EE 679 Computing Assignment 3

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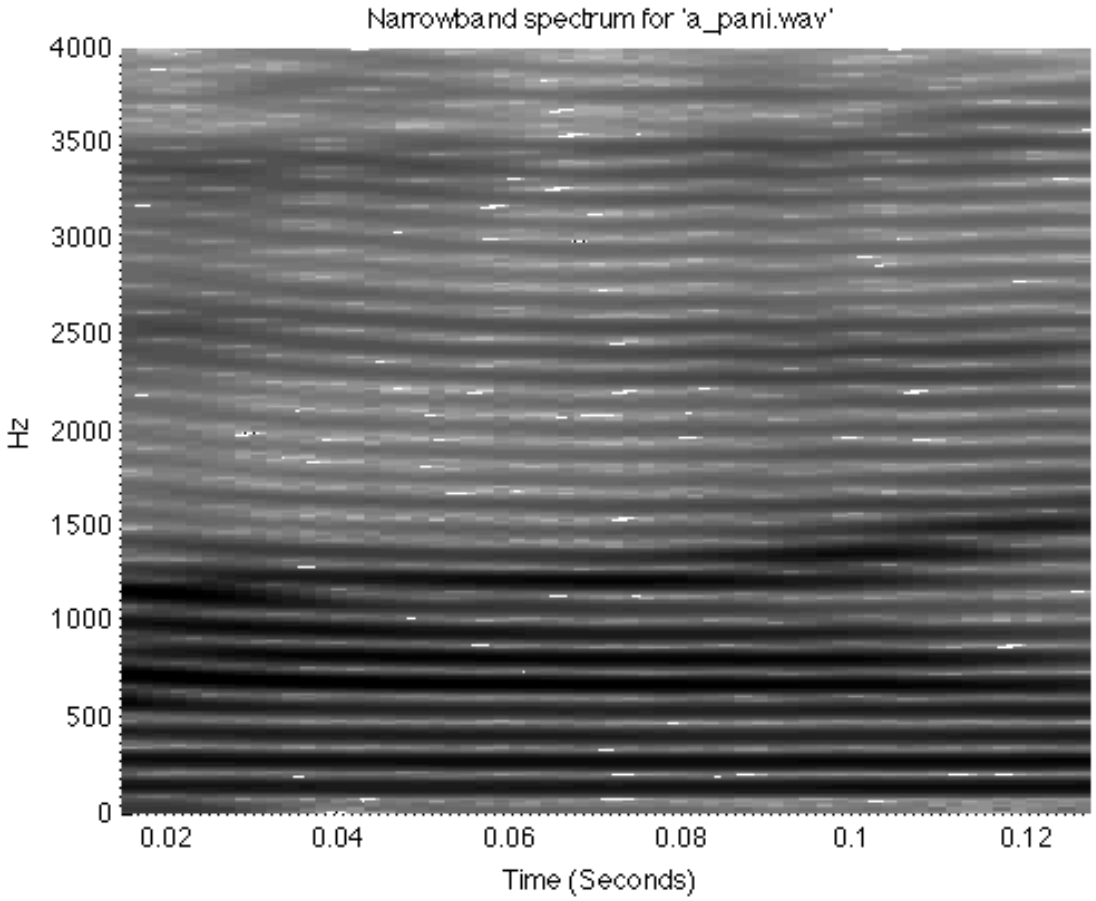
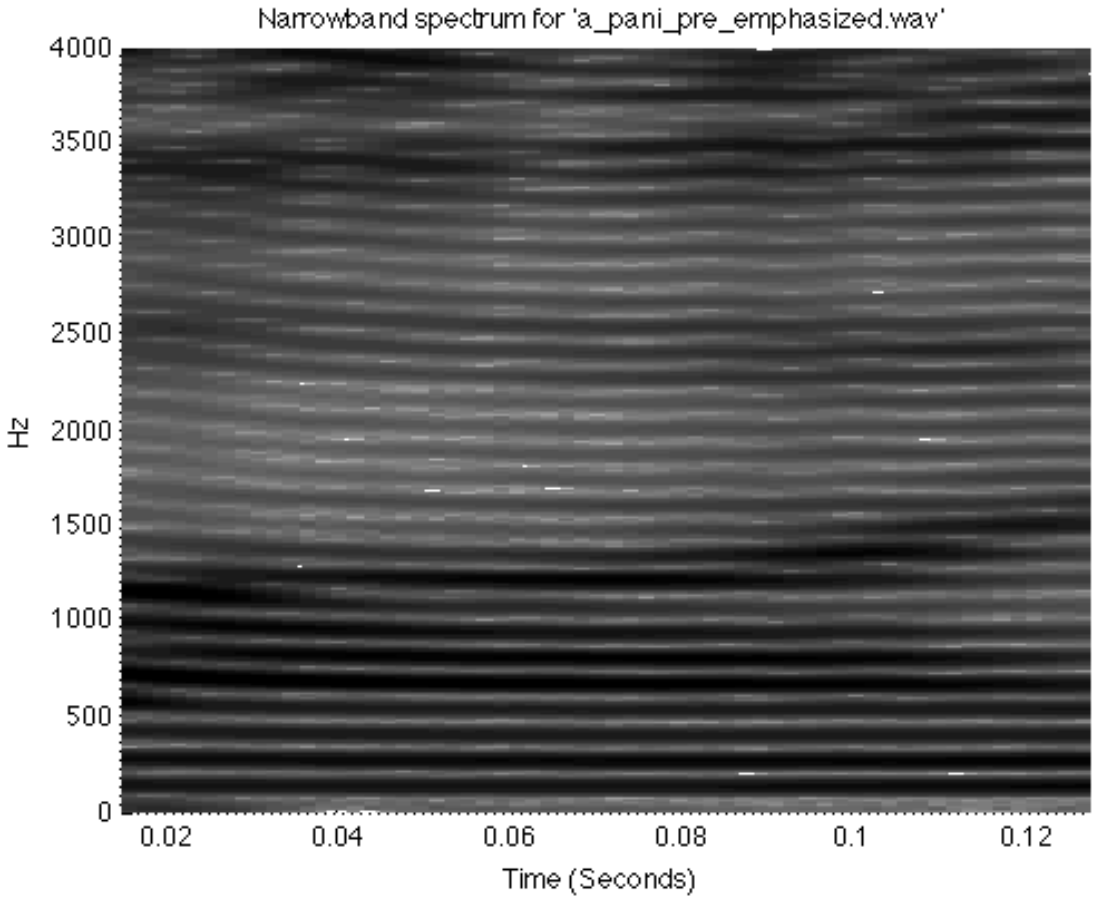
Question 1

Finding the narrowband spectrum of four syllables:

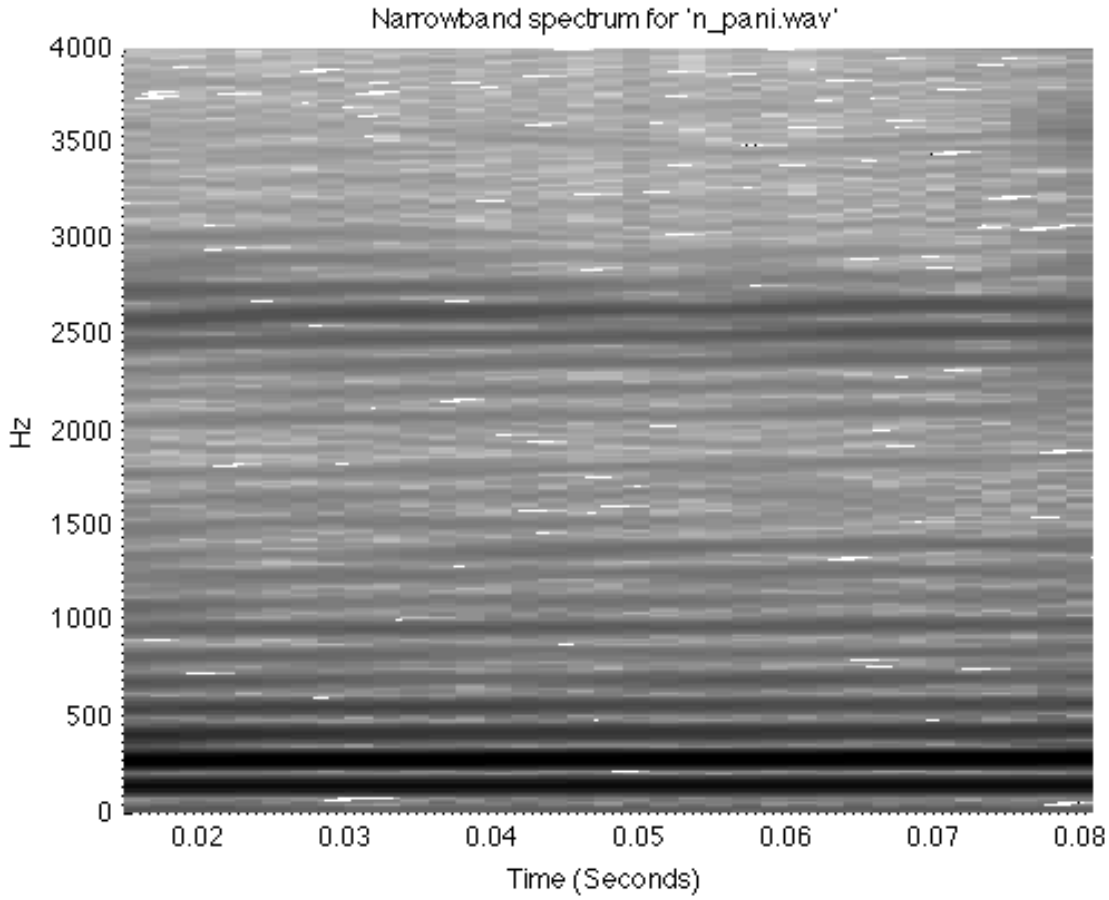
a) /a/ in ‘pani’



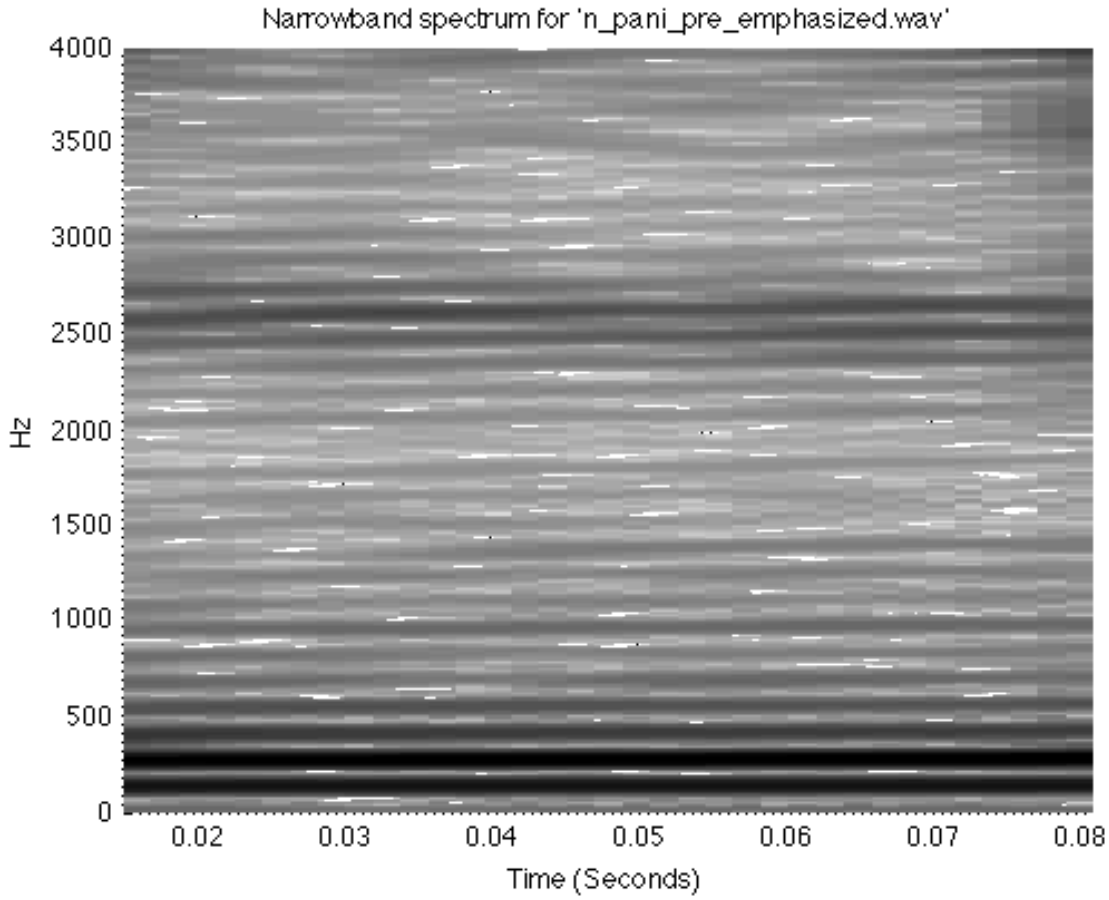
b) /a/ in ‘pani’ pre-emphasized


Narrowband spectrum for 'a_pani_pre_emphasized.wav'
4000
3500
3000
2500
2000
1500
1000
500
0
Hz
0.02
0.04
0.06
0.08
0.1
0.12
Time (Seconds)

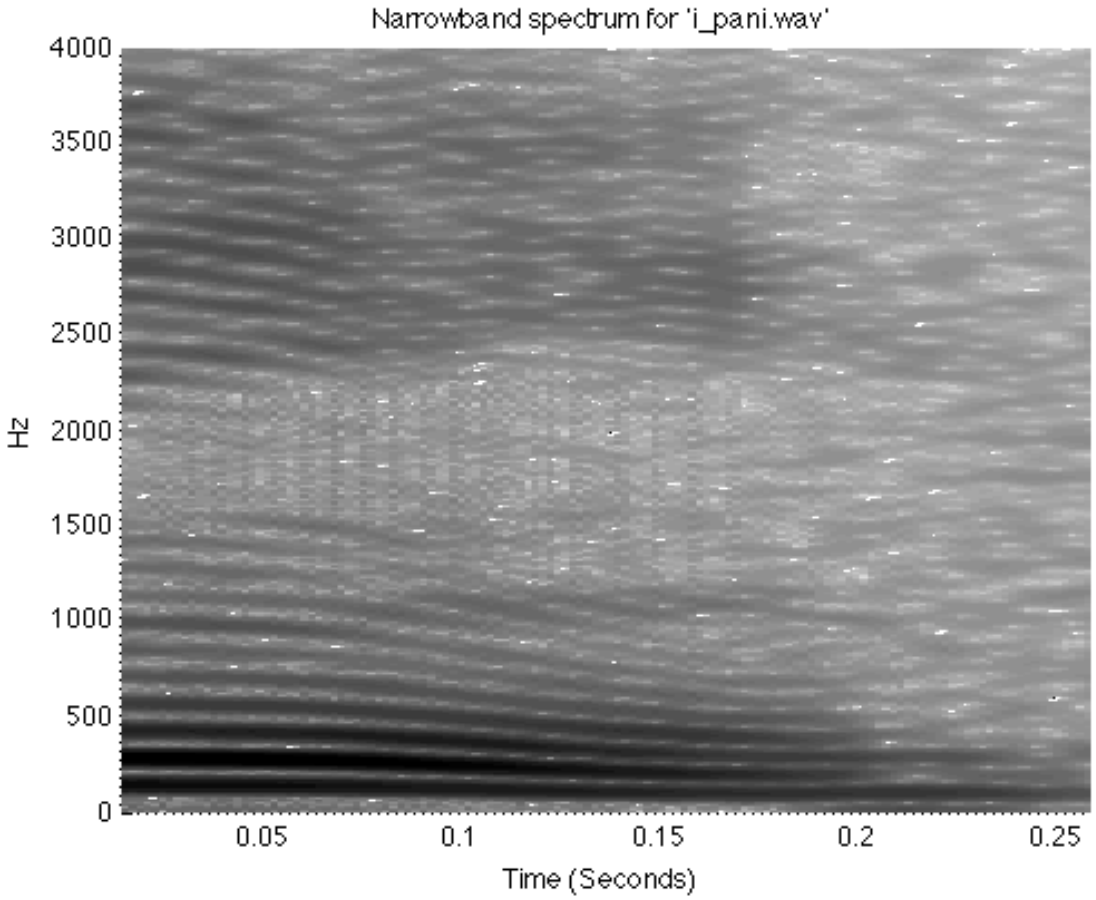
c) /n/ in ‘pani’



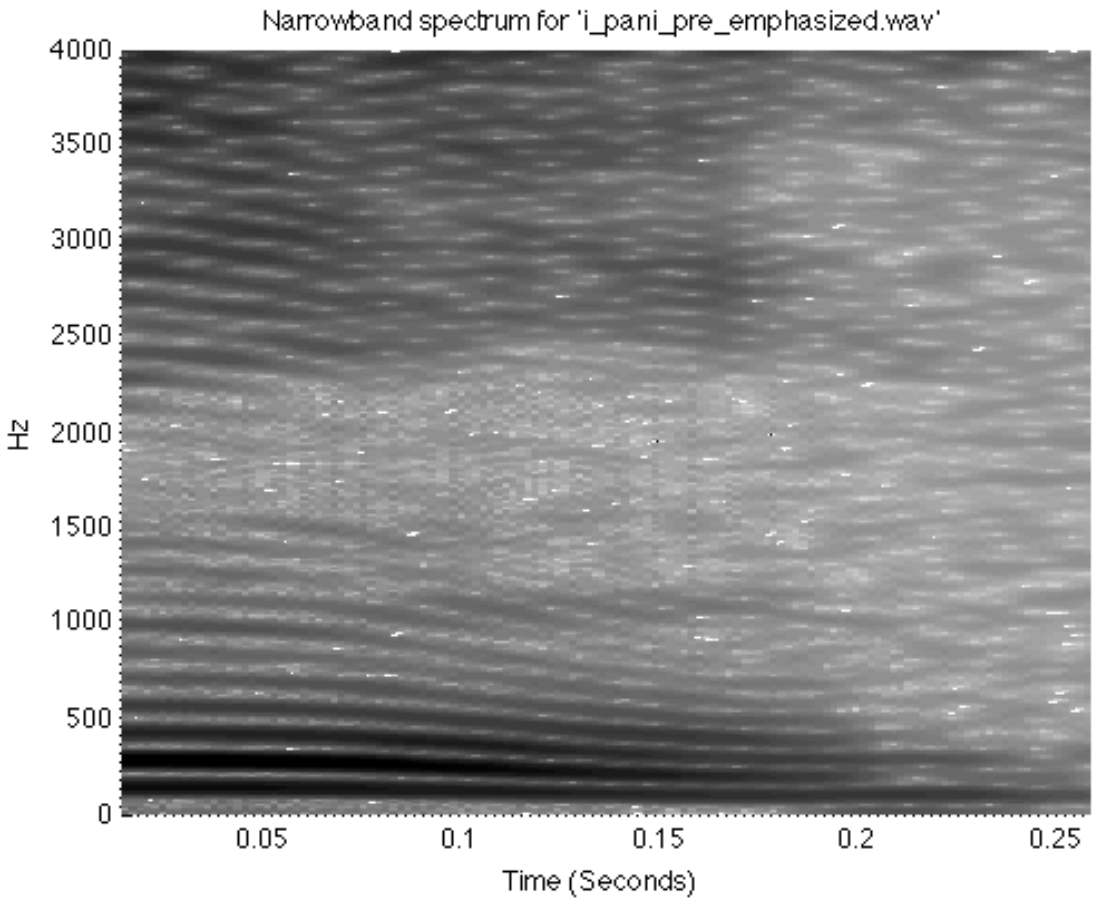
d) /n/ in ‘pani’ pre-emphasized


Narrowband spectrum for 'n_pani_pre_emphasized.wav'
4000
3500
3000
2500
2000
1500
1000
500
0
Hz
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Time (Seconds)

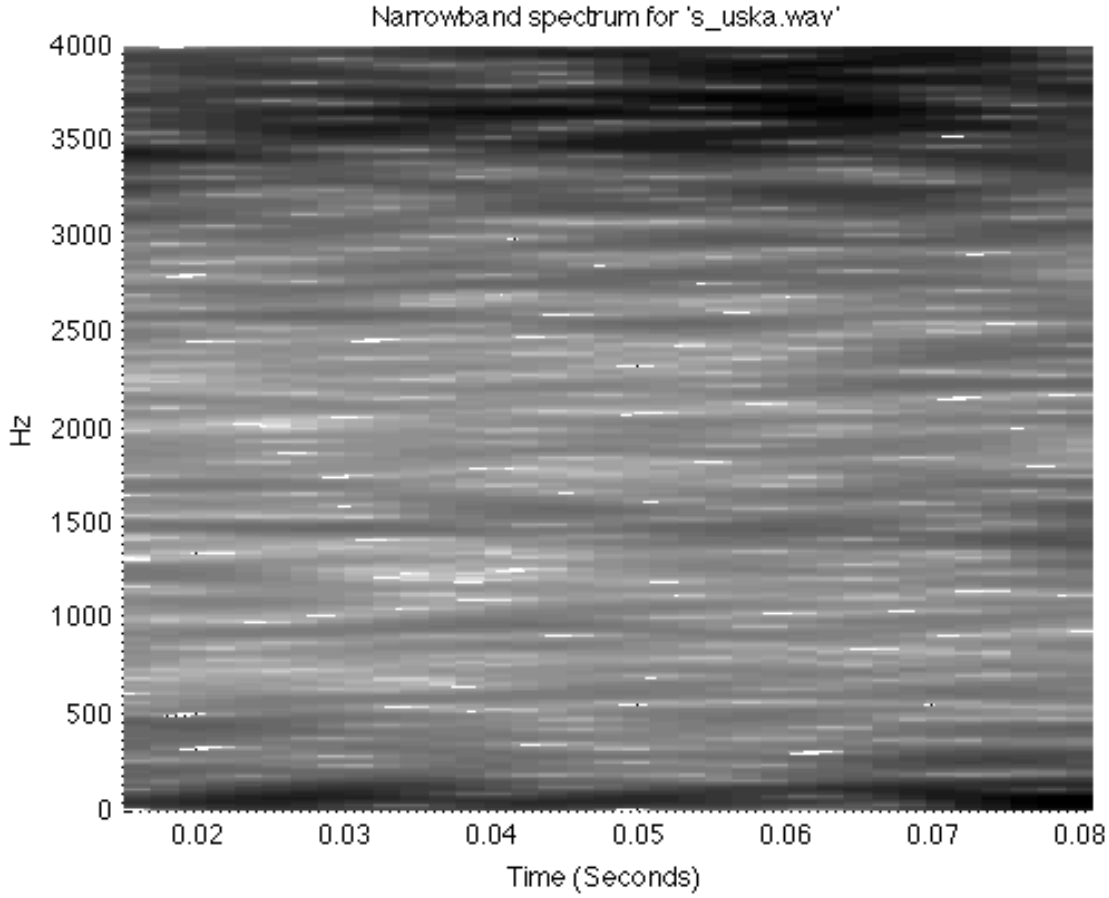
e) /I/ in ‘pani’



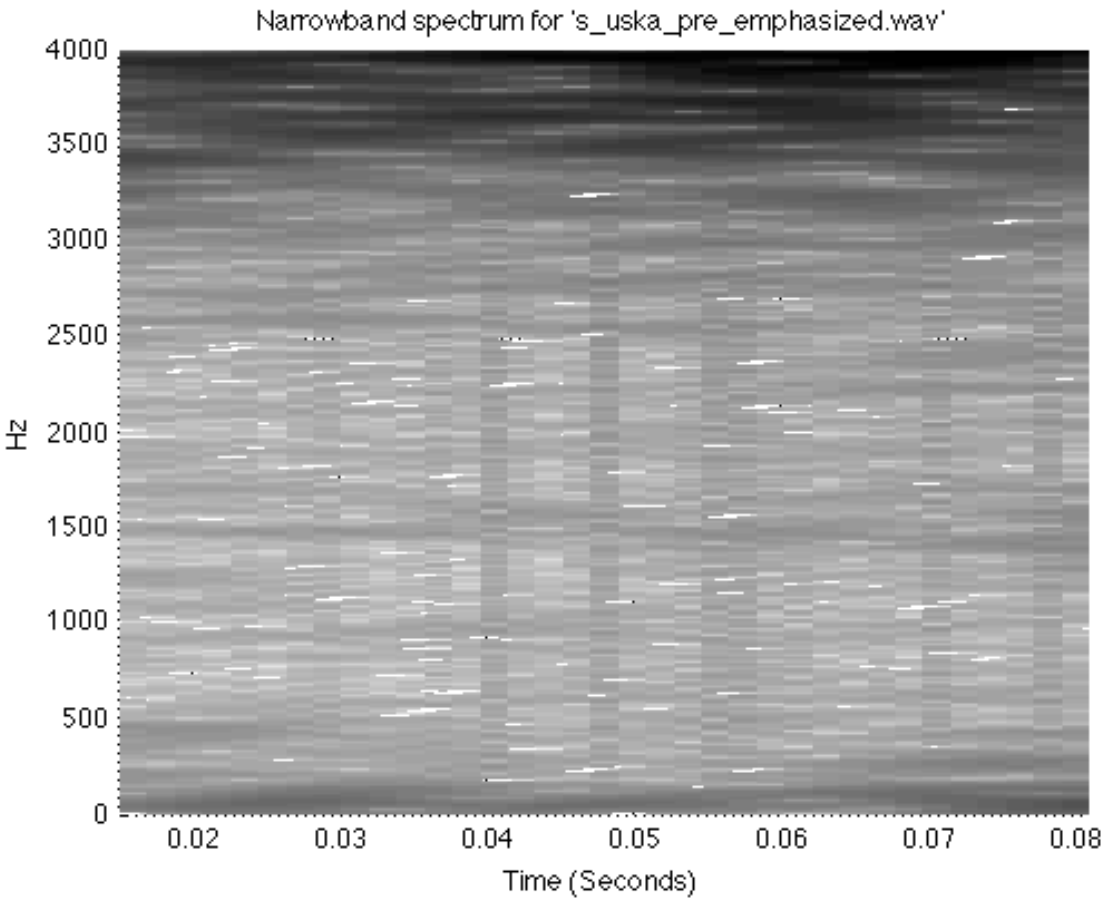
f) /I/ in ‘pani’ pre-emphasized


Narrowband spectrum for 'i_pani_pre_emphasized.wav'
4000
3500
3000
2500
2000
1500
1000
500
0
Hz
0.05
0.1
0.15
0.2
0.25
Time (Seconds)

g) /s/ in ‘uska’



h) /s/ in ‘uska’ pre-emphasized



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');
```

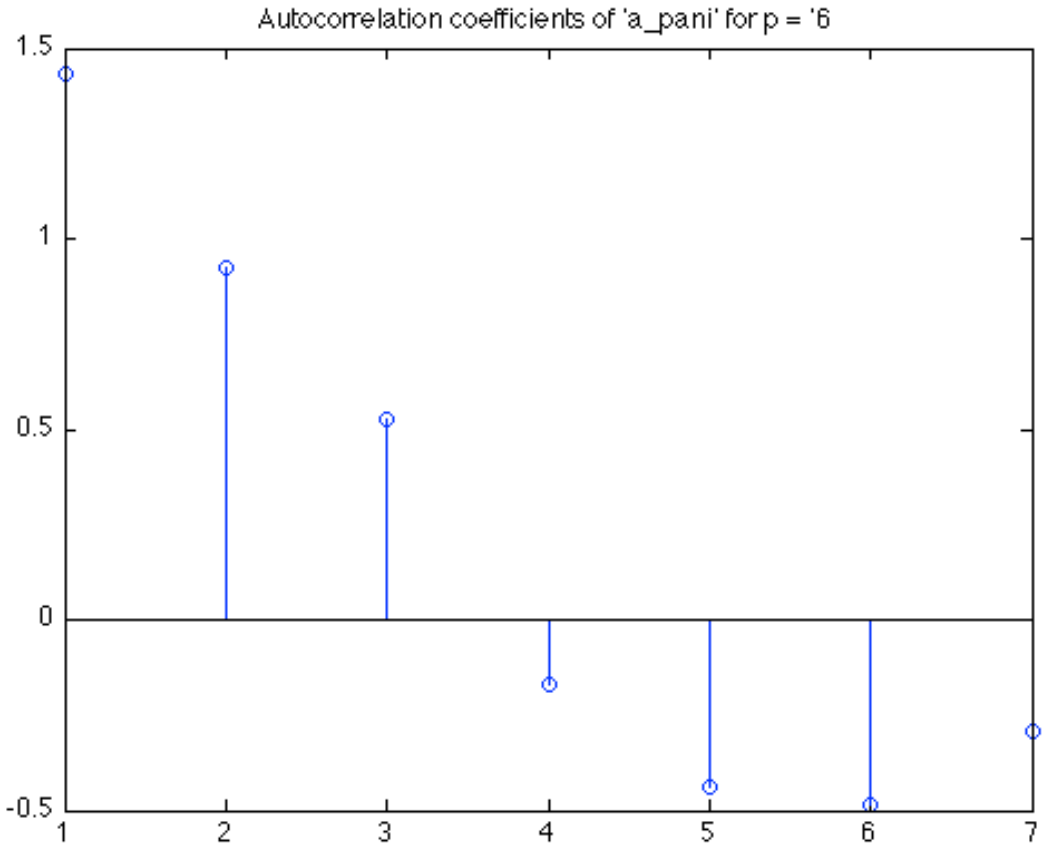
```
figure(500); clf;
printNarrowbandSpectrum('i_pani.wav');
[y, fs] = preEmphasize('i_pani.wav');
wavwrite(y, fs, 32, 'i_pani_pre_emphasized.wav');
figure(600); clf;
printNarrowbandSpectrum('i_pani_pre_emphasized.wav');

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');
```

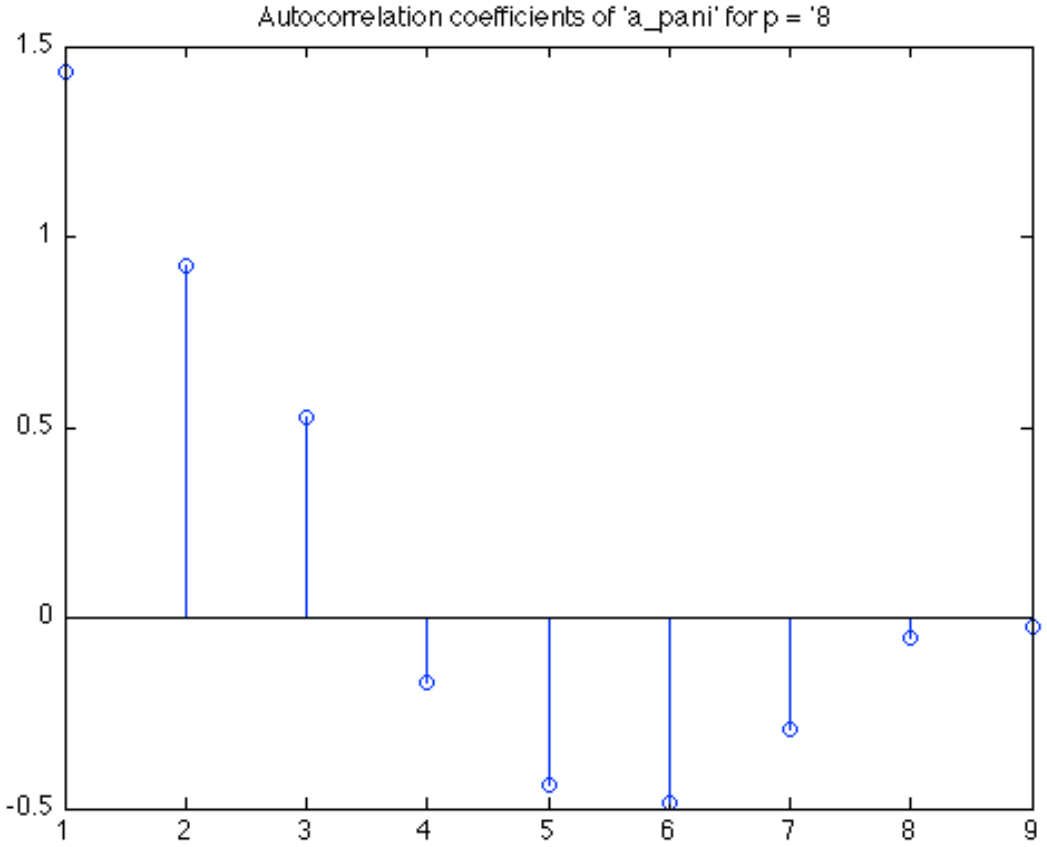
Code for the functions used in finding the narrowband spectrum

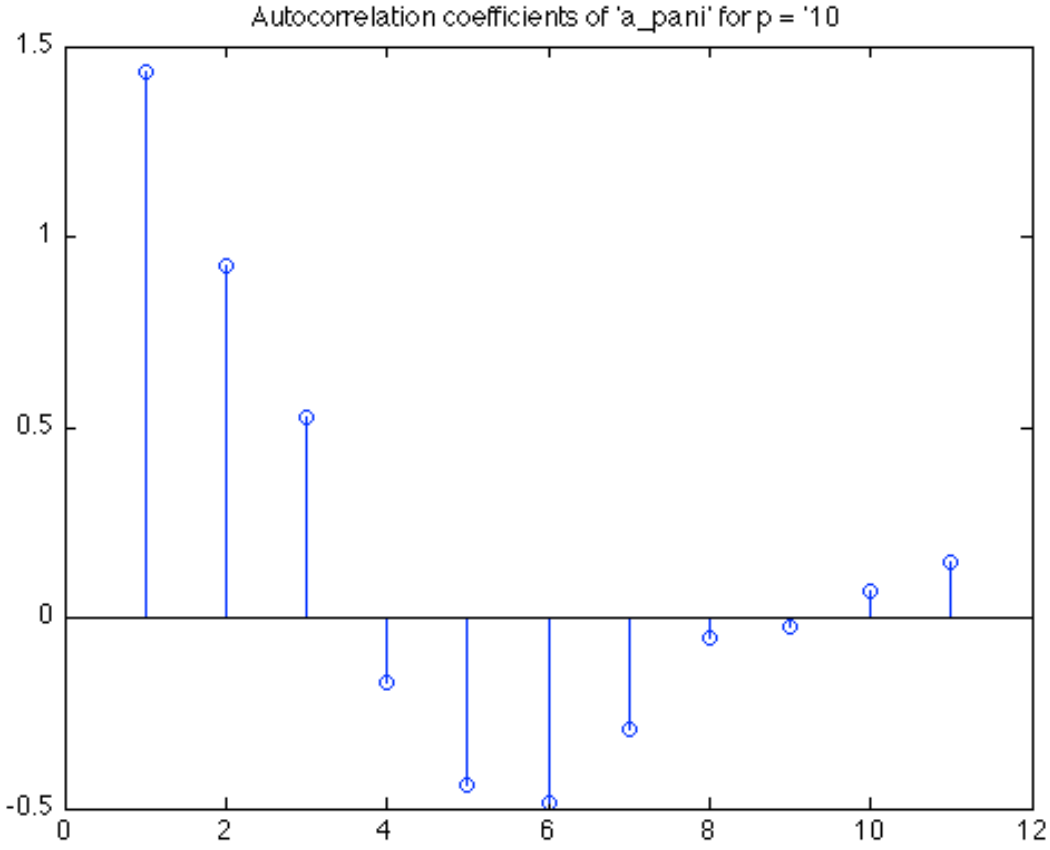
```
function [signal, fs] = preEmphasize(inputFile)

[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);
```

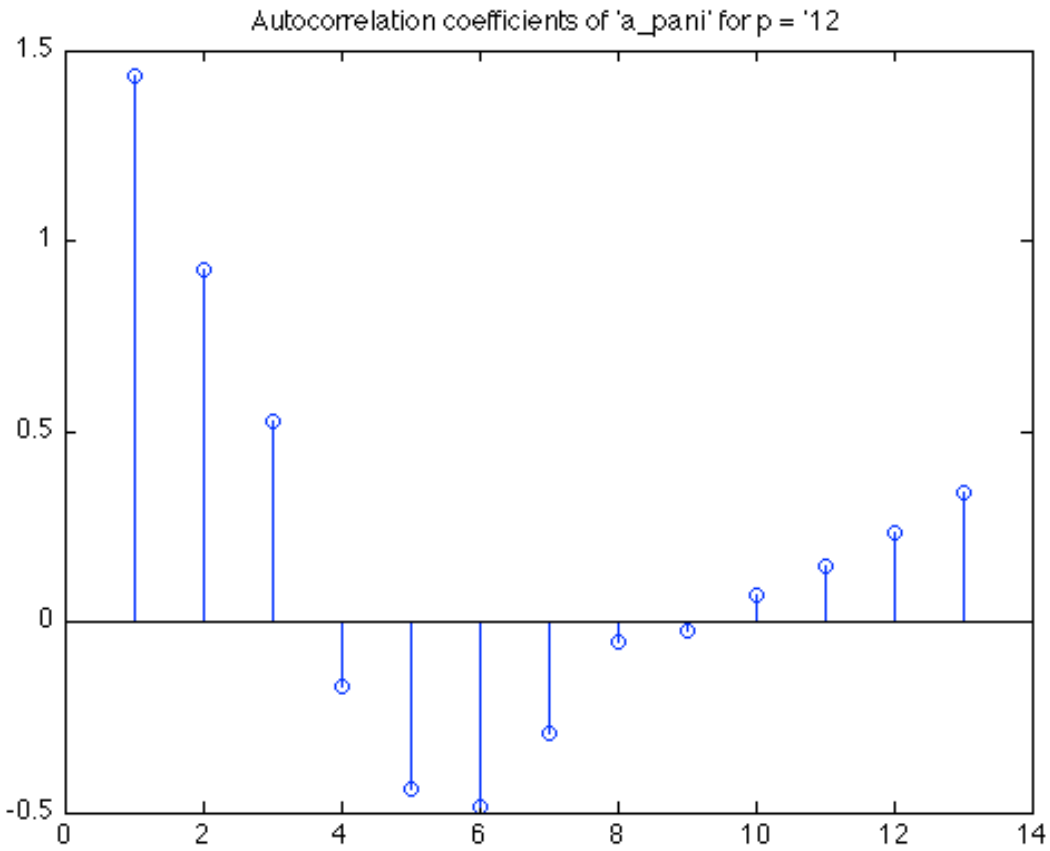
```
surf(T,F,10*log10(P),'edgecolor','none');
title(['Narrowband spectrum for ''', fileInput, ''''],
'interpreter', 'none');
axis tight;
colormap(imap);
view(0,90);
xlabel('Time (Seconds)'); ylabel('Hz');

end
```

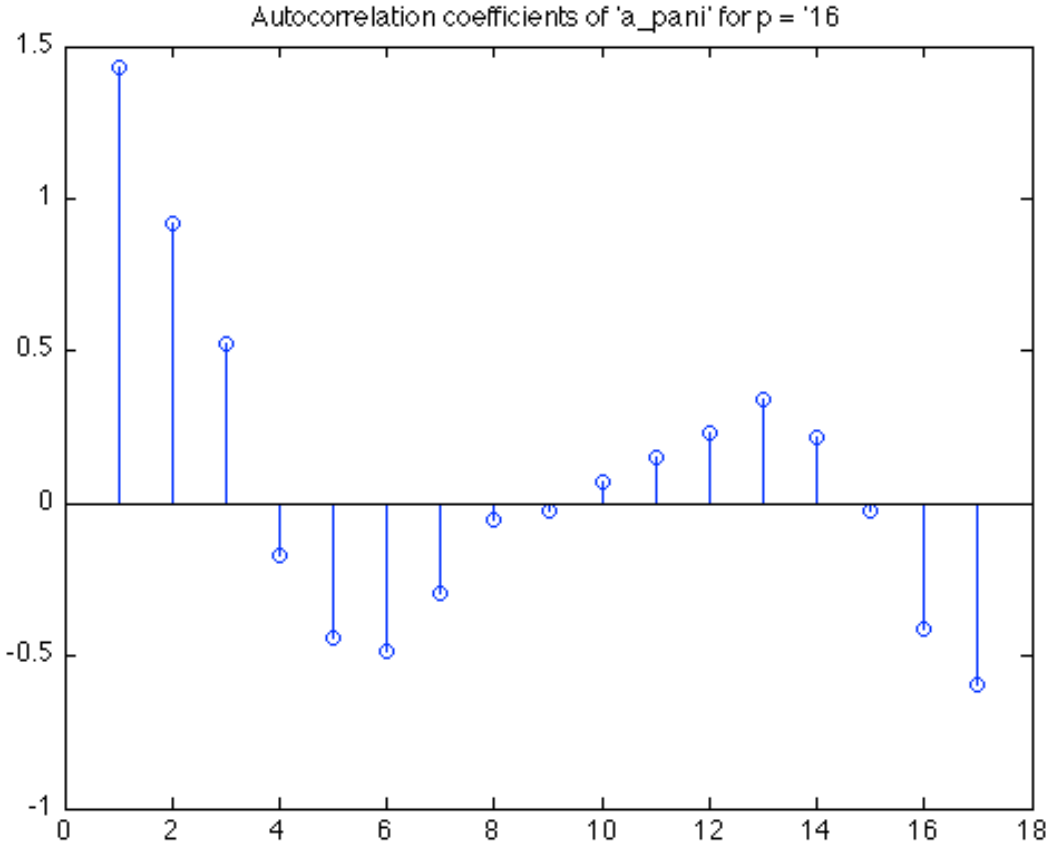
Answer to Question 2(a)

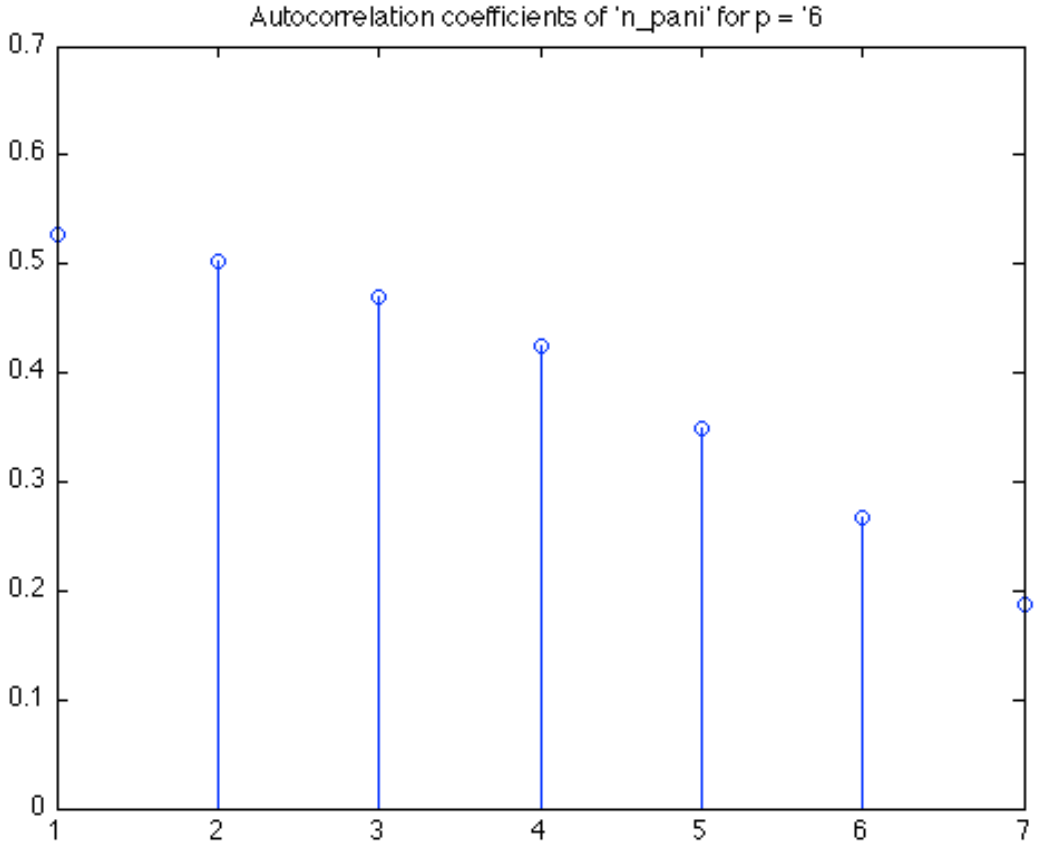


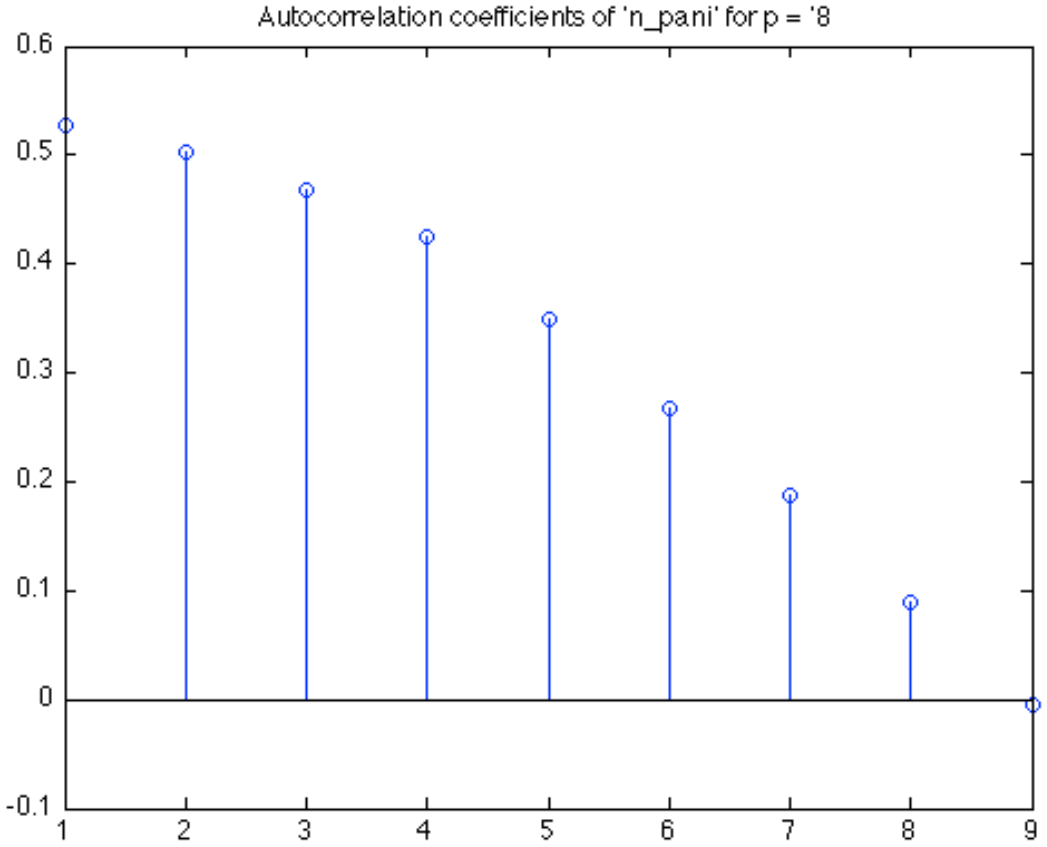

Autocorrelation coefficients of 'a_pani' for p = '8
1.5
1
0.5
0
-0.5
1
2
3
4
5
6
7
8
9

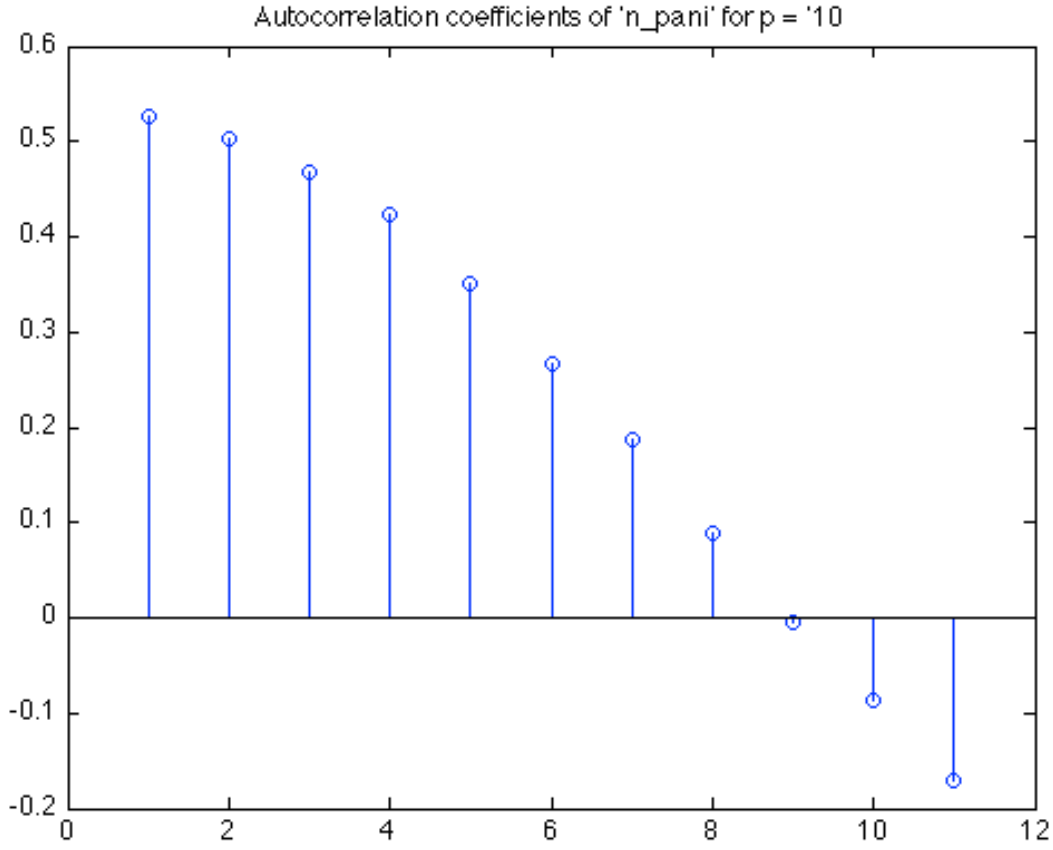

Autocorrelation coefficients of 'a_pani' for p = '10
1.5
1
0.5
0
-0.5
0
2
4
6
8
10
12

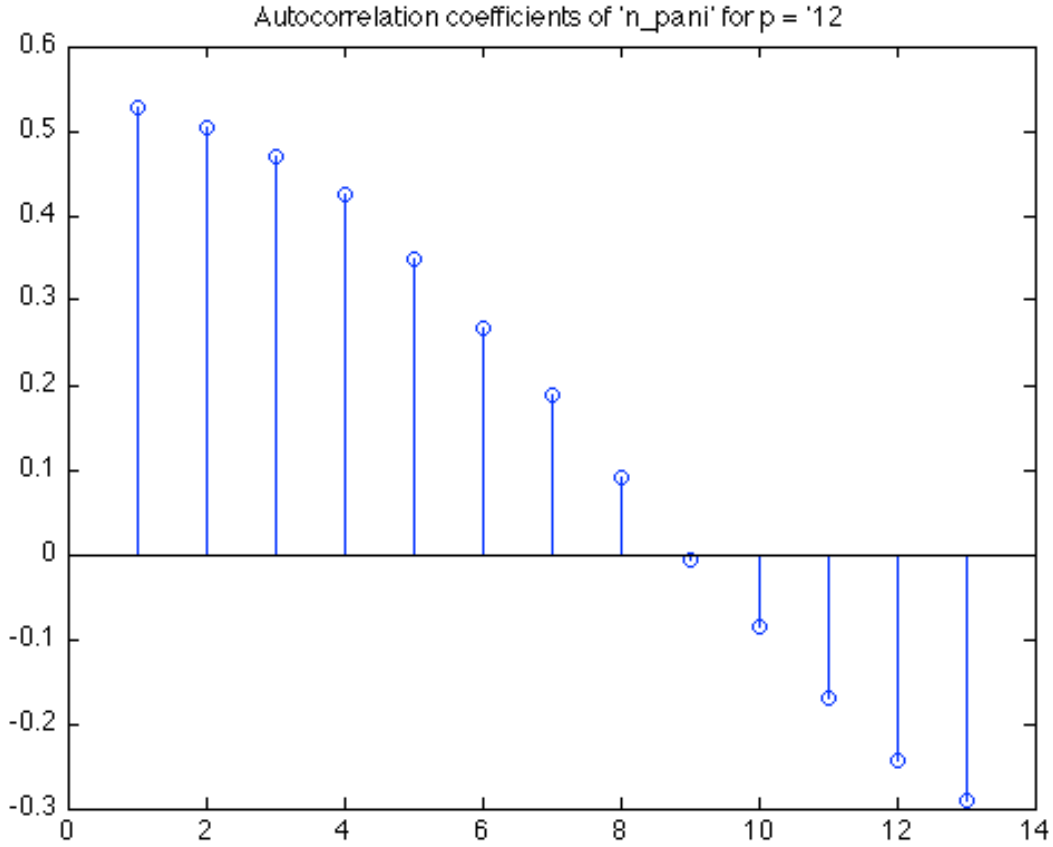

Autocorrelation coefficients of 'a_pani' for p = '12
1.5
1
0.5
0
-0.5
0
2
4
6
8
10
12
14

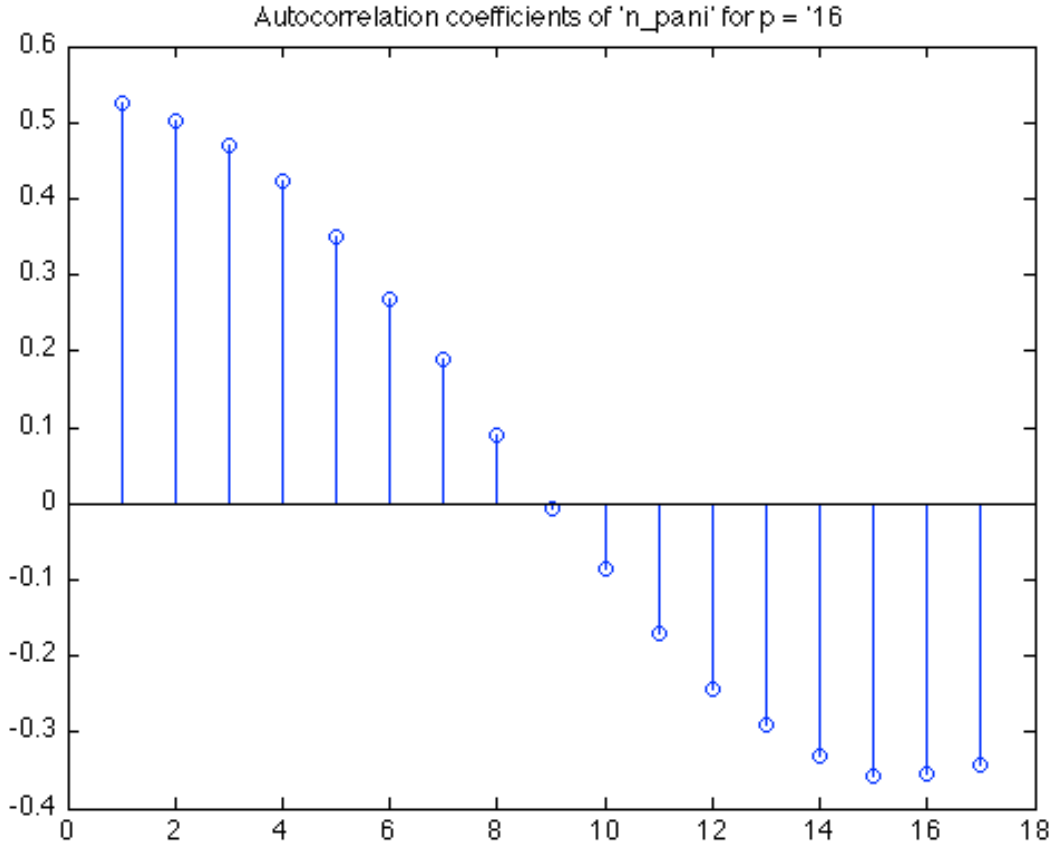

Autocorrelation coefficients of 'a_pani' for p = '16
1.5
1
0.5
0
-0.5
-1
0
2
4
6
8
10
12
14
16
18

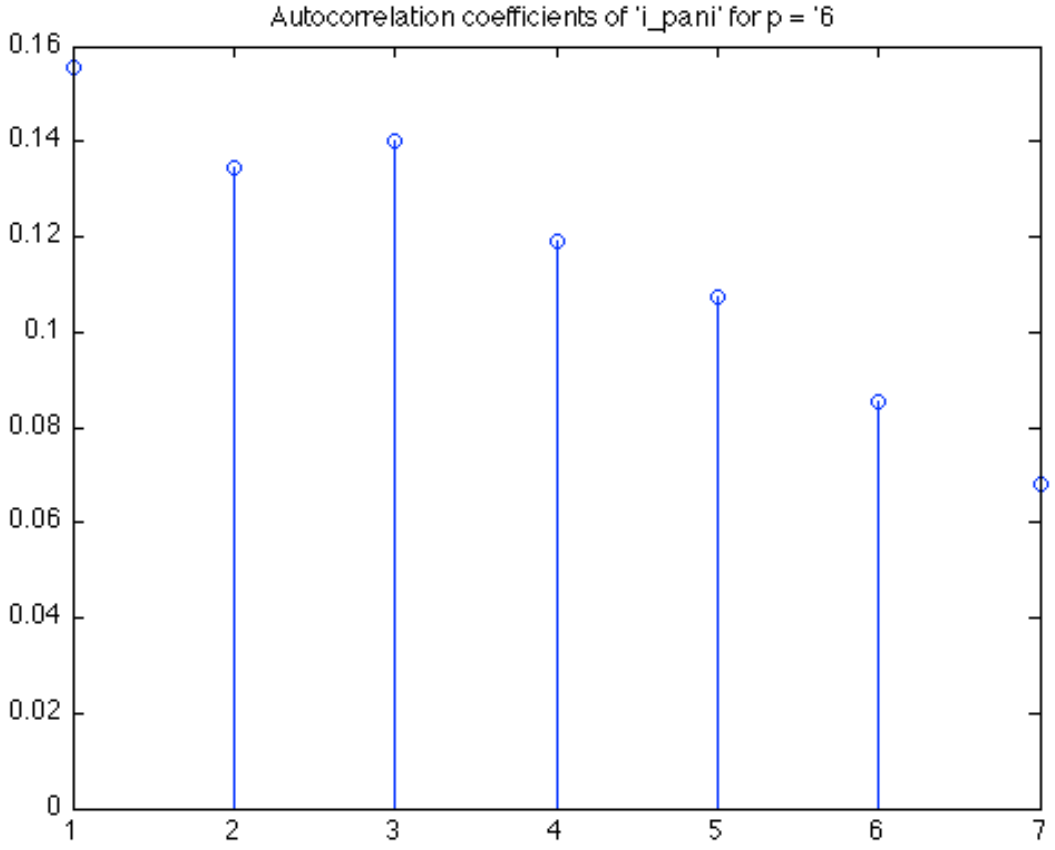

Autocorrelation coefficients of 'n_pani' for p = '6
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7

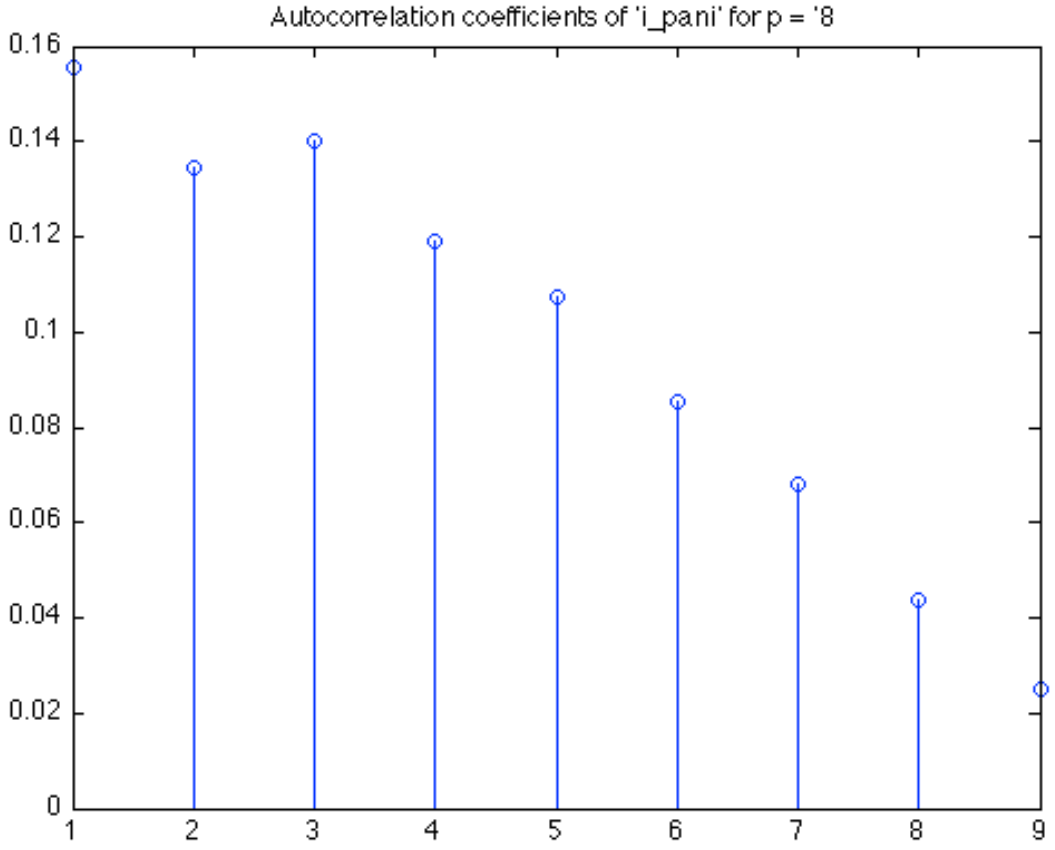

Autocorrelation coefficients of 'n_pani' for p = '8
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
1
2
3
4
5
6
7
8
9

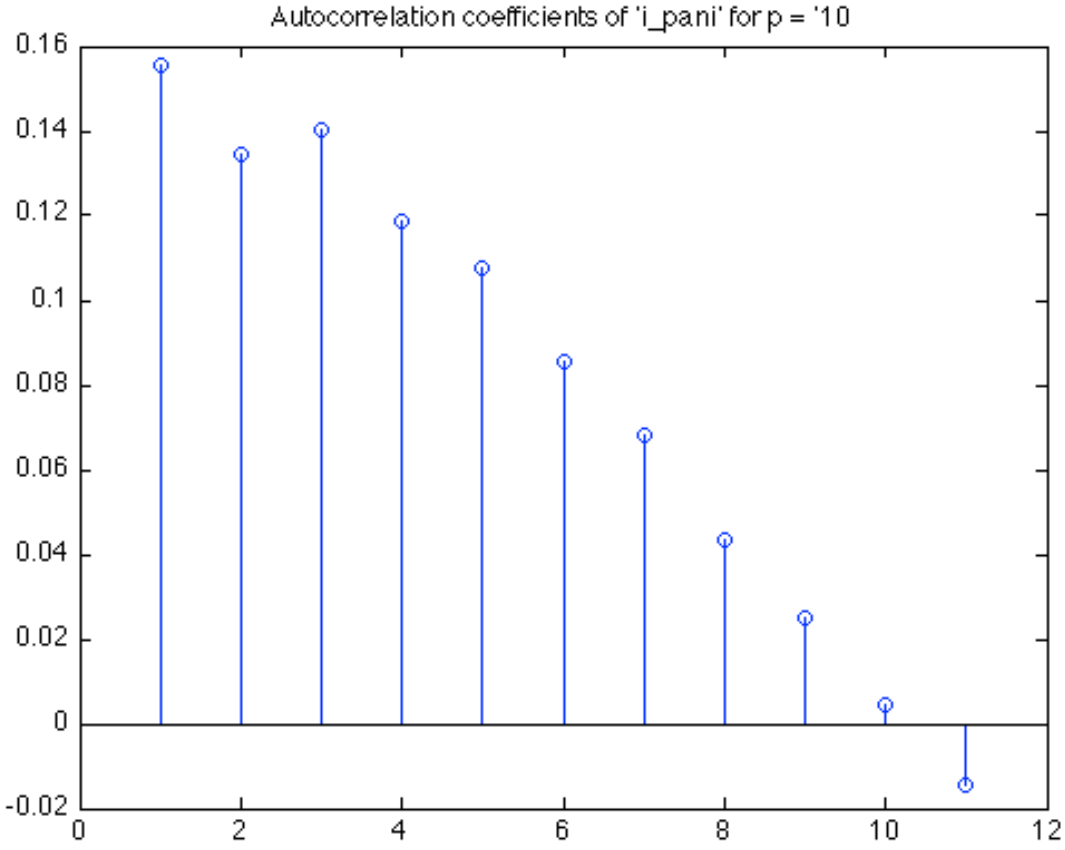

Autocorrelation coefficients of 'n_pani' for p = '10
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0
2
4
6
8
10
12

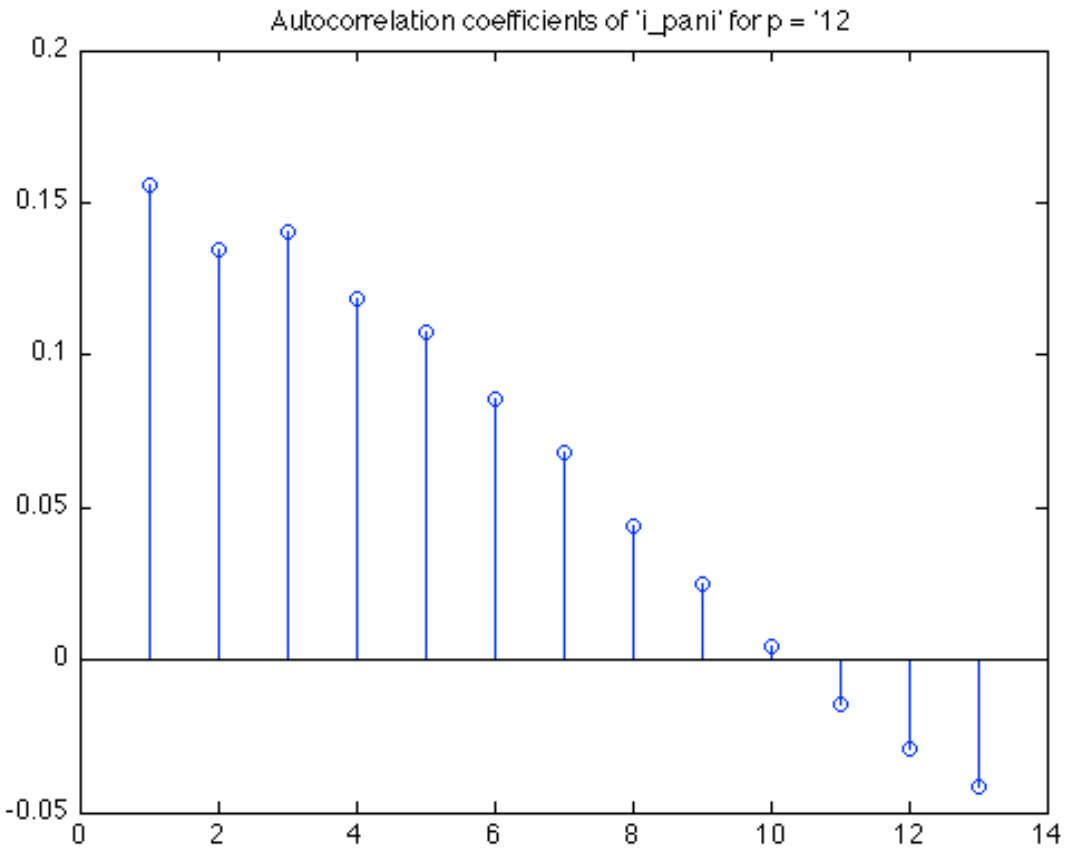

Autocorrelation coefficients of 'n_pani' for p = '12
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
2
4
6
8
10
12
14

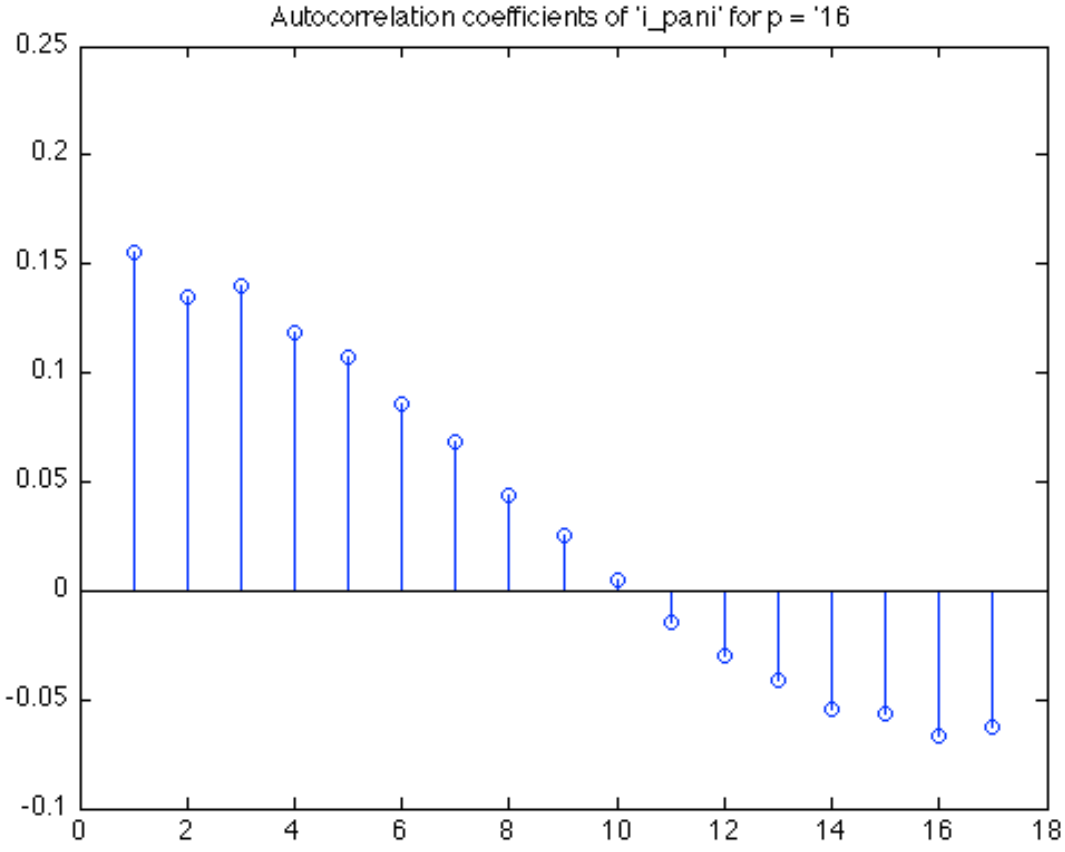

Autocorrelation coefficients of 'n_pani' for p = '16
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
2
4
6
8
10
12
14
16
18

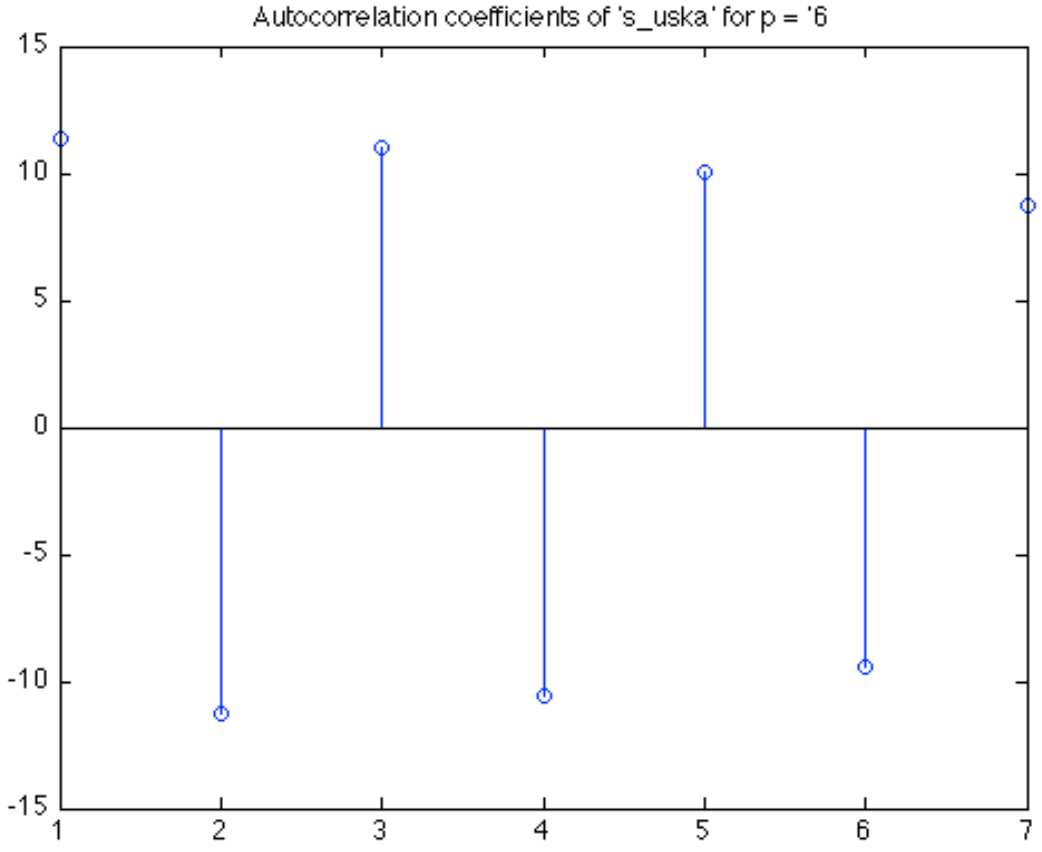

Autocorrelation coefficients of 'i_pani' for p = '6
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1
2
3
4
5
6
7

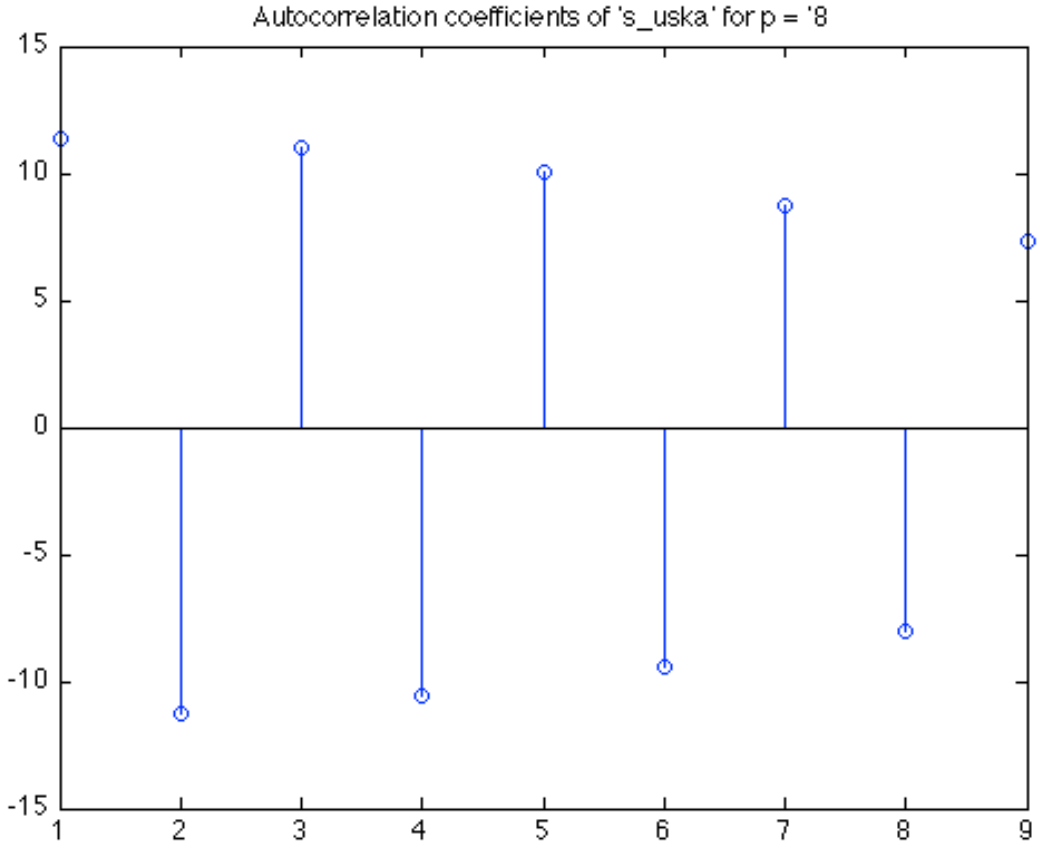

Autocorrelation coefficients of 'i_pani' for p = '8
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1
2
3
4
5
6
7
8
9

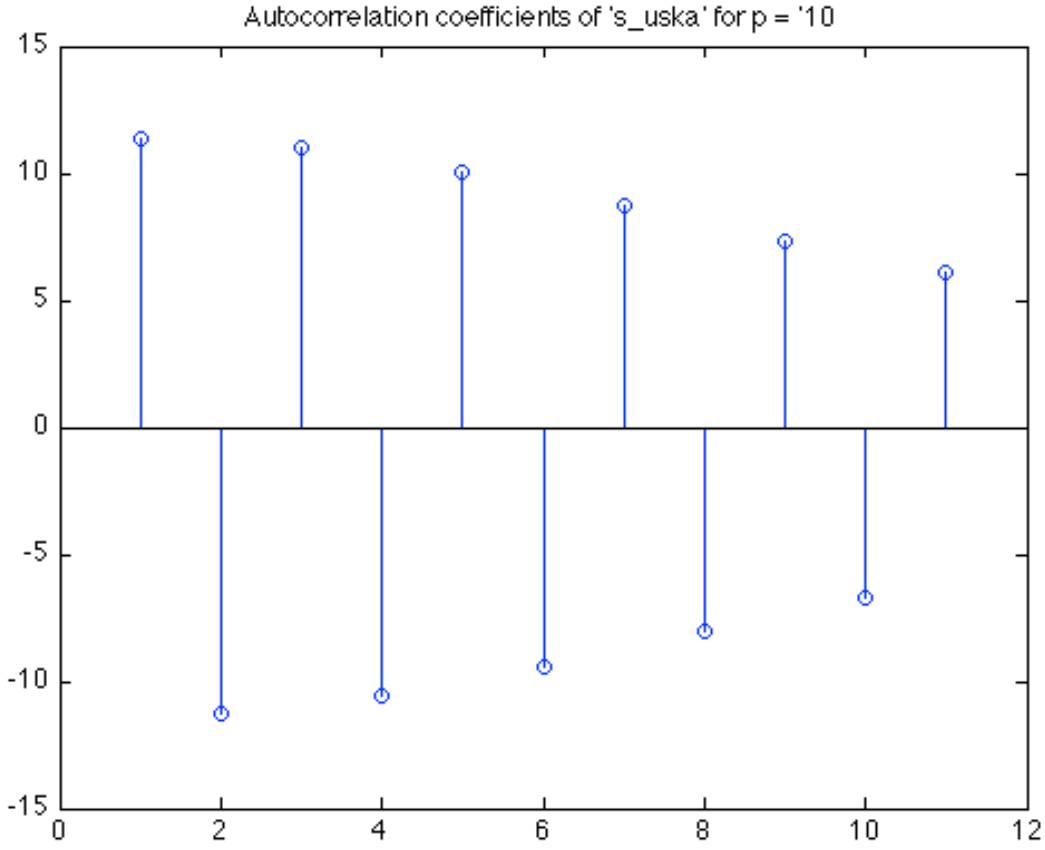

Autocorrelation coefficients of 'i_pani' for p = '10
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
2
4
6
8
10
12

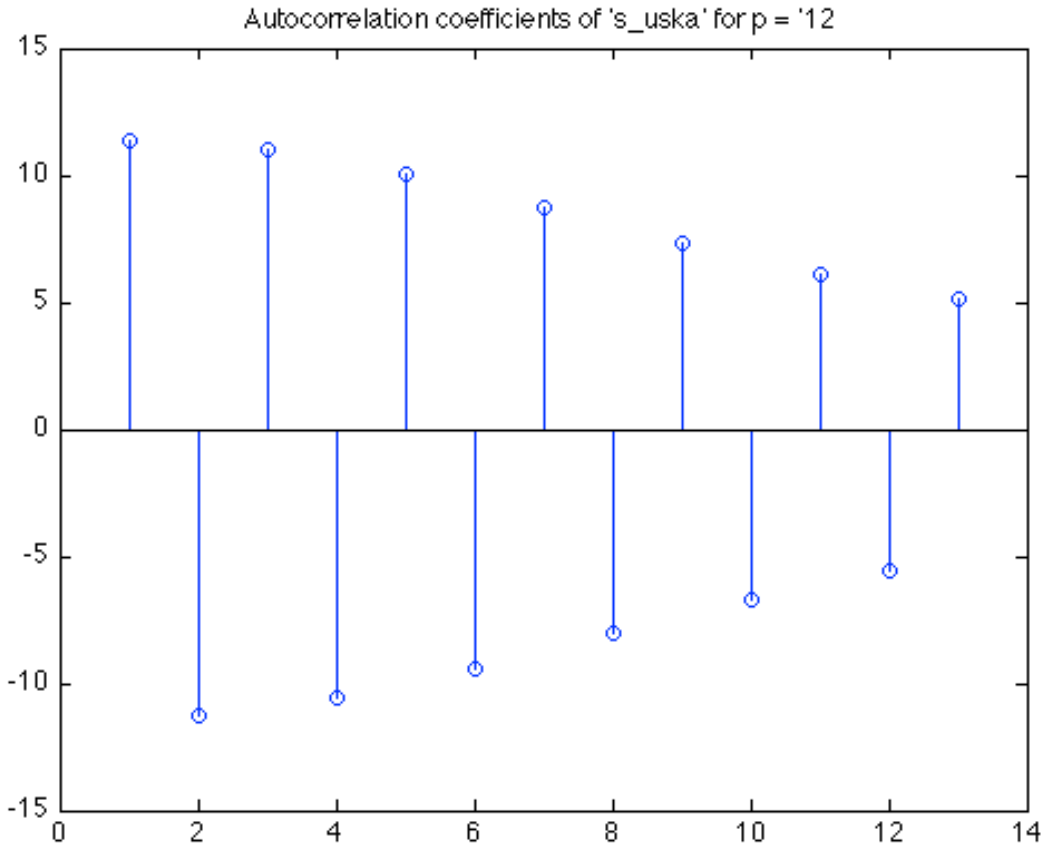

Autocorrelation coefficients of 'i_pani' for p = '12
0.2
0.15
0.1
0.05
0
-0.05
0
2
4
6
8
10
12
14

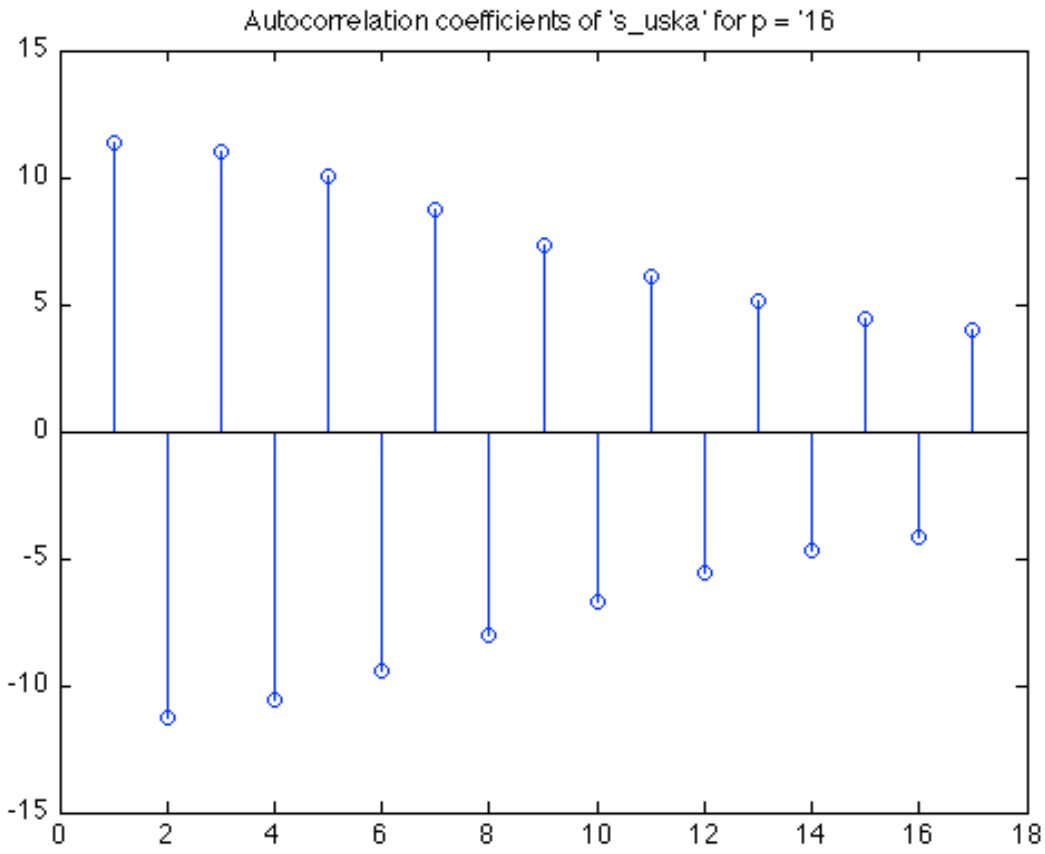

Autocorrelation coefficients of 'i_pani' for p = '16
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
0
2
4
6
8
10
12
14
16
18


Autocorrelation coefficients of 's_uska' for p = '6
15
10
5
0
-5
-10
-15
1
2
3
4
5
6
7

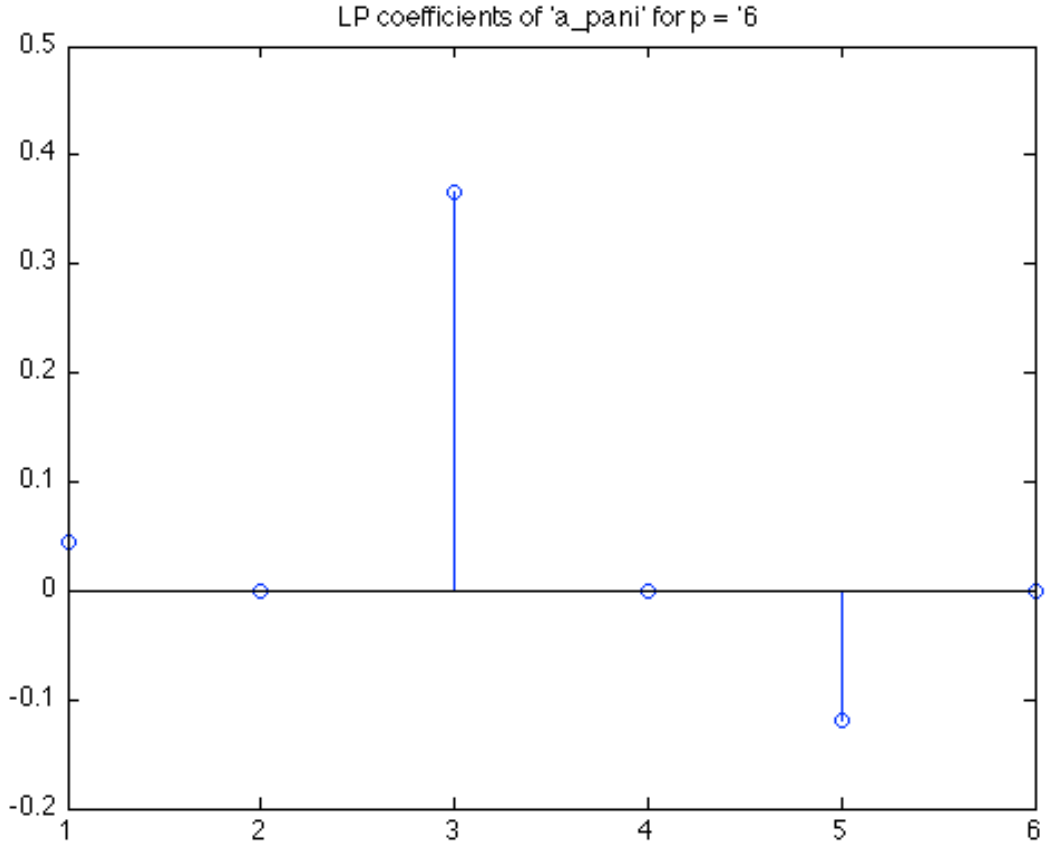

Autocorrelation coefficients of 's_uska' for p = '8
15
10
5
0
-5
-10
-15
1
2
3
4
5
6
7
8
9

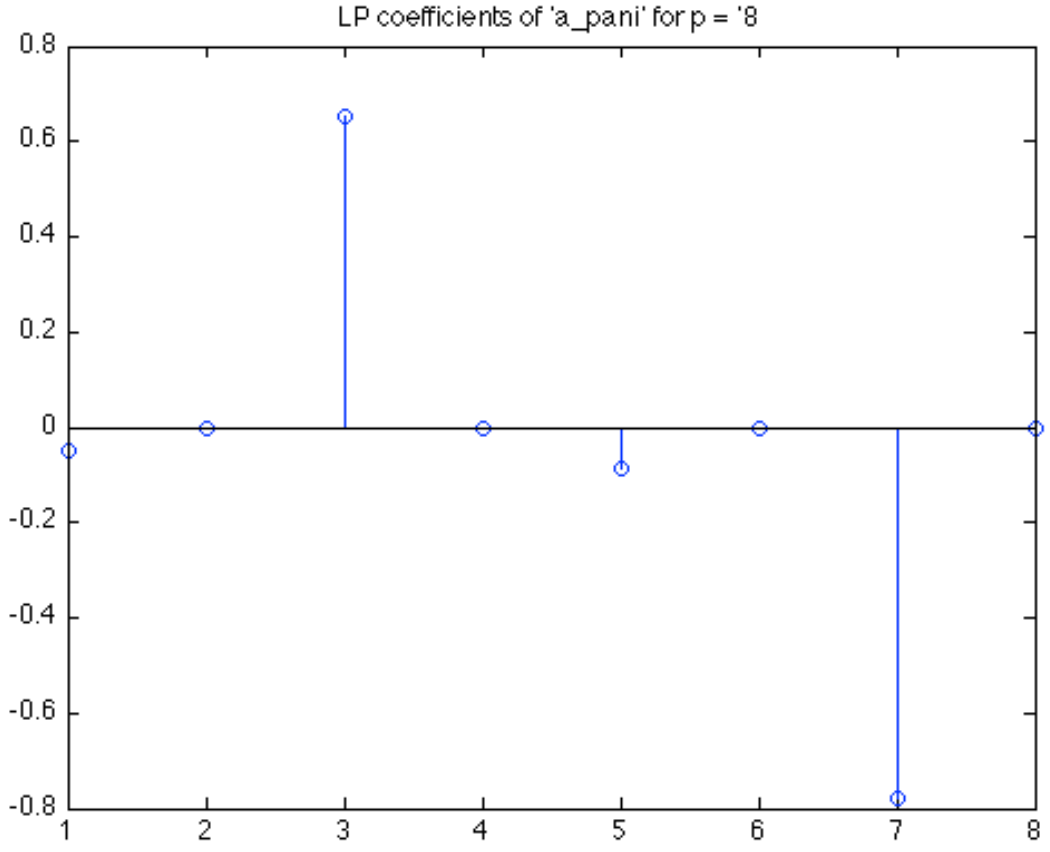

Autocorrelation coefficients of 's_uska' for p = '10
15
10
5
0
-5
-10
-15
0
2
4
6
8
10
12

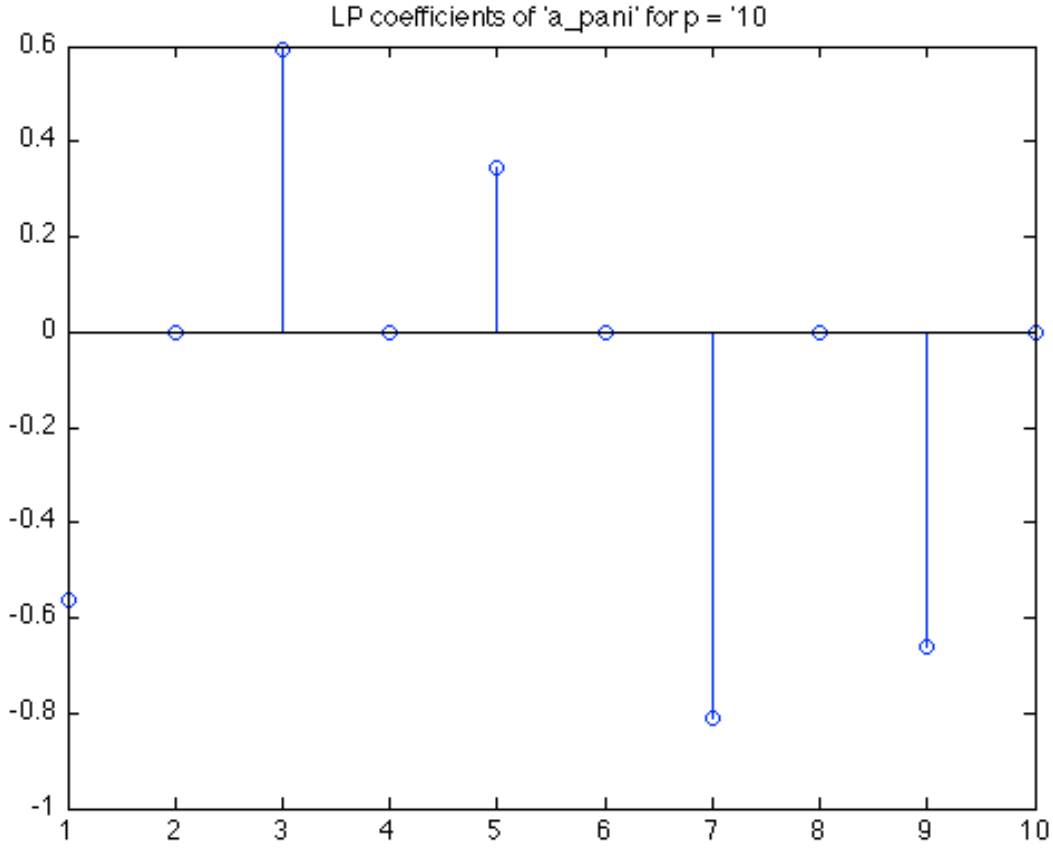

Autocorrelation coefficients of 's_uska' for p = '12
15
10
5
0
-5
-10
-15
0
2
4
6
8
10
12
14

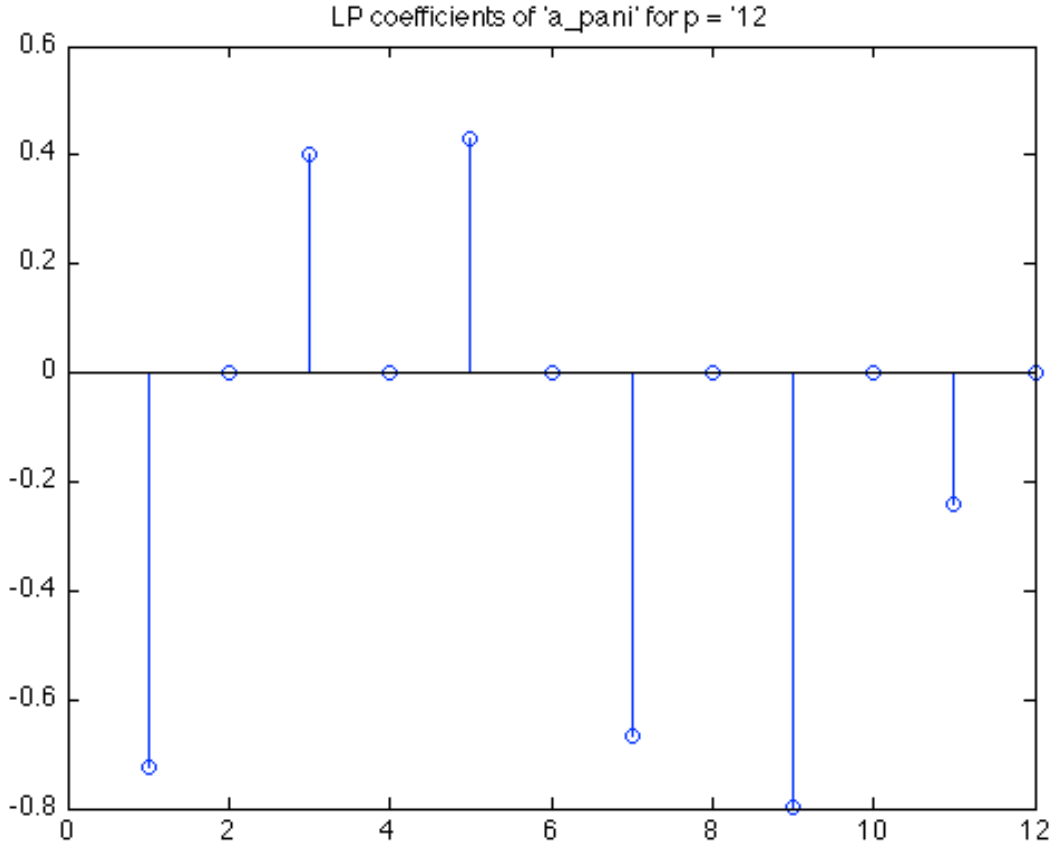


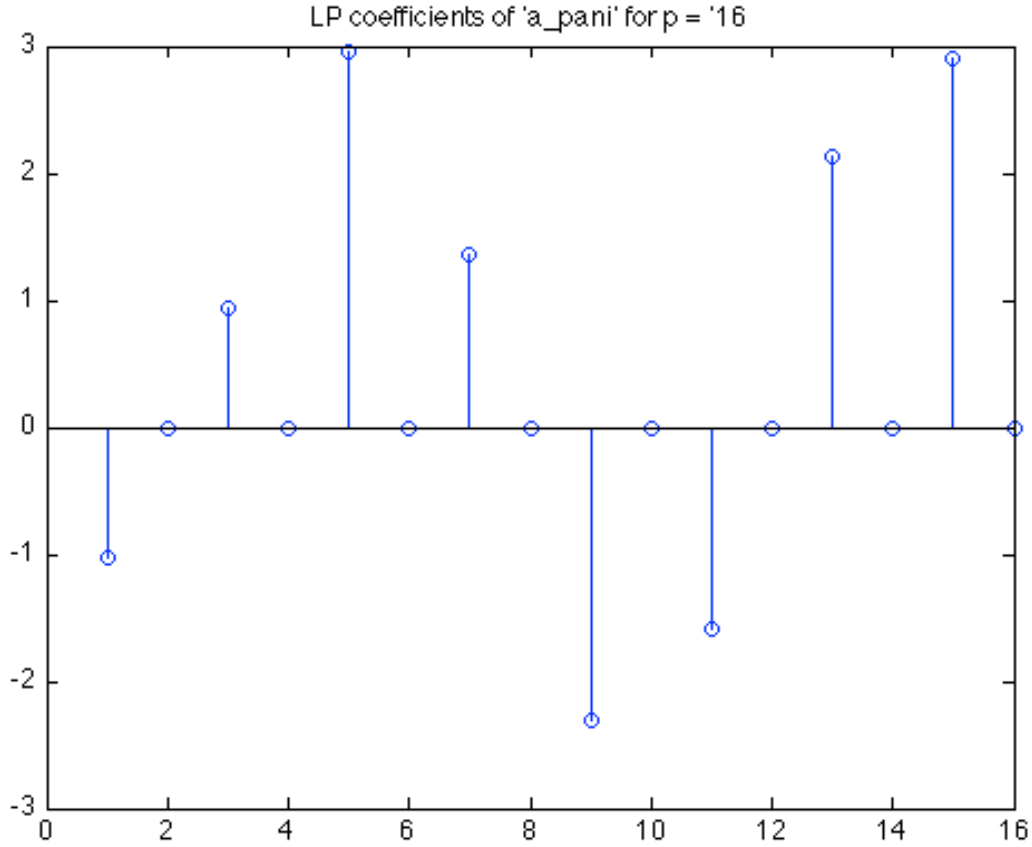
Now the LP coefficient plots:

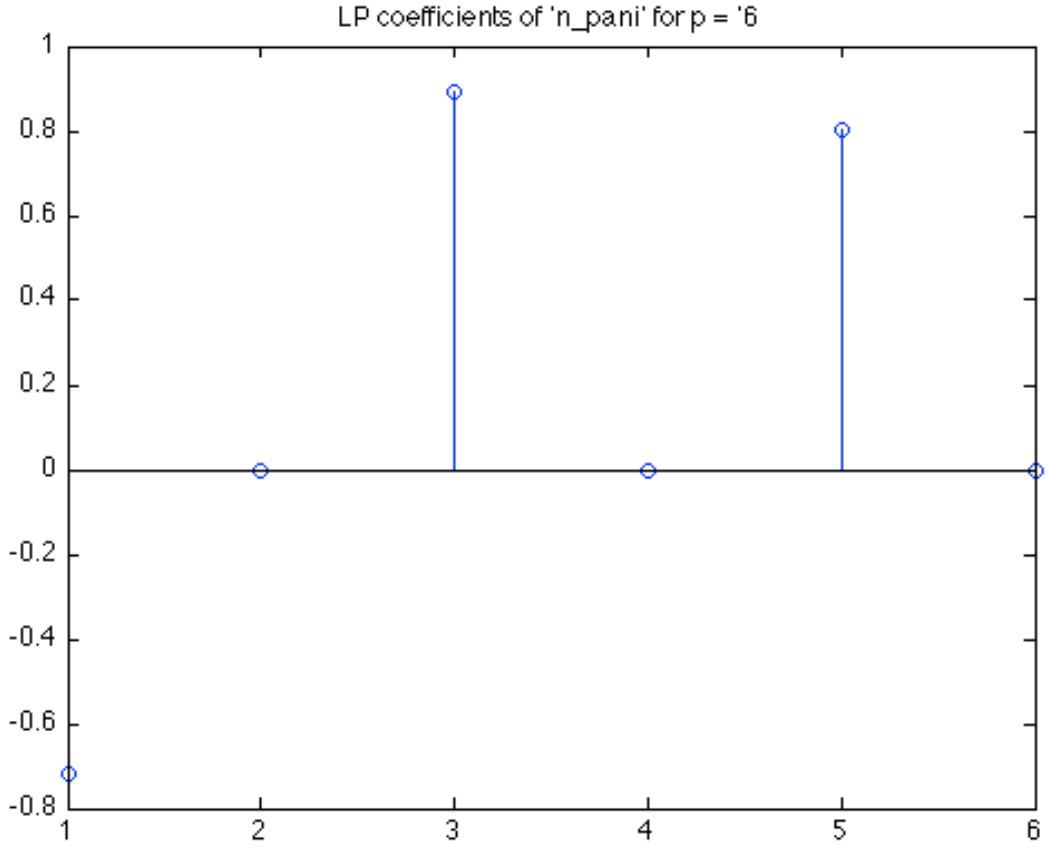

LP coefficients of 'a_pani' for p = '6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
1
2
3
4
5
6

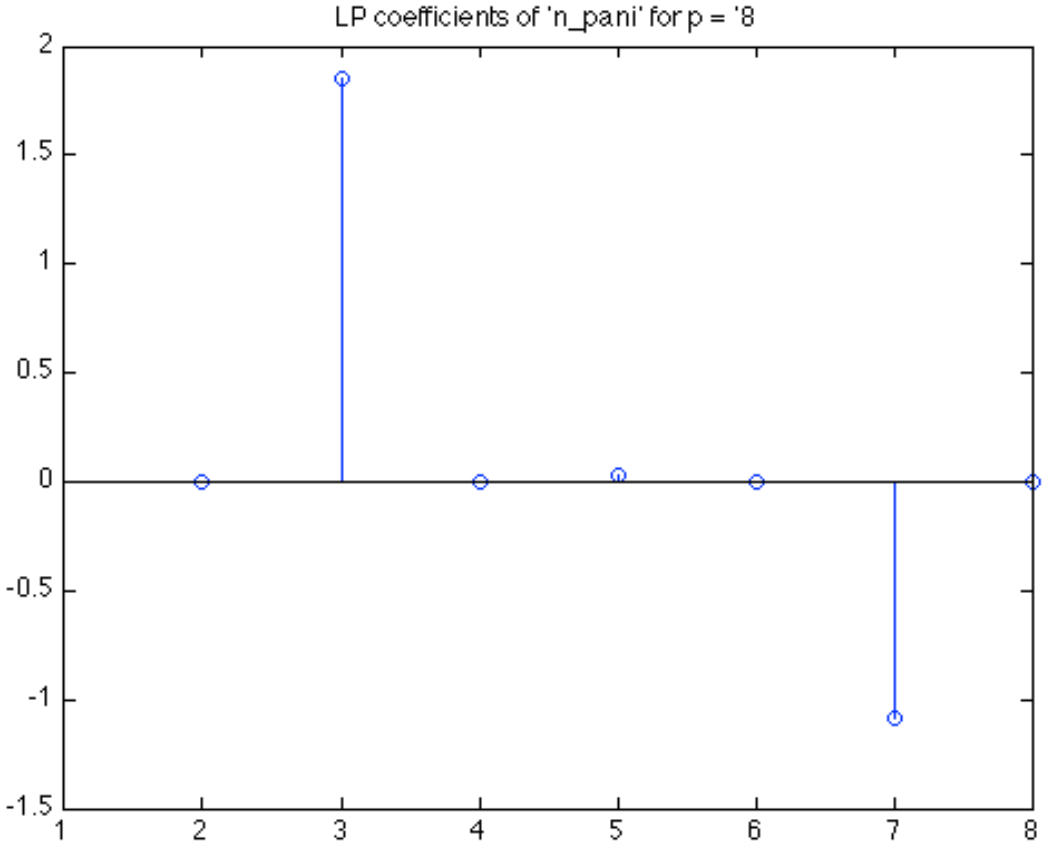

LP coefficients of 'a_pani' for p = '8
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1
2
3
4
5
6
7
8

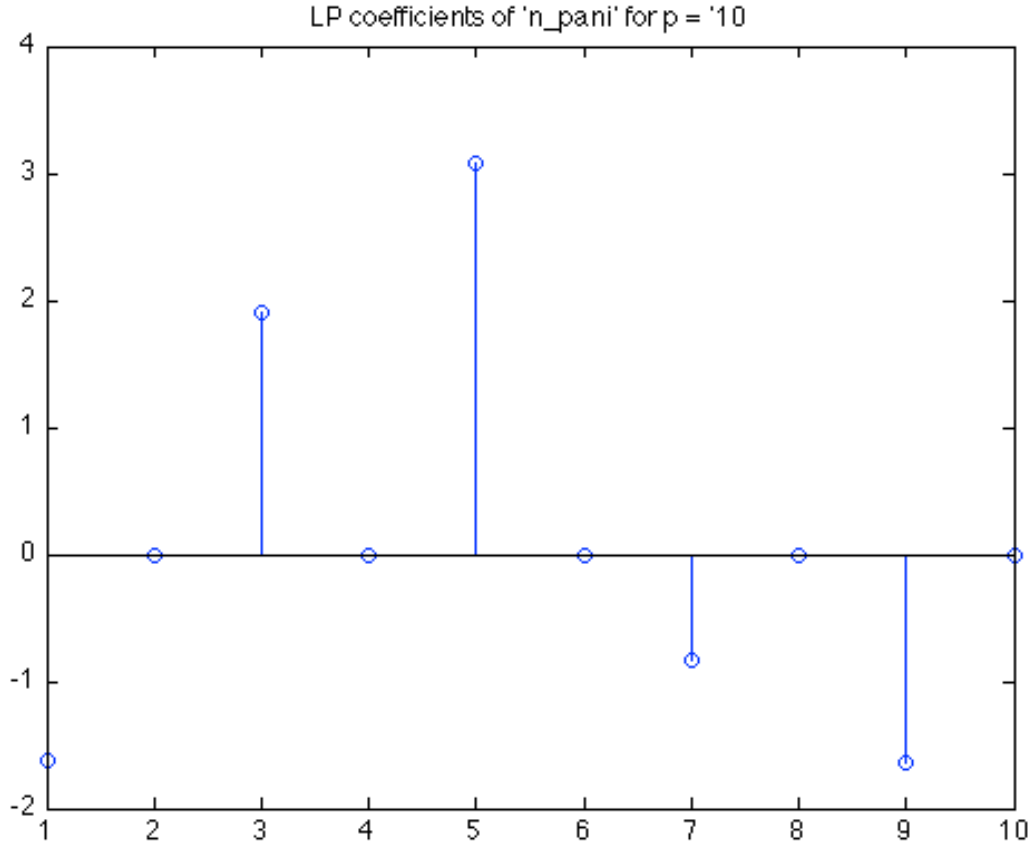

LP coefficients of 'a_pani' for p = '10
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
5
6
7
8
9
10

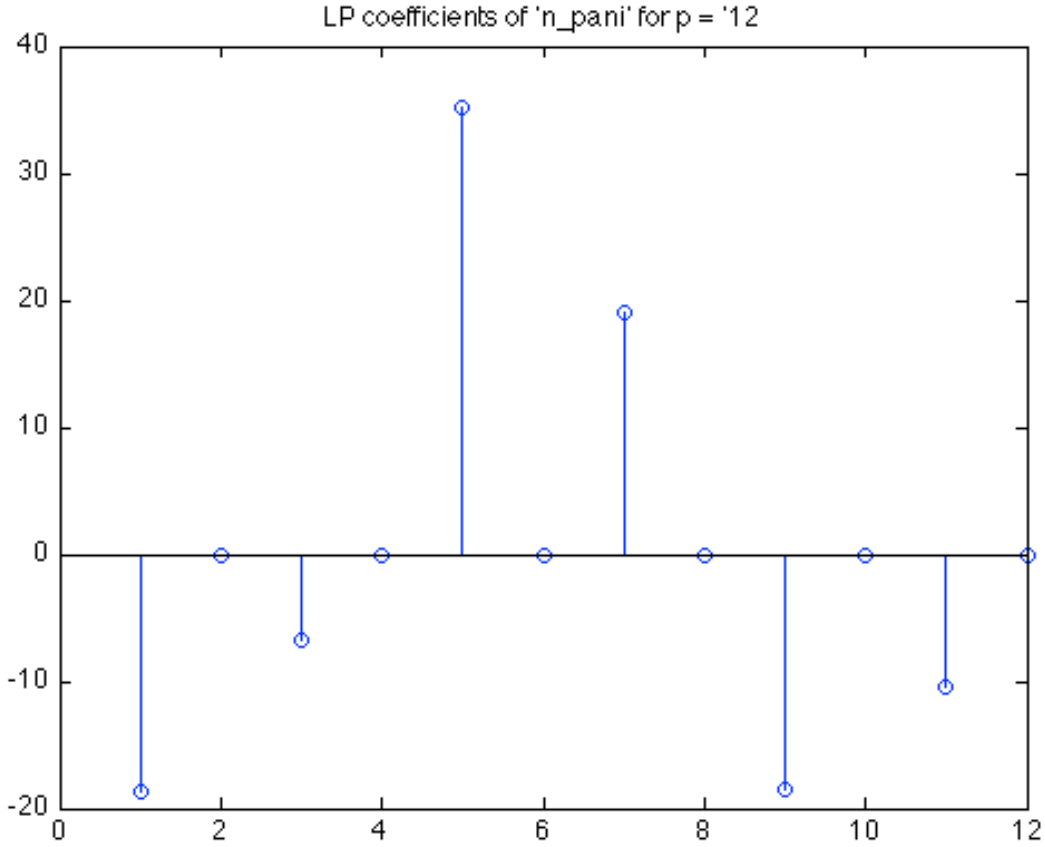

LP coefficients of 'a_pani' for p = '12
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
2
4
6
8
10
12

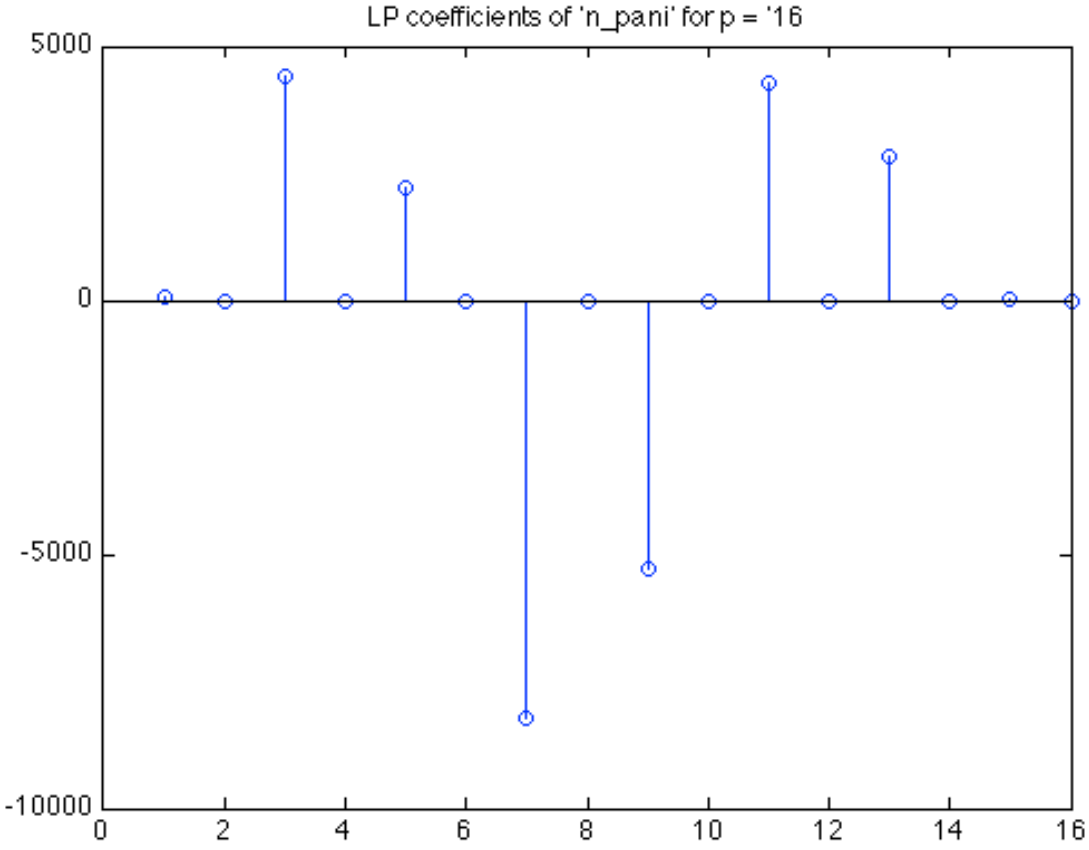

LP coefficients of 'a_pani' for p = '16
3
2
1
0
-1
-2
-3
0
2
4
6
8
10
12
14
16

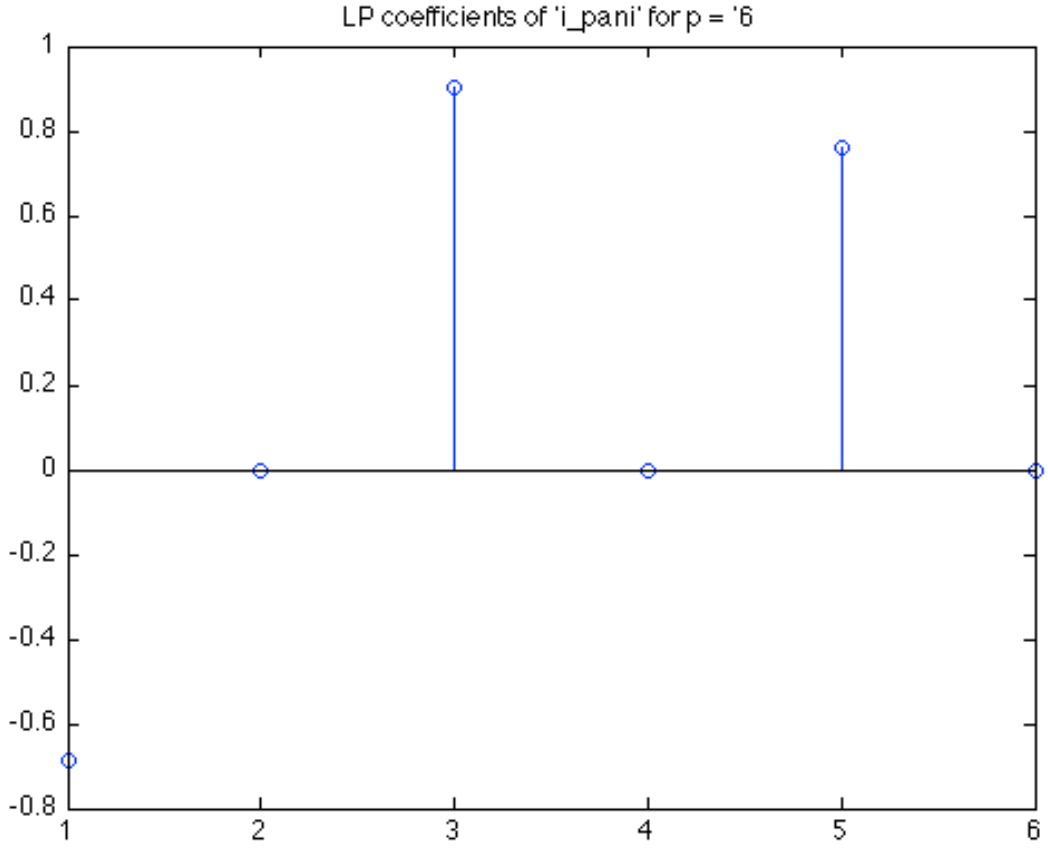

LP coefficients of 'n_pani' for p = '6
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1
2
3
4
5
6

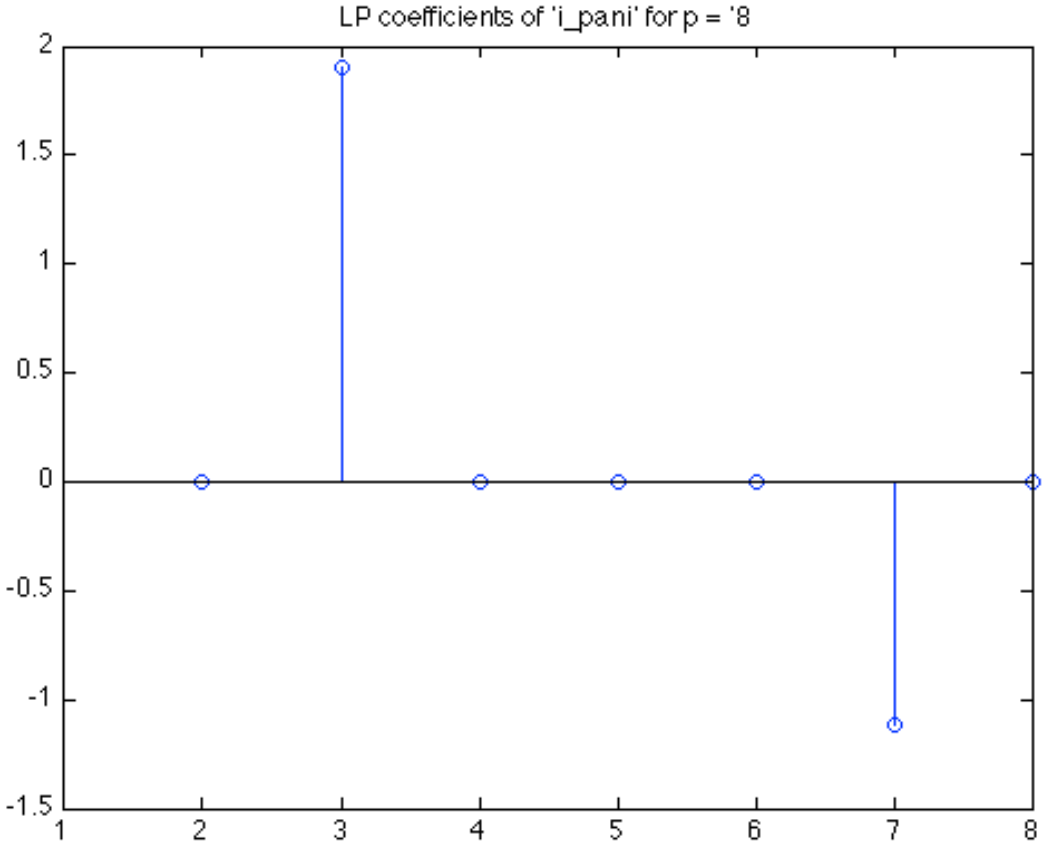

LP coefficients of 'n_pani' for p = '8
2
1.5
1
0.5
0
-0.5
-1
-1.5
1
2
3
4
5
6
7
8

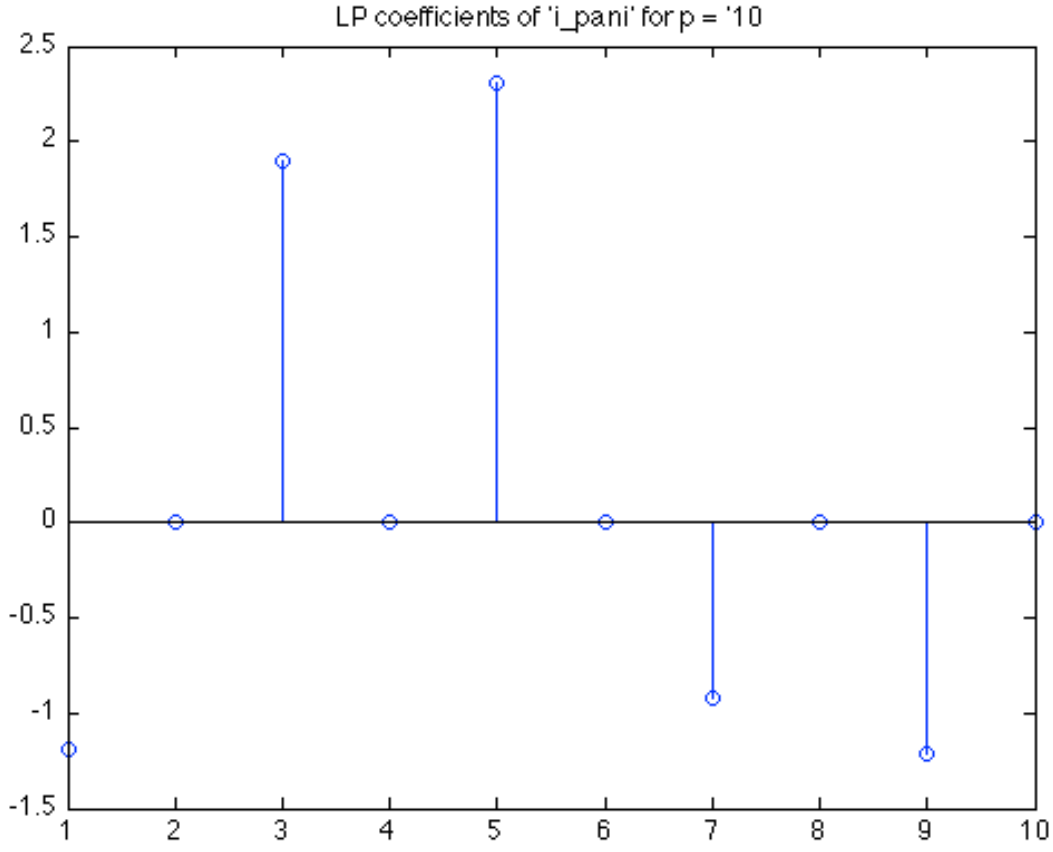

LP coefficients of 'n_pani' for p = '10
4
3
2
1
0
-1
-2
1
2
3
4
5
6
7
8
9
10

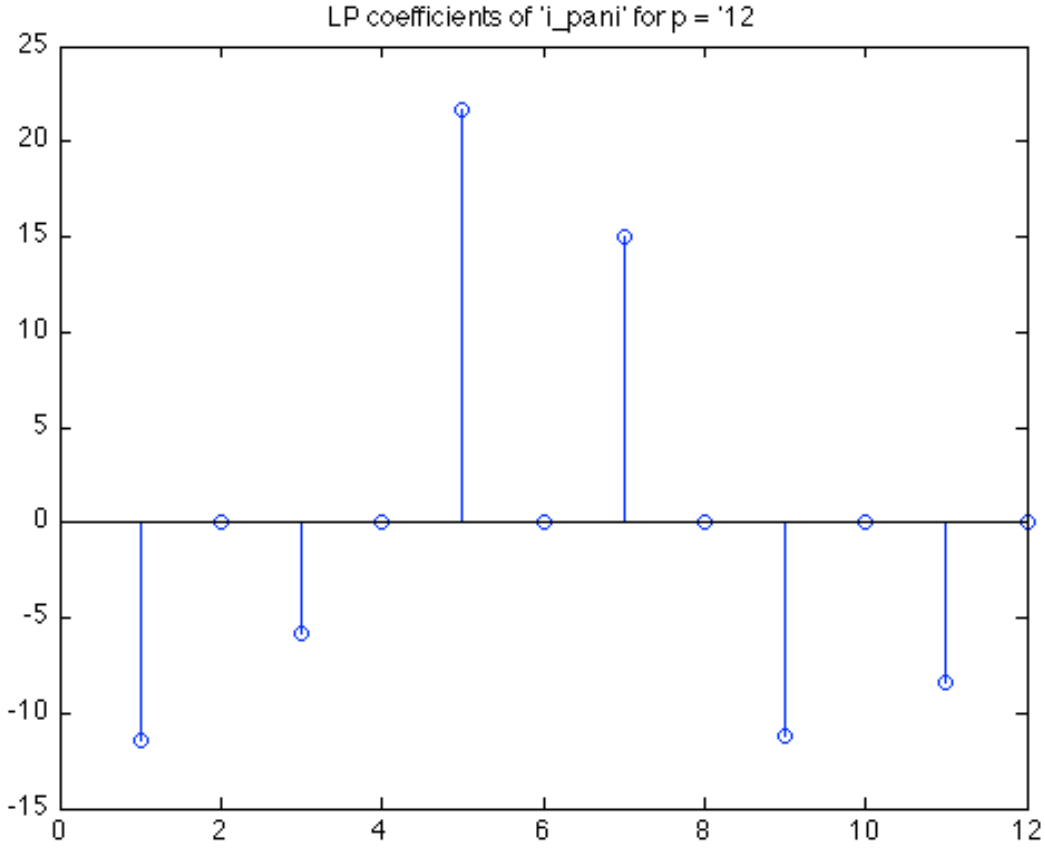

LP coefficients of 'n_pani' for p = '12
40
30
20
10
0
-10
-20
0
2
4
6
8
10
12

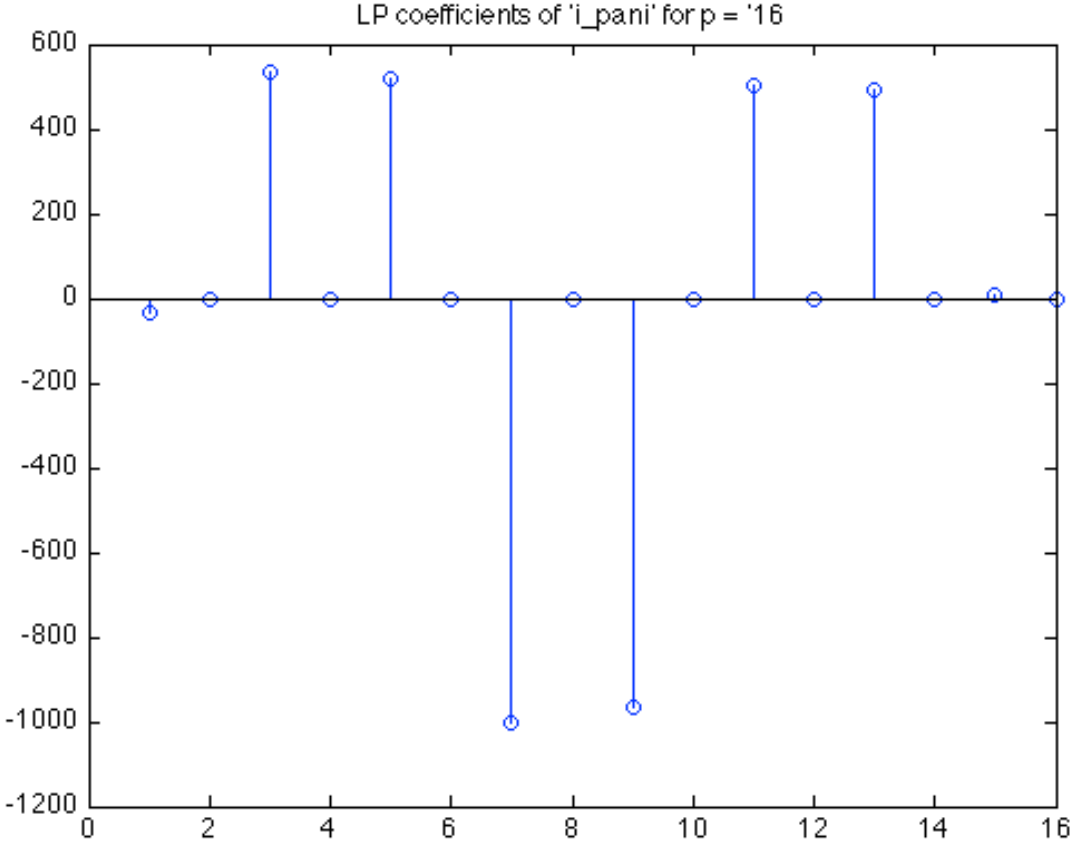

LP coefficients of 'n_pani' for p = '16
5000
0
-5000
-10000
0
2
4
6
8
10
12
14
16

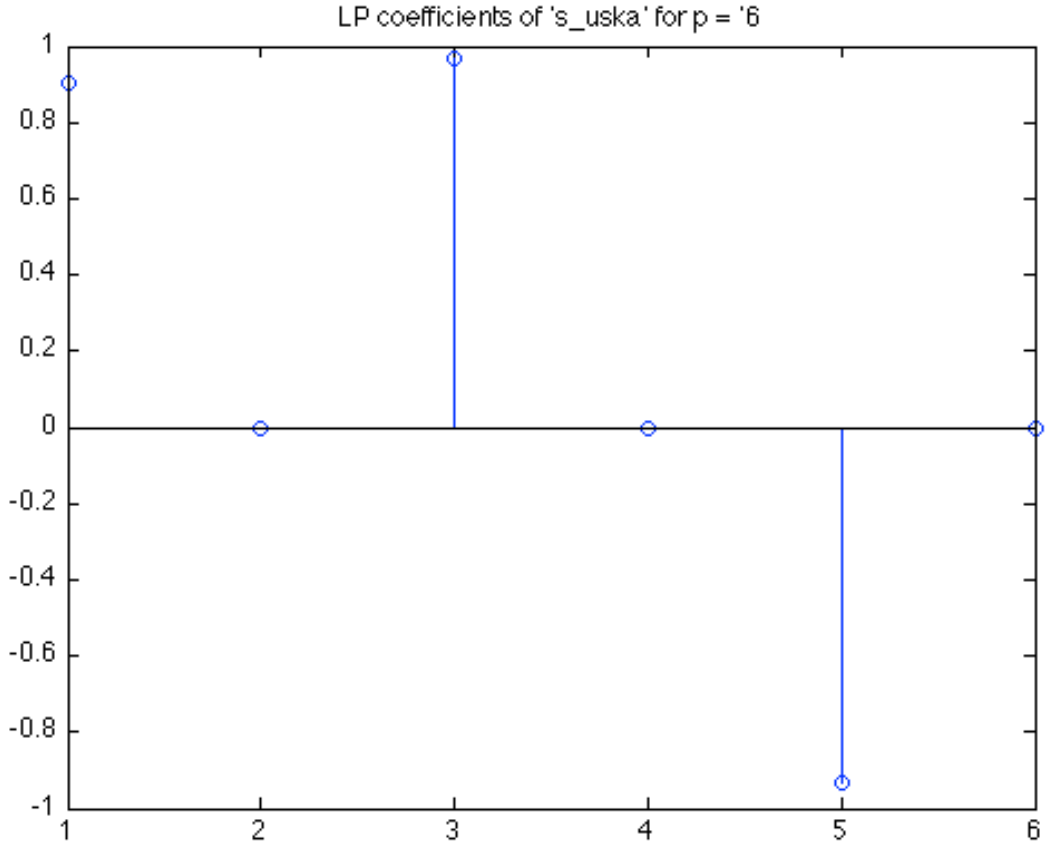

LP coefficients of 'i_pani' for p = '6
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1
2
3
4
5
6

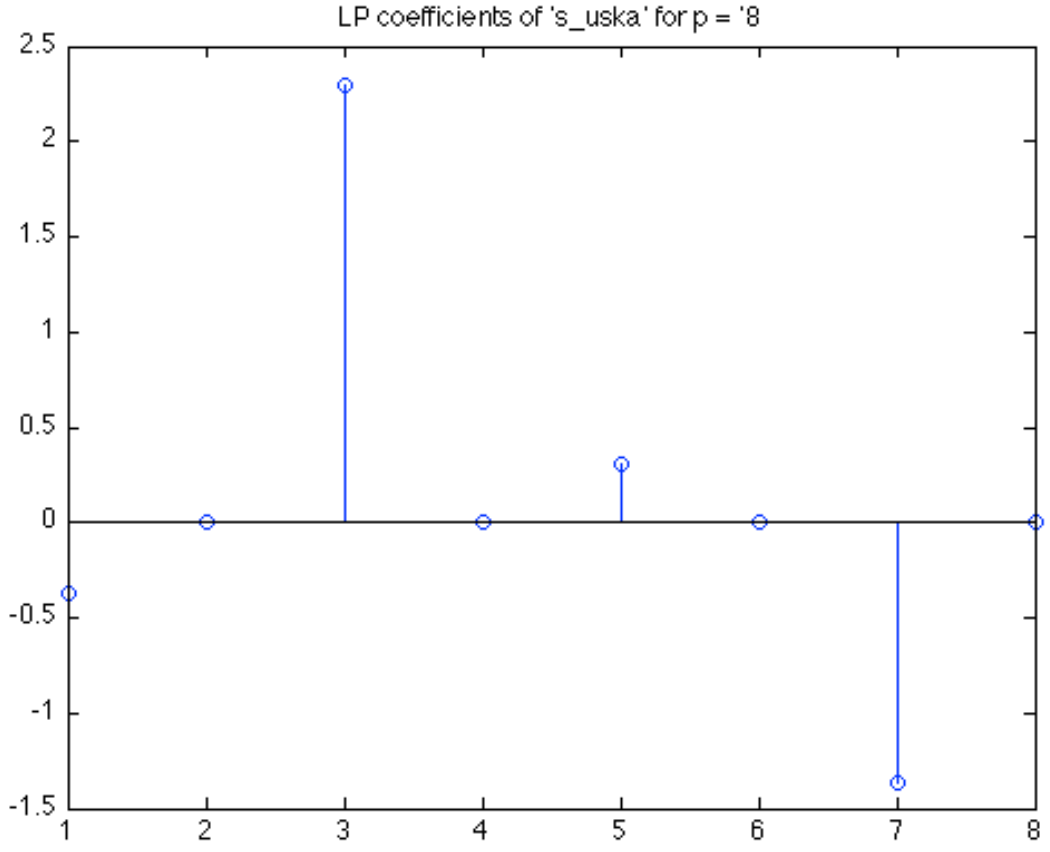

LP coefficients of 'i_pani' for p = '8
2
1.5
1
0.5
0
-0.5
-1
-1.5
1
2
3
4
5
6
7
8

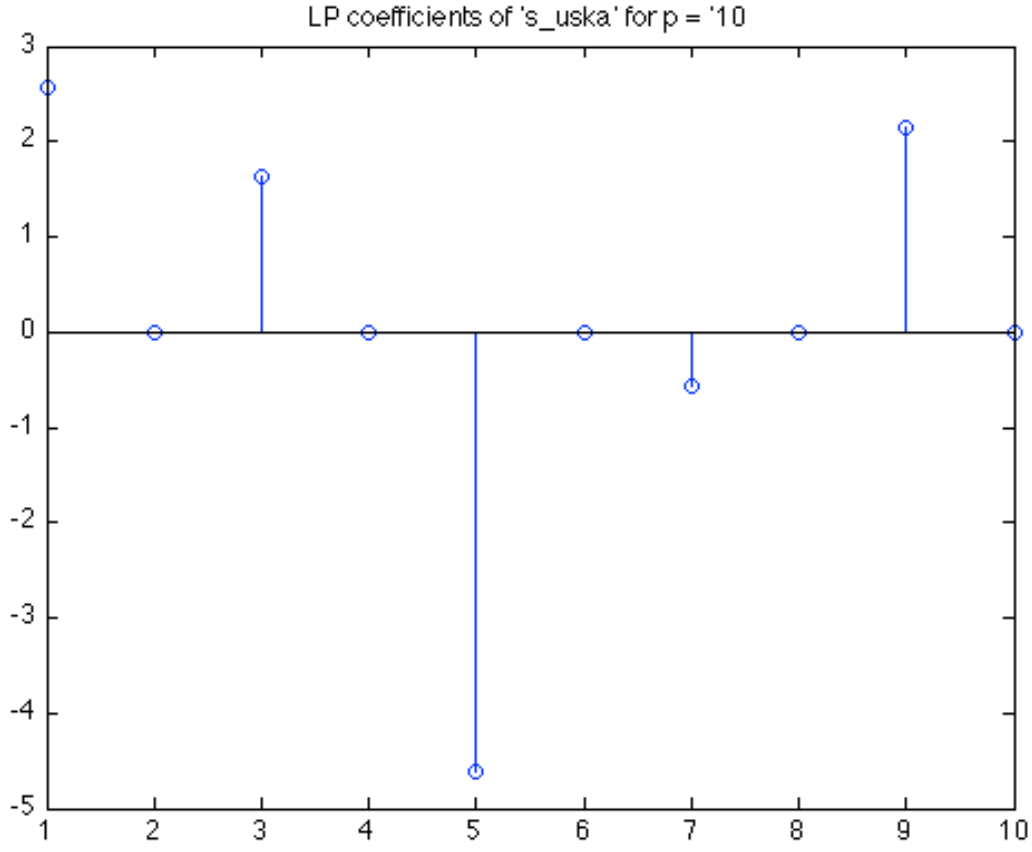

LP coefficients of 'i_pani' for p = '10
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
1
2
3
4
5
6
7
8
9
10

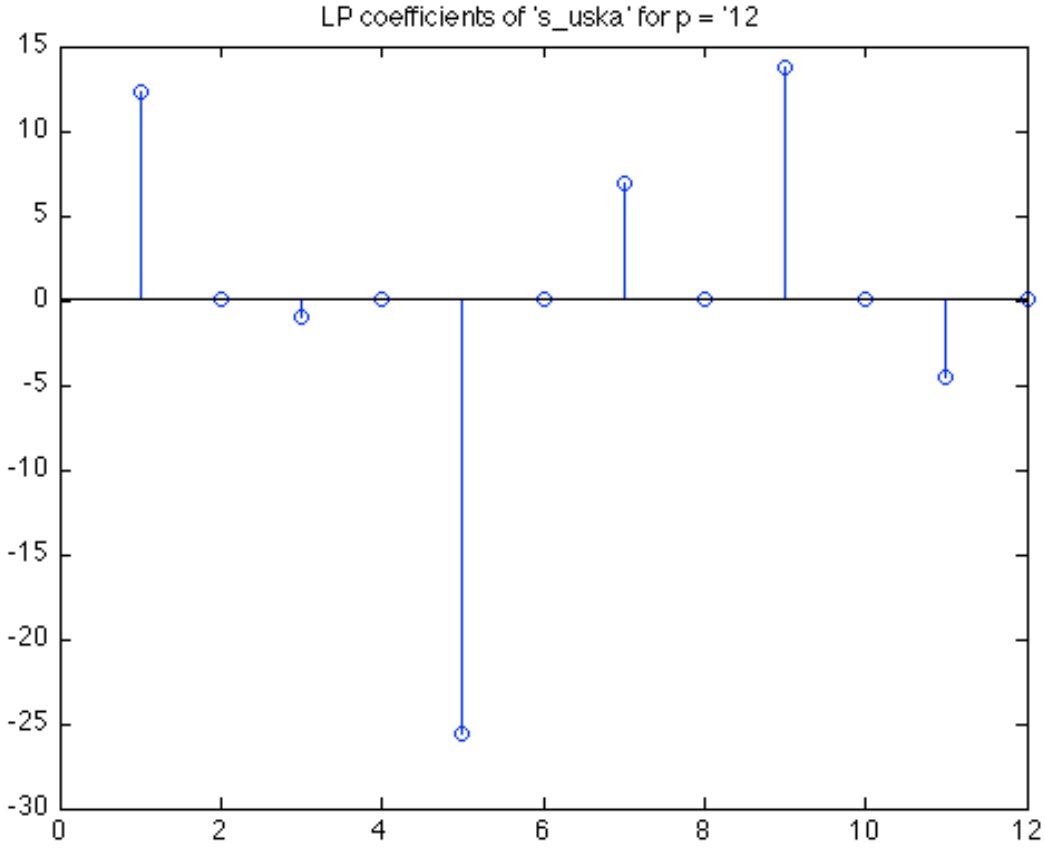

LP coefficients of 'i_pani' for p = '12
25
20
15
10
5
0
-5
-10
-15
0
2
4
6
8
10
12

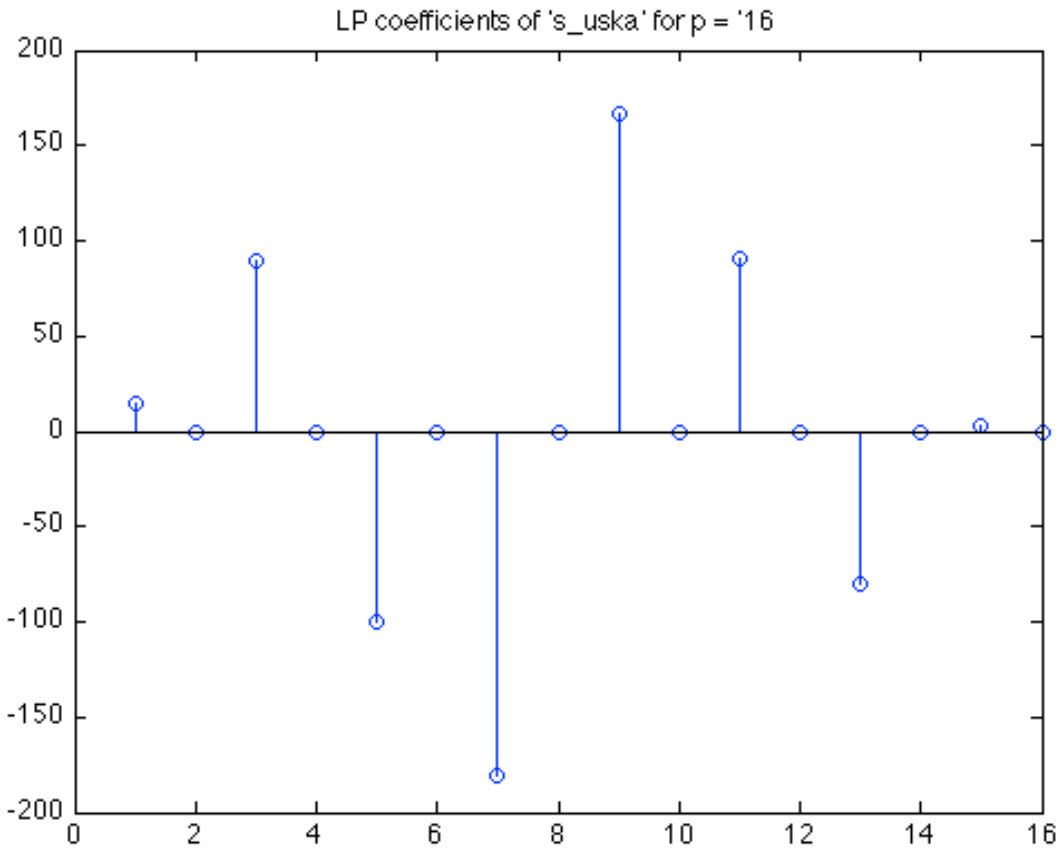

LP coefficients of 'i_pani' for p = '16
600
400
200
0
-200
-400
-600
-800
-1000
-1200
0
2
4
6
8
10
12
14
16


LP coefficients of 's_uska' for p = '6
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
5
6


LP coefficients of 's_uska' for p = '8
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
1
2
3
4
5
6
7
8


LP coefficients of 's_uska' for p = '10
3
2
1
0
-1
-2
-3
-4
-5
1
2
3
4
5
6
7
8
9
10


LP coefficients of 's_uska' for p = '12
15
10
5
0
-5
-10
-15
-20
-25
-30
0
2
4
6
8
10
12



The script:

```
close all; clear all;

getLPCoefficients('a_pani', 6);
getLPCoefficients('a_pani', 8);
getLPCoefficients('a_pani', 10);
getLPCoefficients('a_pani', 12);
getLPCoefficients('a_pani', 16);

getLPCoefficients('n_pani', 6);
getLPCoefficients('n_pani', 8);
getLPCoefficients('n_pani', 10);
getLPCoefficients('n_pani', 12);
getLPCoefficients('n_pani', 16);

getLPCoefficients('i_pani', 6);
getLPCoefficients('i_pani', 8);
getLPCoefficients('i_pani', 10);
getLPCoefficients('i_pani', 12);
getLPCoefficients('i_pani', 16);
```

```
getLPCoefficients('s_uska', 6);
getLPCoefficients('s_uska', 8);
getLPCoefficients('s_uska', 10);
getLPCoefficients('s_uska', 12);
getLPCoefficients('s_uska', 16);
```

The functions:

```
function getLPCoefficients(inputFile, poleOrder)


autocorrCoeffs = getAutoCorrCoefficients(inputFile, poleOrder);
LPCoeffs = levinsonDurbin(autocorrCoeffs, poleOrder);
figure, stem(LPCoeffs);
title(['LP coefficients of ''', inputFile, ''' for p = ''',
num2str(poleOrder), ''''], 'interpreter', 'none');

end


function autocorrelationCoefficients =
getAutoCorrCoefficients(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);
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( data , p)


rx = data; % 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 = 1:p;
    G(j) = rx(j+1);
    sum = 0;
    for i = 2:j;
        sum = sum + (a(j, i)*rx(j-i+1));
    end
    G(j) = G(j) + sum;
    reflected(j+i) = -G(j)/e(j);

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

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