

# Chapter 16

## Baseline Drift Removal of ECG Signal: Comparative Analysis of Filtering Techniques

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### ABSTRACT

*The filtering techniques are primarily used for preprocessing of the signal and have been implemented in a wide variety of systems for Electrocardiogram (ECG) analysis. It should be remembered that filtering of the ECG is contextual and should be performed only when the desired information remains undistorted. Removal of baseline drift is required in order to minimize changes in beat morphology that do not have cardiac origin, which is especially important when subtle changes in the “low-frequency” ST segment are analyzed for the diagnosis of ischemia. Here, for baseline drift removal different filters such as Median, Low Pass Butter Worth, Finite Impulse Response (FIR), Weighted Moving Average and Stationary Wavelet Transform (SWT) are implemented. The fundamental properties of signal before and after baseline drift removal are statistically analyzed.*

### INTRODUCTION

ECG measures electrical potentials on the body surface *via* contact electrodes. Conditions such as movement of the patient, breathing, and interaction between the electrodes and skin cause baseline wandering of the ECG signal. Baseline drift may sometimes be caused by variations in temperature and bias in the instrumentation and amplifiers as well. Baseline wandering noise can mask some important features of

DOI: 10.4018/978-1-5225-3158-6.ch016

the ECG signal; hence it is desirable to remove this noise for proper analysis of the ECG signal. The frequency range of the ECG signal is 0 - 150 Hz and the frequency range of the baseline noise based on respiration frequency is 0 - 0.3 Hz and it is altering with the movement of the patient. The American Heart Association states that the filter's cut-off frequency should be in the order of 0.67 Hz, since it is generally thought that the slowest heart rate is 40 bpm, implying the lowest frequency to be 0.67 Hz. But when the heart rate increases, this frequency also changes. Thus, an adaptive cut-off frequency selection is required. Lisette et al. (2004) has designed a heart rate adaptive real-time bidirectional baseline drift suppression filter for multiple lead ECG. The filter is optimized for minimal delay, minimal non-linear phase shift, minimal calculation power and maximal signal-to-noise ratio and minimal ECG signal. Lisheng et al. (2002); Rangayyan (2002) discusses in their research that clinicians measure slopes and time intervals in ST, RR and QT segments to predict any abnormalities in the cardiac activity. Therefore, the slope of the baseline should be zero for clean ECG data. When there is baseline wandering noise in the ECG signal, the slope deviates from zero, and this causes difficulties in the evaluation of ECG recordings. For example, baseline drift makes analysis of isoelectric part of the ST segment difficult especially when there is an ST segment elevation or depression, where the slope of the interval is significant. If there is baseline wandering noise, it would be hard to differentiate noise related slope from the slope of the ST segment. Also, a large baseline drift may cause the positive or negative parts in the ECG to be clipped or badly detected by the analog to digital converter (ADC) or the other hardware. Jane, R. & Laguna, P. (1992) describes the most basic techniques for removing baseline wandering noise, which is known as the cubic spline method. This method is used as a reference method in many studies and performances of other filters are compared with cubic spline. In this method, first the QRS complexes are detected. Then the baseline wander is estimated with a third order polynomial using various points on the ECG such as Q, R and S points or isoelectric baseline locations as the knots of the splines. Finally, the estimated noise is subtracted from the ECG signal. Cubic spline method has a number of disadvantages; for example, in the presence of high amplitude noise, QRS detector may not operate correctly. Also, baseline wander with sharp transitions may not be accurately described by a cubic polynomial so the order of filter should be increased.

Pottala, E. W. & Gradwohl, J. R. (1992) have employed a good method of correcting baseline distortion implementing high pass filtering technique. One such filtering technique is to employ Finite Impulse Response (FIR) filters where the output of the FIR filter is combined with a group delay. As the filter order increases, the complexity of the filter increases. However, if the filter order is selected to be low, then the noise suppression performance of the filter will decrease. Infinite Impulse Response (IIR) filters, on the other hand, can achieve a sharp transition region with a small number of coefficients. However, an IIR filter that has a cut-off frequency high enough to remove baseline wander has a non-linear phase response which distorts meaningful components of the ECG waveform. To avoid this distortion, bidirectional filters are used that filter the signal in a forward direction over a selected window and then the same window is filtered in a reverse direction. Pottala, E. W. (1989) has designed a filter having a non-linear phase response using bilinearly transform to filter baseline from an ECG waveform. In this approach, the data are filtered both forward and backward in time, thereby, removing nonlinearities injected by the IIR filter. A short window was selected so that the filter could be used for real time purposes. Avionics, D.M. (1993); Patricia, A., & Tim. L. (1992) describes bidirectional IIR filters and methods for removing baseline from ECG signal for online and offline cases and these filters are licensed by US Patents.

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