Ankit Agrawal

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10D070027

```
clear all
close all
clc

sounds = ['aa', 'nn', 'ee', 'ss', 'as'];
for index = 1:5


    sound = sounds(2*index-1:2*index);
```

Speech signal

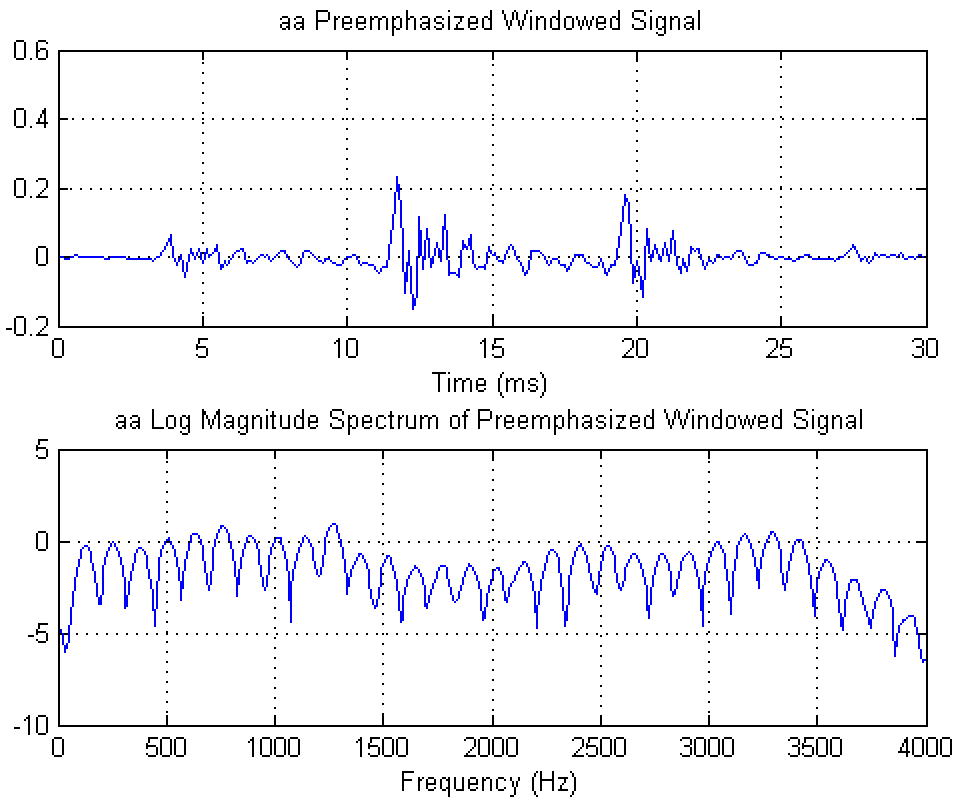
Preparing the initial parameters

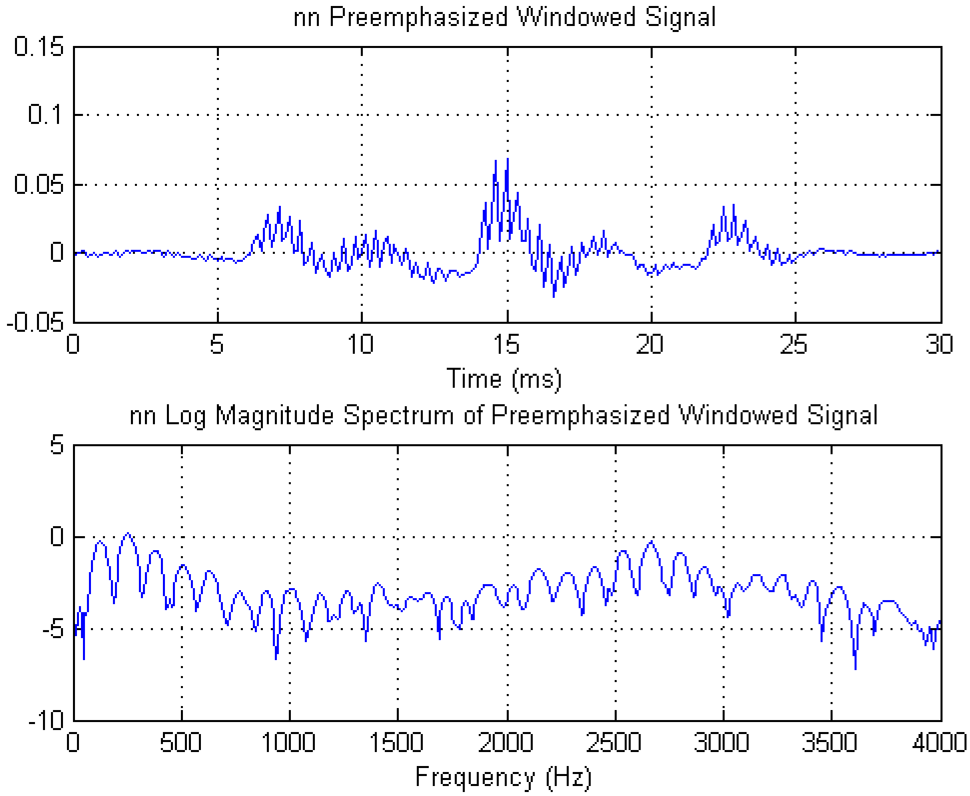
```
    if sound == 'as'
        sound_name = 'aa resynthesized';
    else
        sound_name = sound;
    end
    [x fs] = wavread(strcat(sound, '.wav'));
    x = x';
    nfft = 1024;
    window_len = 0.03*fs;
    n = 0:window_len-1;
    hw = 0.54-0.46*cos(2*pi*n/(window_len-1));

    freq_axis = (fs/nfft).*(0:(nfft/2 - 1));
    time_axis = 1000*[0:(1/fs):(window_len - 1)/fs];
```

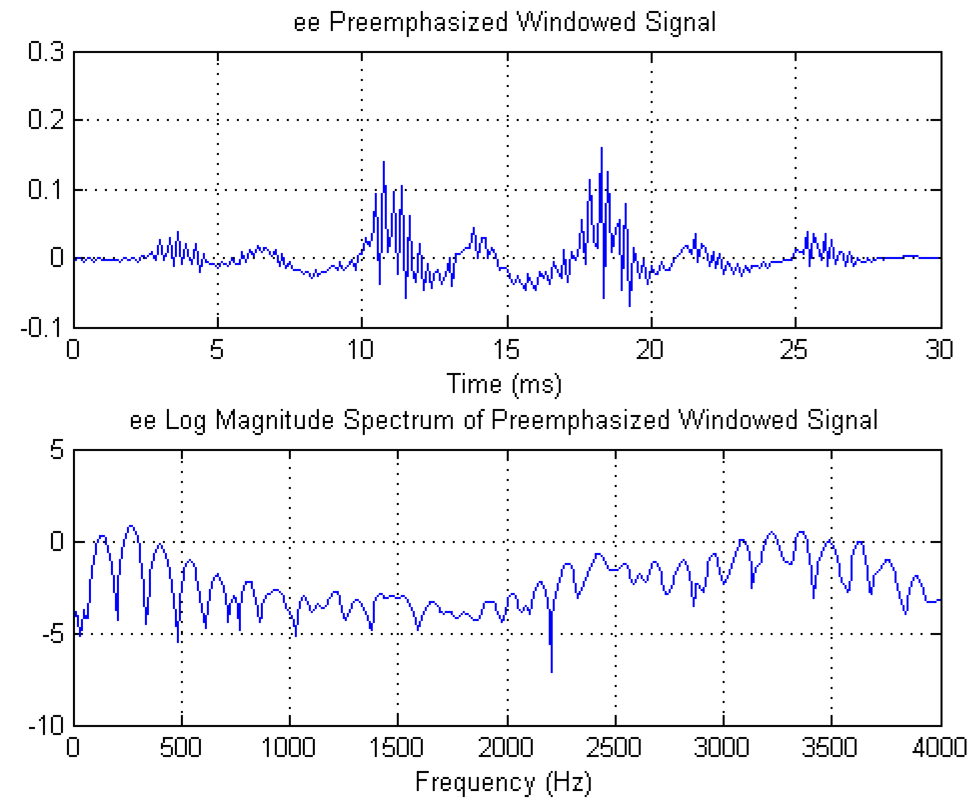
Pre-Emphasized Windowed Signal

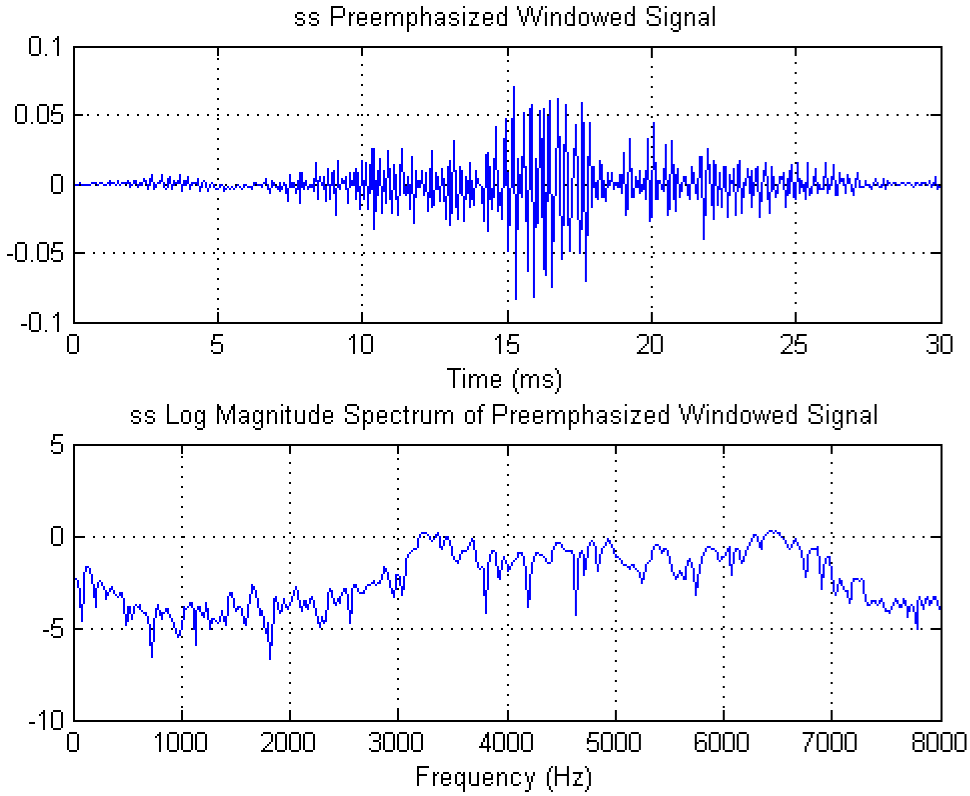
```
    b = 0.95;
    x_pe = zeros(1, length(x));
    x_pe(1) = x(1);
    for n = 2:length(x)
        x_pe(n) = x(n) - b*x(n-1);
```

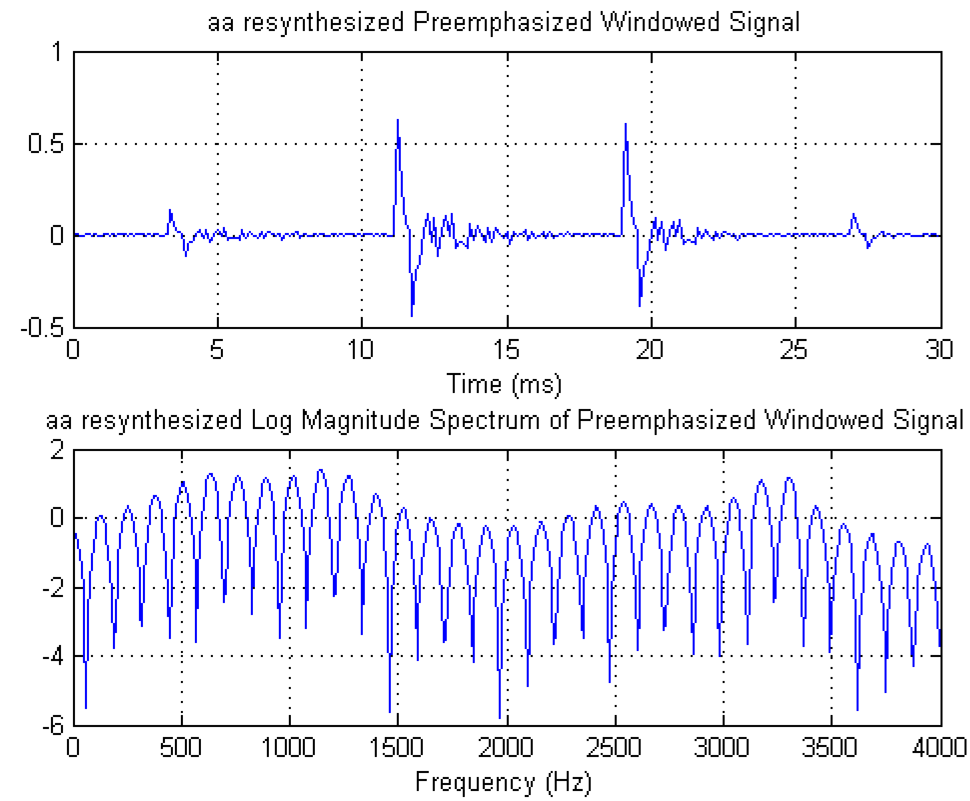
```
end

Windowed_signal_preemp = x_pe(100:100+window_len-1).*hw;
spectrum_preemp = fft(Windowed_signal_preemp,nfft);

figure()
subplot(211)
plot(time_axis, Windowed_signal_preemp)
grid on
title(strcat(sound_name, ' Preemphasized Windowed Signal'));
xlabel('Time (ms)');
grid on;
subplot(212)
plot(freq_axis, log(abs(spectrum_preemp(1:(nfft/2)))))
grid on
title(strcat(sound_name, ' Log Magnitude Spectrum of Preemphasized Windowed Si
xlabel('Frequency (Hz)');
grid on;
```




nn Preemphasized Windowed Signal
0.15
0.1
0.05
0
-0.05
0
5
10
15
20
25
30
Time (ms)
nn Log Magnitude Spectrum of Preemphasized Windowed Signal
5
0
-5
-10
0
500
1000
1500
2000
2500
3000
3500
4000
Frequency (Hz)

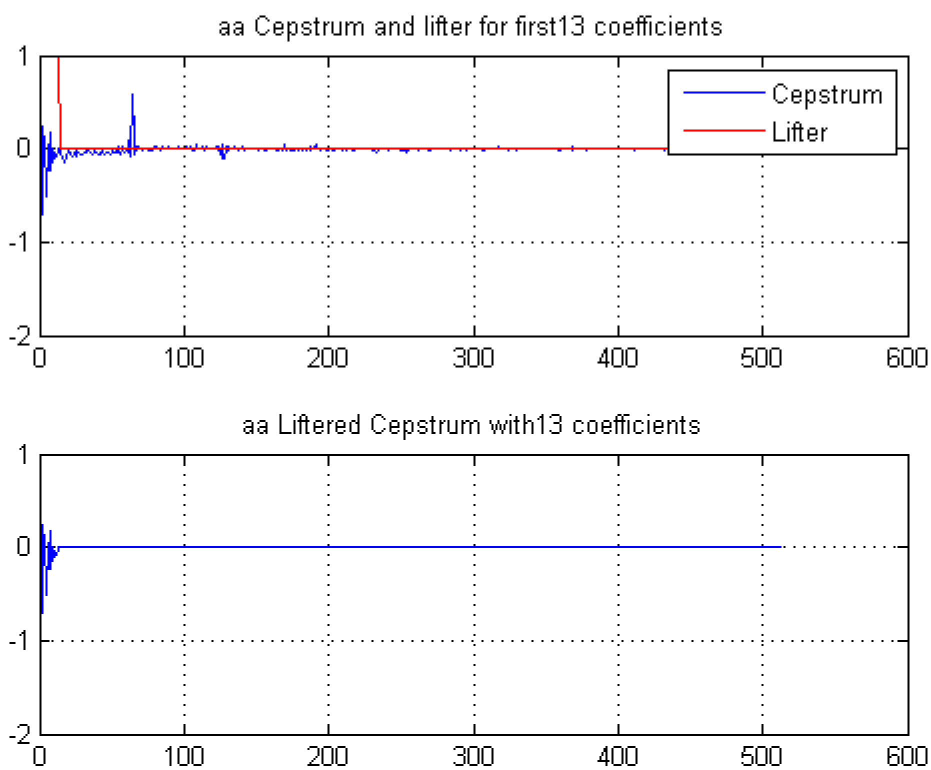

ee Preemphasized Windowed Signal
0.3
0.2
0.1
0
-0.1
0
5
10
15
20
25
30
Time (ms)
ee Log Magnitude Spectrum of Preemphasized Windowed Signal
5
0
-5
-10
0
500
1000
1500
2000
2500
3000
3500
4000
Frequency (Hz)

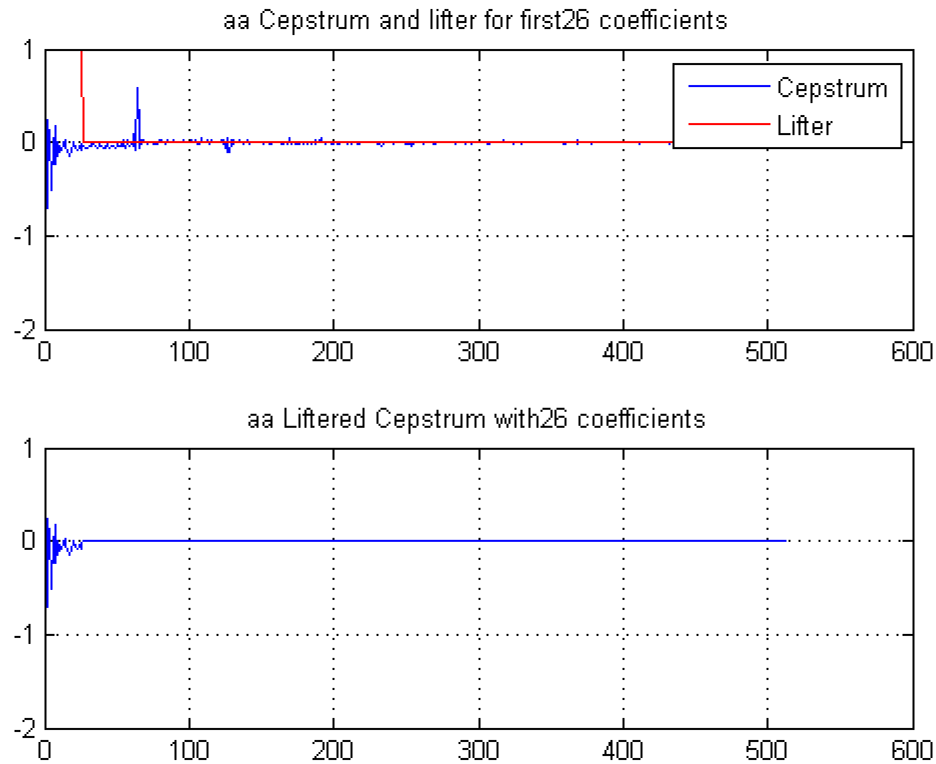

ss Preemphasized Windowed Signal
0.1
0.05
0
-0.05
-0.1
0
5
10
15
20
25
30
Time (ms)
ss Log Magnitude Spectrum of Preemphasized Windowed Signal
5
0
-5
-10
0
1000
2000
3000
4000
5000
6000
7000
8000
Frequency (Hz)

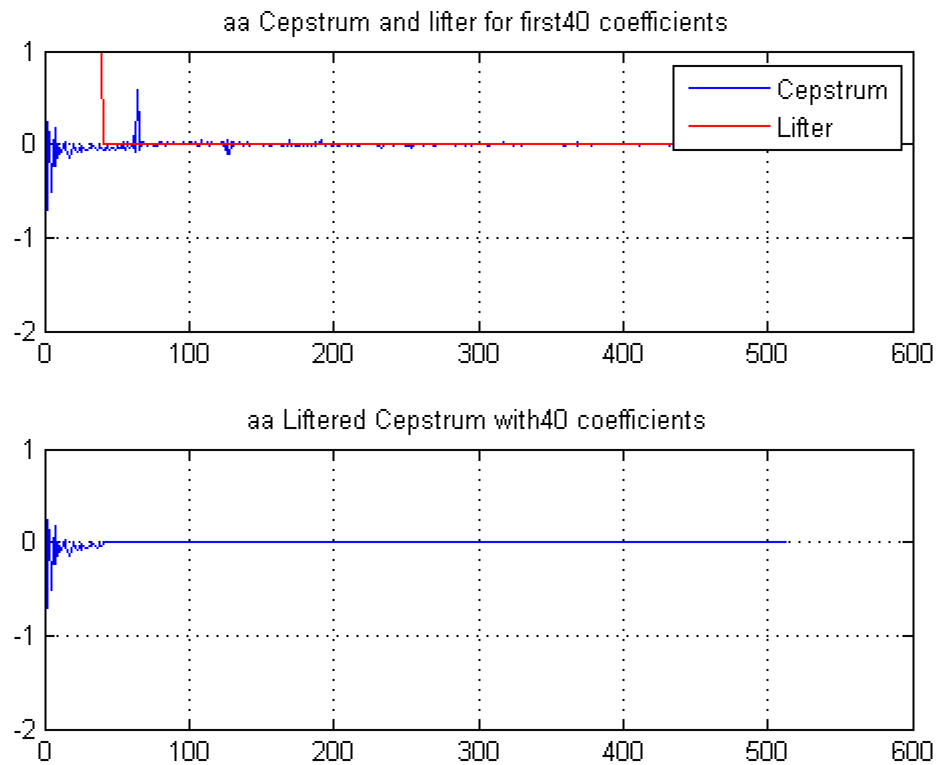

aa resynthesized Preemphasized Windowed Signal
1
0.5
0
-0.5
0
5
10
15
20
25
30
Time (ms)
aa resynthesized Log Magnitude Spectrum of Preemphasized Windowed Signal
2
0
-2
-4
-6
0
500
1000
1500
2000
2500
3000
3500
4000
Frequency (Hz)

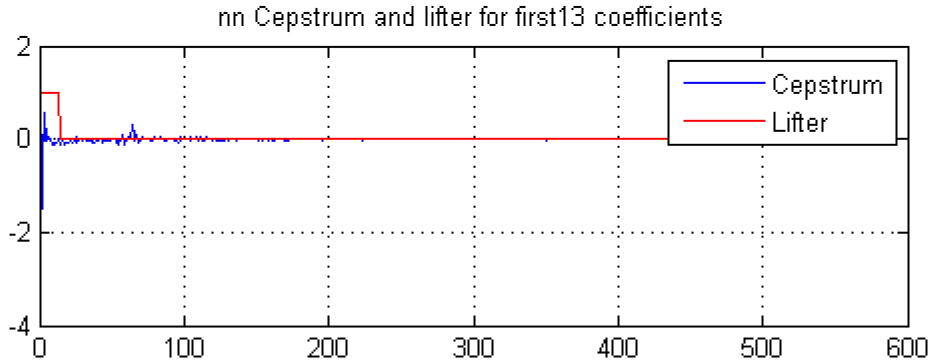
Cepstral Analysis

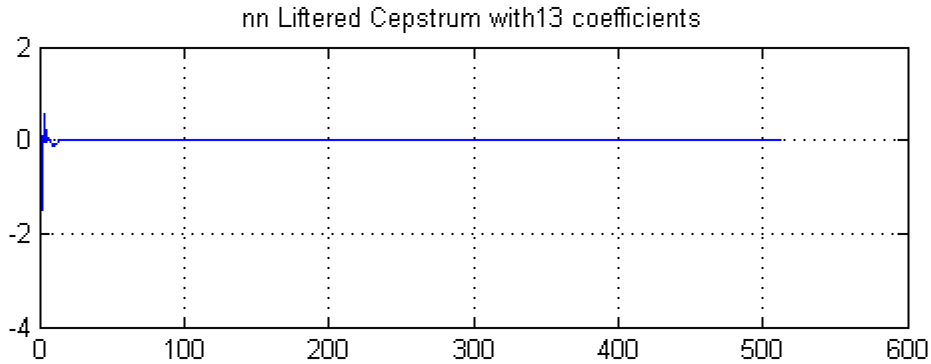
```
cepstrum_preemp = ifft(log(abs(fft(Windowed_signal_preemp,nfft))));
ncep_array = [13, 26, 40];
for i=1:3


    ncep = ncep_array(i);
    lifter = zeros(1,nfft);
    lifter(1:ncep) = 1;
    lifter((end-ncep):end) = 1;

    liftered_spectrum = cepstrum_preemp.*lifter;
    figure()
    subplot(211)
    grid on
    plot(cepstrum_preemp(1:(nfft/2)));
    title(strcat(sound_name, ' Cepstrum and lifter for first ', int2str(ncep),
    hold on
    plot(lifter(1:(nfft/2)), 'r');
    legend ('Cepstrum','Lifter')

    grid on
    subplot(212)
    plot(liftered_spectrum(1:(nfft/2)))
    grid on
    title(strcat(sound_name, ' Liftered Cepstrum with ', int2str(ncep), ' coef
```

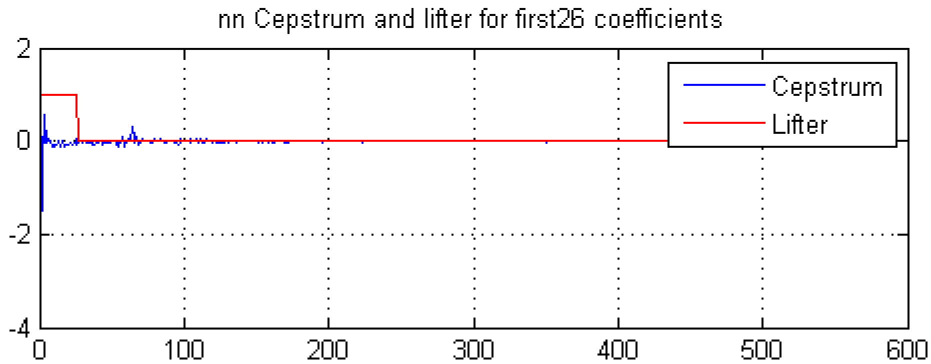


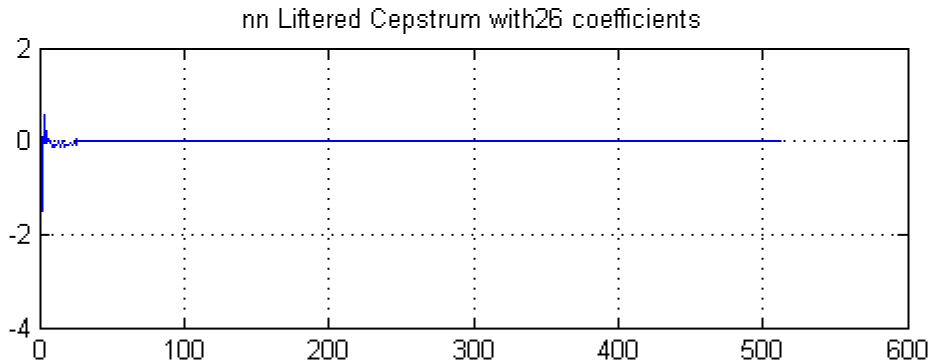

aa Cepstrum and lifter for first26 coefficients
Cepstrum
Lifter
1
0
-1
-2
0
100
200
300
400
500
600
aa Liftered Cepstrum with26 coefficients
1
0
-1
-2
0
100
200
300
400
500
600

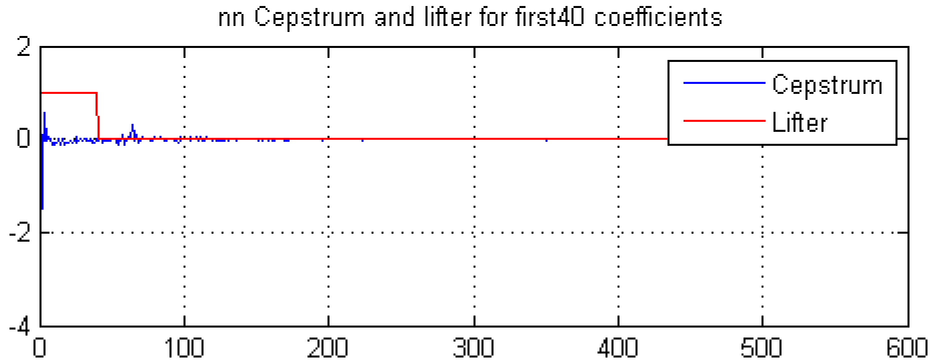

aa Cepstrum and lifter for first40 coefficients
Cepstrum
Lifter
1
0
-1
-2
0
100
200
300
400
500
600
aa Liftered Cepstrum with40 coefficients
1
0
-1
-2
0
100
200
300
400
500
600

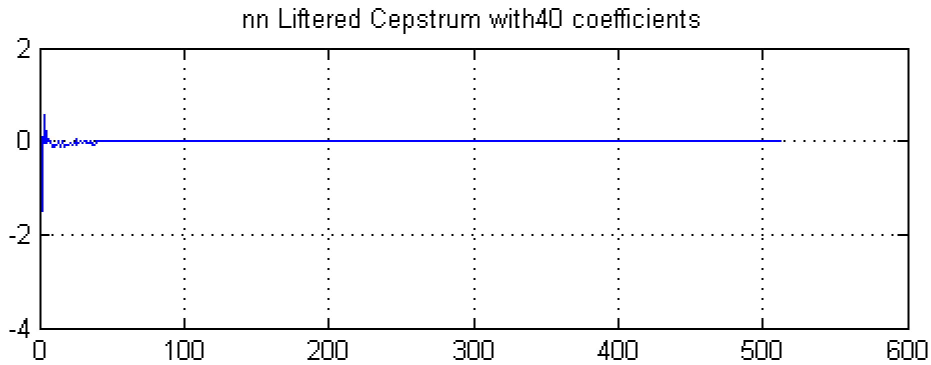

nn Cepstrum and lifter for first13 coefficients
Cepstrum
Lifter
2
0
-2
-4
0
100
200
300
400
500
600

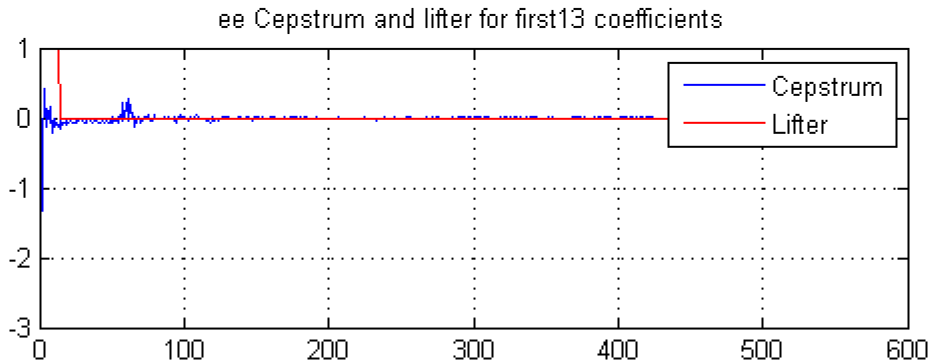

nn Liftered Cepstrum with13 coefficients
2
0
-2
-4
0
100
200
300
400
500
600

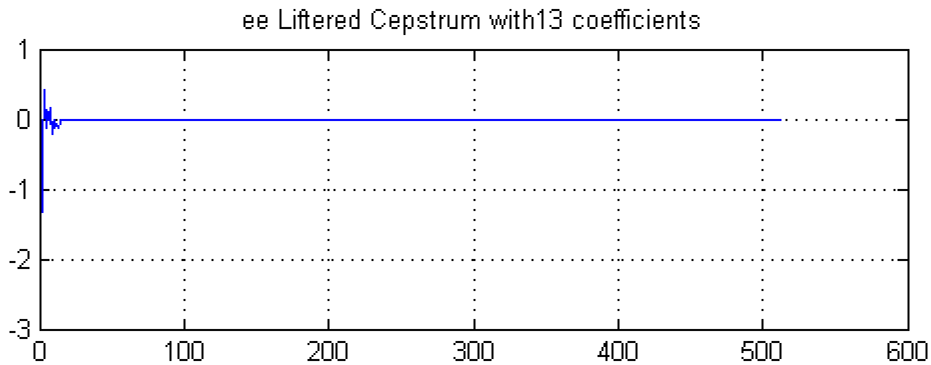

nn Cepstrum and lifter for first26 coefficients
Cepstrum
Lifter
2
0
-2
-4
0
100
200
300
400
500
600

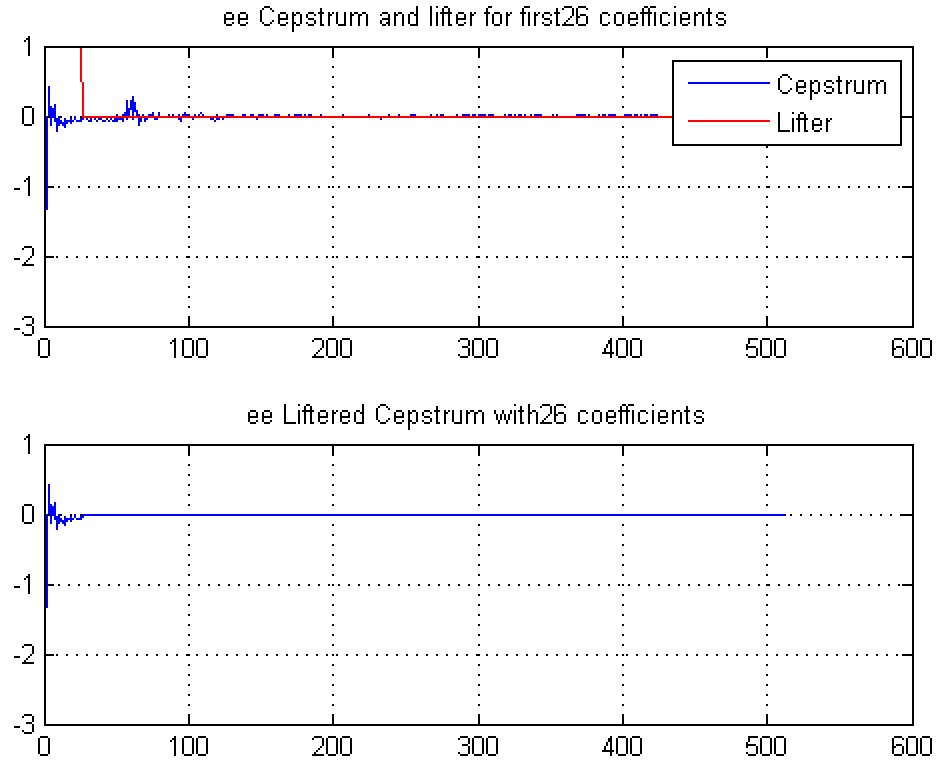

nn Liftered Cepstrum with26 coefficients
2
0
-2
-4
0
100
200
300
400
500
600

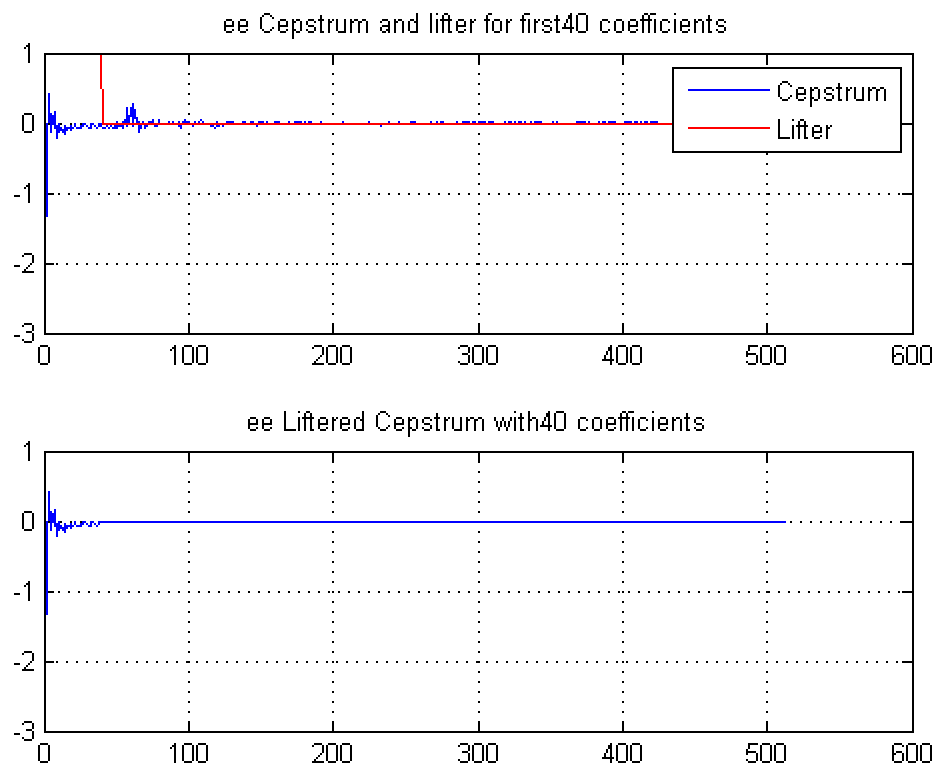

nn Cepstrum and lifter for first40 coefficients
Cepstrum
Lifter
2
0
-2
-4
0
100
200
300
400
500
600

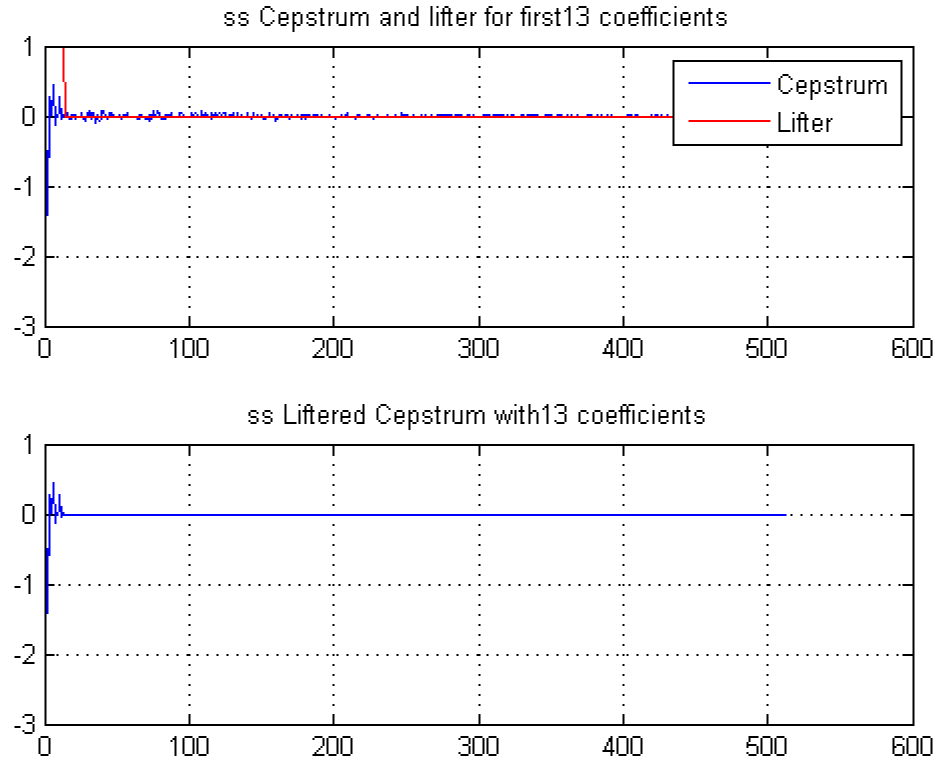

nn Liftered Cepstrum with40 coefficients
2
0
-2
-4
0
100
200
300
400
500
600

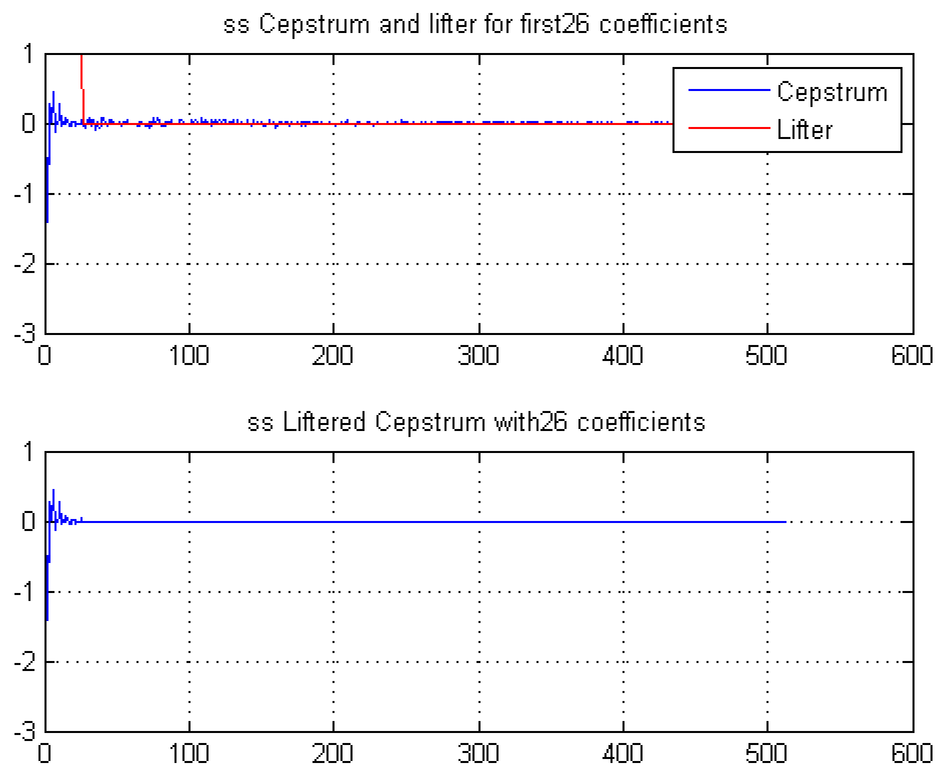

ee Cepstrum and lifter for first13 coefficients
Cepstrum
Lifter
1
0
-1
-2
-3
0
100
200
300
400
500
600

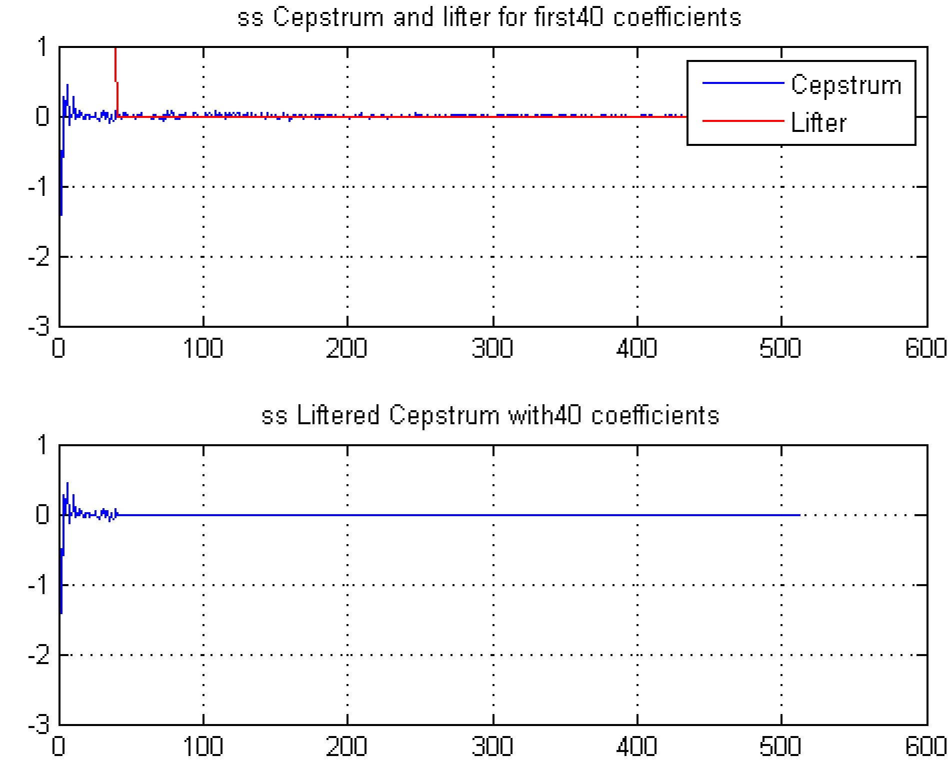

ee Liftered Cepstrum with13 coefficients
1
0
-1
-2
-3
0
100
200
300
400
500
600

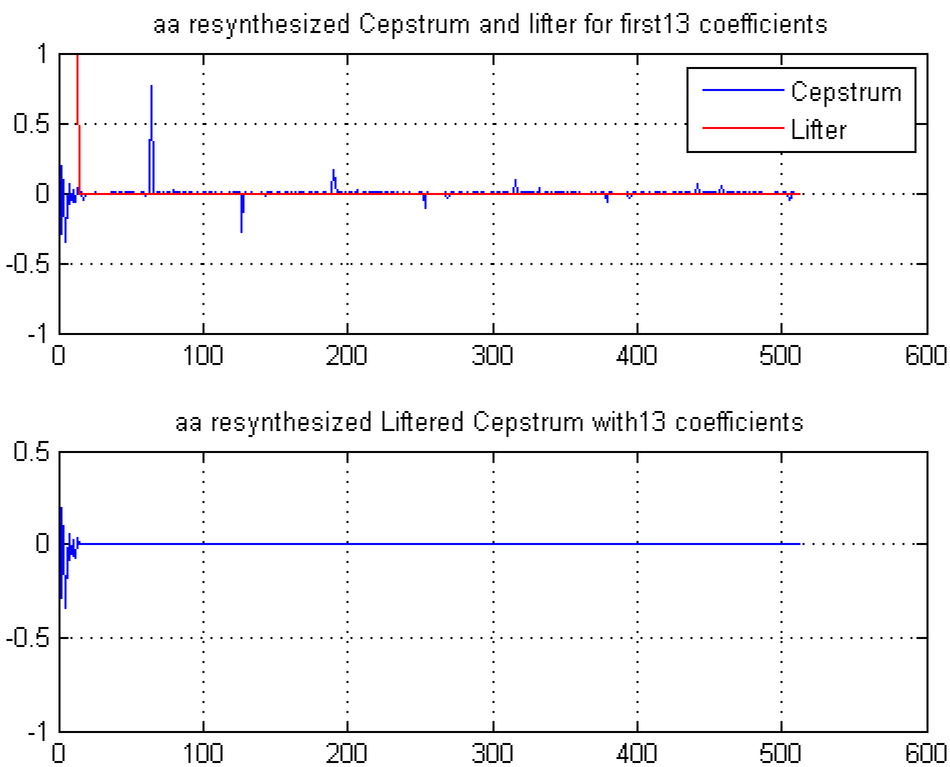

ee Cepstrum and lifter for first26 coefficients
Cepstrum
Lifter
1
0
-1
-2
-3
0
100
200
300
400
500
600
ee Liftered Cepstrum with26 coefficients
1
0
-1
-2
-3
0
100
200
300
400
500
600

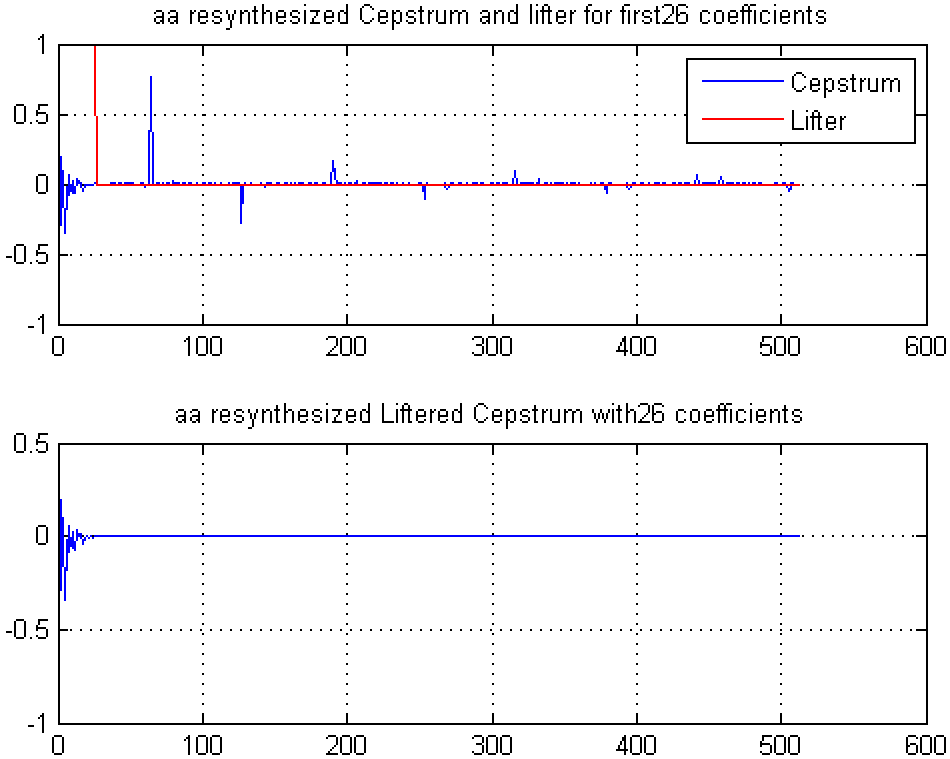

ee Cepstrum and lifter for first40 coefficients
Cepstrum
Lifter
1
0
-1
-2
-3
0
100
200
300
400
500
600
ee Liftered Cepstrum with40 coefficients
1
0
-1
-2
-3
0
100
200
300
400
500
600

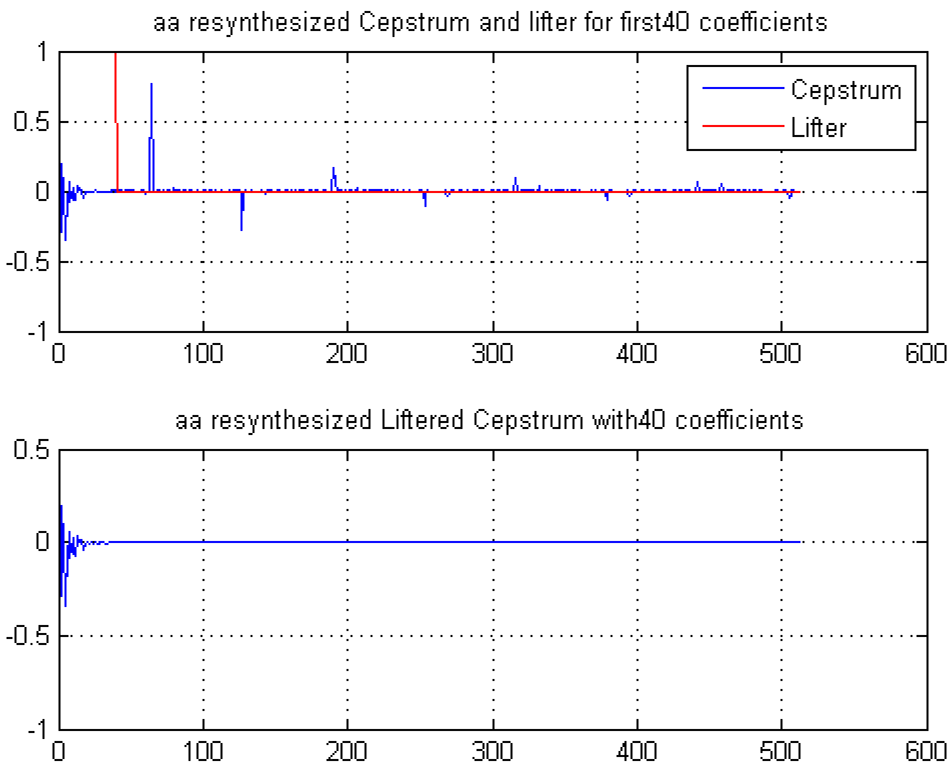

ss Cepstrum and lifter for first13 coefficients
Cepstrum
Lifter
1
0
-1
-2
-3
0
100
200
300
400
500
600
ss Liftered Cepstrum with13 coefficients
1
0
-1
-2
-3
0
100
200
300
400
500
600


ss Cepstrum and lifter for first26 coefficients
Cepstrum
Lifter
1
0
-1
-2
-3
0
100
200
300
400
500
600
ss Liftered Cepstrum with26 coefficients
1
0
-1
-2
-3
0
100
200
300
400
500
600


ss Cepstrum and lifter for first40 coefficients
Cepstrum
Lifter
ss Liftered Cepstrum with40 coefficients


aa resynthesized Cepstrum and lifter for first13 coefficients
Cepstrum
Lifter
aa resynthesized Liftered Cepstrum with13 coefficients

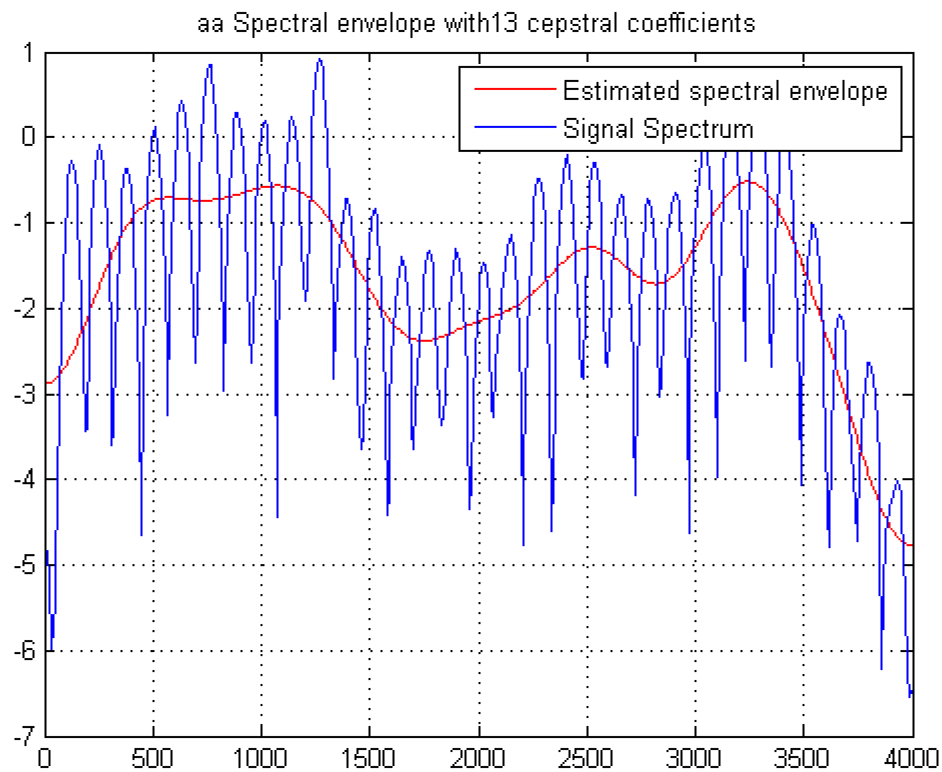

aa resynthesized Cepstrum and lifter for first26 coefficients
Cepstrum
Lifter
1
0.5
0
-0.5
-1
0
100
200
300
400
500
600
aa resynthesized Liftered Cepstrum with26 coefficients
0.5
0
-0.5
-1
0
100
200
300
400
500
600

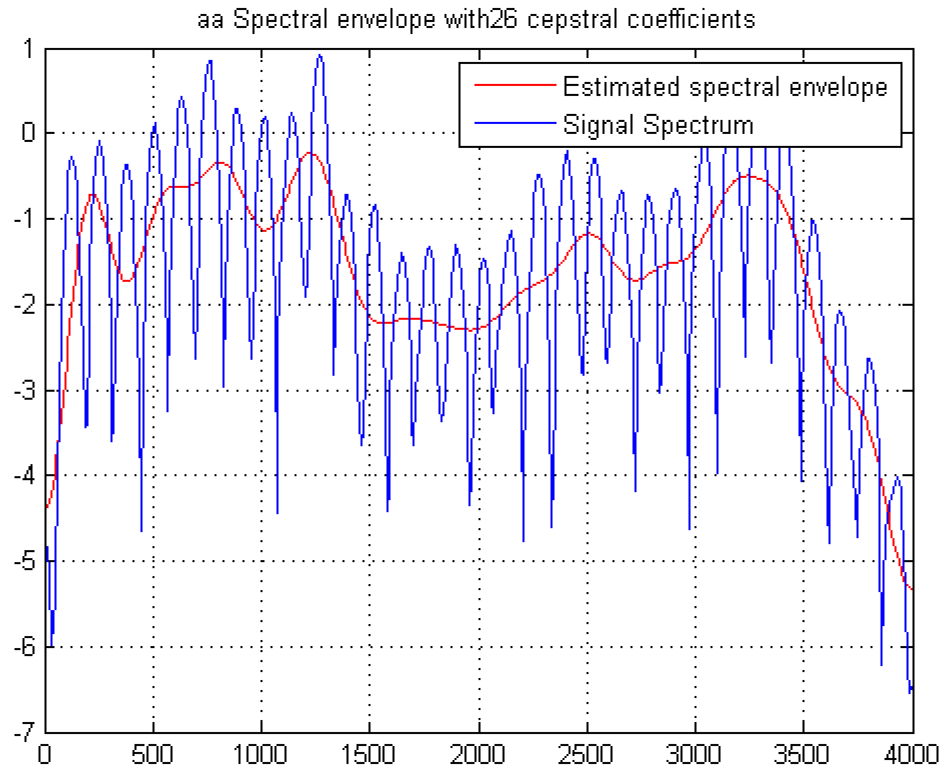

aa resynthesized Cepstrum and lifter for first40 coefficients
Cepstrum
Lifter
1
0.5
0
-0.5
-1
0
100
200
300
400
500
600
aa resynthesized Liftered Cepstrum with40 coefficients
0.5
0
-0.5
-1
0
100
200
300
400
500
600

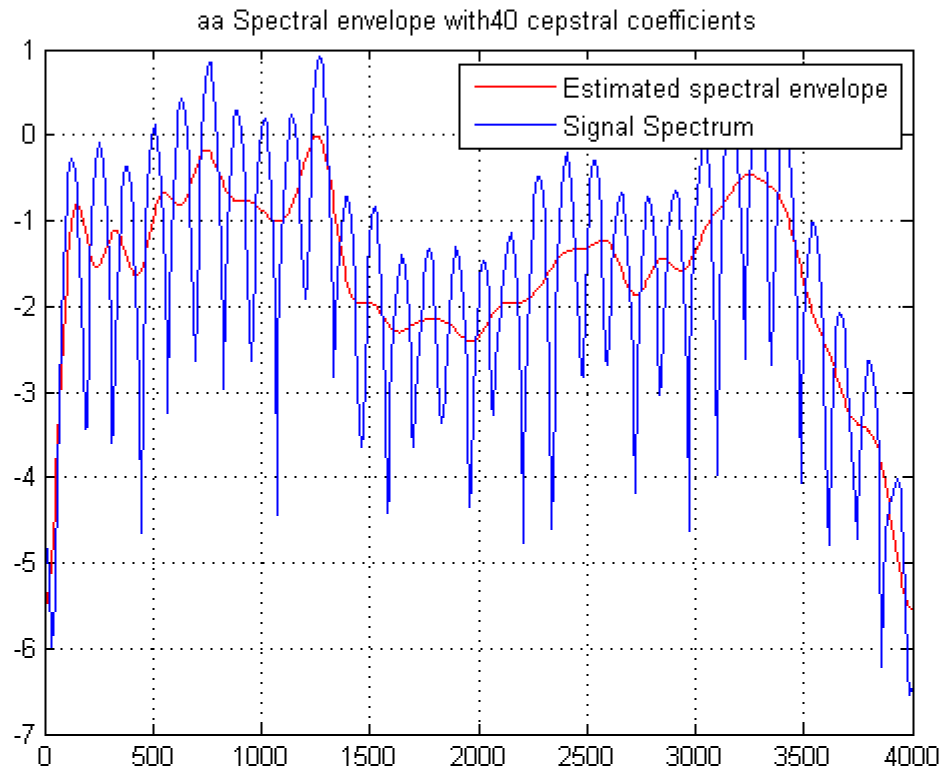
Estimating Spectral Envelope using Cepstral Coefficients

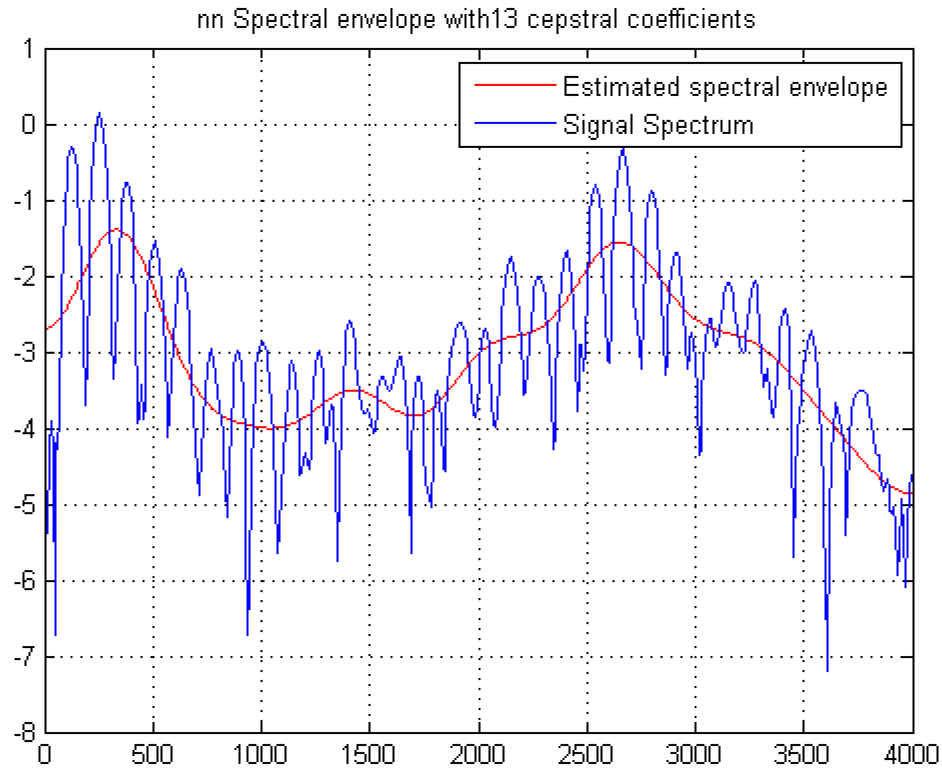
In all the cases, the spectrum envelope generated from 13 co-efficients models the the actual spectrum smoothly while the envelope generated from 40 co-efficients seems to overfit the spectrum by trying to capture the harmonic nature of the spectrum.

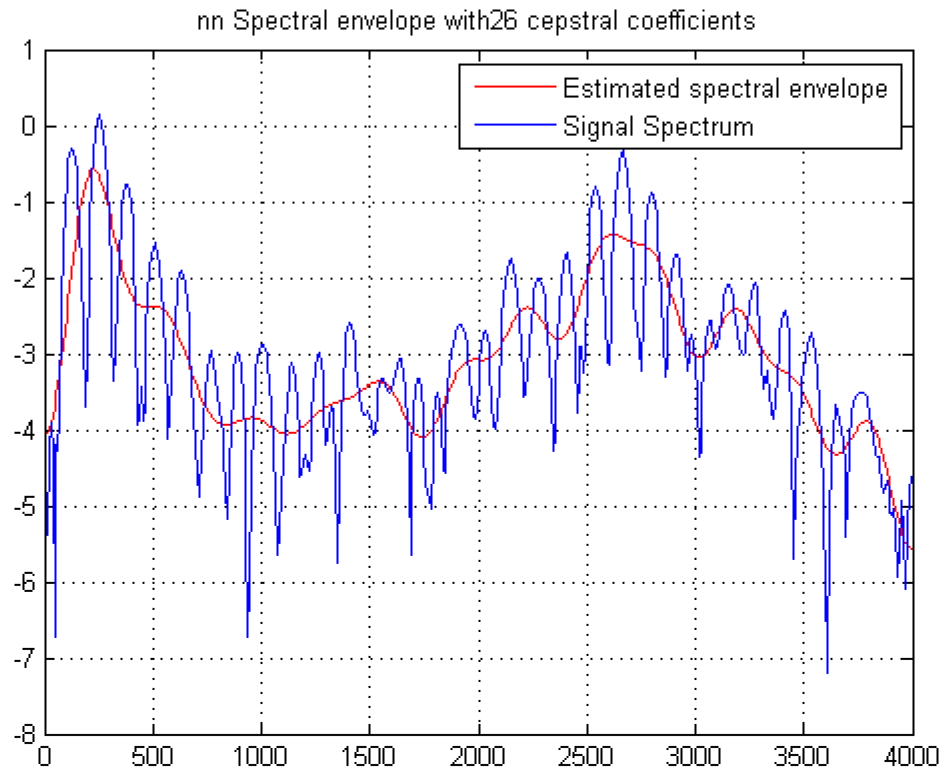
```
liftered_spectrum_fft = (fft(liftered_spectrum, nfft));
figure
plot(freq_axis, log(abs(exp(liftered_spectrum_fft(1:(nfft/2))))), 'r')
grid on
title(strcat(sound_name, ' Spectral envelope with ', int2str(ncep), ' ceps
hold on
plot(freq_axis, log(abs(spectrum_preemp(1:(nfft/2)))))
legend ('Estimated spectral envelope','Signal Spectrum')
```

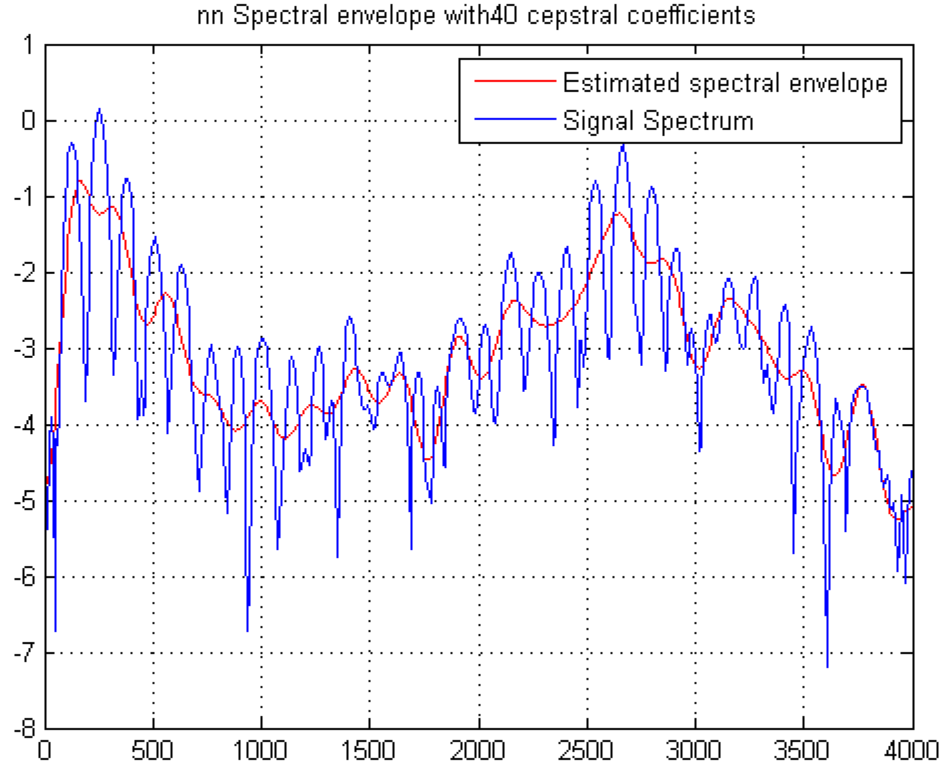


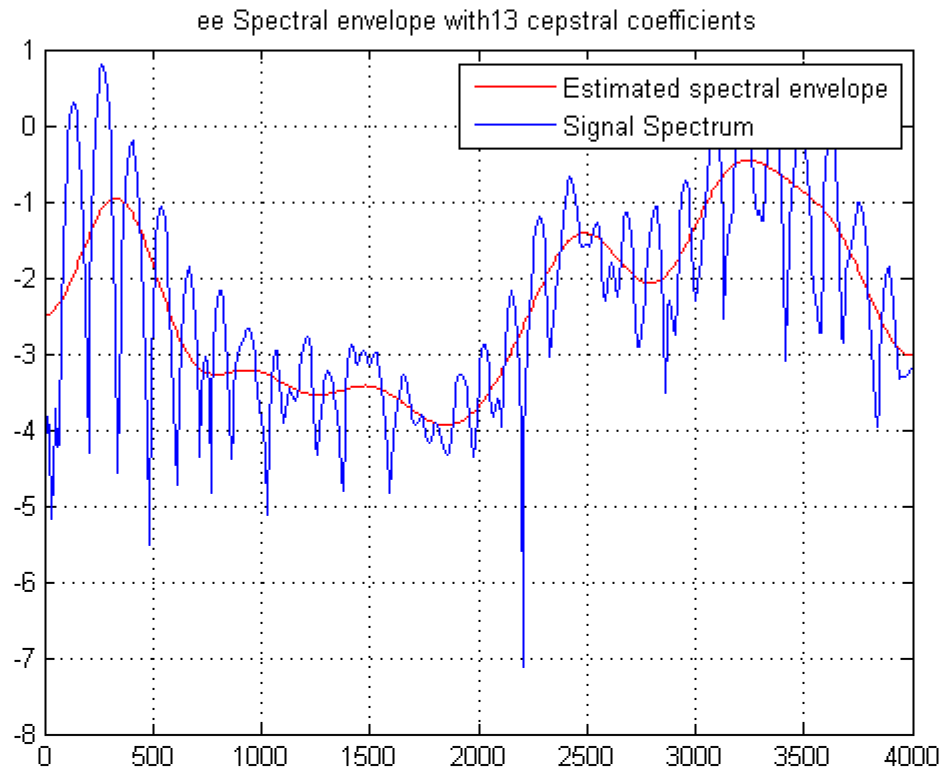

aa Spectral envelope with26 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
0
500
1000
1500
2000
2500
3000
3500
4000

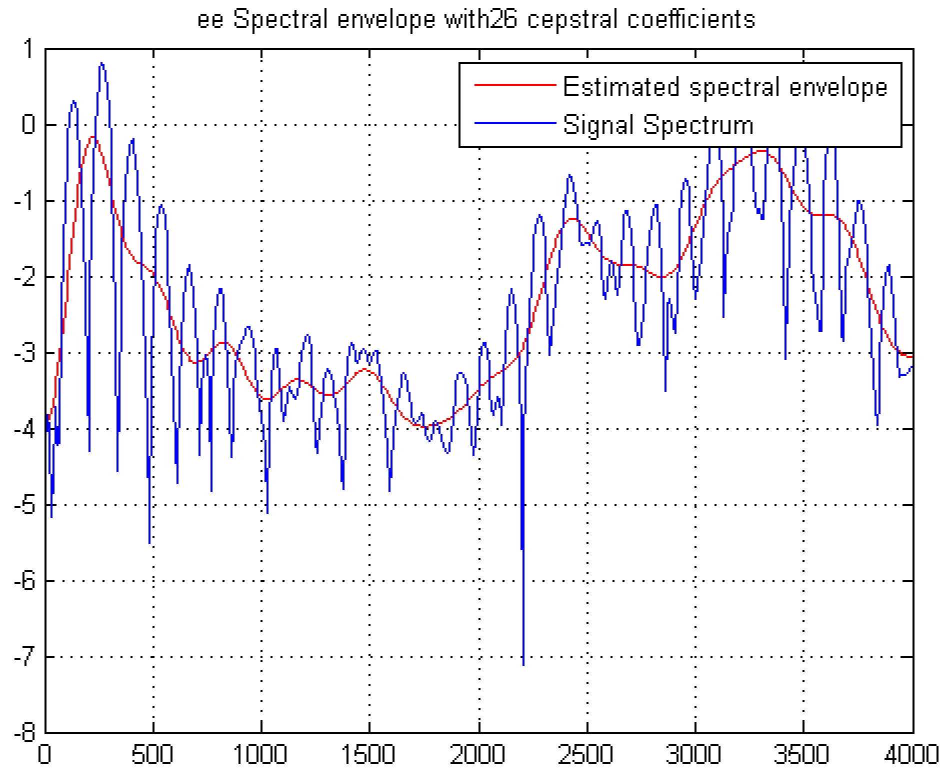

aa Spectral envelope with40 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
0
500
1000
1500
2000
2500
3000
3500
4000

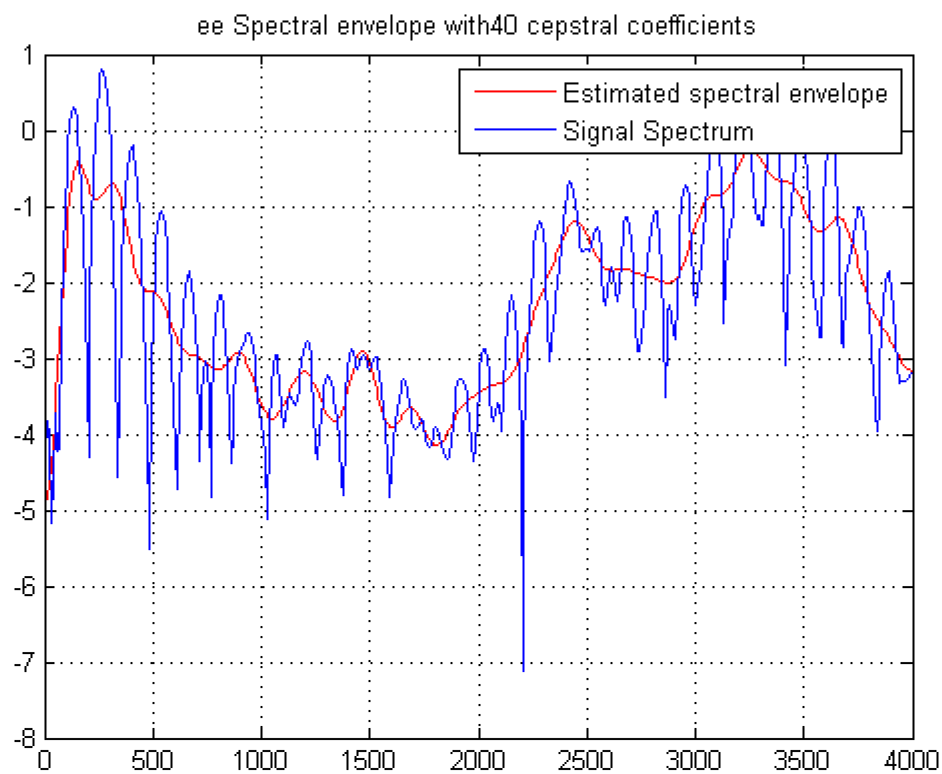

nn Spectral envelope with13 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
500
1000
1500
2000
2500
3000
3500
4000

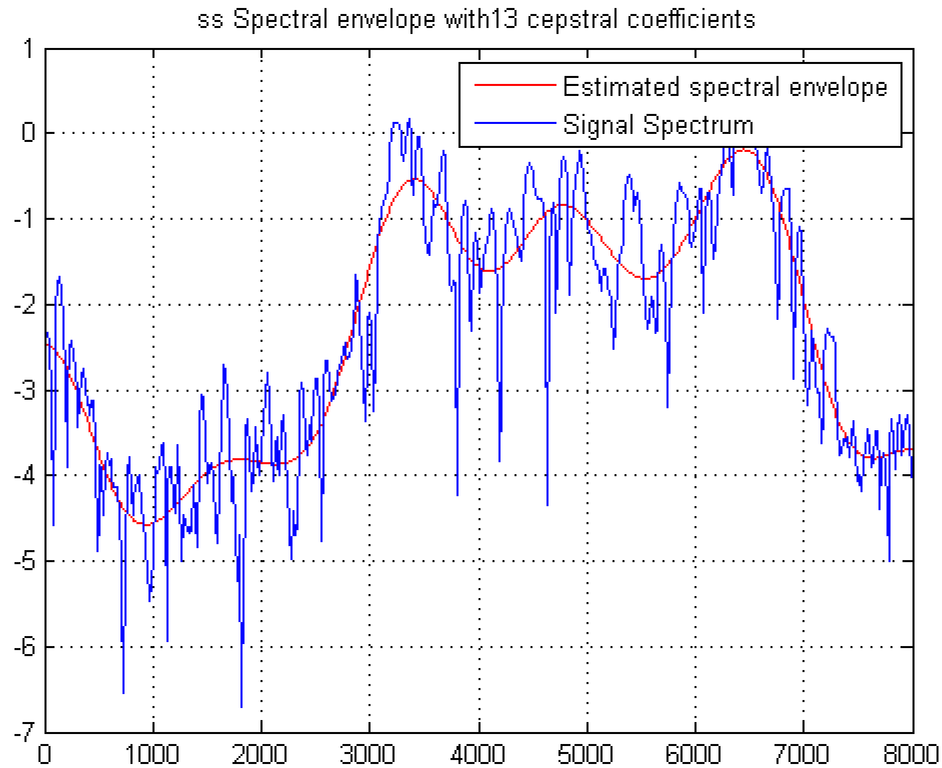

nn Spectral envelope with26 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
500
1000
1500
2000
2500
3000
3500
4000

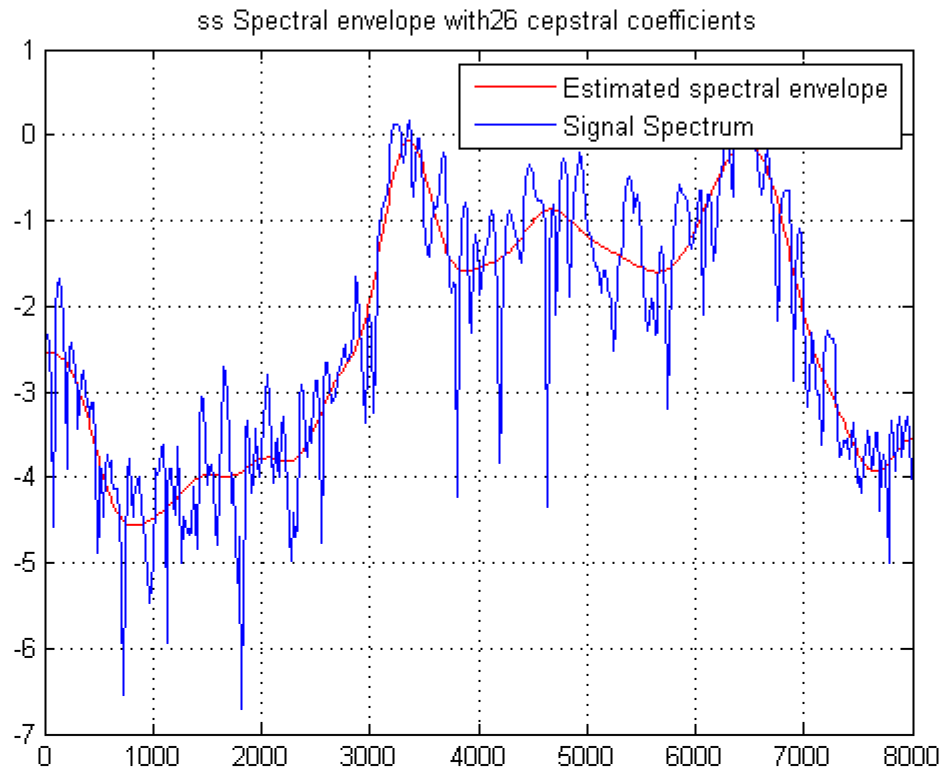

nn Spectral envelope with40 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
500
1000
1500
2000
2500
3000
3500
4000

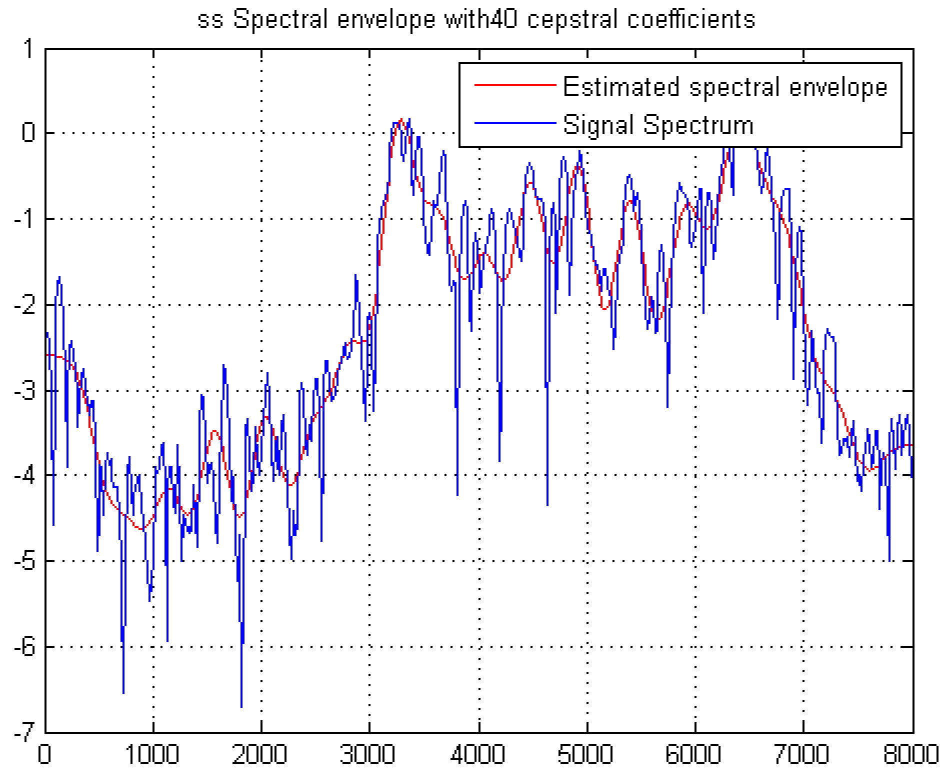

ee Spectral envelope with13 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
500
1000
1500
2000
2500
3000
3500
4000

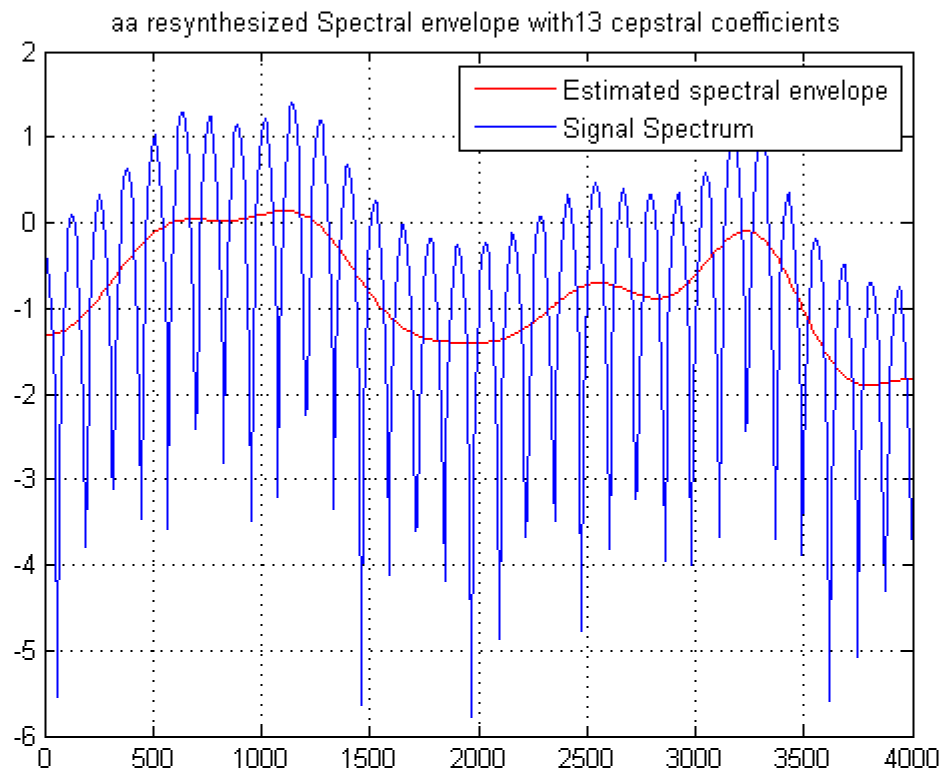

ee Spectral envelope with26 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
500
1000
1500
2000
2500
3000
3500
4000

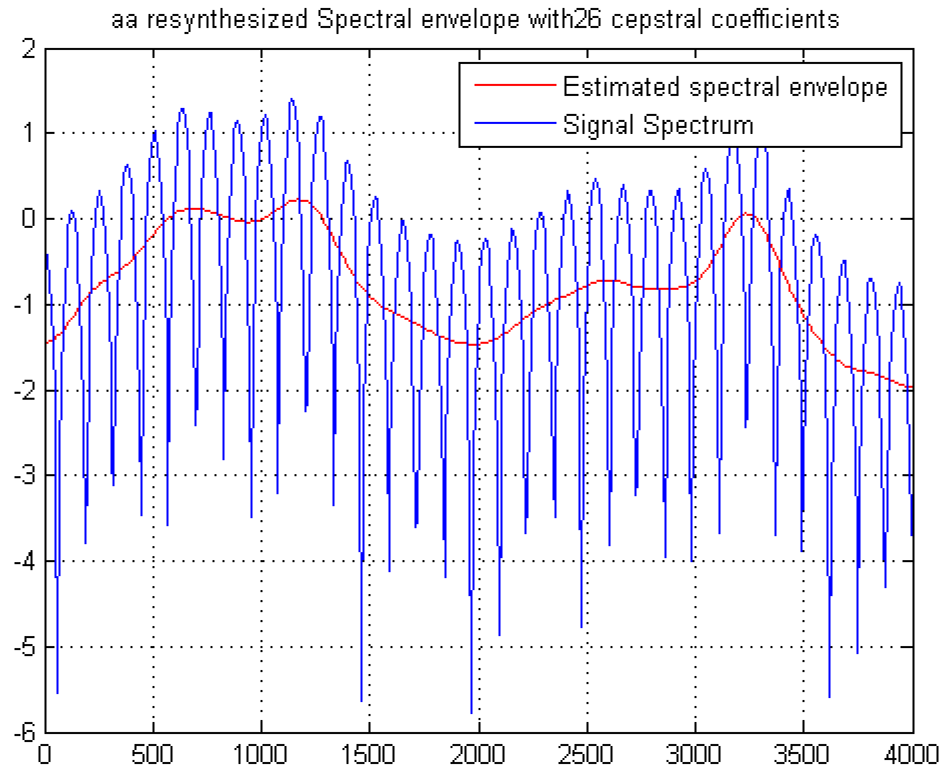

ee Spectral envelope with40 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
500
1000
1500
2000
2500
3000
3500
4000

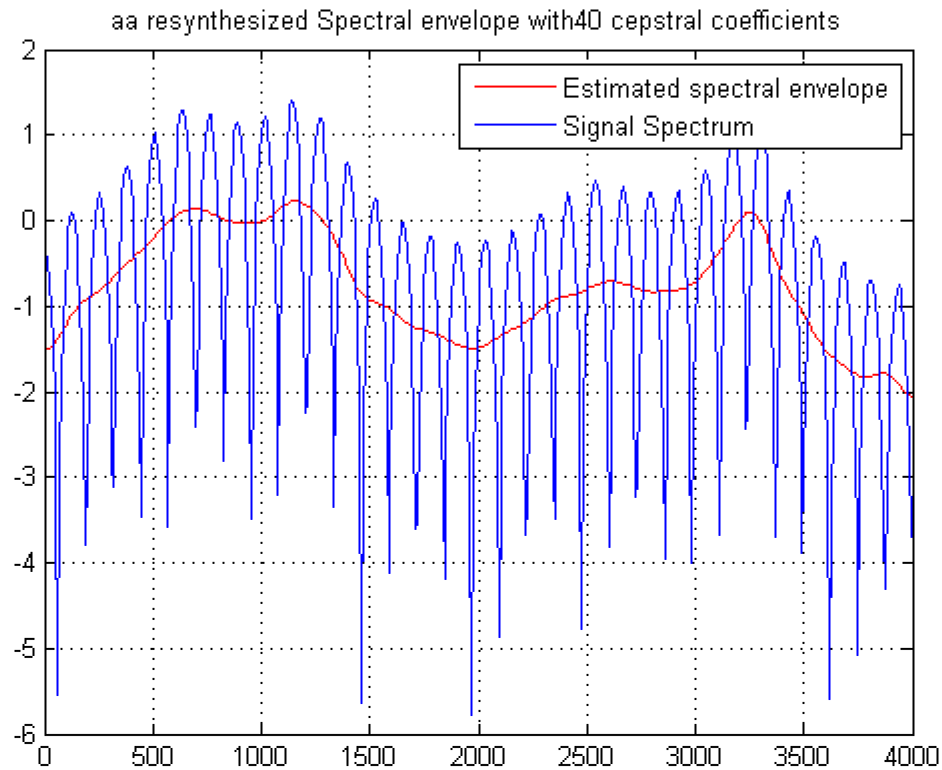

ss Spectral envelope with13 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
0
1000
2000
3000
4000
5000
6000
7000
8000


ss Spectral envelope with26 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
0
1000
2000
3000
4000
5000
6000
7000
8000


ss Spectral envelope with40 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
0
1000
2000
3000
4000
5000
6000
7000
8000


aa resynthesized Spectral envelope with13 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
2
1
0
-1
-2
-3
-4
-5
-6
0
500
1000
1500
2000
2500
3000
3500
4000


aa resynthesized Spectral envelope with26 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
2
1
0
-1
-2
-3
-4
-5
-6
0
500
1000
1500
2000
2500
3000
3500
4000


aa resynthesized Spectral envelope with40 cepstral coefficients
Estimated spectral envelope
Signal Spectrum
2
1
0
-1
-2
-3
-4
-5
-6
0
500
1000
1500
2000
2500
3000
3500
4000

Pitch Estimation

```
        pitch_lifter = ones(1, nfft) - lifter;
        pitch_liftered_spectrum = cepstrum_preemp.*pitch_lifter;
        [max_value, max_index] = max(pitch_liftered_spectrum(1:(nfft/2)));
        pitch_freq = fs / max_index;
        if i == 1
            disp(strcat(sound, ' Pitch Frequency estimated : ',  num2str(pitch_fre
        end
```

aa Pitch Frequency estimated :125

nn Pitch Frequency estimated :125

ee Pitch Frequency estimated :131.1475

ss Pitch Frequency estimated :1066.6667

as Pitch Frequency estimated :125

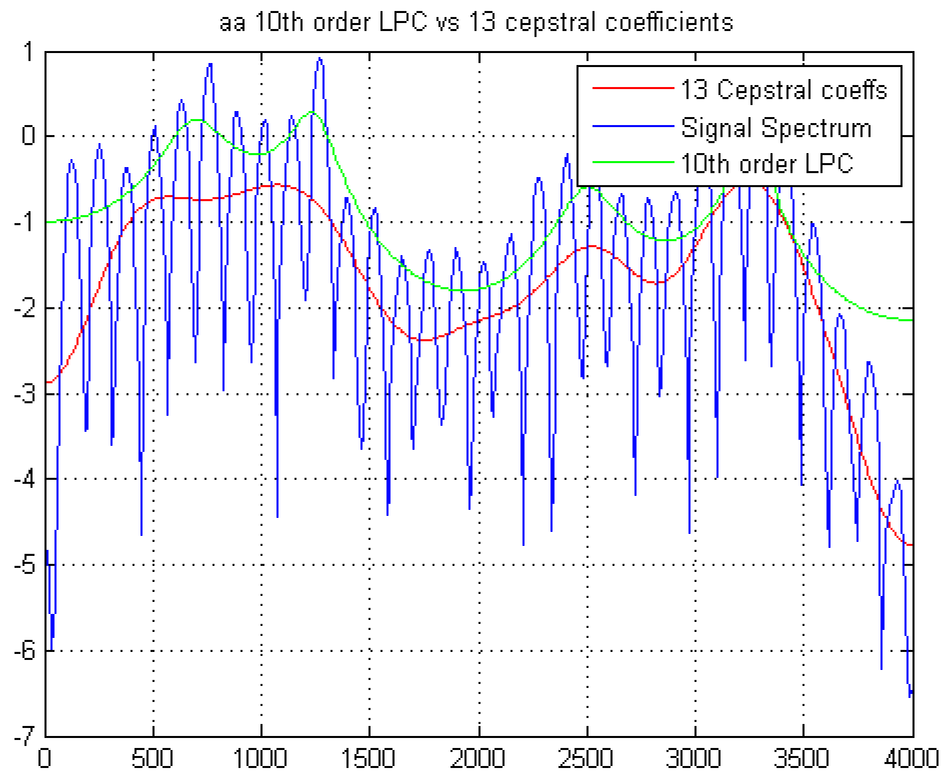
```
    end
```

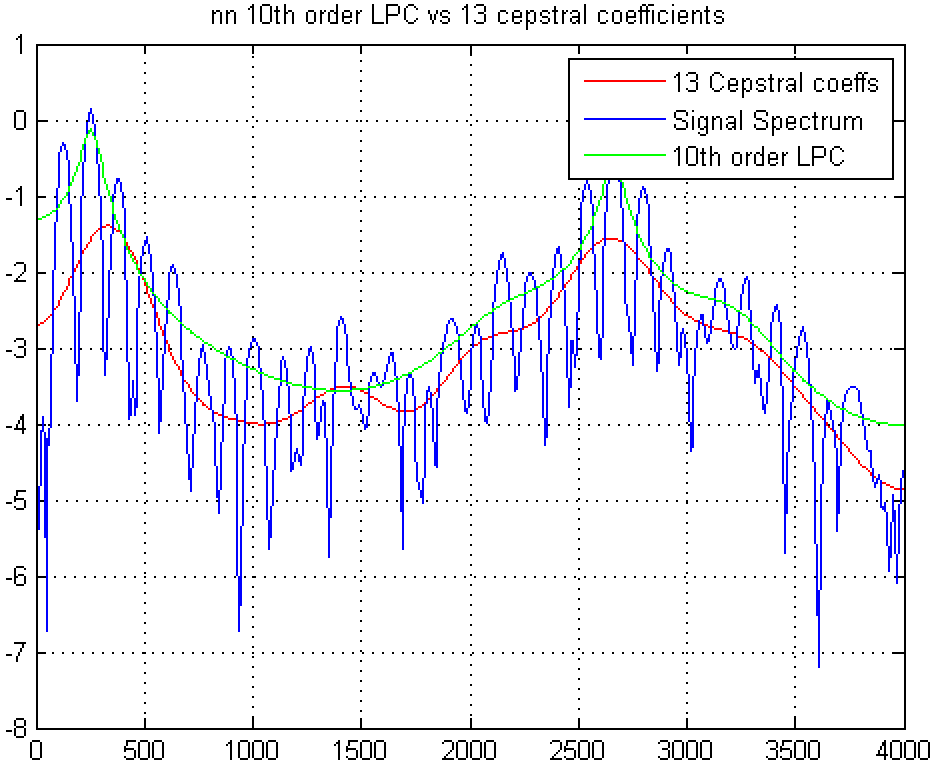
Comparison of estimations using 10th order LPC and 13 Cepstral coefficients

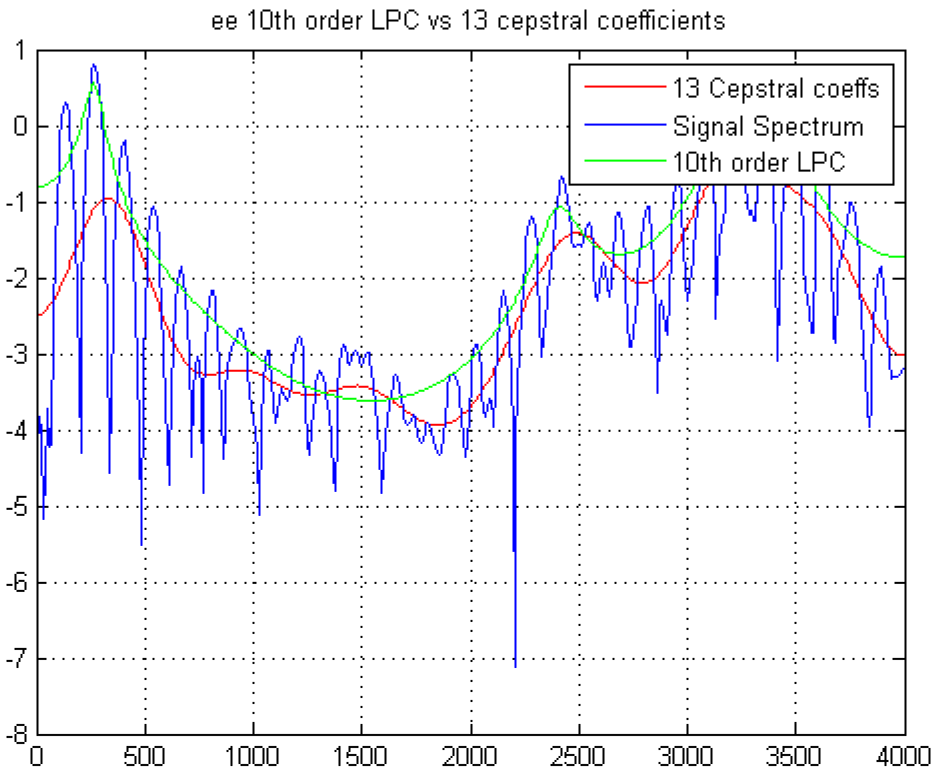
As can be observed in the plots below, the Spectrum envelope estimated using the Cepstral co-efficients models the actual signal spectrum shape much more smoothly than the spectral envelope estimated using LPC which is more biased towards the peaks than the pits.

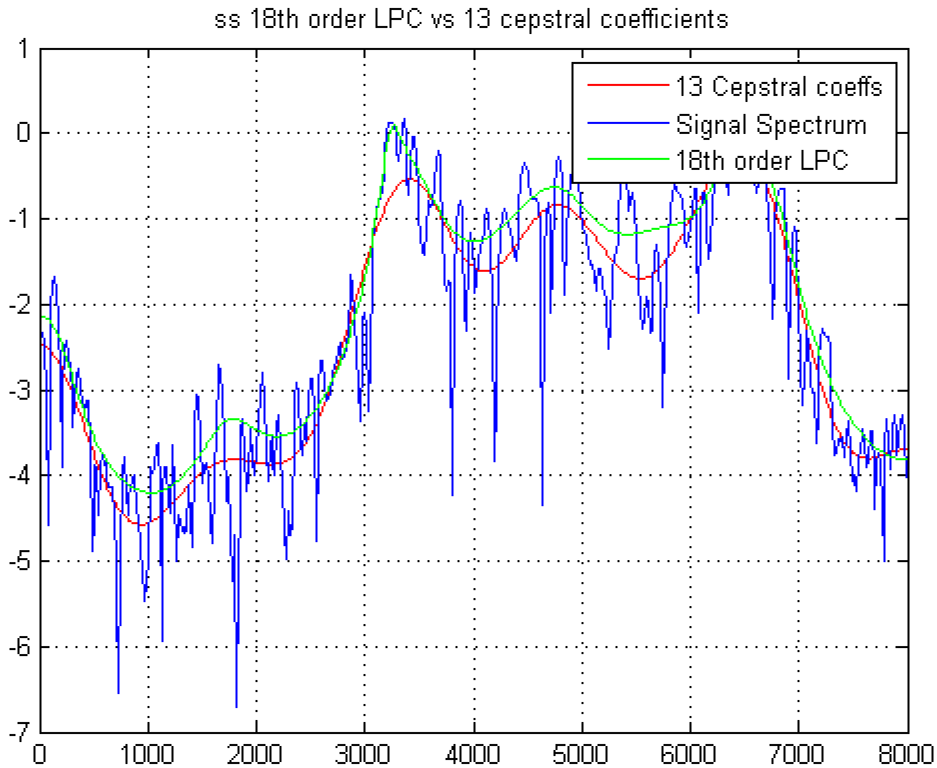
```
    % 10th Order LPC
    p = 10;
    if sound == 'ss'
        p = 18;
    end
    r = zeros(1,p+1);
    for k = 1:(p+1)
        acr_sum = 0;
        for g = 1:(window_len-k+1)
            acr_sum = Windowed_signal_preemp(g).*Windowed_signal_preemp(g+k-1) + a
        end
        r(k) = acr_sum;
    end

    [A, EE, K] = levinson(r, p);
    %f_axis = -4000:4000/(nfft/2):4000 - 4000/(nfft/2);
    %Residual_error_energy(c) = EE;
    A_z = sqrt(EE)./((fft(A,nfft)));

    % 13 Cepstral Coefficients
    lifter = zeros(1,nfft);
    lifter(1:13) = 1;
    lifter((end-13):end) = 1;
```

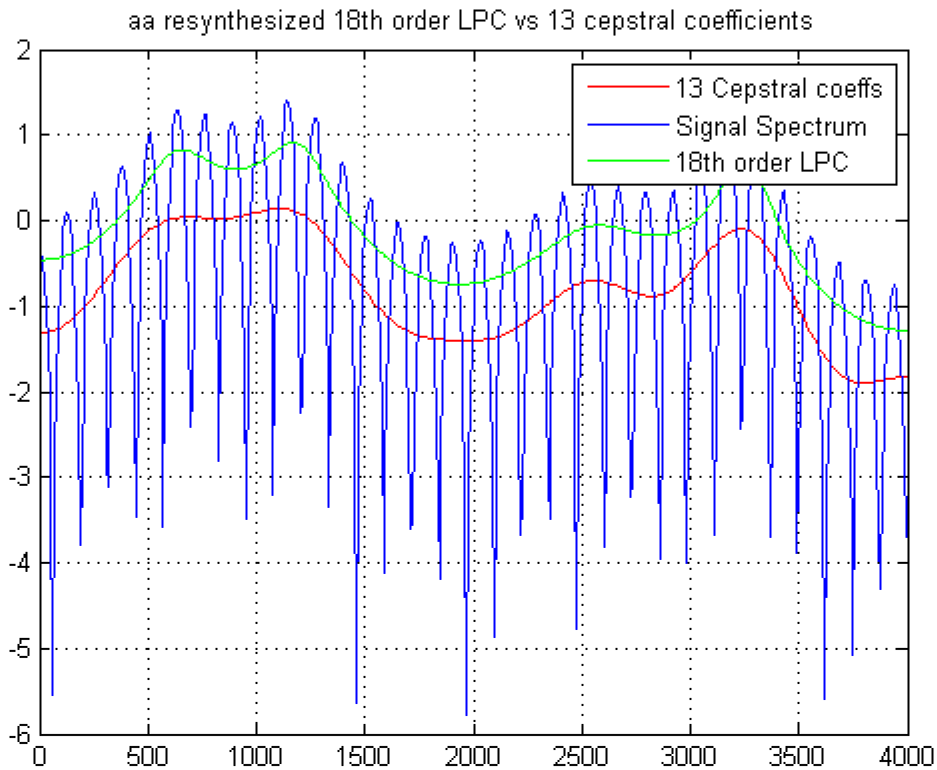
```
liftered_spectrum = cepstrum_preemp.*lifter;
liftered_spectrum_fft = (fft(liftered_spectrum, nfft));


if sound ~= 'ss'
    figure
    plot(freq_axis, log(abs(exp(liftered_spectrum_fft(1:(nfft/2))))), 'r')
    grid on
    title(strcat(sound_name, ' 10th order LPC vs 13 cepstral coefficients'));
    hold on
    plot(freq_axis, log(abs(spectrum_preemp(1:(nfft/2)))))
    hold on
    plot(freq_axis,log(abs(A_z(1:(nfft/2)))),'g');
    legend ('13 Cepstral coeffs','Signal Spectrum','10th order LPC')

else
    figure
    plot(freq_axis, log(abs(exp(liftered_spectrum_fft(1:(nfft/2))))), 'r')
    grid on
    title(strcat(sound_name, ' 18th order LPC vs 13 cepstral coefficients'));
    hold on
    plot(freq_axis, log(abs(spectrum_preemp(1:(nfft/2)))))
    hold on
    plot(freq_axis,log(abs(A_z(1:(nfft/2)))),'g');
    legend ('13 Cepstral coeffs','Signal Spectrum','18th order LPC')

end
```




nn 10th order LPC vs 13 cepstral coefficients
13 Cepstral coeffs
Signal Spectrum
10th order LPC
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
500
1000
1500
2000
2500
3000
3500
4000


ee 10th order LPC vs 13 cepstral coefficients
13 Cepstral coeffs
Signal Spectrum
10th order LPC
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
500
1000
1500
2000
2500
3000
3500
4000


ss 18th order LPC vs 13 cepstral coefficients
13 Cepstral coeffs
Signal Spectrum
18th order LPC
1
0
-1
-2
-3
-4
-5
-6
-7
0
1000
2000
3000
4000
5000
6000
7000
8000


aa resynthesized 18th order LPC vs 13 cepstral coefficients
13 Cepstral coeffs
Signal Spectrum
18th order LPC
2
1
0
-1
-2
-3
-4
-5
-6
0
500
1000
1500
2000
2500
3000
3500
4000

```
end
```

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