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```
%%%%%%%%%%%%%%%%%%%%%%%% P R O J E C T  2016/2017
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% Ylopoihthikan ola ta meri tis ergasia ektos apo to upoerwtima sto B meros
% tis 1is askisis gia N = 512, afou to sxima den itan to epithimito

%%%%%%%%%%%%%%%%%%%% M E R O S  A ' SXEDIASMOS FILTRWN %%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

A1. FIR Filter

- Efarmozoume ti methologia gia to FIR filtro, to opoio prokuptei 5ou vathmou - Apta dedomena vriskoume tin suxnotita apokopis (ws+wp)/2 - Prokuptei vathmos filtrou N = 40 kai einai megaluteros aptou IIR afto simainei oti to filtro exei megaluteri kathisteri sto na katevei apto ena sto miden

```
clear; clear all; close all;
fsample = 16000;
As = 40;Ap = 1;%db

fs = 0.15; fp = 0.05;
ws=0.3*pi; wp=0.1*pi;

% find min filter length M from hamming's equation:
N = ceil( 4/(fs-fp) );
%discrete time fir-hamming-lowpass coefficients
filtCoe = fir1(N, (wp+ws)/2, 'low', hamming(N+1));
```

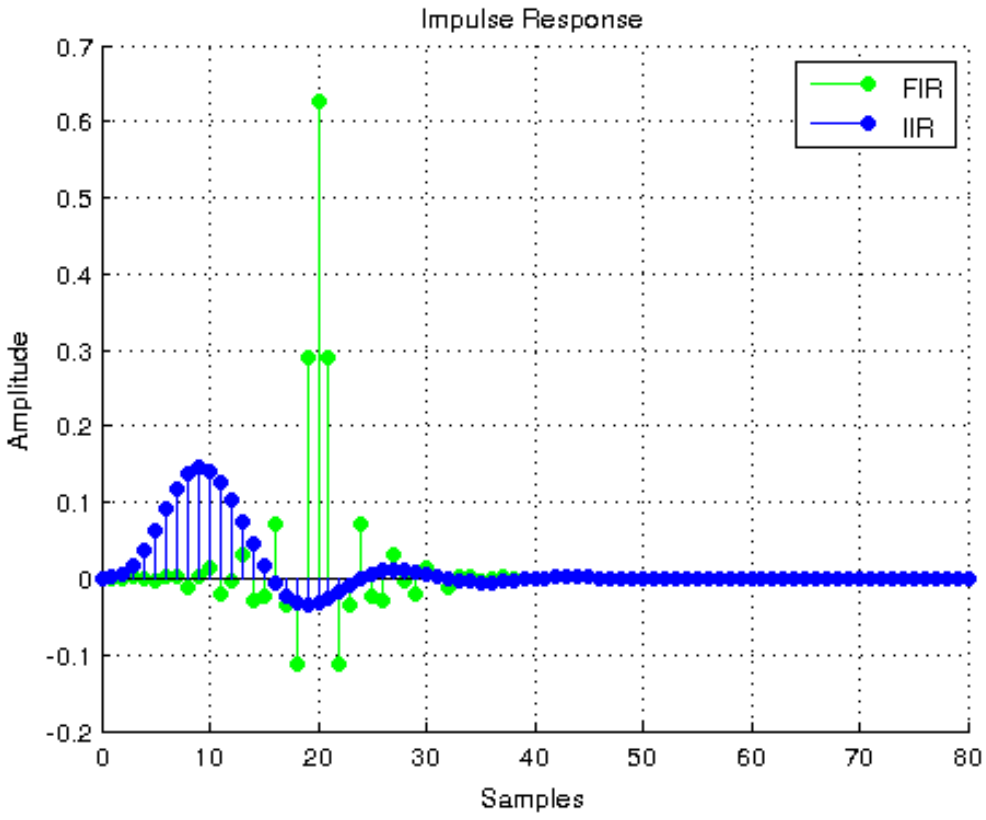
A2. IIR Filter

- Kataskevi IIR filtrou me vasi tou digrammikou metasximatismou, gnwstis methodologias - Prokuptei filtro vathmou N = 5 poly mikrotero apto FIR s=jW...s=e^jw

```
WP = 2*fsample*tan(wp/2);%convert to analog
WS = 2*fsample*tan(ws/2);
[N,Wn] = buttord(WP, WS, Ap, As, 's');
[z, p] = butter(N, Wn, 'low', 's');
[num, den] = bilinear(z, p, fsample);
```

A3.Impulse response

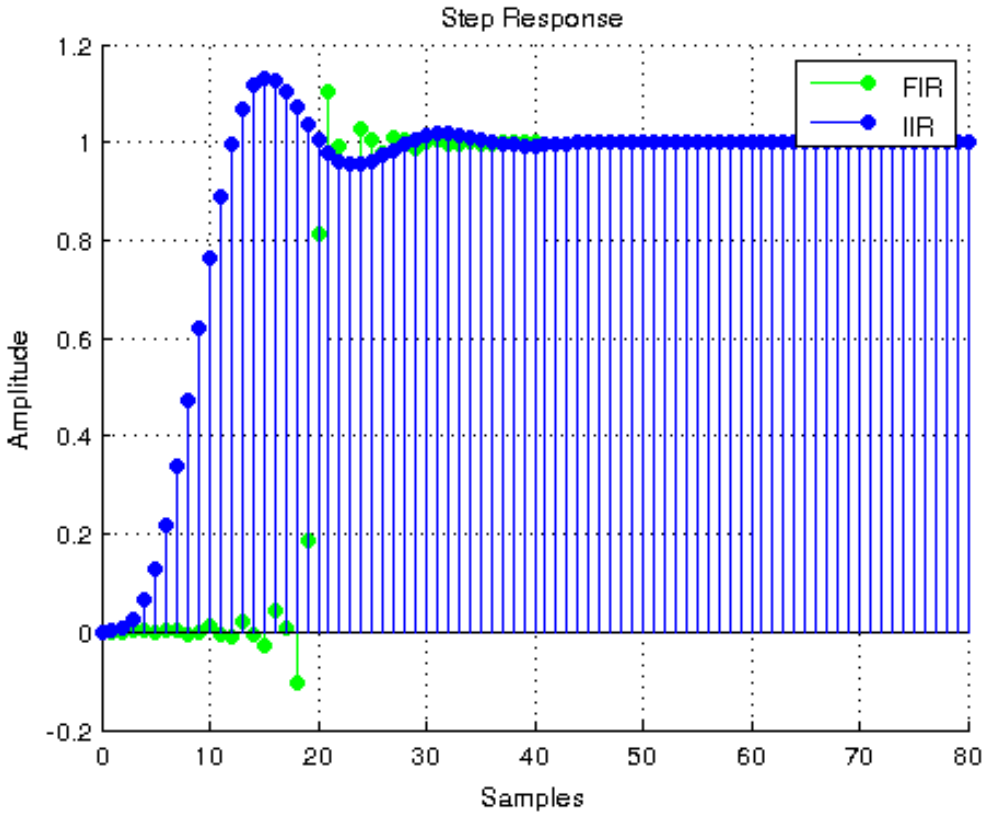
```
hold on; figure (1);  title('Impulse Response'); grid('ON');
xlabel('Samples'); ylabel('Amplitude');

[firY, firX] = impz(filtCoe);
[iirY, iirX] = impz(num, den);
stem(firX, firY, 'g', 'filled');
hold on;
stem(iirX, iirY, 'b', 'filled');
legend('FIR', 'IIR');
hold off;
```



A4.Step response

```
figure (2); hold on; title('Step Response'); grid('ON');
xlabel('Samples'); ylabel('Amplitude');

[firY, firX] = stepz(filtCoe);
```

```
[iirY, iirX] = stepz(num, den);
stem(firX, firY, 'g', 'filled');
hold on;
stem(iirX, iirY, 'b', 'filled');
legend('FIR', 'IIR');
hold off;
```

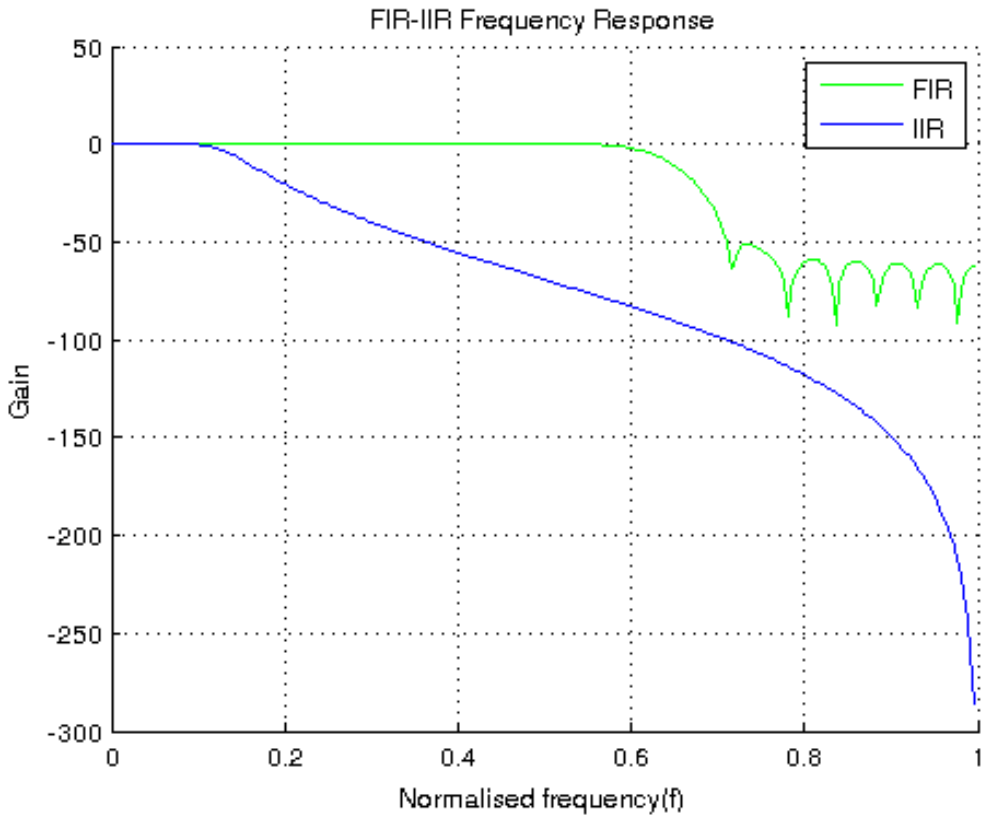


A5. Frequency response H(e^jw)

- Sxima ilopoieitai se DB - An koitousame tin metavoli tou platous apo 1 se miden paratiroume oti to IIR filtro kanei tin metavasi aftin se stenotero euros suxnotitwn, pragma pou einai epithimito. To FIR/ hamming omws exei megaluteri statherothta opws dixnei to sxima twn DB, afou stin xeiroteri periptwsi ftanei ta -70dB - Oi suxnotites tou sximatos einai ston aksona tou x kai einai kanonikopoihmenes kata Nyquist, diladi kata w/pi

```
%frequency domain FIR-IIR
[hFir,wFir]=freqz(filtCoe,1,256);
[hIir,wIir]=freqz(num,den,256);

%amplitute-gain in dB
hFirDB = 20*log10(abs(hFir));
hIirDB = 20*log10(abs(hIir));

%plot
figure(3); hold on; title('FIR-IIR Frequency Response');
grid('ON'); ylabel('Gain');xlabel('Normalised frequency(f)');
```

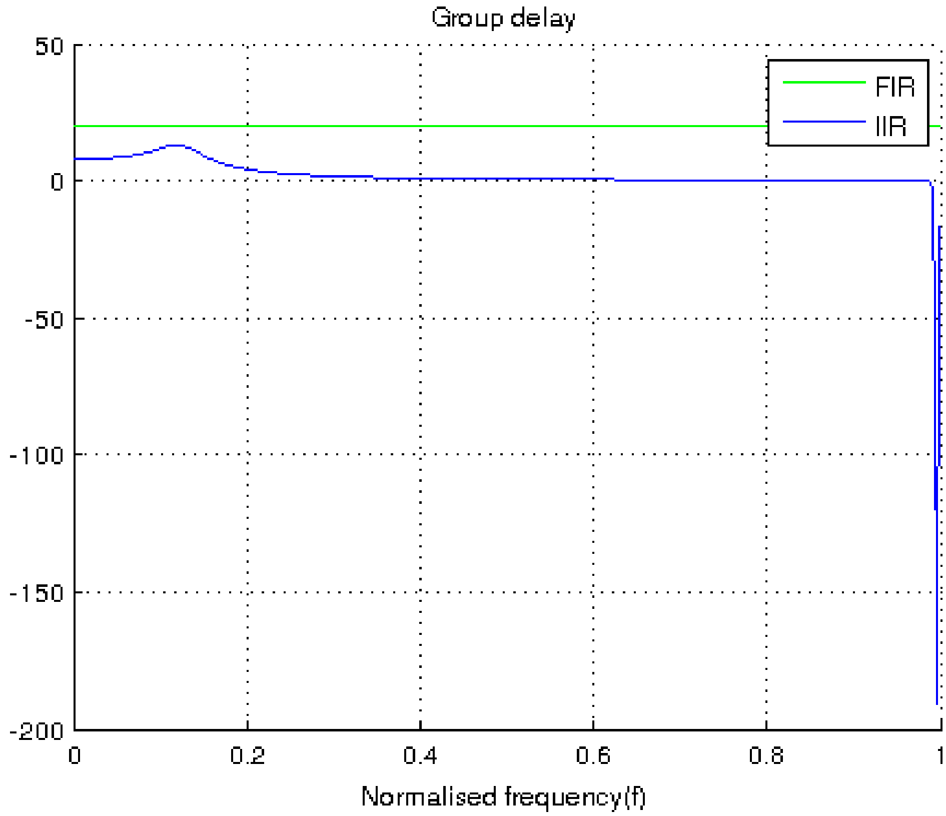
```
plot(wFir/(pi), hFirDB, 'g');%normalized frequency(Nyquist)
hold on;
plot(wIir/(pi), hIirDB,'b');%Normalized frequency(Nyquist)
legend('FIR', 'IIR');
hold off;
```



A6. Group delay

-d/dw{ -tan^-1(Im(H(e^jw))/Re(H(e^jw)) } paratiroume oti gia fsample <1641.25 oso i normalised freq teinei sto 1 to group delay teinei sto + apeiro enw apo tin oriaki syxnotita fsample fsample=1641.5 allazei to prosimo tou group delay kai teinei sto - apeiro

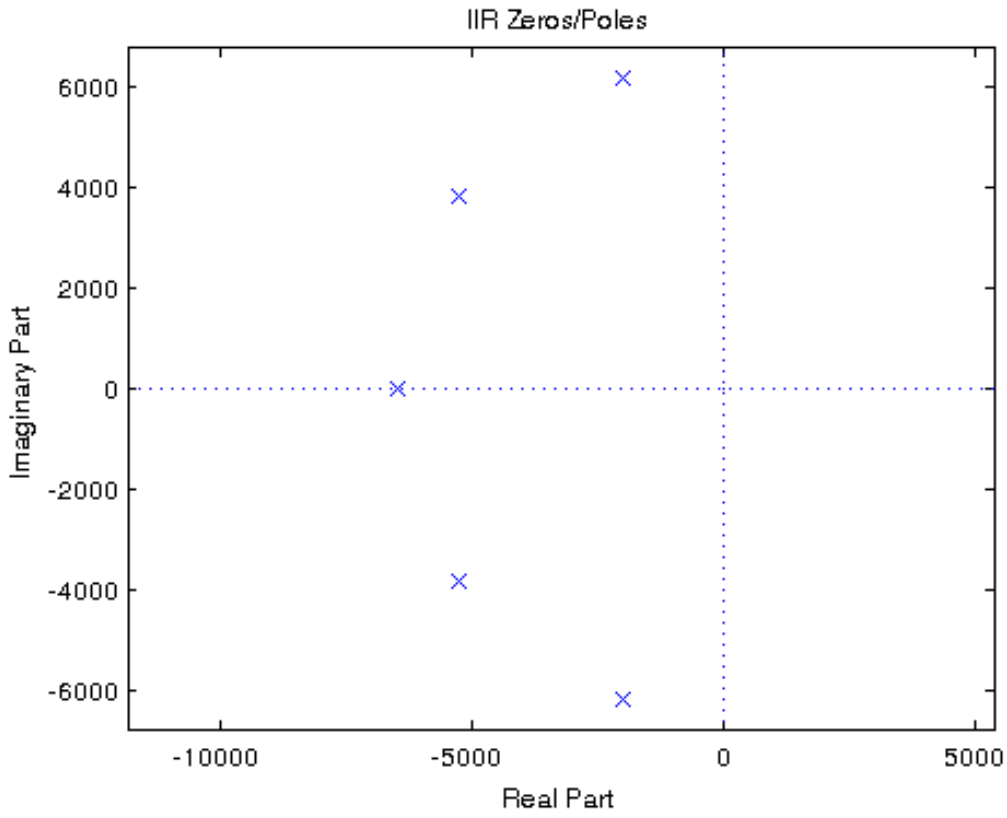
```
[gdFir, wFir] = grpdelay(filtCoe);%default 8192 samples
[gdIir, wIir] = grpdelay(num, den);%default 8192 samples
%plot
figure(4); hold on; title('Group delay');
grid('ON');xlabel('Normalised frequency(f)');
plot(wFir/pi,gdFir, 'g');
hold on;
plot(wIir/pi, gdIir,'b');
legend('FIR', 'IIR');
hold off;
```



A7. Zeros/Poles

- Afto afora mono to IIR, afou to FIR den exei polous kai ara einai efstathi

```
[b, a] = zplane(z, p);
hold on; title('IIR Zeros/Poles');
hold off;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%   M E R O S   B ' %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%** Ypologismos DFT  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% - Edw upologizoume tous DFT mesw tis fft gia diaforetika N
```



B1.1 Input Signal

```
%Configure signal x[n] = A1 * cos(w1*n) + A2*cos(w2*n)
A1 = 1;
A2 = 0.50;

l1 = length('stathopoulos');
l2 = length('axelos');

w1 = pi*mod( (10/7.5)*( max(l1,l2)/(l1+l2) ), 1 );
w2 = mod( w1 + pi/4, pi);
Dw = abs(w1-w2);
```

B1.2 Windowing and FFT

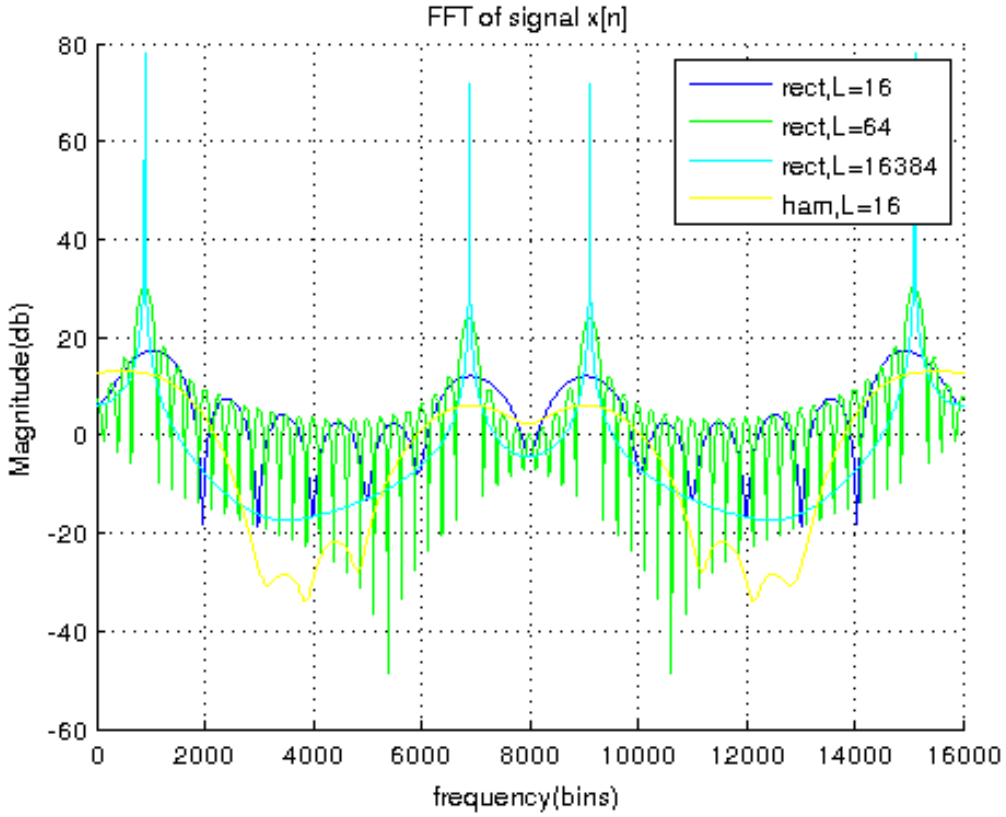
```
Nbig = 2^14;
Nbins = 16000;

%L=16
rectw = rectwin(16);
hamw = hamming(16);
```

B1.3 DFT with windows

```
figure(5); hold on; title('FFT of signal x[n]');
```

```
grid('ON'); xlabel('frequency(bins)'); ylabel('Magnitude(db)');

for n = 1:16
  x16(n) = (A1*cos(w1*n) + A2*cos(w2*n) ) *rectw(n);
end
plot( 20*log10(abs(fftshift(fft(x16, Nbins)))), 'b' ); hold on;

%L=64
rectw = rectwin(64);
for n = 1:64
  x64(n) = (A1*cos(w1*n) + A2*cos(w2*n) ) *rectw(n);
end
plot( 20*log10( abs(fftshift( fft(x64, Nbins)) )), 'g'); hold on;
%
% %L=512
% rectw = rectwin(512);
% for n = 1:512
%   x512(n) = (A1*cos(w1*n) + A2*cos(w2*n) ) *rectw(n);
% end
% plot( 20*log10( fftshift(abs(fft(x512, Nbins)) )) , 'r');
%exw problima edw

L=2^14;
rectw = rectwin(2^14);
for n = 1:2^14
  xbig(n) = (A1*cos(w1*n) + A2*cos(w2*n) ) *rectw(n);
end
plot( 20*log10(abs(fftshift( fft(xbig, Nbins)))), 'c');

for n = 1:16
  x16(n) = (A1*cos(w1*n) + A2*cos(w2*n) ) *hamw(n);
end
plot( 20*log10(abs(fftshift( fft(x16, Nbins)))), 'y' );


legend('rect,L=16', 'rect,L=64', 'rect,L=16384', 'ham,L=16');
hold off;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%% MEROS B2  Voice recording, spectrogram %%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% fs: sampling frequency
% noverlap: number of samples each segment overlaps
% F: frequency interpolation
% den exei sumperilifthei o thorivos sto fasmatograma
%%%%% for fsample = 22KHz
% wind1 = hamming(2200); % points per segment for 22KHZ
% wind2 = hamming(220);
% noverlap = 110;

%%%%% for fsample = 16KHz %%%%%%%%%%
freqs = 0:10:5000;
fsample = 16000;
```

```
wind1 = hamming(1600); % points per segment for 16KHZ
wind2 = hamming(160); % points per segment, oso afksanetai exoume kaluteri poiotit
noverlap = 80; % overlap with 80 points per segment
```



B2.1 Record 20secs

-Se periptwsi pou den exoume ixografisei kati r = audiorecorder(fsample, 16, 1); recordblocking(r, 20); % speak into microphone... p = play(r); % listen to complete recording mySpeech = getaudiodata(r, 'double'); audiowrite('voice_no_filter16KHZ.wav', mySpeech, fsample);

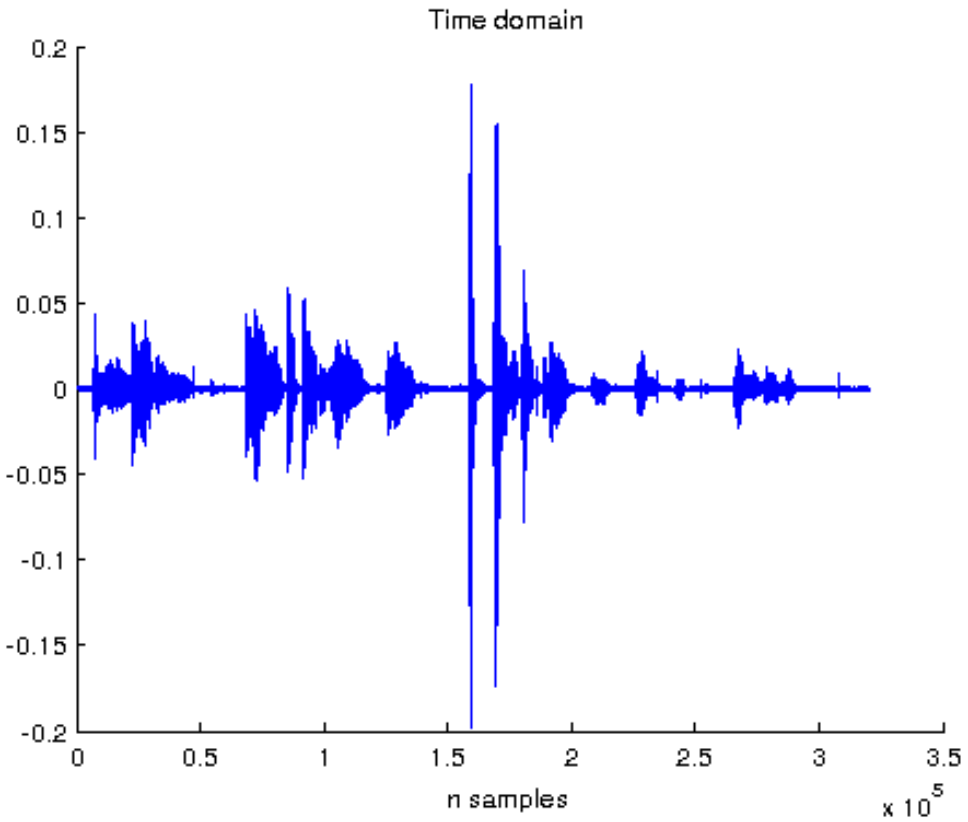
```
% -Se periptwsi pou exoume idi ixografisei kati
[mySpeech, fsample] = audioread('voice_no_filter16KHZ.wav');
```

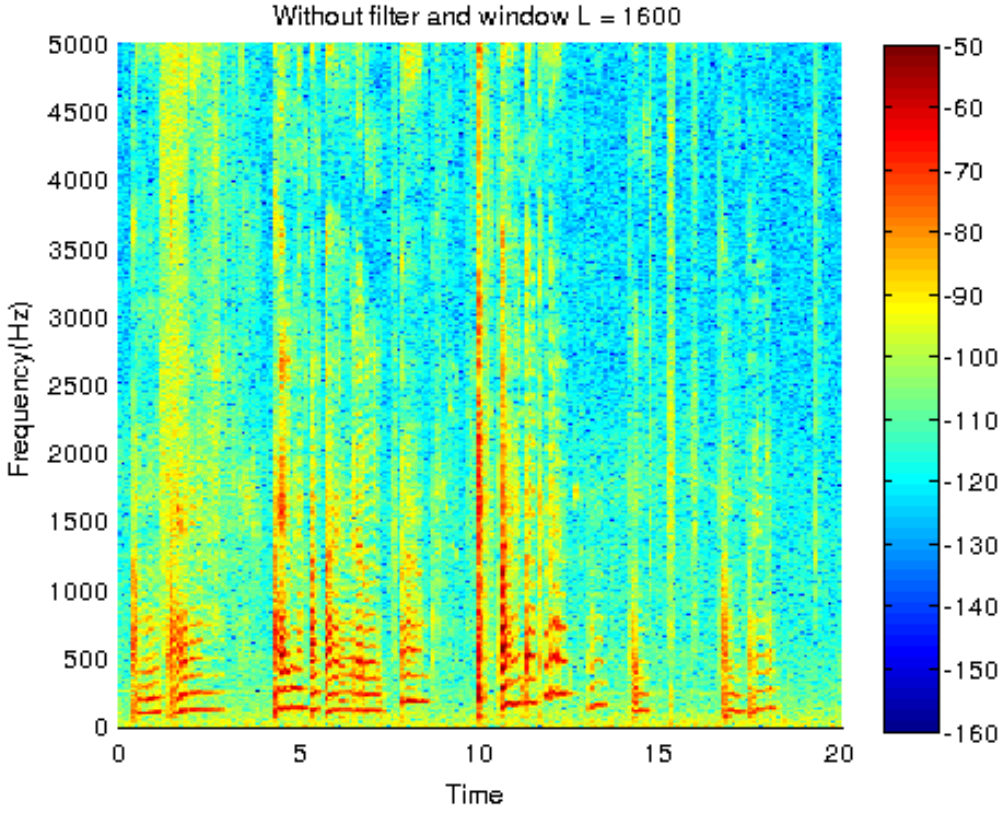
B2.2 Sound spectrograms, without lowpass

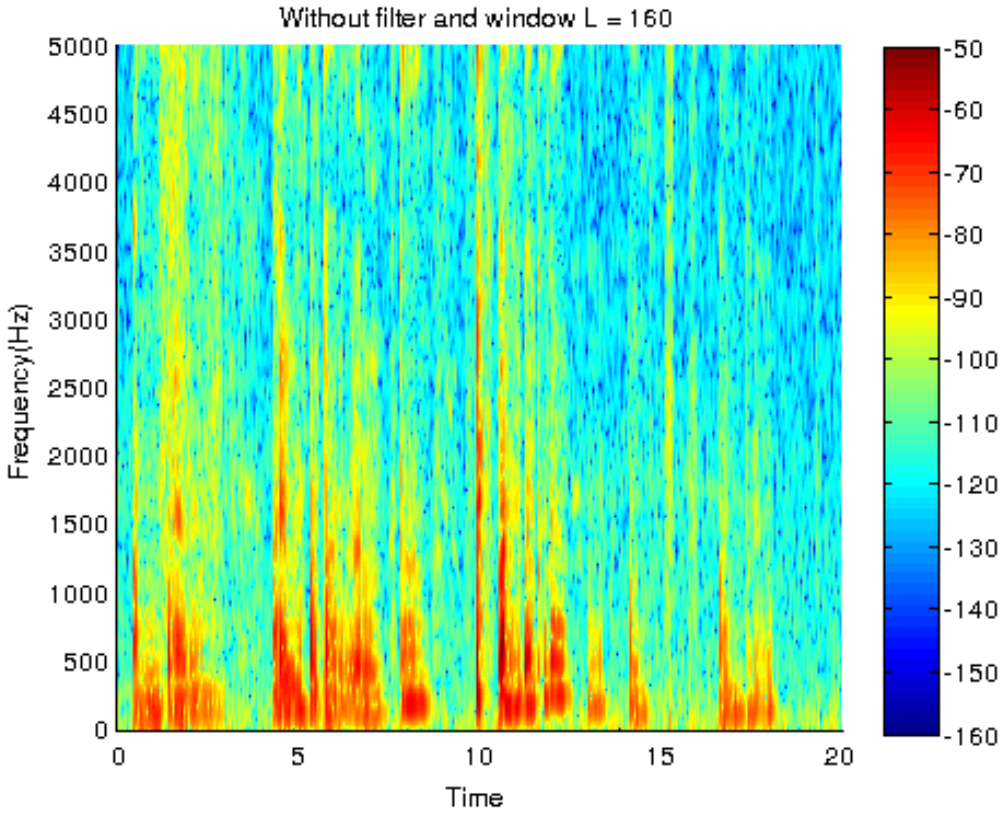
- Xrisimopoiw tin sinartisi imagsc wste na metaferw to sxima se morfi pdf. Alliws mporousa apla na xrisimopoihsw tin spectrogram xwris outputs - Gia L = 1600, paratiroume oti to dinatotero sima vrisketai sto diastima suxnotitwn [70, 180]. - Sima iparxei kai se psiloteres sixnotites(ana oktava diplasiazetai i suxnotita tou simatos) alla me mikrotero platos - An meiwthei to megethos tou parathirou se 160, den mporoume na analusoume tis suxnotites tou deigmatos to idio efkola - Stin prwti periptosi pou exoume megalutero mikos parathirou, iparxei kalyteri analusi(perissotera deigmata ana segment) kai etsi to ovelap epidra se mikrotero pososto

```
figure(9); hold on; title('Time domain'); plot(mySpeech);
xlabel('n samples'); hold off;
```

```
% window1
figure(10); hold on; title('SEGMENT SIZE = 1600 using hamming window');
[S, F, T, P] = spectrogram(mySpeech, wind1, noverlap, freqs, fsample, 'yaxis');
imagesc([0:0.1:20], F, 10*log10(abs(P)), [-160 -50] );
xlabel('Time'); ylabel('Frequency(Hz)'); title('Without filter and window L = 1600
axis xy; axis tight; colormap(jet); view(0,90);
colorbar();
hold off;

% window2
figure (11); hold on; title('SEGMENT SIZE = 160 using hamming window');
[S, F, T, P] = spectrogram(mySpeech, wind2, noverlap, freqs, fsample, 'yaxis');
imagesc([0:0.1:20], F, 10*log10(abs(P)), [-160 -50] );
xlabel('Time'); ylabel('Frequency(Hz)'); title('Without filter and window L = 160'
axis xy; axis tight; colormap(jet); view(0,90);
colorbar();
hold off;
```




Without filter and window L = 1600
Frequency(Hz)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
Time
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160

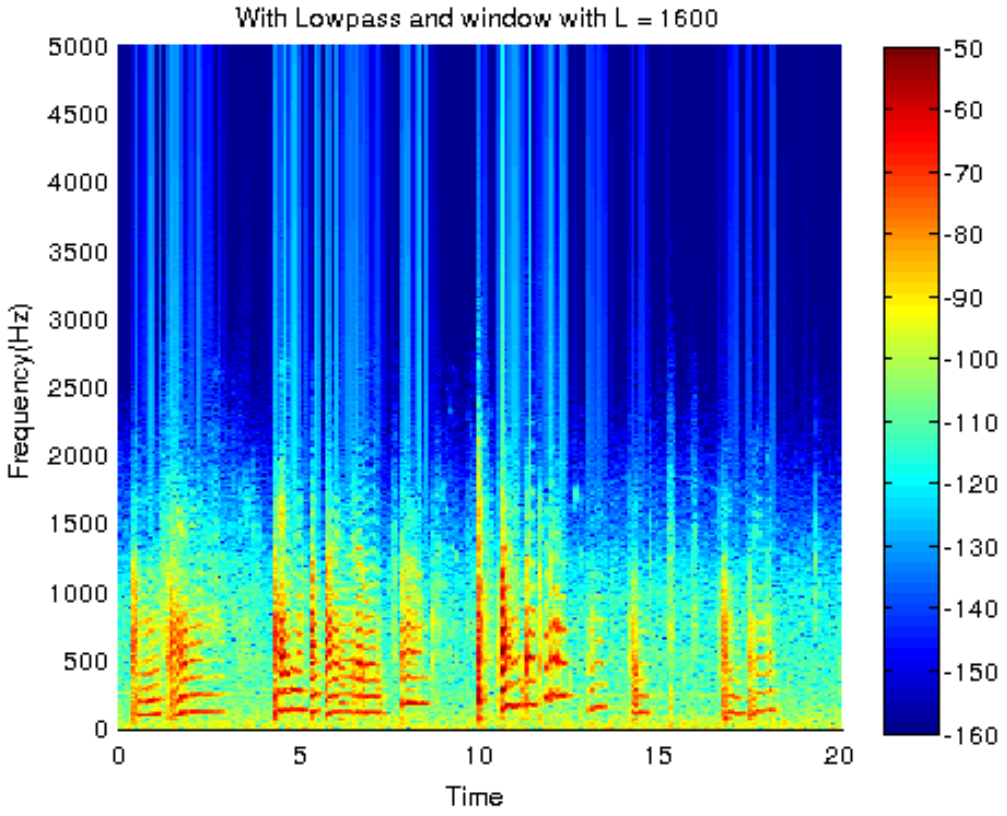

Without filter and window L = 160
Frequency(Hz)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
Time
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160

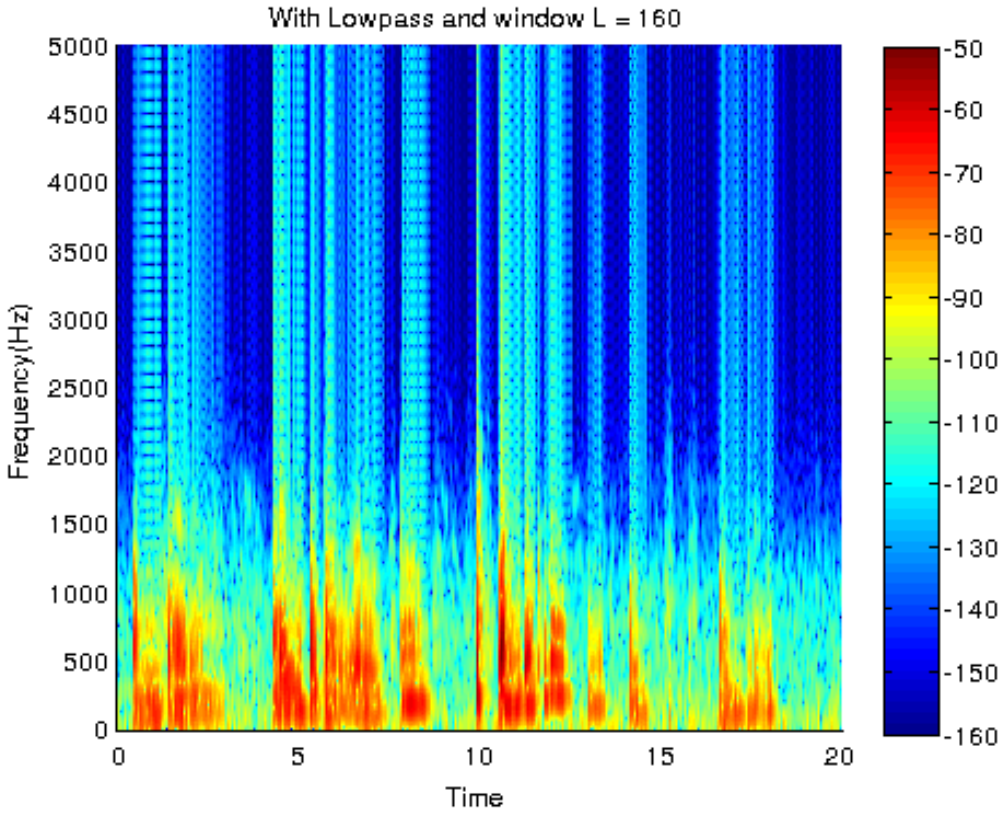
B2.3 Sound spectrograms with lowpass(IIR)

- Edw ilopoieitai to xamiloperato filtro - Syxnotita deigmatolipsias xrisimopoiw ta 16KHz

- Meta tin efarmogi toy katwperatou filtrou paratiroume oti ektos tou oti kovontai oi psiles sixnotites mikrainei kai to platos tou DFT epomenws meiwnetai i entasi. Afto ofeiletai ston metasximatismo Fourier afou an efarmosoume ena xamiloperato filtro Nvathmou, oso megalutero einai to N, toso mikrotero platos pairnoume - Dokimasame proeraitika na enisxusw to sima pollaplasiazontas to sto pedio tou xronou me to 2 alla fainetai pws to teliko sima den einai toso katharo

```
%speechFilt = filter(filtCoe, 1, mySpeech); dialeksa telika to IIR
speechFilt = filter(num, den, mySpeech);

audiowrite('voice_with_filter16KHZ.wav', speechFilt, fsample);
audiowrite('voice_amplified16KHZ.wav', 2 .*speechFilt, fsample);

% window1
figure (12); hold on; title('10ms Hamming with 5ms shift');
[S, F, T, P] = spectrogram(speechFilt, wind1, noverlap, freqs, fsample, 'yaxis');
imagesc([0:0.1:20], F, 10*log10(abs(P)), [-160 -50] );
xlabel('Time'); ylabel('Frequency(Hz)'); title('With Lowpass and window with L = 1
axis xy; axis tight; colormap(jet); view(0,90);
colorbar();
hold off;

% window2
figure (13); hold on; title('10ms Hamming with 5ms shift'); colorbar();
[S, F, T, P] = spectrogram(speechFilt, wind2, noverlap, freqs, fsample, 'yaxis');
imagesc([0:0.1:20], F, 10*log10(abs(P)), [-160 -50] );
xlabel('Time'); ylabel('Frequency(Hz)'); title('With Lowpass and window L = 160');
axis xy; axis tight; colormap(jet); view(0,90);
colorbar();
hold off;
```


With Lowpass and window with L = 1600
Frequency(Hz)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
Time
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160


With Lowpass and window L = 160
Frequency(Hz)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
Time
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160

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