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THE UNIVERSITY OF HONG KONG

THE UNIVERSITY OF HONG KONG

DEPARTMENT OF ELECTRICAL & ELECTRONIC ENGINEERING

ELEC6081/MEDE4504 Biomedical Signals and Systems

Assignment Cover Sheet

Assignment No.:	**1**
Submission Date:	**10/10/2014**
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Date Received:	
Grade:	
Comments:	
Teaching Assistant:	

1. EMG Analysis

1.1. EMG Signal and Periodogram. Downsampled EMG Signal and Periodogram.

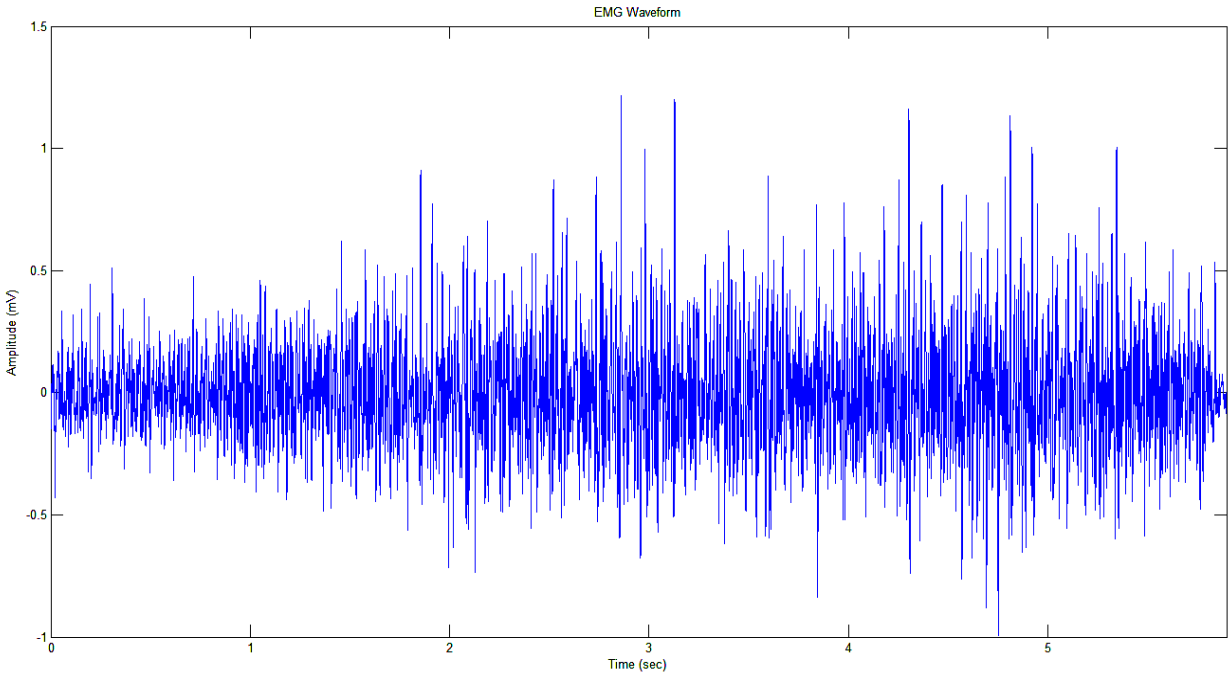

Figure 1: Original EMG Signal

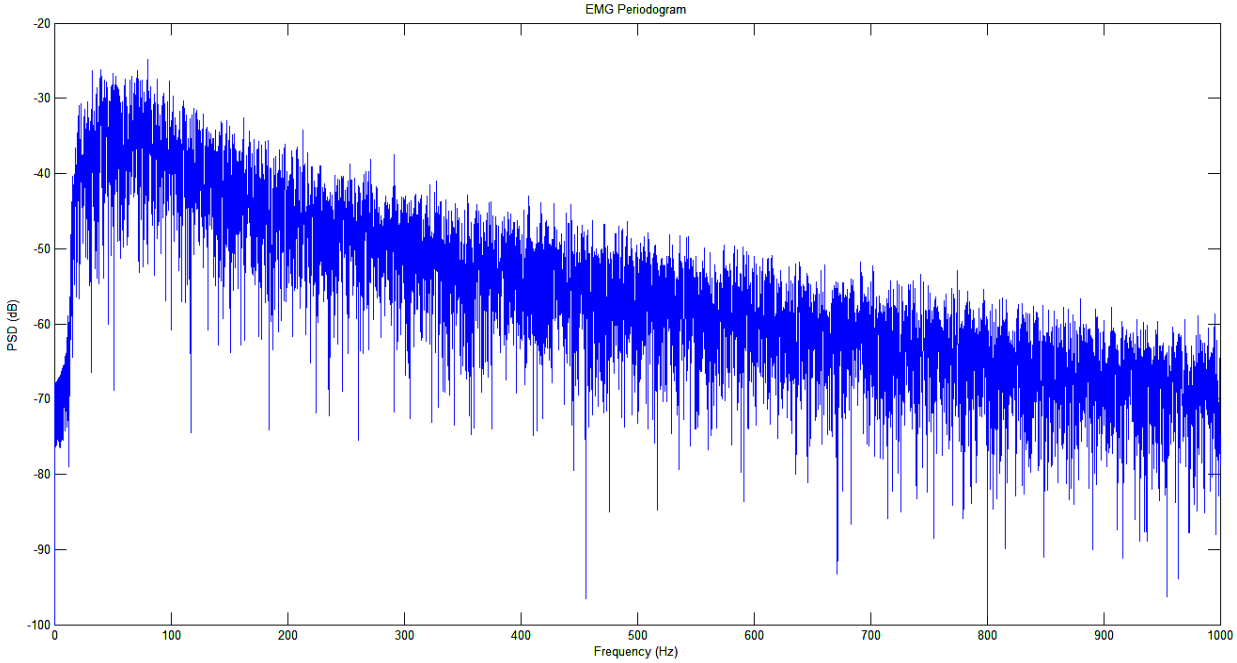

Figure 2: Periodogram of Original EMG Signal

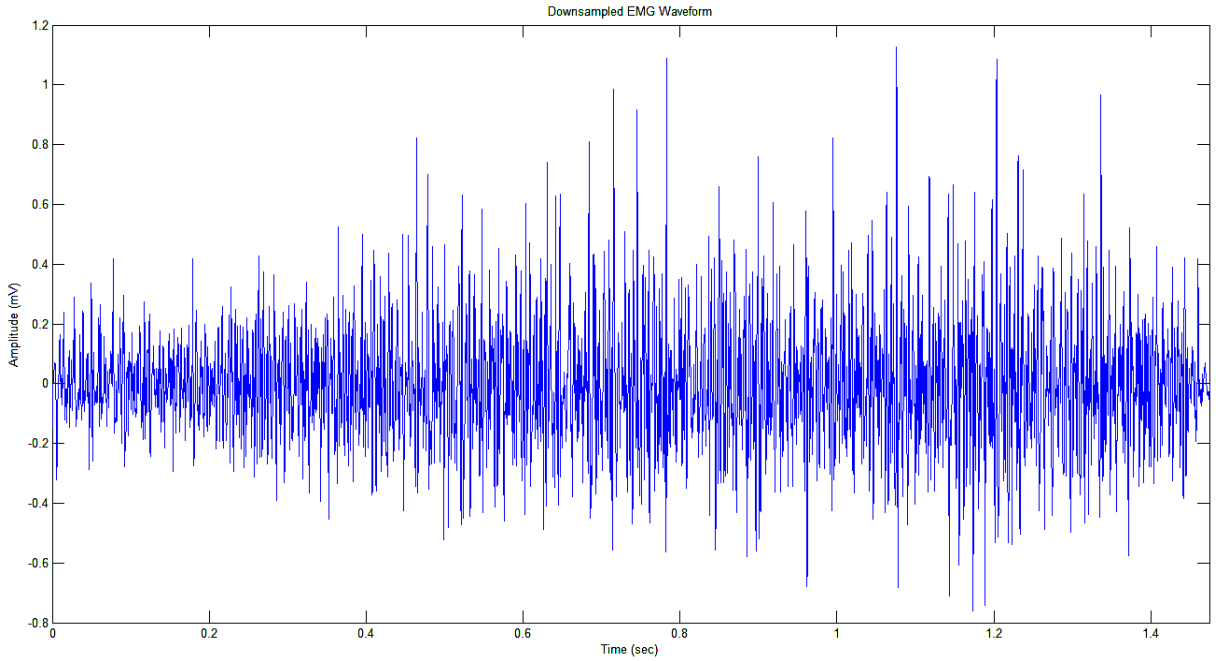

Figure 3: Downsampled EMG Signal

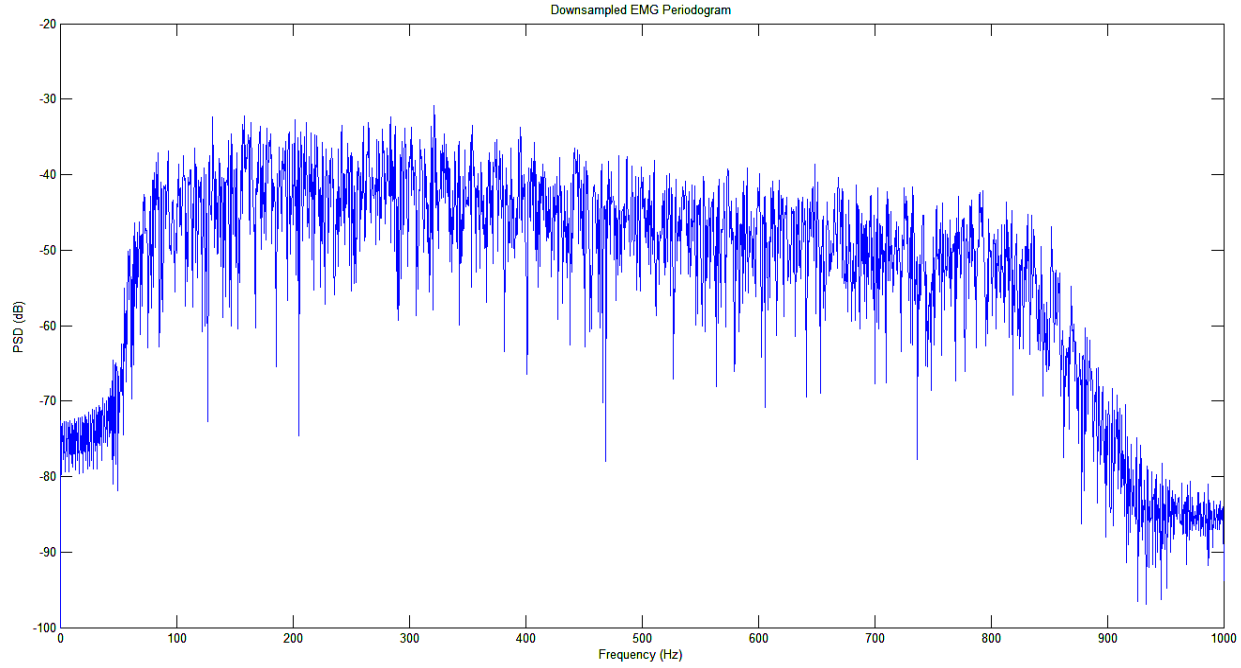

Figure 4: Periodogram of downsampled signal

Describe the difference between the periodograms of the original signal and the downsampled signal.

The periodogram of the downsampled signal seems to have gone through a bandpass filter with cut off frequencies around 100 Hz and 800 Hz, whereas the orginal signal's periodogram doesn't seem to have this filter. The original periodogram had the highest frequency at 1000 Hz, so the minimum sampling

frequency should be 2000 Hz, however when we downsampled, our new sampling frequency is 500 Hz, this violates the Nyquist-Shannon Sampling theorem causing incorrect sampling. The periodogram of the downsampled signal is aliased and has frequencies above Fs/2 duplicated (indistringuishable).

1.2. PSD using Welch Method, with 2000, 1000, and 5000 segment lengths.

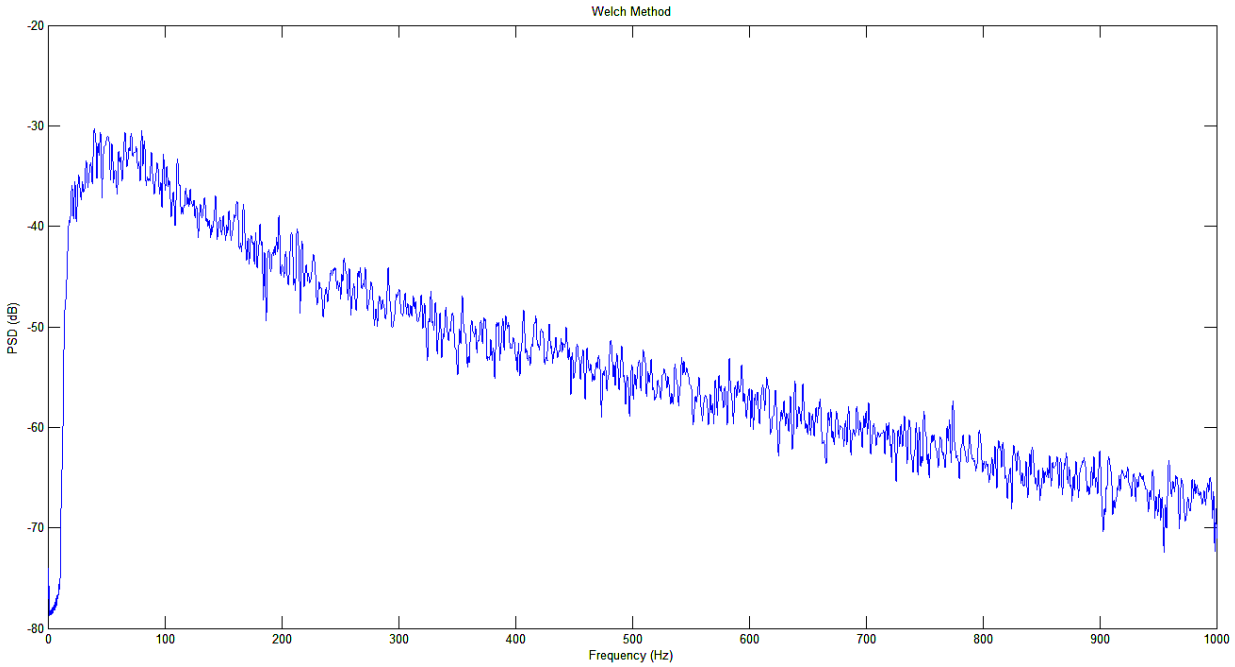

Figure 5: Welch's Method at 2000 samples

Describe the difference between periodogram and Welch's Method.

The periodogram is noisy and has large variance, whereas the Welch's Method is smoother, with less variance and less noise. The Welch's Method also has less frequency resolution compared to the periodogram.

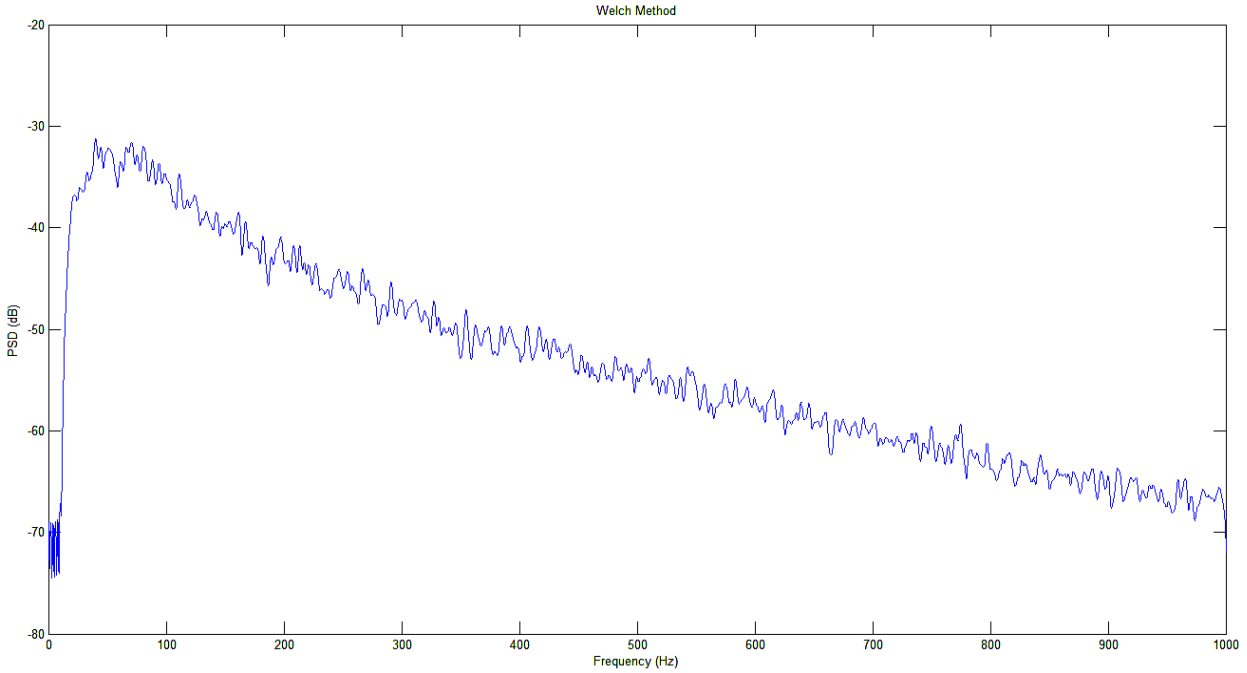

Figure 6: Welch's Method at 1000 Samples

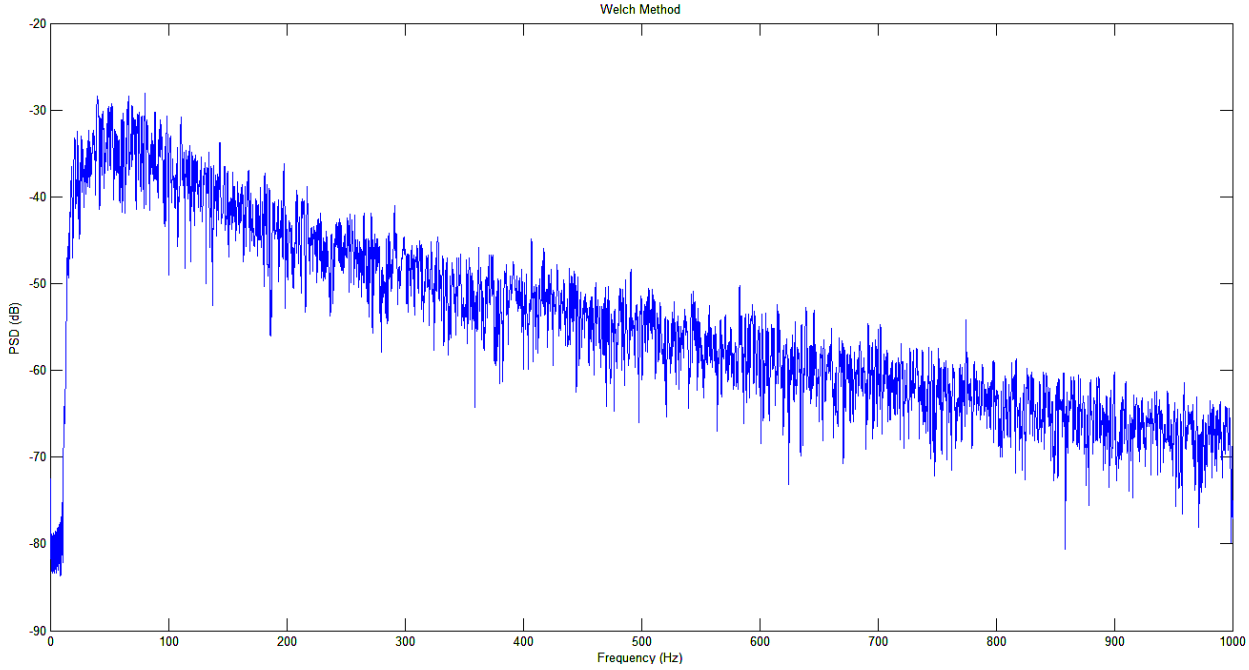

Figure 7: Welch's Method at 5000 samples

Describe how the length of the segment influences the PSD estimates of the Welch's Method.

As the segment length increases the variance of the PSD increases. Variance of PSD estimate is proportional to segment length. Increase in segment length increases frequency resolution.

1.3. AR-based PSD using Yule-Walker Method. AIC selected model order, model order 20 and 500.

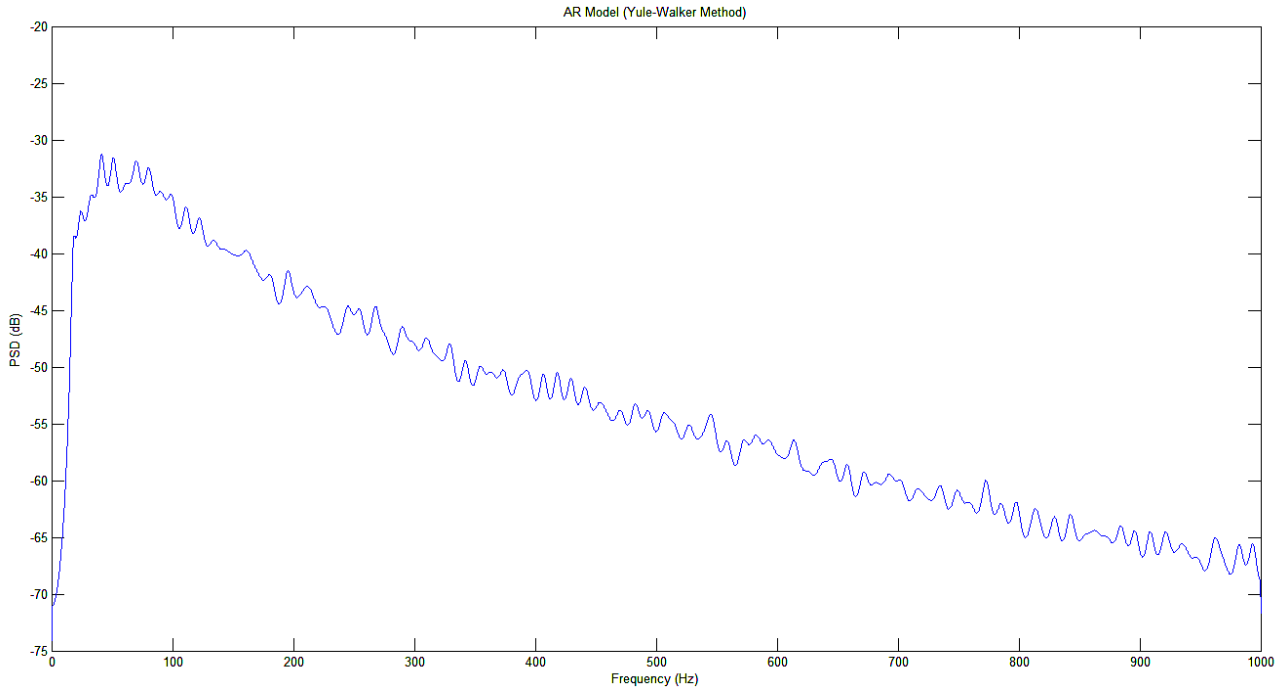

Figure 8: AR (Yule-Walker) Method using AIC order selection (model order = 188)

Describe the difference between the periodogram and the AR PSD.

The AR PSD is smoother compared to the periodogram. The AR model represents the peaks in the spectrum well. However, it doesn't represent the dips in the spectrum well compared to the periodogram. The AR PSD has less variance compared to the periodogram.

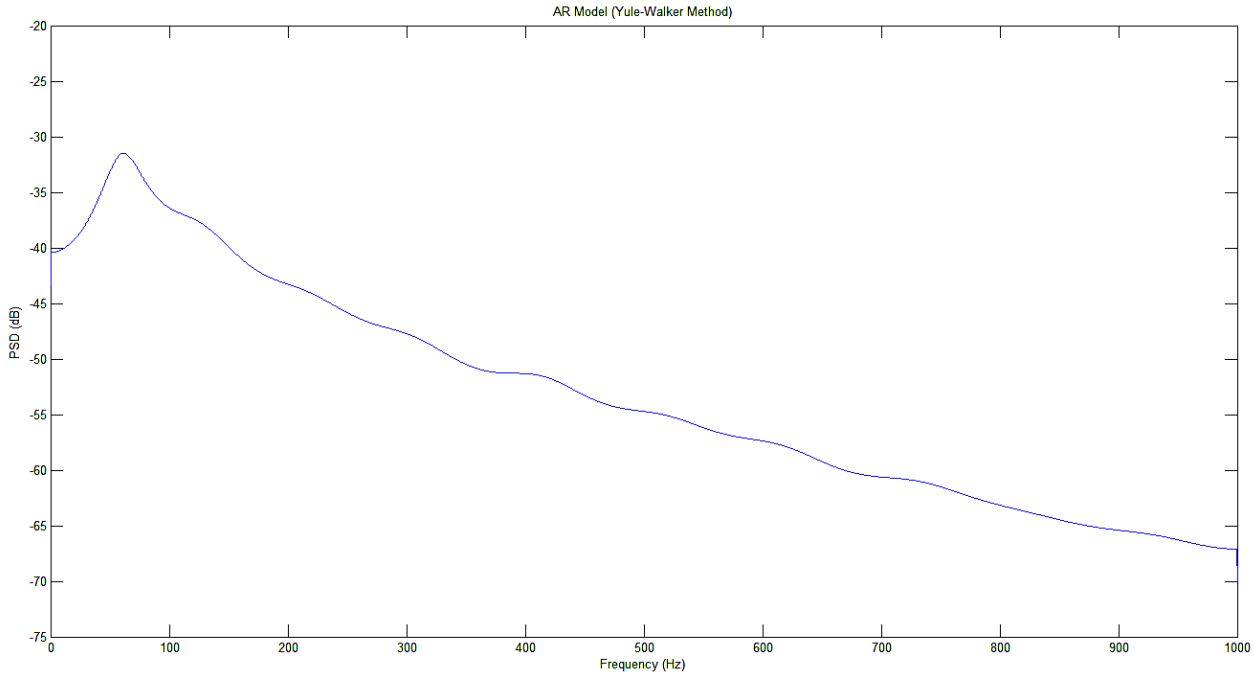

Figure 9: AR PSD with model order 20

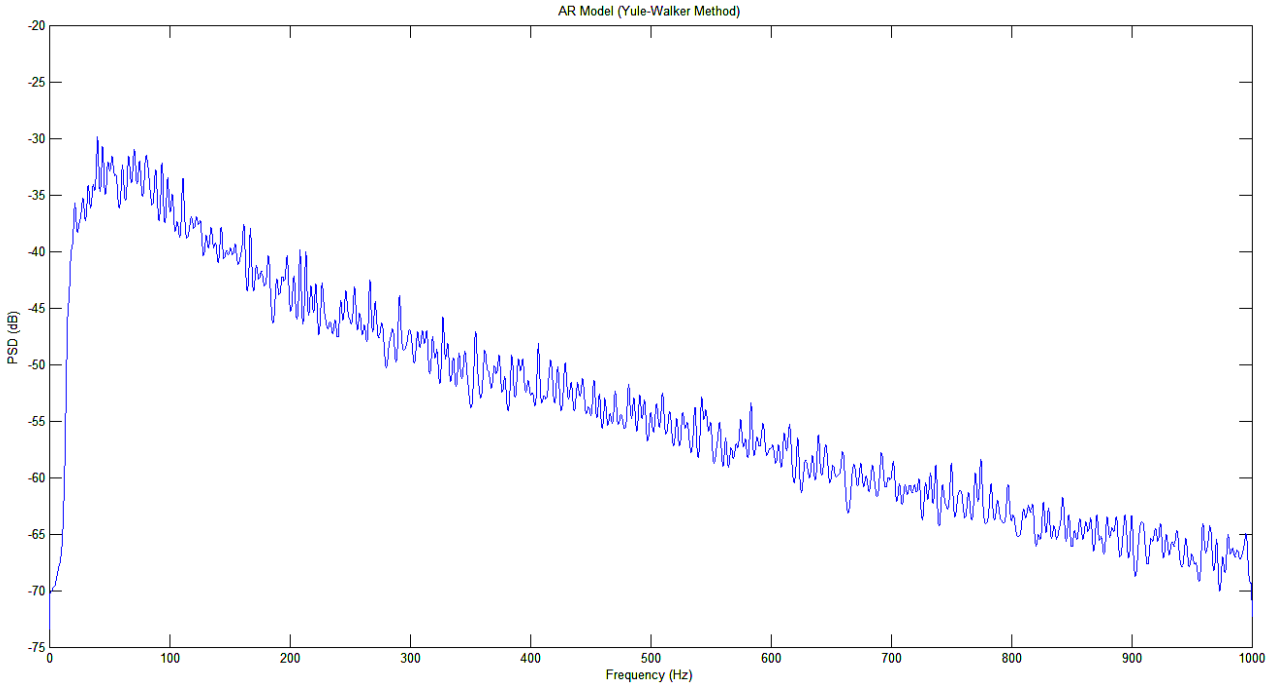

Figure 10: AR PSD with model order 500

Describe how the model order influences the AR-based PSD estimates.

Increasing the model order increases the variance of the AR PSD estimate. Increasing the model order also increases the frequency resolution of the PSD estimate.

1.4. Frequency Response of 6-order Butterworth bandpass filter (10 Hz to 250 Hz). 101 – 200 samples of original signal, and filtered signals, *'filter.m'* and *'filtfilt.m'*.

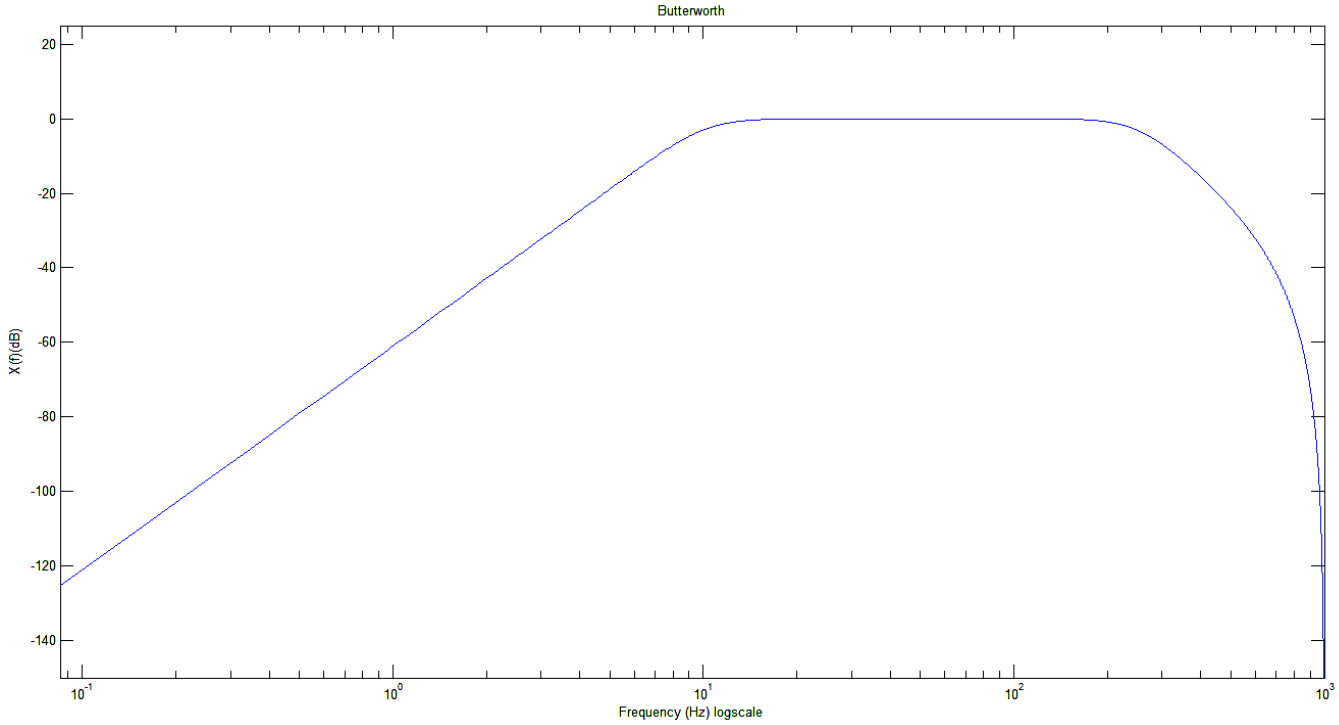

Figure 11: Frequency Response of 6-order Butterworth bandpass filter (10-250 Hz)

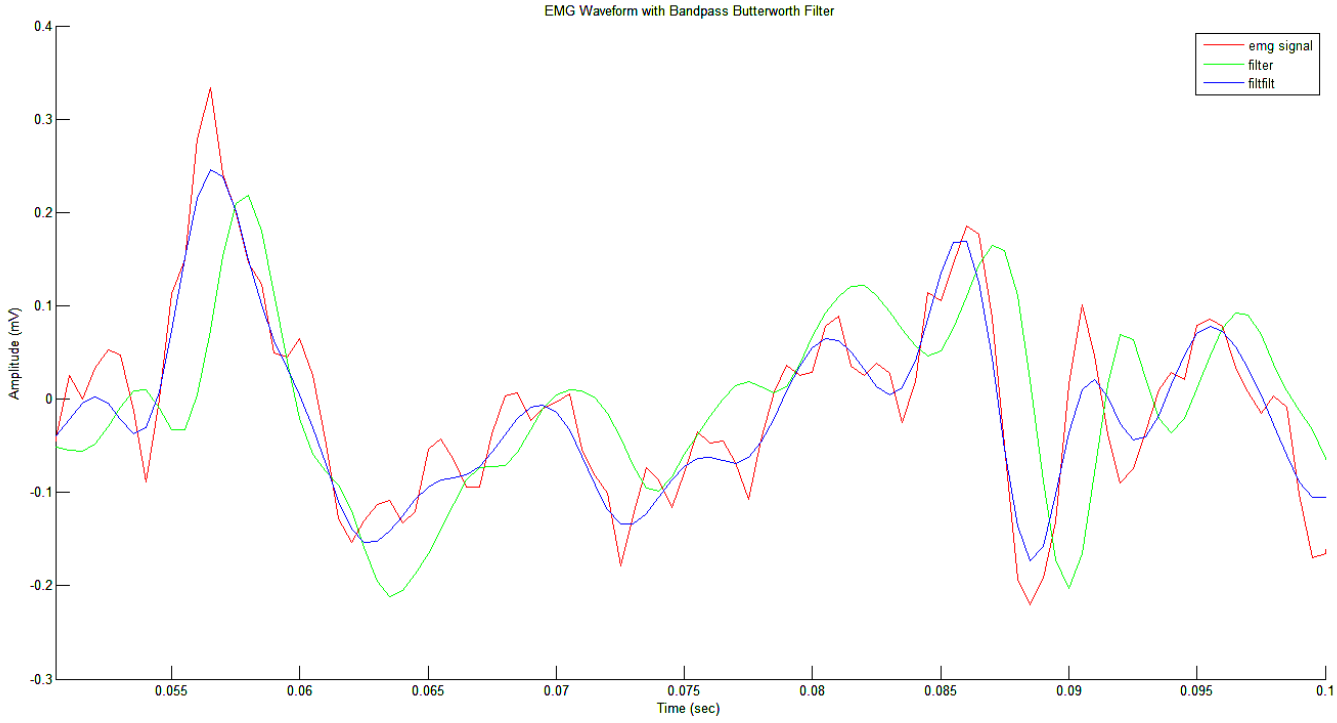

Figure 12: EMG signal, filtered signal (filter, filtfilt)

Discuss the difference in filtered results and explain the reason.

The 'filter.m' result has a phase shift from the original signal, whereas the 'filtfilt.m' result doesn't have a phase shift from the original signal. This is due to the introduction of phase delay by the 'filter.m' when filtering, however 'filtfilt.m' performs bidirectional filtering (filters in forward and then in the backward direction), resulting in an exact zero-phase response (no phase delay). The filtered signal using 'filter.m' also has a change in morphology compared to the original signal, however, filtered signal using 'filtfilt.m' has no change in morphology compared to the original signal. Also, since the filter is not ideal, there is some attenuation in the filtered results compared to the original signal.

1.5. PSD of filtered signal (filtfilt.m) using Periodogram, Welch's Method, AR Method. PSD estimates (Welch's Method) of original signal and filtered signal.

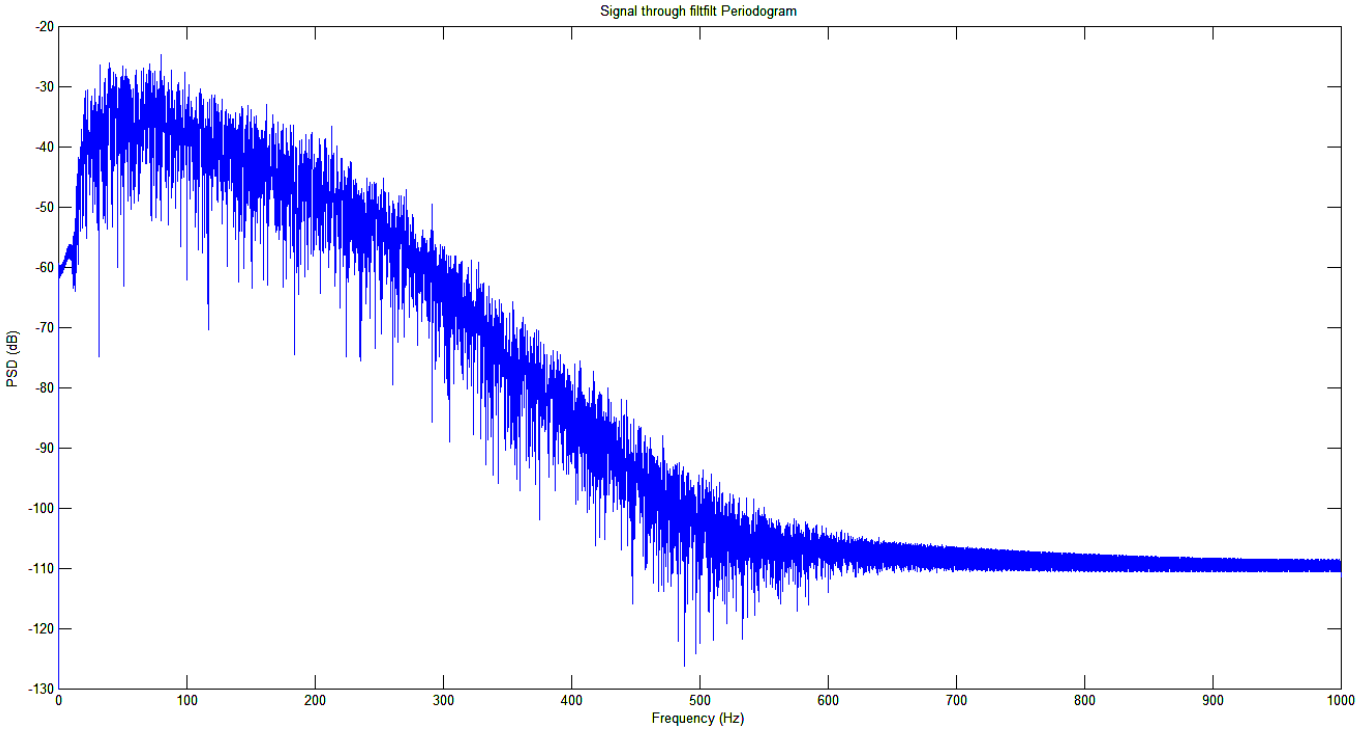

Figure 13: PSD of filtered signal using periodogram

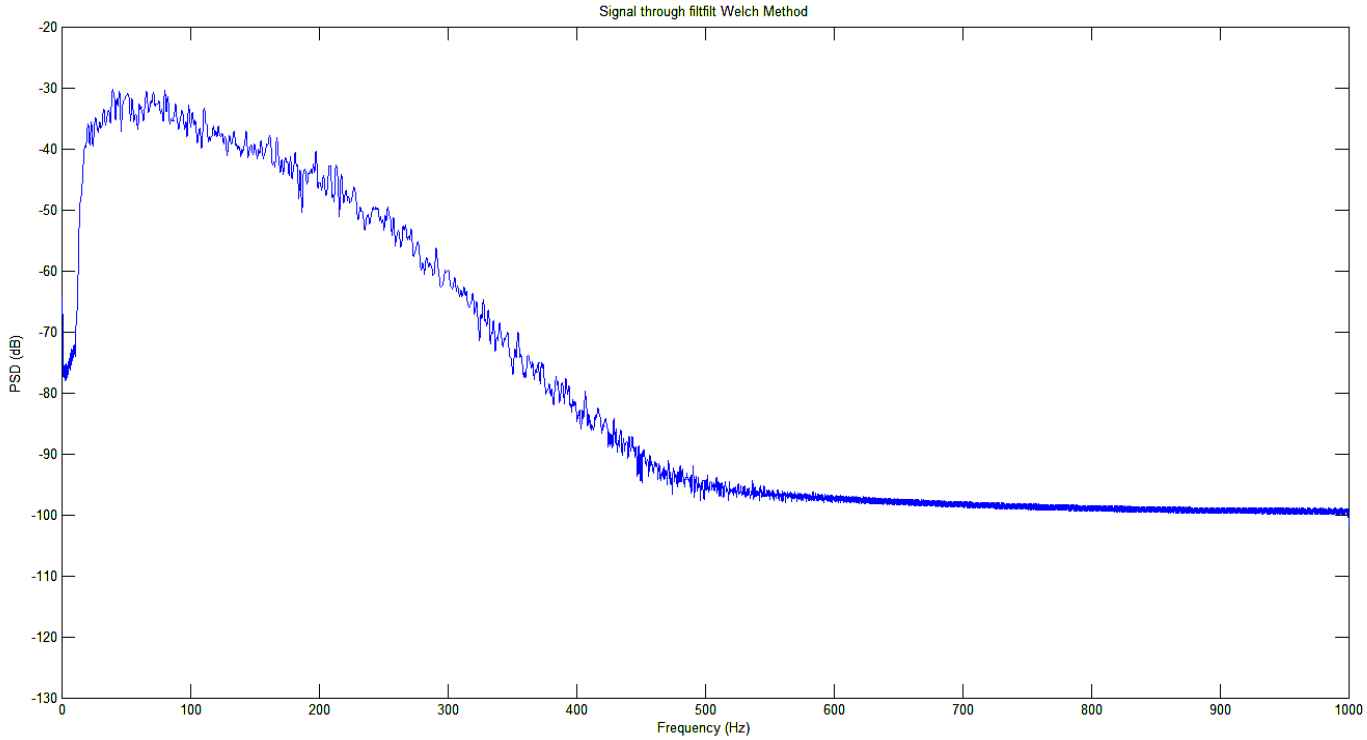

Figure 14: PSD of filtered signal using Welch's Method (hamming, M = 2000)

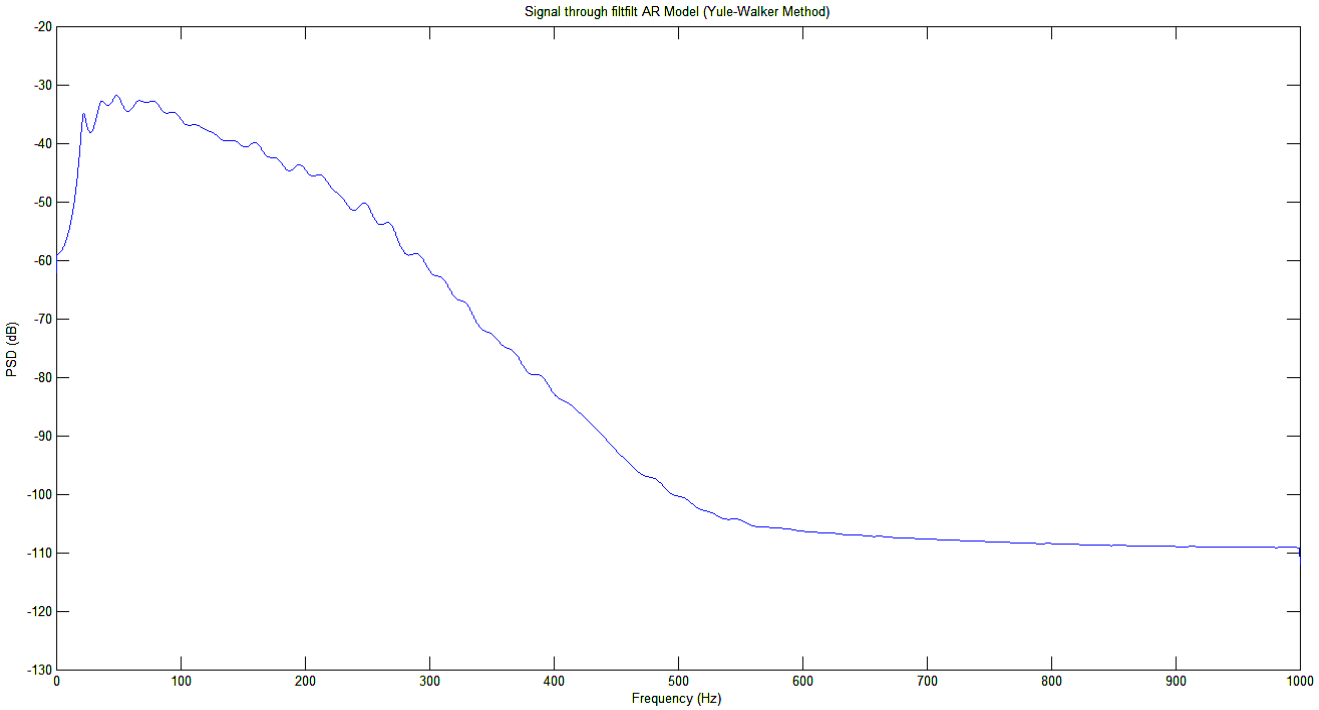

Figure 15: PSD of filtered signal using AR method (model order = 108)

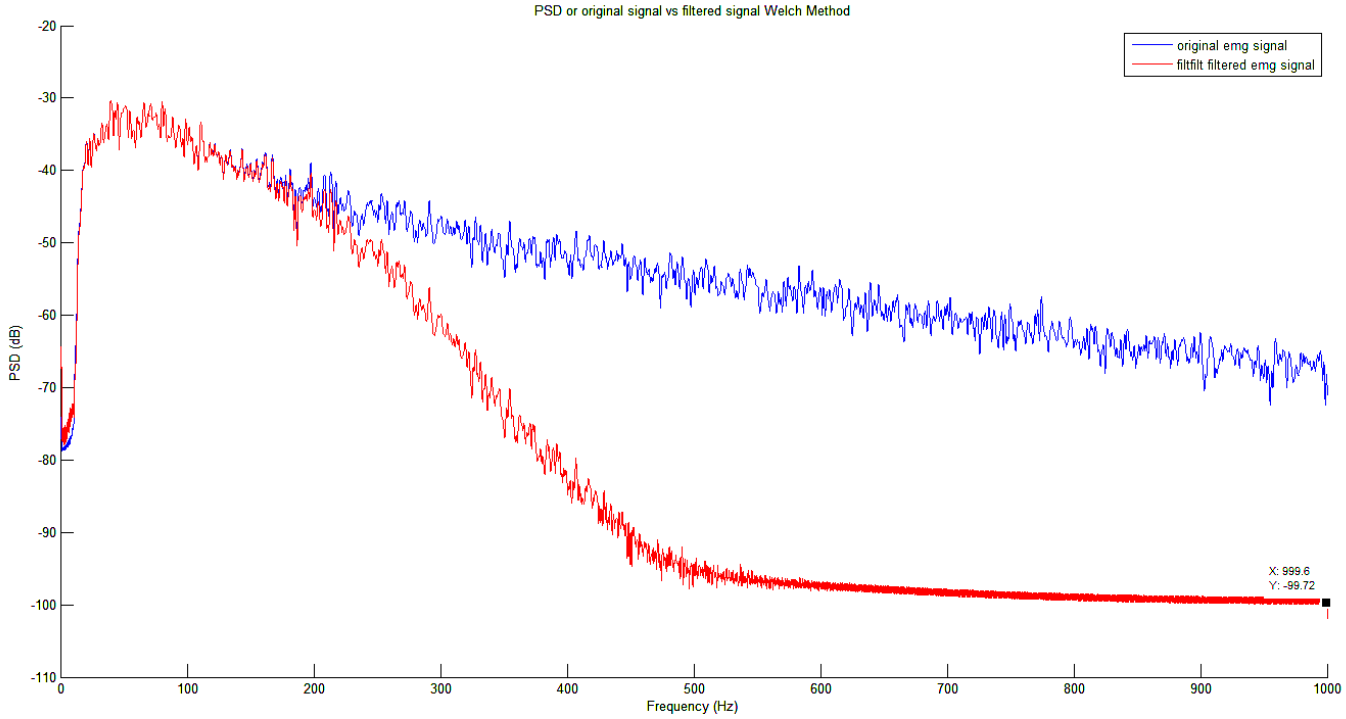

Figure 16: PSD of filtered signal vs PSD of original signal (Welch's Method)

Describe the difference between PSD of filtered signal and PSD of original signal.

The PSD of the original signal covers the full range of the signal's spectrum, however the PSD of the filtered signal attenuates between 0 to 10 Hz and from 250 Hz onwards. Due to the non-deal nature of the filter there is gradual attenuation on the edges of the filter.

2. EEG Analysis

2.1. EEG Signal.

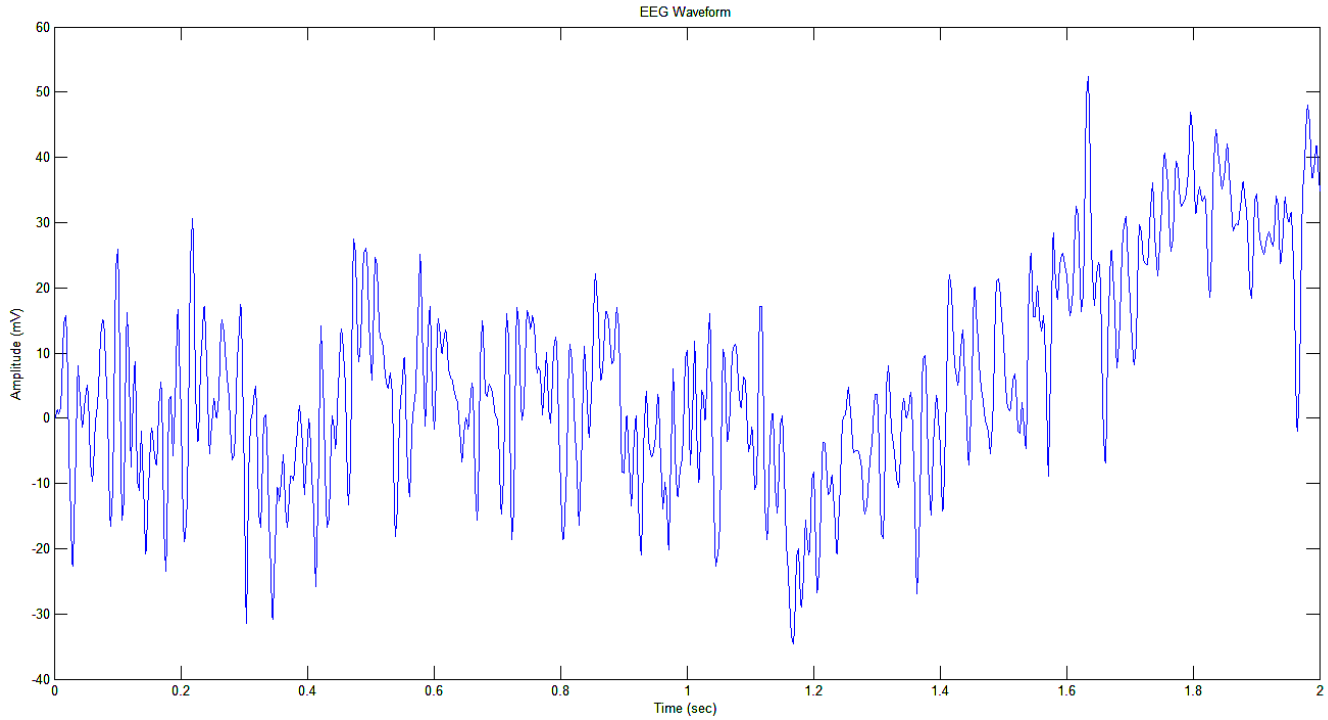

Figure 17: EEG Signal

2.2. PSD of EEG Signal using Periodogram, Welch's Method and AR Method.

Parameters Used

nfft: 1024, Fs: 500

Periodogram: `[P_per, f] = periodogram(x,[],nfft,Fs); % calculate periodogram`

Welch's Method: `[wPS,wF] = pwelch(detrend(eeg),hamming(500),[],nfft, Fs);%default is hamming window with 50% overlap`

AR Method: `[arPS, arF] = pyulear(eeg, p, nfft, Fs); % p = 12`

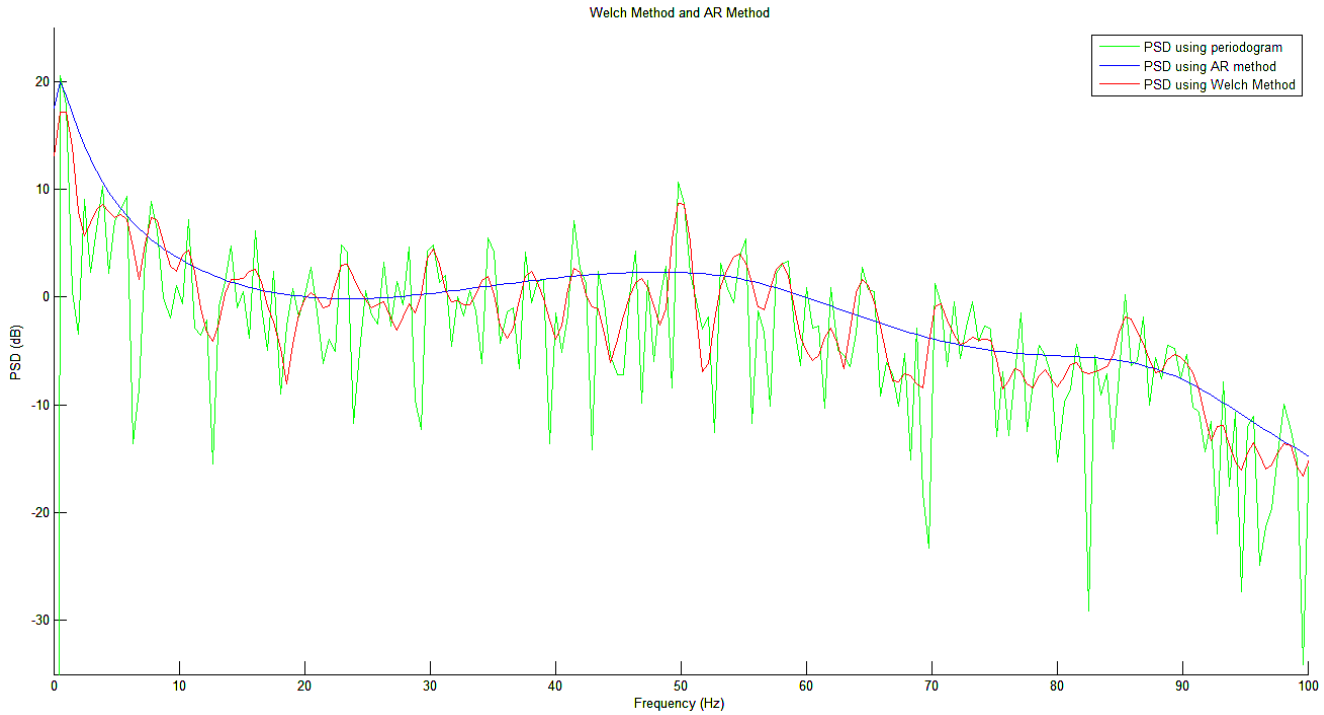

Figure 18: PSD of EEG signal, Periodogram, Welch's Method (hamming, M=500), AR Method (model order = 12)

2.3. High Pass and then Low Pass Filtering.

2.3.1. Output of Highpass filter, signal and its PSD estimated (Periodogram, Welch's Method, AR Method).

2.3.2. Output of Lowpass filter, signal and its PSD estimated (Periodogram, Welch's Method, AR Method).

Parameters used:

nffts: 1024, Fs: 500

Filters:

```
%% highpass filter
Wp = 3/(Fs/2);
Ws = 1/(Fs/2);
Rp = 3;
Rs = 60
[n, Wn] = buttord(Wp,Ws,Rp, Rs); % n = 7, filter order
[b a] = butter(n, Wn, 'high');

%% lowpass filter
Wp = 30/(Fs/2);
Ws = 50/(Fs/2);
Rp = 3;
Rs = 60
[n, Wn] = buttord(Wp,Ws,Rp, Rs); % n = 13, filter order
[c d] = butter(n, Wn, 'low');
```

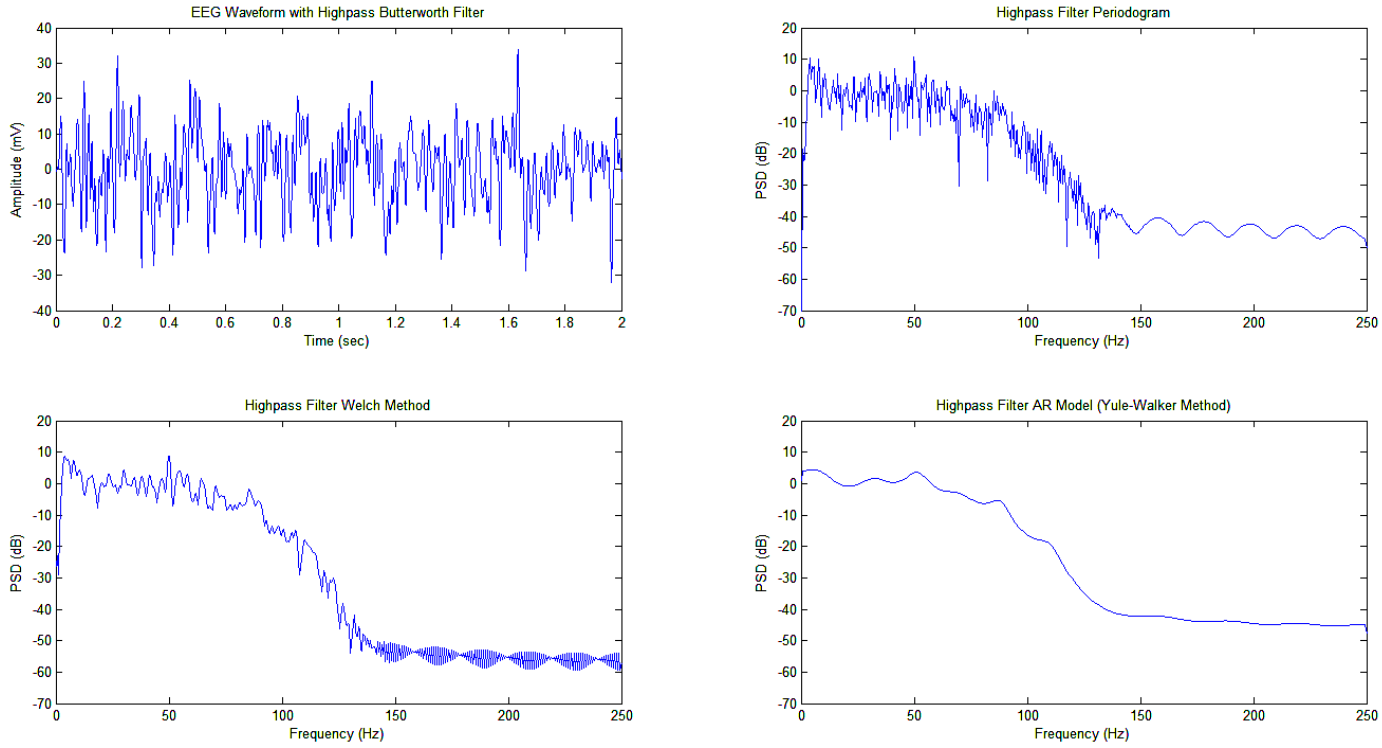

Figure 19: Output from High Pass Filter

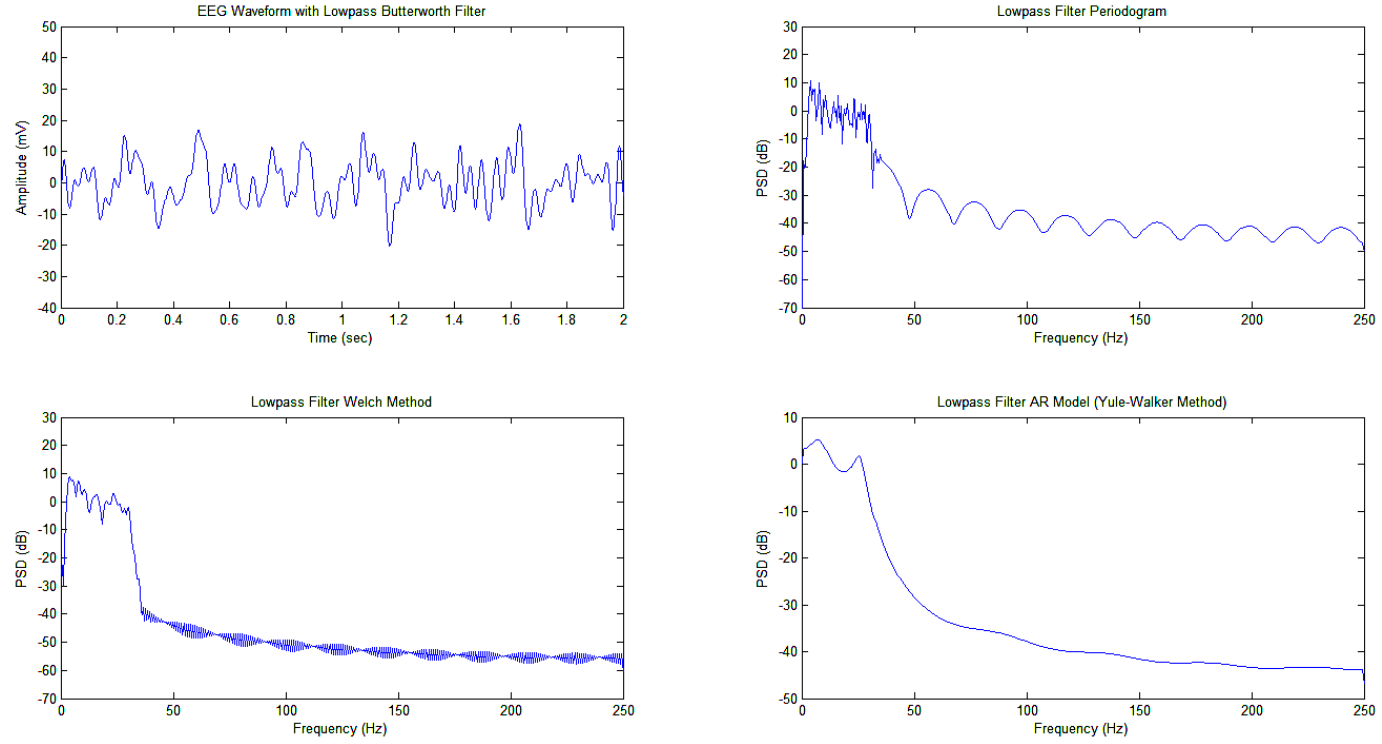

Figure 20: Cascaded Output from Low Pass Filter

For Output form High Pass Filter the PSD Parameters are:
Welch Method (hamming, M = 500), AR Method (model order = 19)

For Output form High Pass Filter the PSD Parameters are:
Welch Method (hamming, M = 500), AR Method (model order = 12)