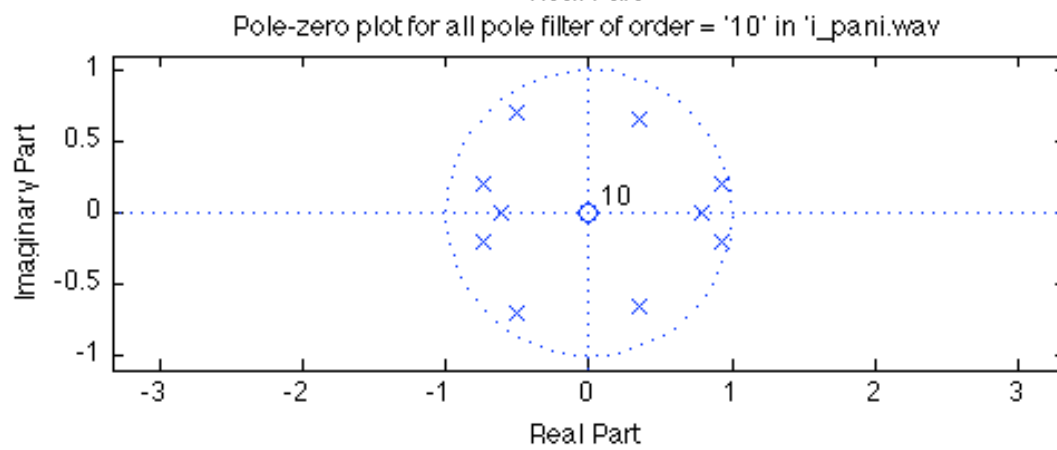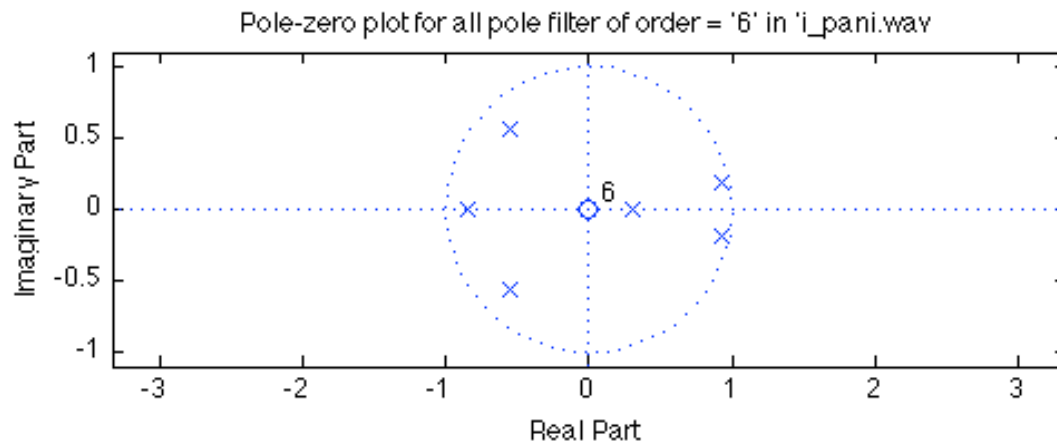
The plots:

Pole-zero plot for all pole filter of order = '6' in 'a_pani.wav'

Pole-zero plot for all pole filter of order = '10' in 'a_pani.wav'

Pole-zero plot for all pole filter of order = '6' in 'n_pani.wav'

Pole-zero plot for all pole filter of order = '10' in 'n_pani.wav'

Pole-zero plot for all pole filter of order = '6' in 'i_pani.wav'

Pole-zero plot for all pole filter of order = '10' in 'i_pani.wav'

Pole-zero plot for all pole filter of order = '6' in 's_uska.wav'

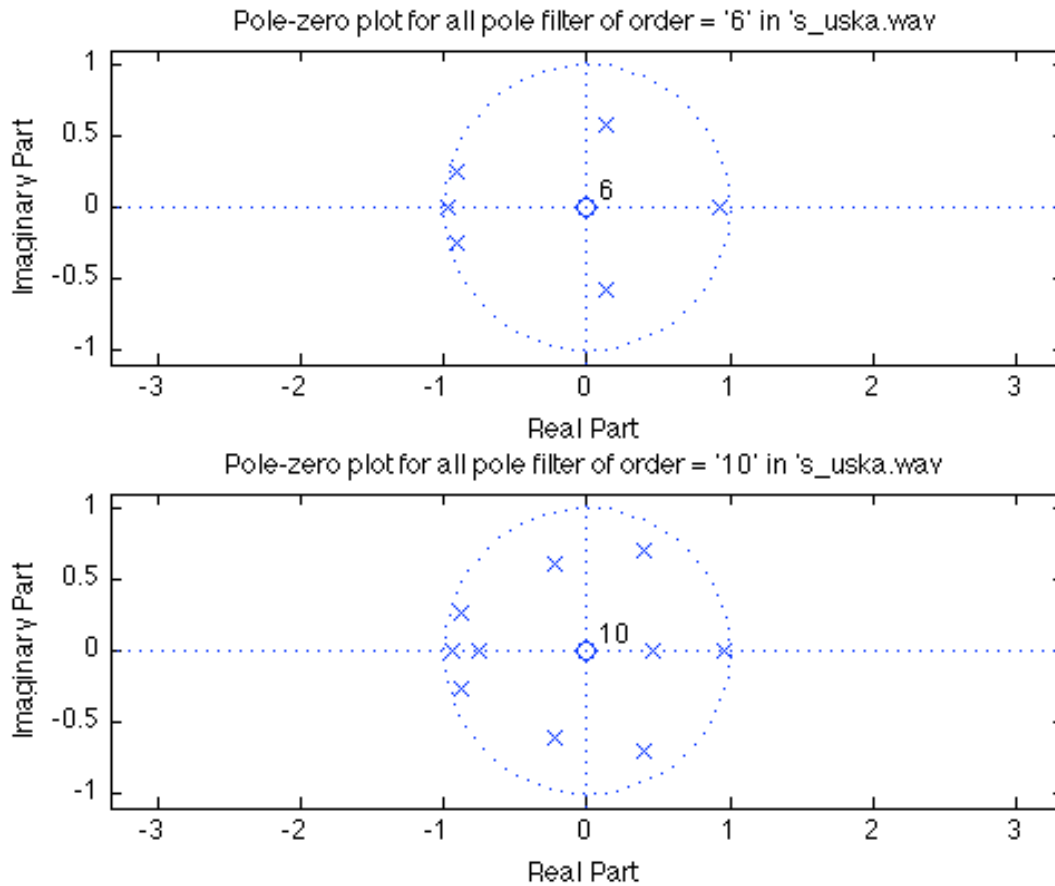Pole-zero plot for all pole filter of order = '10' in 's_uska.wav'

Answer to Q2(b)

The script:

```
close all; clear all;
poleOrder = [6 8 10 12 16];
siz = size(poleOrder(:));
length = siz(1);

for k = 1:length;
    getHammingNarrowbandSpectrum('a_pani.wav', poleOrder(k));
end

for k = 1:length;
    getHammingNarrowbandSpectrum('n_pani.wav', poleOrder(k));
end
```

```matlab
for k = 1:length;
    getHammingNarrowbandSpectrum('i_pani.wav', poleOrder(k));
end

for k = 1:length;
    getHammingNarrowbandSpectrum('s_uska.wav', poleOrder(k));
end
```

The function:

```matlab
function [narrowbandSpectrum, LPCSpectrum, w ]=
getHammingNarrowbandSpectrum(inputFile, poleOrder)

% poleOrder = 6;
% inputFile = 'a_pani.wav';

windowDuration = 0.030; % in ms

[y, fs] = preEmphasize(inputFile);

siz = size(y(:));
length = siz(1);
centralIndex = round(length/2);
M = round(windowDuration * fs);
startIndex = round(centralIndex - M/2);

windowedSignal = y(startIndex:startIndex + M-1);

narrowbandSpectrum = abs(fft(windowedSignal));
narrowbandSpectrum = narrowbandSpectrum(1:round(M/2));
narrowbandSpectrum = 10 * log10(abs(narrowbandSpectrum));

% getting the LPC spectrum

LPCoeffs = getLPCoefficients(inputFile, poleOrder);
frequencies = (fs/M) * (0:M-1);

denominator = 1;
numerator = 1;

for k = 1:poleOrder
    denominator = denominator - (LPCoeffs(k) * (exp(-1i * 2 * pi
* frequencies ./ fs) .^ k));
end
```
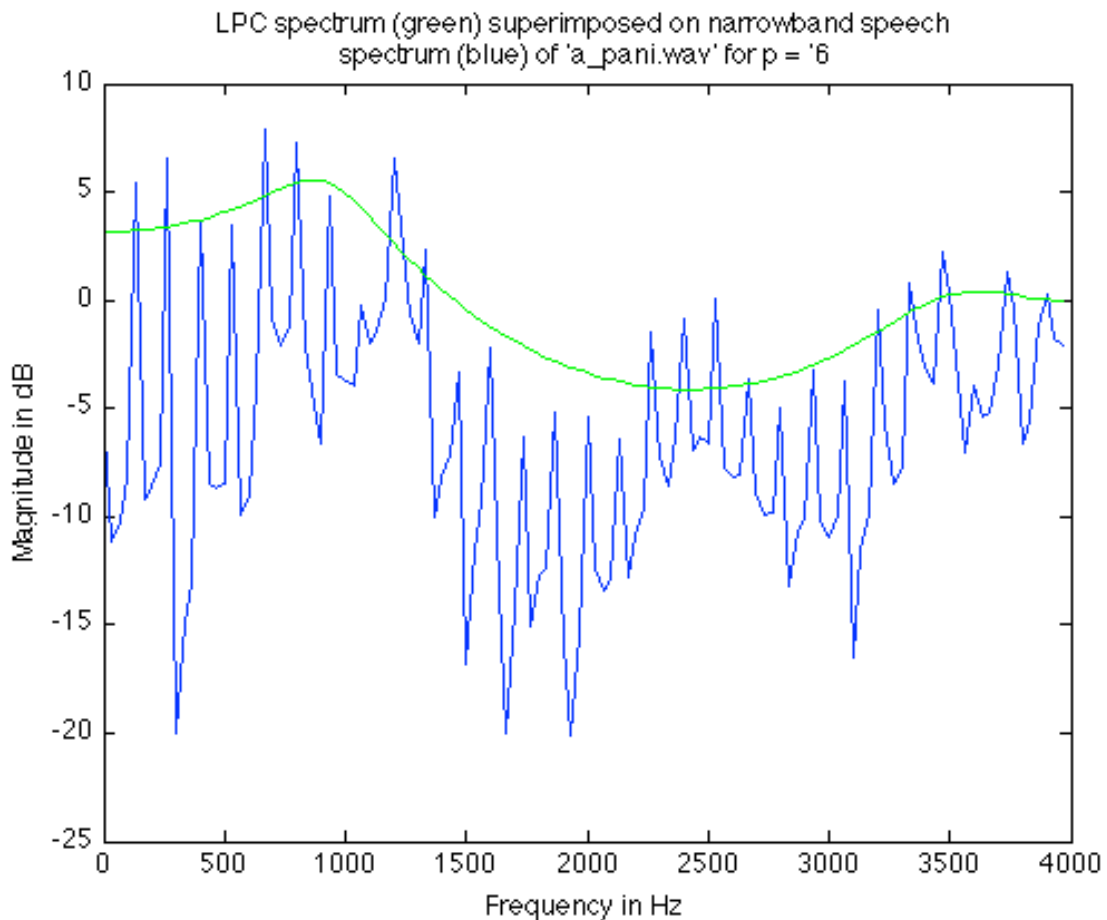
```matlab
H = numerator ./ denominator;
LPCSpectrum = 10 * log10(abs(H));
LPCSpectrum = LPCSpectrum(1:round(M/2));
w = frequencies(1:round(M/2));

figure, plot(w, narrowbandSpectrum);
hold on;
linePlot = plot(w, LPCSpectrum);
set(linePlot,'Color','green');
hold off;
title({'LPC spectrum (green) superimposed on narrowband
speech'; ...
    ['spectrum (blue) of ''', inputFile, ''' for p = ''', ...
    num2str(poleOrder), '''']}, 'interpreter', 'none');
xlabel('Frequency in Hz');
ylabel('Magnitude in dB');

end
```
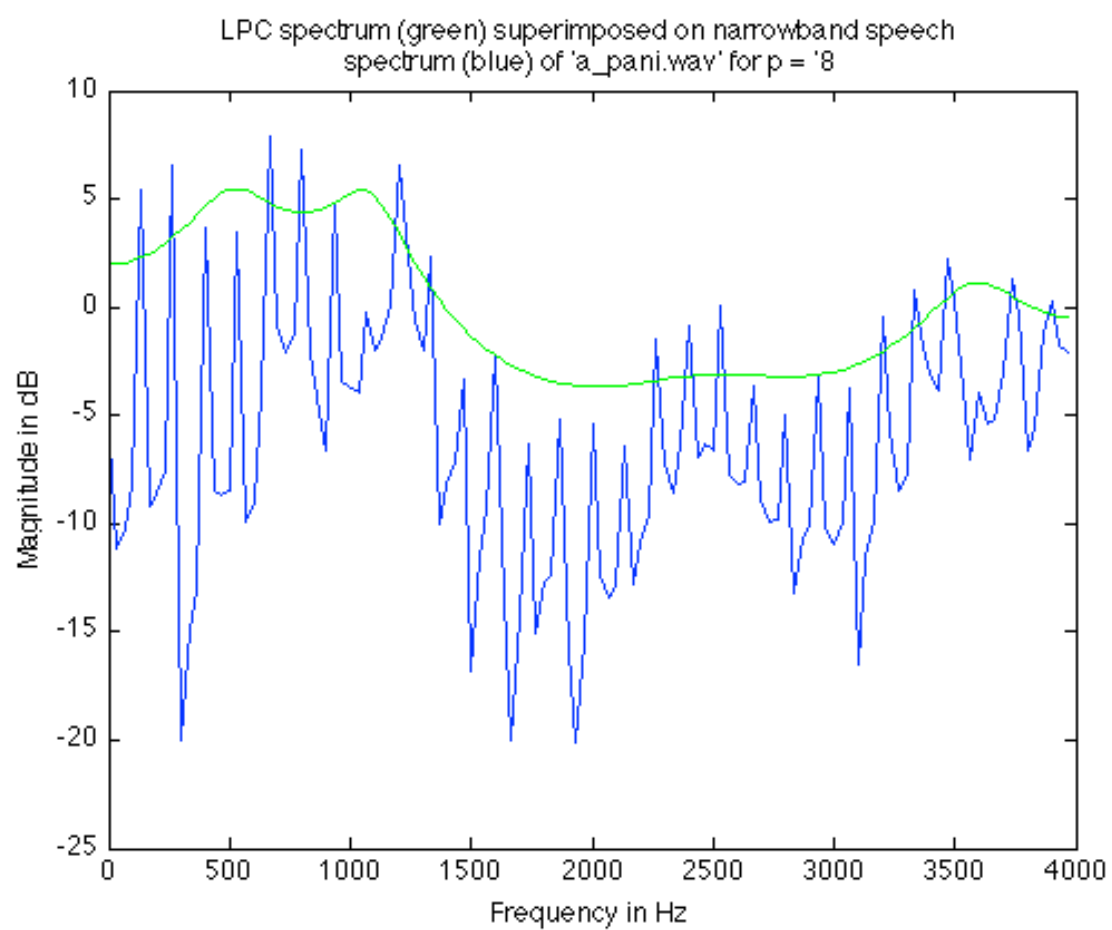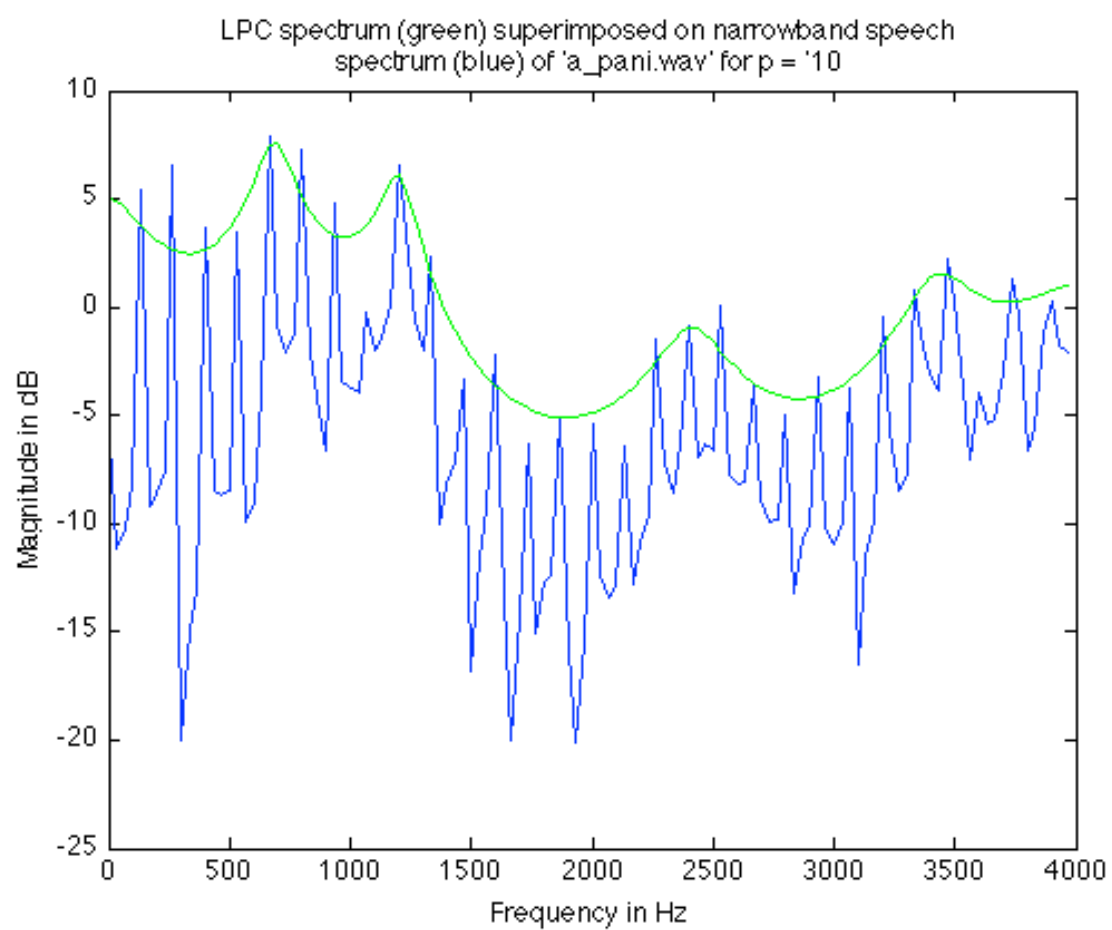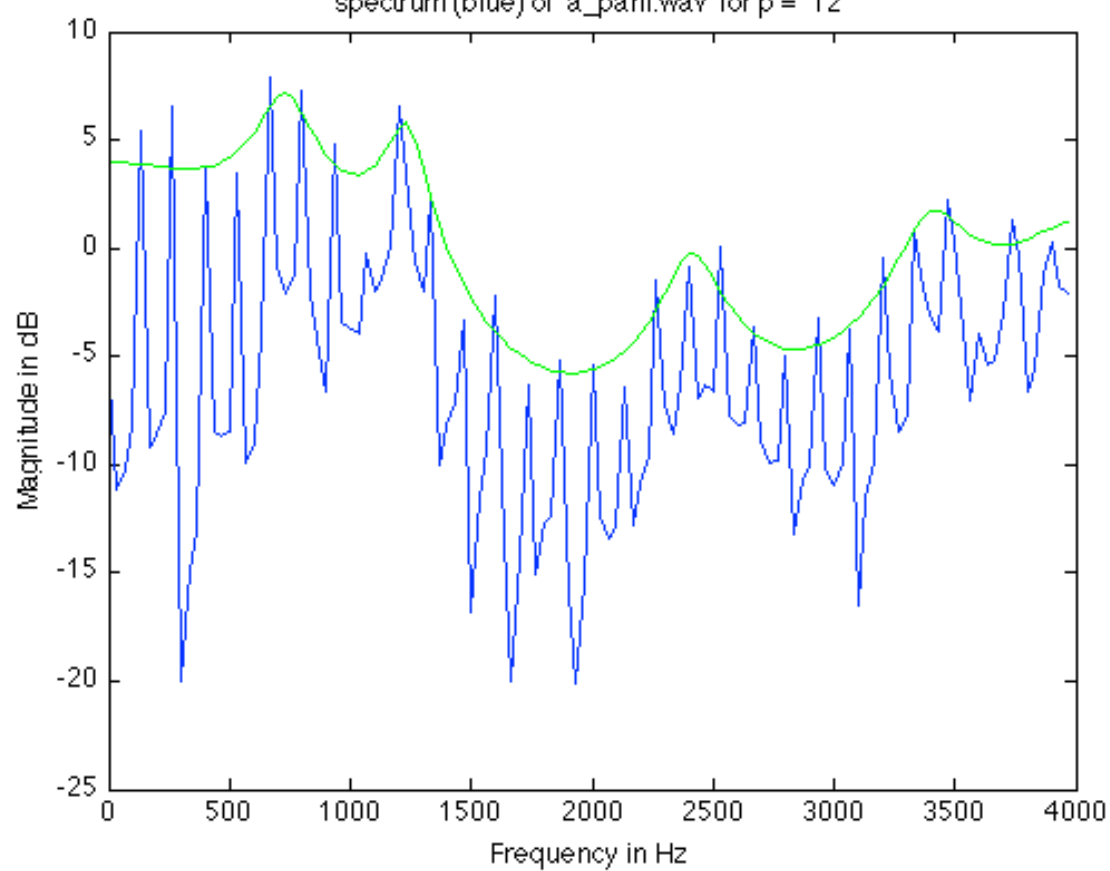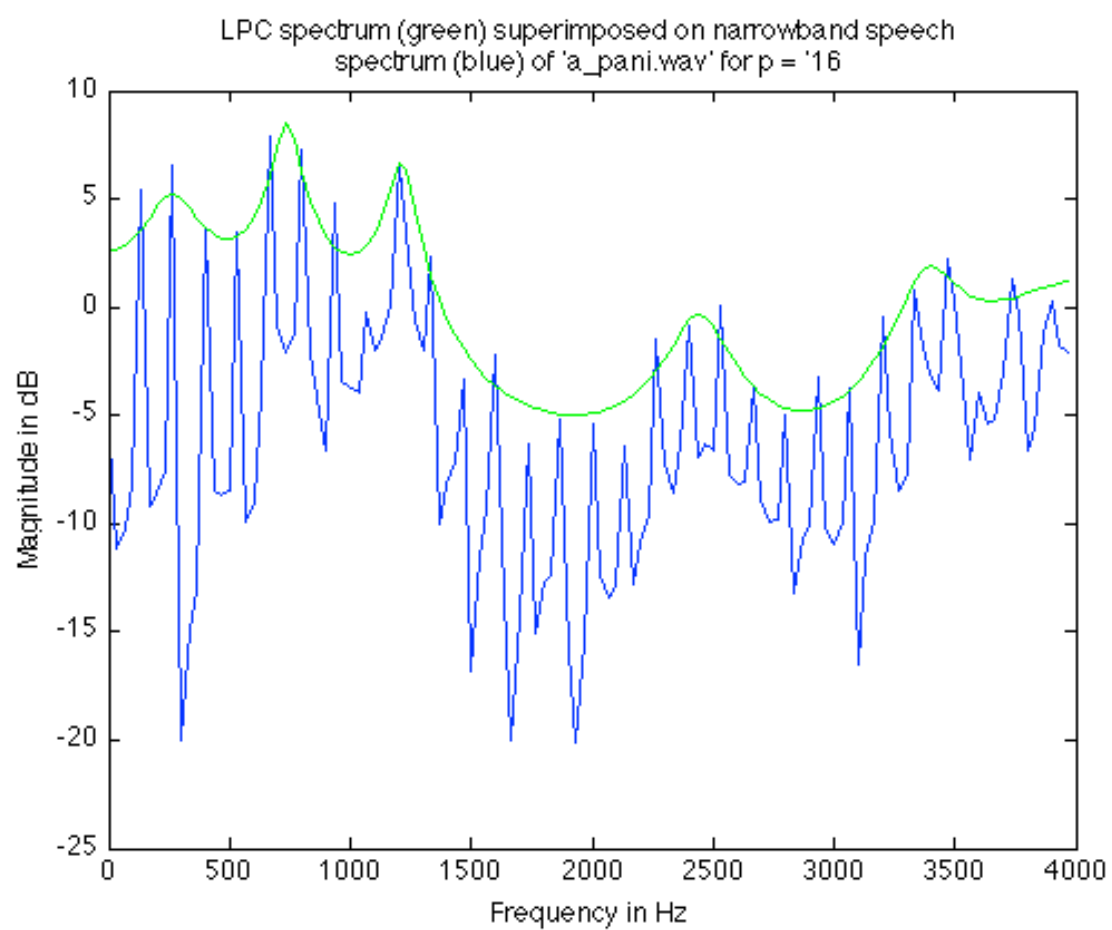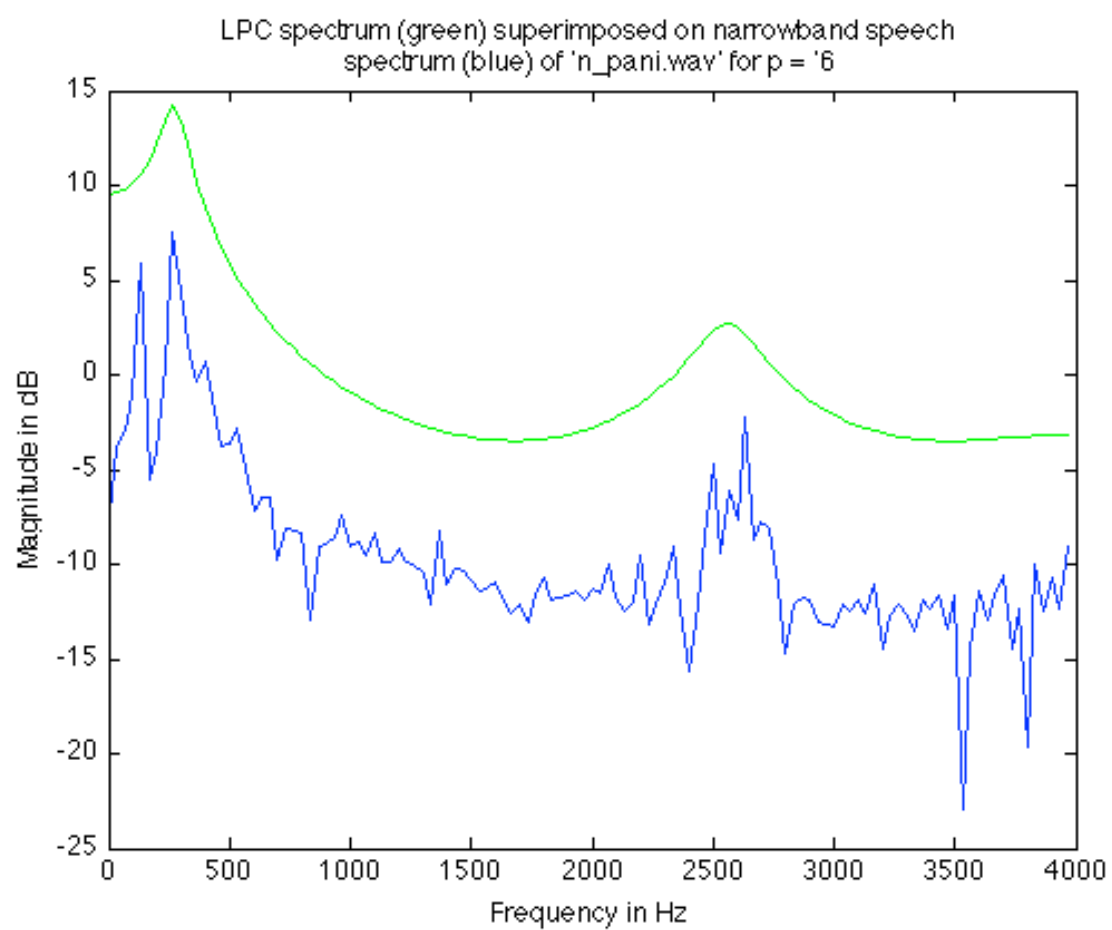
The plots:

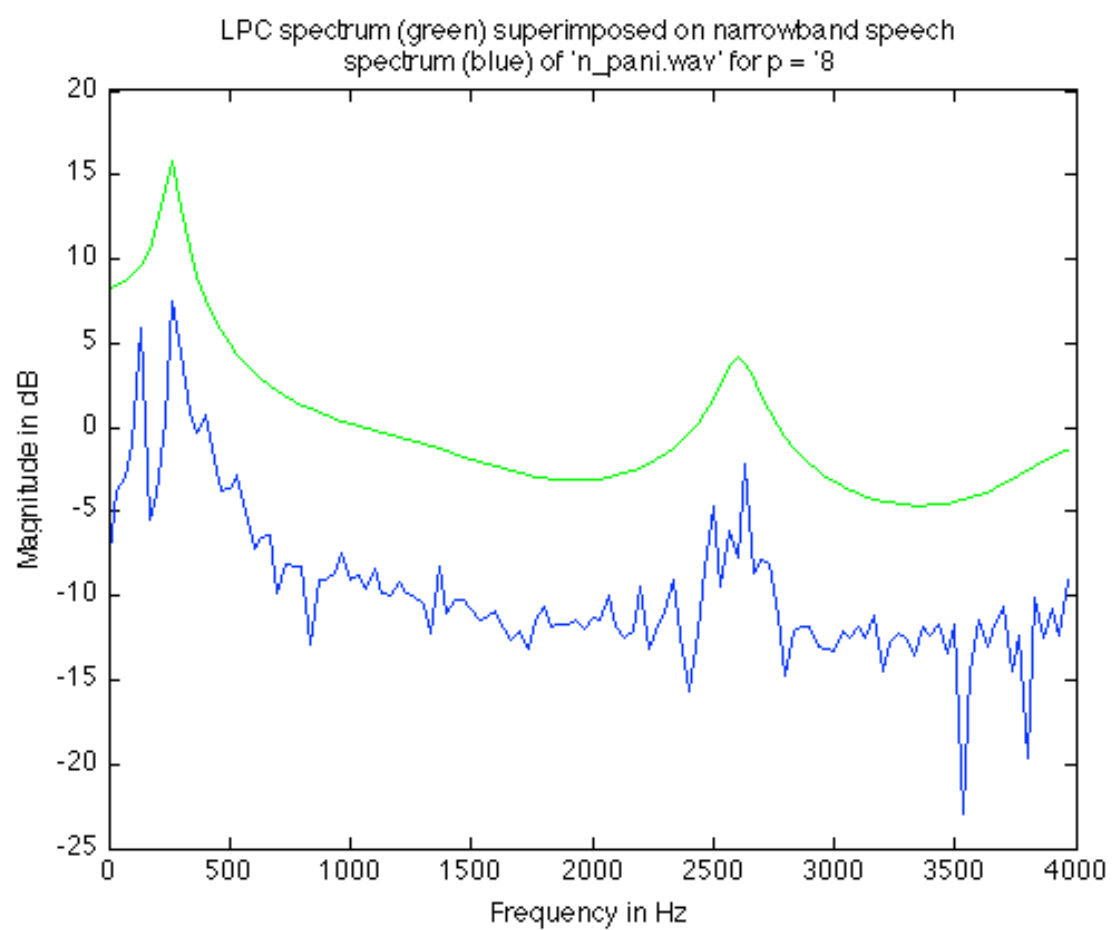
LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'a_pani.wav' for p = '6

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'a_pani.wav' for p = '8

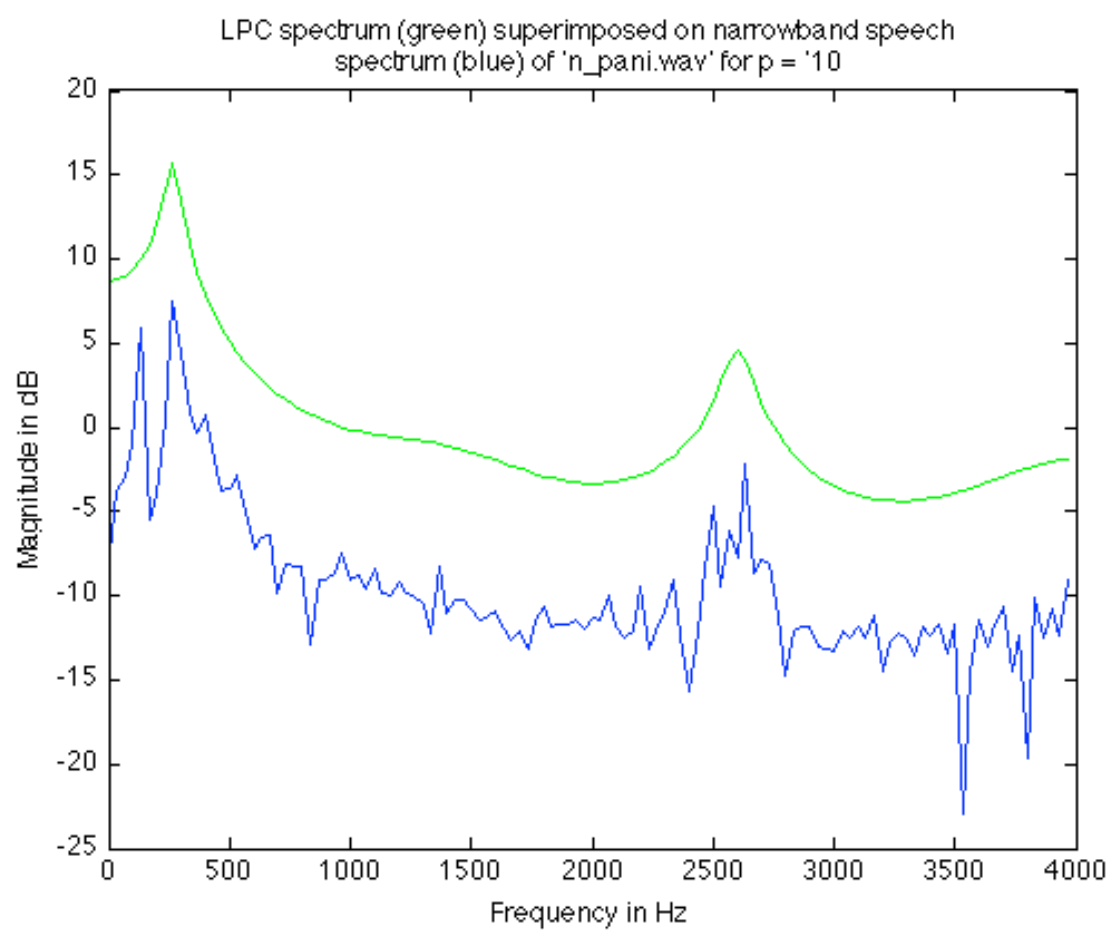LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'a_pani.wav' for p = '10

LPC spectrum (green) superimposed on narrowband speech
spectrum (blue) of 'a_pani.wav' for p = '12

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'a_pani.wav' for p = '16

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'n_pani.wav' for p = '6

LPC spectrum (green) superimposed on narrowband speech
spectrum (blue) of 'n_pani.wav' for p = '8

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'n_pani.wav' for p = '10

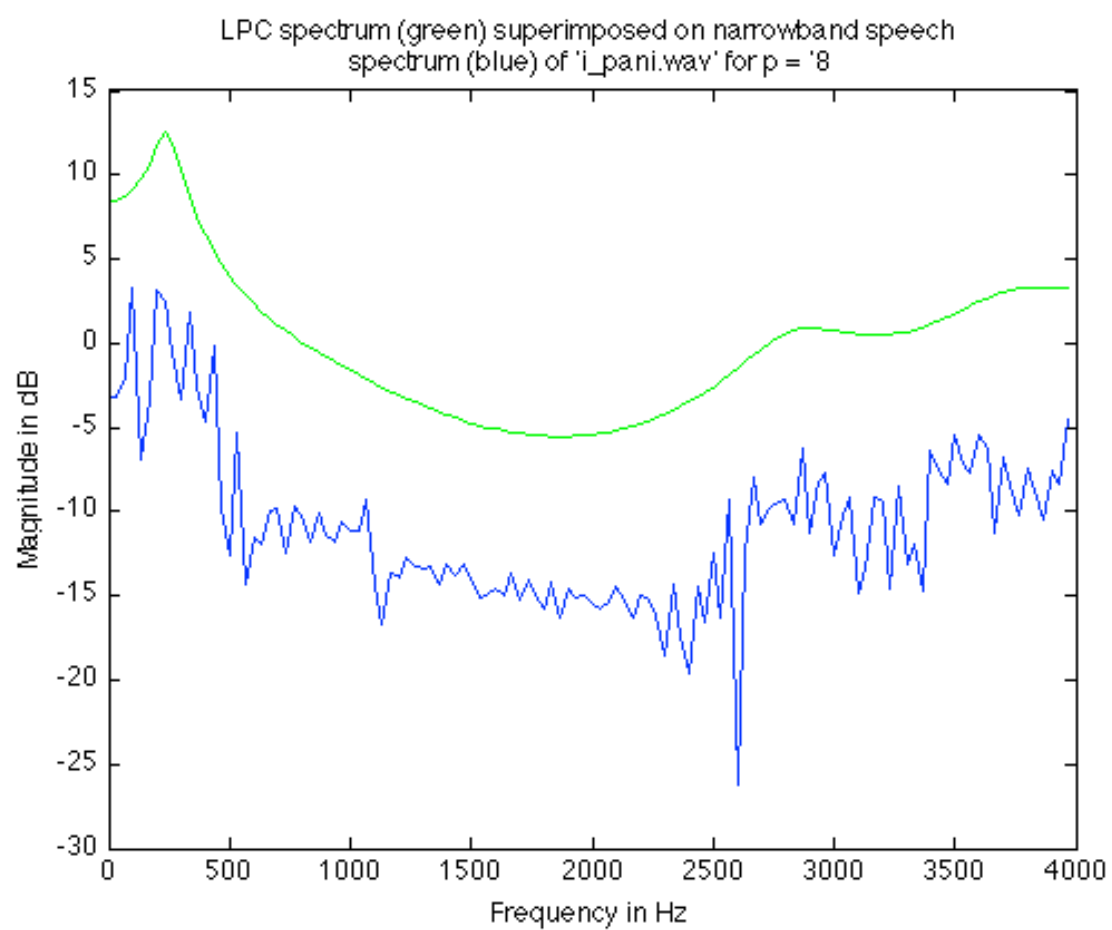LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'n_pani.wav' for p = '12

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'n_pani.wav' for p = '16

LPC spectrum (green) superimposed on narrowband speech
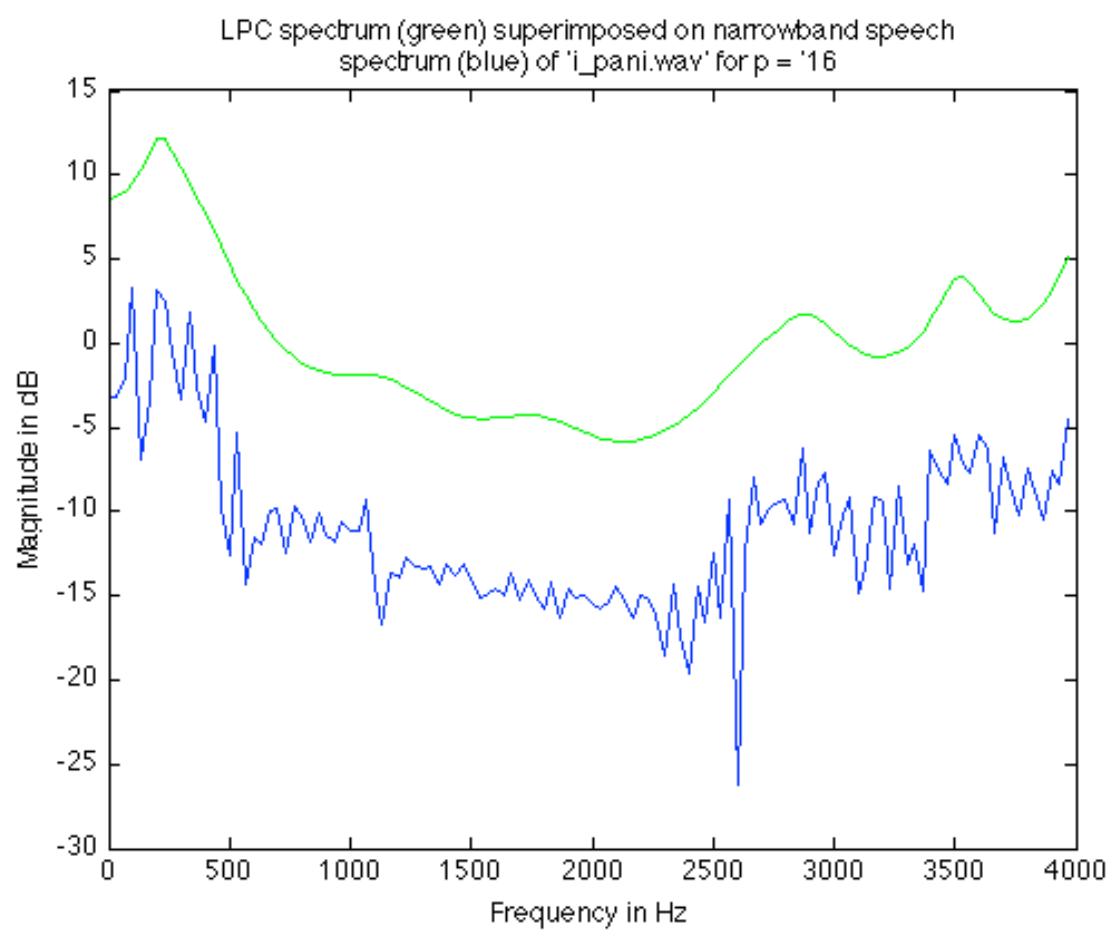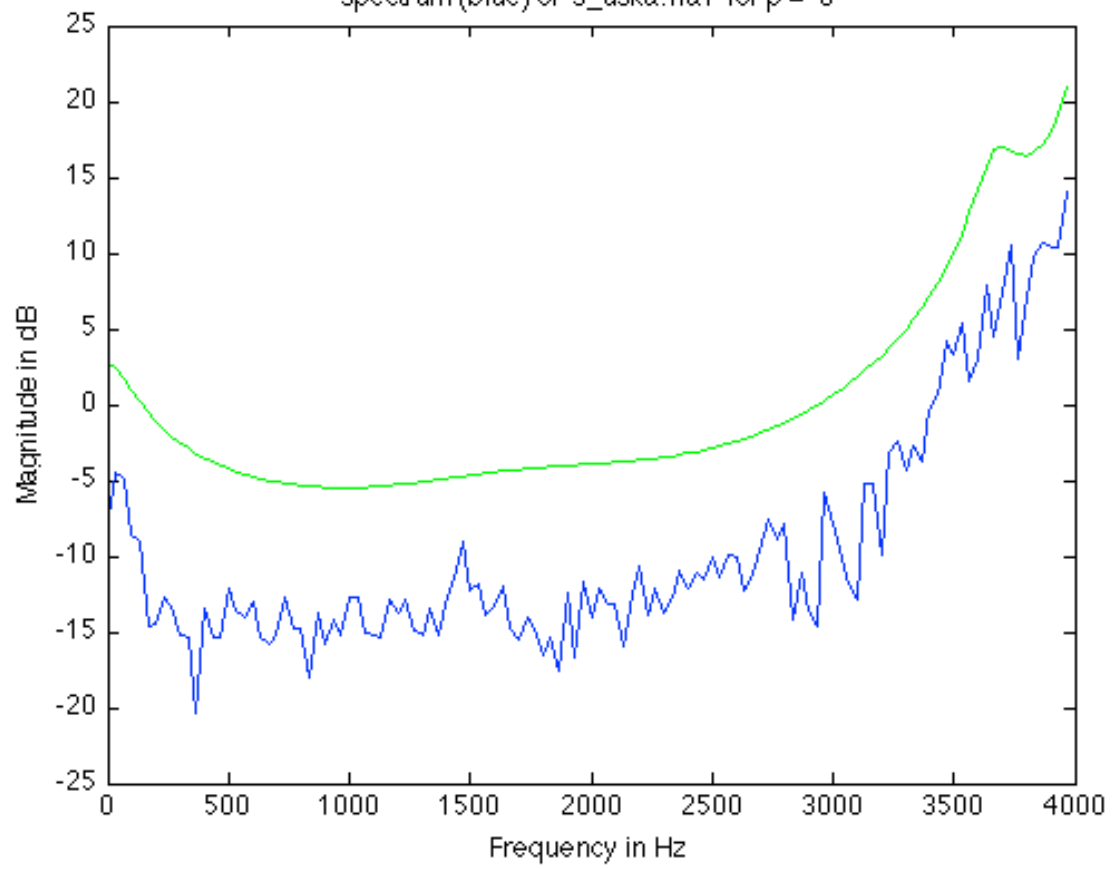spectrum (blue) of 'i_pani.wav' for p = '6

LPC spectrum (green) superimposed on narrowband speech
spectrum (blue) of 'i_pani.wav' for p = '8

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'i_pani.wav' for p = '10

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 'i_pani.wav' for p = '12

LPC spectrum (green) superimposed on narrowband speech
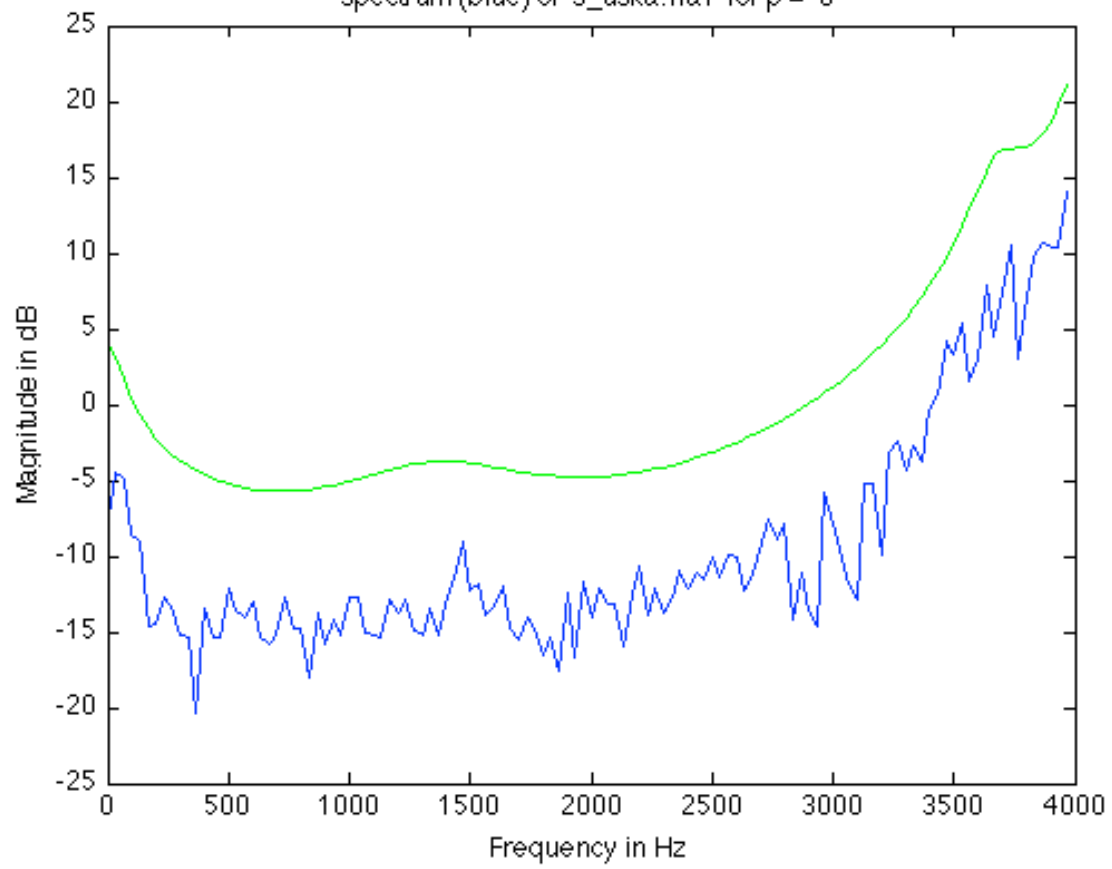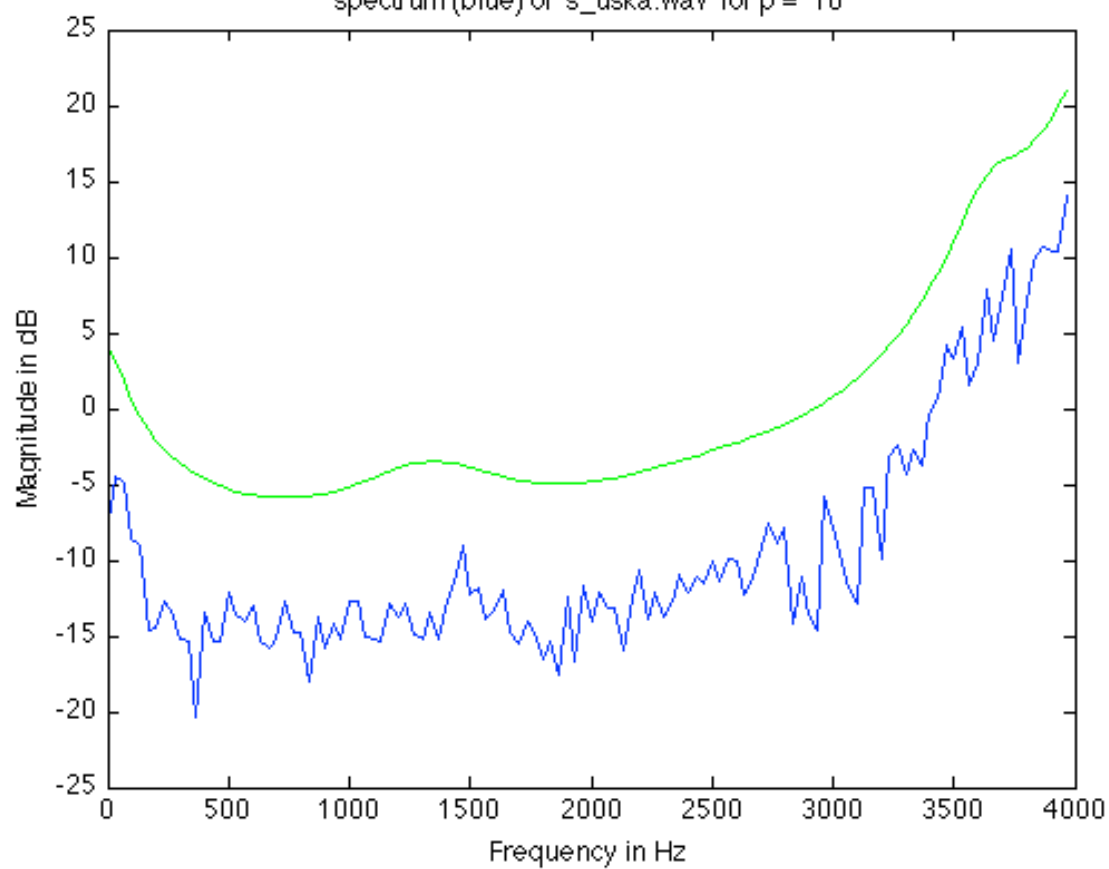spectrum (blue) of 'i_pani.wav' for p = '16

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 's_uska.wav' for p = '6

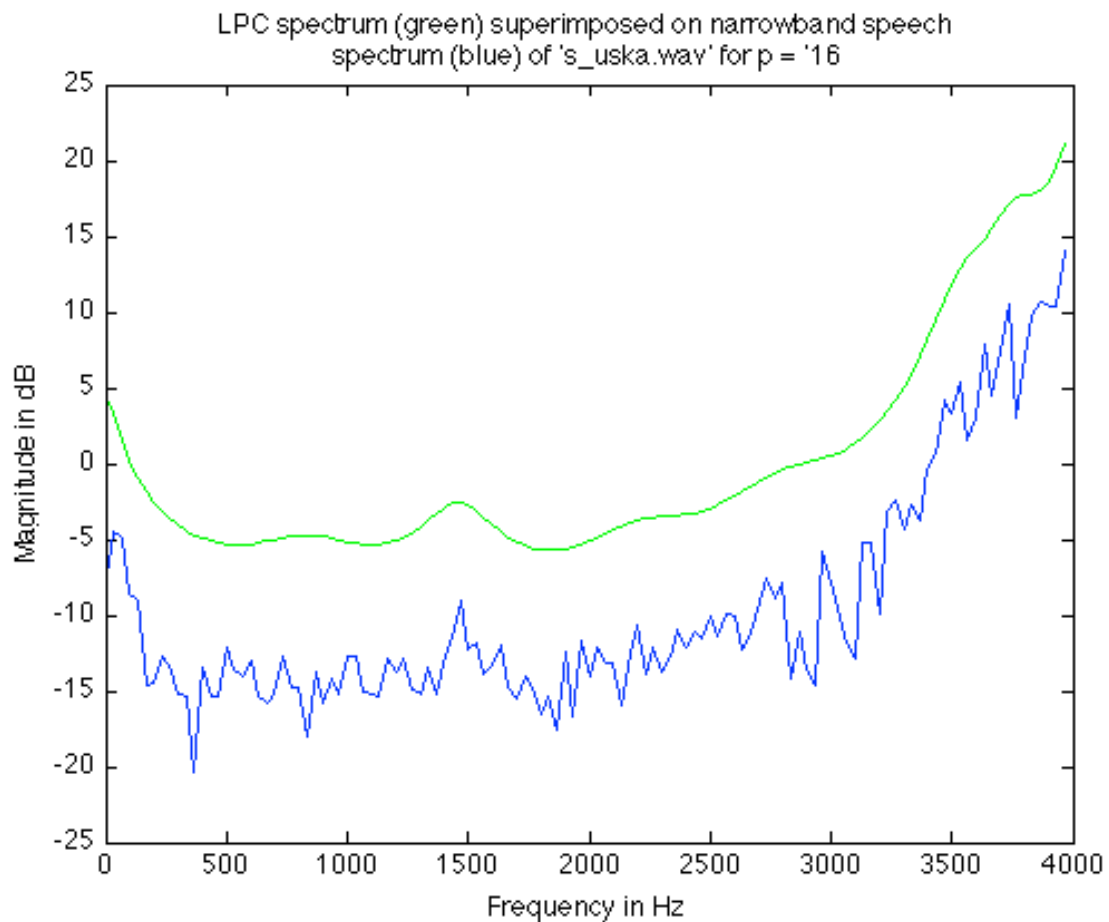LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 's_uska.wav' for p = '8

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 's_uska.wav' for p = '10

LPC spectrum (green) superimposed on narrowband speech
spectrum (blue) of 's_uska.wav' for p = '12

LPC spectrum (green) superimposed on narrowband speech spectrum (blue) of 's_uska.wav' for p = '16
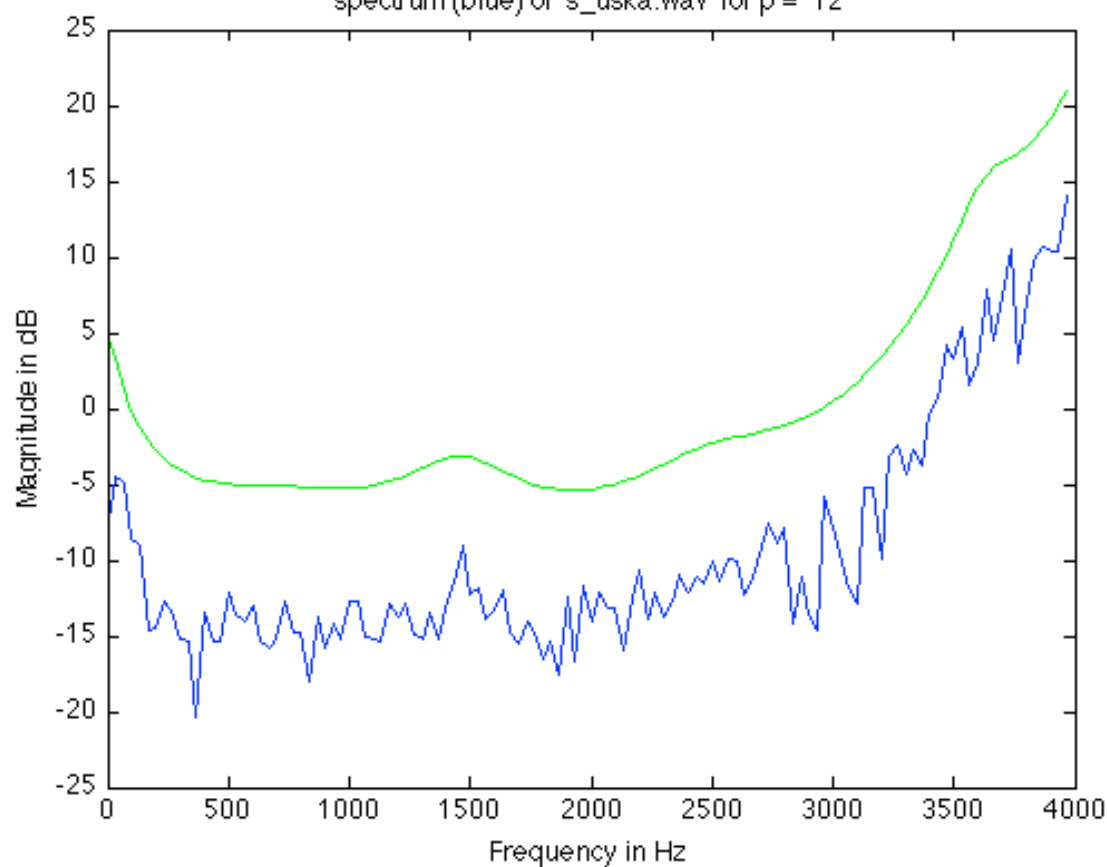
The speech spectrum (in blue) follows the LPC spectrum (in green) closely. This means the ratio of their magnitudes lie close to 1 reducing the overall error to a minimum. The parts of the speech spectrum above the LPC spectrum contribute more to the error than the portions below (the valleys). For example |2-1| = 1 is greater than |1-(1/2)| = 1/2.