Power Line Interference and Baseline Removal in ECG

Sai Venkatesh Balasubramanian

Sree Sai Vidhya Mandhir, Mallasandra, Bengaluru-560109, Karnataka, India

saivenkateshbalasubramanian@gmail.com

Abstract:

Power Line Interference, typically occurring at 50-60Hz frequencies and baseline drift at sub-Hertz ranges are two of the key sources of corruption of ECG signals. In this short article, elimination/mitigation of these effects using notch and high pass filters termed DC notch filters are discussed. The results plotted highlight effective removal of PLI and baseline effects.

Keywords: ECG, Power Line Interference, Baseline, Signal Processing, Digital Filters

1. Introduction

The importance of electrocardiogram (ECG) signals in diagnosis of various cardiac pathologies such as arrhythmia, tachy/brady-cardia and hypertrophy can hardly be over-emphasized [1-3]. Most of these diagnoses depend on reading the widths of various components of the ECG signal, such as the P wave, the QRS complex and the T wave [1-3]. In state-of-the-art signal processing systems, this is typically carried out using wavelets [4-6]. However, before wavelet based algorithms can be applied on a real-time ECG signal, appropriate signal conditioning needs to be performed to remove the corrupting sources in the ECG [4-6].

Taking note of the fact that a typical ECG signal is periodic corresponding to a heart rate of 60-72 beats per minute (1-1.2Hz), two of the main corrupting sources in an ECG are the power line interference, occurring as a high frequency noise at 50Hz and the baseline drift of sub-Hertz frequencies, which causes the ECG base line to fluctuate slowly [7-9]. In the present work, the design of a notch filter at 50Hz to remove power line interference, and the design of a high pass filter to remove baseline effects are briefly discussed.

2. Methodology

The power line interference is assumed to occur at 50Hz, and a baseline of 0.1Hz is assumed. A sample ECG signal is taken for analysis from http://forums.ni.com/ni/attachments/ni/170/322886/1/ecg.txt and is illustrated in Fig. 1.

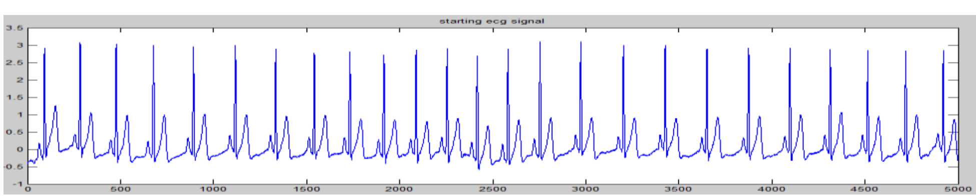

Figure 1 A Sample ECG Signal

In the original signal, each cycle lasts for 800 samples, and by using a decimation factor of 4, this number is reduced to 200 samples. Assuming a heart rate of 75 beats per minute, one obtains a sample duration of 4ms, and a sampling frequency of 250Hz. The PLI amplitude is set to 16.67% and baseline amplitude to 20% of ECG peak amplitude.

3. Power Line Interference (PLI) Removal

To remove PLI a notch filter with notch frequency at 20% sampling rate and Nyquist frequency at 50% of sampling rate is set up. The relative notch width is set to 0.3, and this factor determines the roll-off rate and Q Factor. The poles and zeros of such a notch filter are shown in Fig. 2, and the corresponding filter characteristics are shown in Fig. 3.

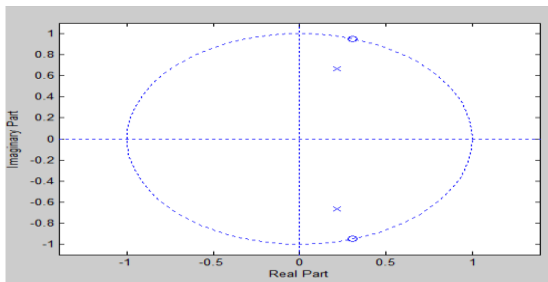

Figure 2 Poles and Zeros of the Notch Filter

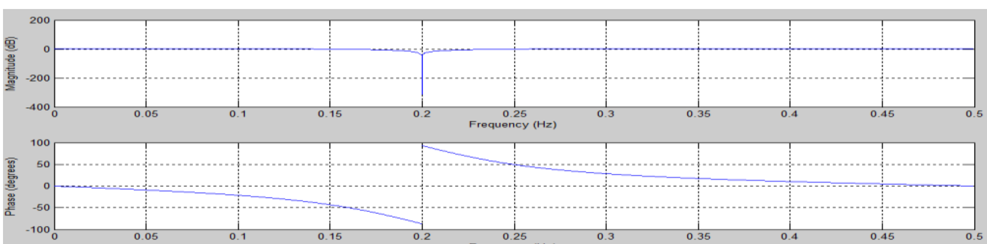

Figure 3 Notch Filter Characteristics

The ECG signal added with a simulated Power Line Interference at 50Hz and 16.67% amplitude is shown in Fig. 4, along with the filtered output using the designed notch filter, implemented using MATLAB.

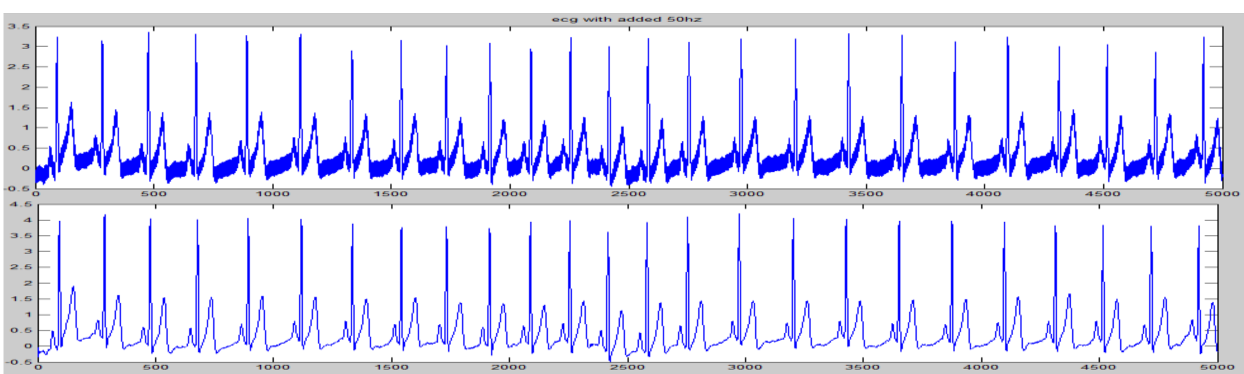

Figure 4 Application of Notch filter to ECG with PLI

It can be seen from Fig. 4, that the Notch filter is able to significantly remove the noise caused due to PLI.

4. Baseline Removal

To remove baseline, a high pass filter, termed the "DC Notch Filter" is used, with the z-domain Response given as follows:

$$H(z) = \frac{1 - z^{-1}}{1 - \gamma z^{-1}} \qquad (1)$$

Thus, the poles and zeros are given using b=[1 -1] and a=[1 - γ], with the factor 'γ' determining the filter characteristics. Setting γ to 0.99, one obtains the filter characteristics as in Fig. 5.

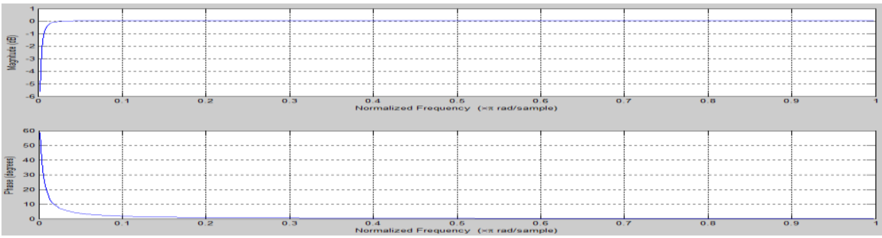

Figure 5 DC Notch Filter Characteristics

The ECG signal added with a simulated Baseline at 0.1Hz and 20% amplitude is shown in Fig. 6, along with the filtered output using the designed DC notch filter.

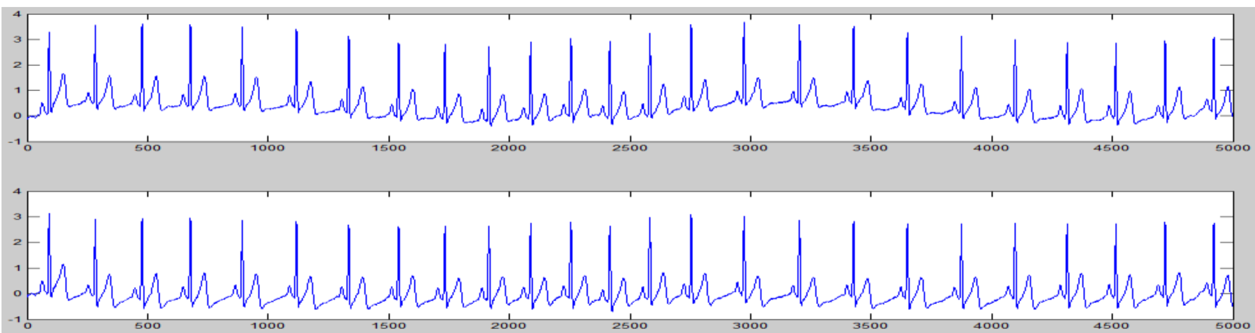

Figure 6 Application of DC Notch filter to ECG with Baseline

It can be seen from Fig. 6, that the designed filter is able to remove the baseline drift in the ECG signal.

Finally, the effect of both Notch Filter and DC Notch Filter applied in Tandem to an ECG signal with added PLI and baseline is studied and plotted in Fig. 7.

The effective removal of Baseline and PLI effects from the ECG signal is clearly seen.

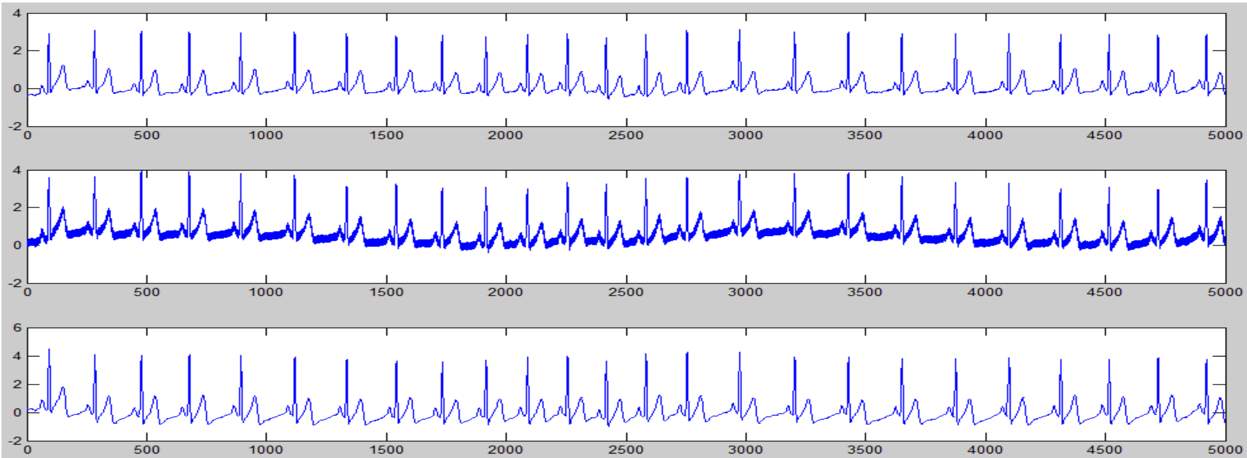

Figure 7 Application of Notch DC Notch filter to ECG with PLI and Baseline

5. Conclusion

In the present work, digital filters for the removal of two key sources of corruption in ECG signals, namely power line interference and baseline are discussed. Notch filters and DC notch filters are designed and are implemented using MATLAB. The results plotted highlight effective removal of PLI and baseline effects. The novelty of the present work lies in the simplicity of the designed filters, which enable them to be used for other applications such as pulse oximetry and respiratory signal extraction, apart from ECG signal processing.

References

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