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# Elimination of Baseline Fluctuation in EMG Signal Using Digital Filter

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**ABSTRACT:** Electromyography (EMG) is the study of the skeletal muscle function and the contraction of the skeletal muscle result in the generation of action potential in the individual muscle fibers, it from get information in the diagnosis of neuromuscular disorders. Suitable removal of baseline fluctuation of EMG signals is very important issue when recoding EMG signals as it may be degrade quality and quantitative analysis. In this paper focus on digital filter design technique for removal of noise present in the baseline of the EMG signal. The method is to estimate the spectral contents of the BLF, and then to use this estimation to design a high pass chebyshev filter by using Bilinear Transformation that cancel the BLF in the EMG signal. This technique on real and simulated EMG signal gives their advantages and disadvantages in term of both visual inspection and merit figures. We analyzed EMG signal from the muscles in a healthy subjects at low force level, using the concentric needle electrode.

**KEYWORDS:** EMG signal, MUAP, Motor unit, Segmentation and Baseline fluctuation

## I. INTRODUCTION

The electromyography (EMG) signal is a signal and is measuring electrical signal associated with the activation of muscle, generated in muscles during its contraction representing neuromuscular activities. The EMG signal is a complex signal, which is controlled by the nervous system and is dependent on the anatomical and physiological properties of neuromuscular.

Electromyography (EMG) is the study of electrical activity of muscle and the study of electromyography (EMG) signal is a study of the properties and activities of the muscles. EMG signals are detected by placing and electrode into or over a muscles and detecting the extracellular voltage produced by the electrical activity of the muscle fibers. Electromyography (EMG) signal decomposition is the process of resolving an EMG signal into its constituent motor unit action potential trains (MUAPTs). The function of EMG signal decomposition is to provide an estimate of the firing pattern and motor unit action potential (MUAP) pattern of each active motor unit (MU) that contributed significant MUAPs to the EMG signal. The motor unit action potential (MUAP) expresses the electrical activity of the muscle fibers of a motor unit (MU) recorded from a concentric needle electrode, the shape of MUAP waveforms and the degree of similarity in consecutive firings contain important information about the nature and shape of a muscle. The quality of the EMG signal may be reduced by baseline oscillations, disturbing the processes of MUAP extraction, classification and analysis. The characteristics of EMG signals are dependent on a number of factors, including the anatomical and physiological of the muscle contraction, the types of electrode used and the location of the electrode relative the contracting muscle fibers. The shape of motor unit action potential (MUAP) reflects the pathological and functional shapes of the motor unit (MU). If rising muscle force then the EMG signal an increase in the number of activated MUAPs recruited at increasing firing rate, making it complicated for the neurophysiologist to distinguish individual MUAP waveforms. The baseline fluctuation (BLF) present in the recorded EMG signals is due to artifacts of different nature for example movement of the recording concentric needle electrode relative to the muscle, variation of skin potential induced by the needle electrode and electrical drifts in the acquisition equipment. When a small number of motor unit action potential train (MUAPT) are present in the EMG signal then much of the baseline fluctuation

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actually arises from variations in an MUAP waveform from one firing to the next and a larger amount of MUAPs are present in the EMG signal, the additional noise is produced by low amplitude MUAP waveforms. The information extracted from the EMG signal is of importance and is used for the diagnosis and treatment of the different neuromuscular disorders. An adequate removal of the baseline fluctuation (BLF) would enhance quality of the EMG signals. Electromyography signals can be used for variety of applications like clinical, biomedical and human machine interaction, prosthetic hand control etc.

The objective of in this work is to elimination of noise present in baseline of EMG signal. In this paper, digital filter designing technique is devised for cancellation of baseline fluctuation in EMG signal.

## II. MATERIAL

Analysis of the EMG signals from the muscles in healthy subjects at low force level, using concentric needle electrode. The signal was analogue band pass filtered at 3 Hz to 10 KHz and sampled at 20 KHz. The EMG signal was then low pass filtered at 8 KHz and down sampled by a factor of two at 10 KHz. The Recording equipment comprises an electromyography (EMG) and concentric needle electrodes. The electromyography amplifies the input EMG signals according to a manually selected gain. An EMG signal with baseline fluctuation is shown in Figure1.

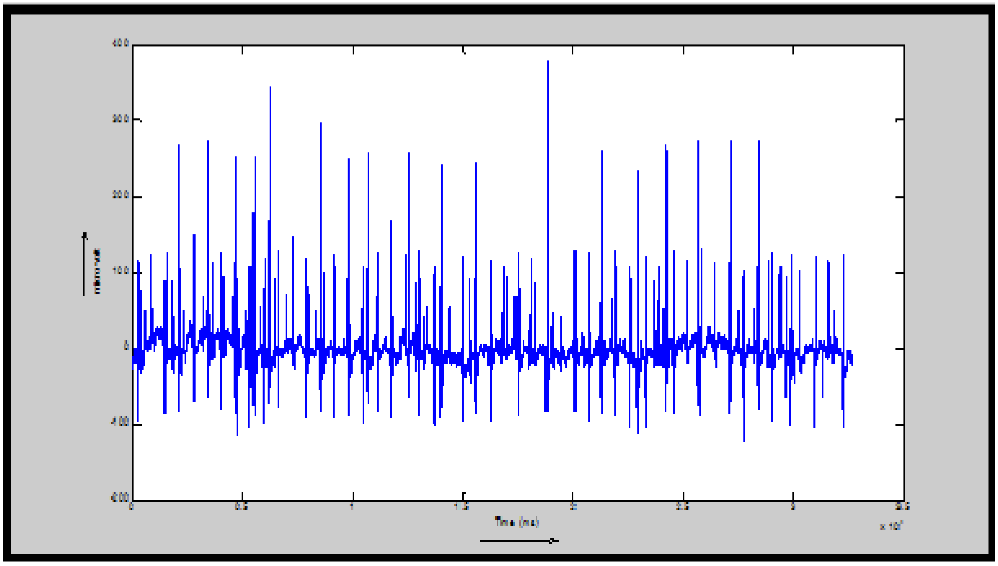

Fig.1. EMG signal

## III. METHOD

The technique is used for elimination of noise present in the baseline of the EMG signal using the Digital filter designing for cancellation of baseline fluctuation (BLF).

### *A. Digital filter designing for cancellation of baseline fluctuation (BLF):*

Digital filter design technique used for cancellation of baseline fluctuation (BLE) an EMG signal. In this technique, an EMG signal passed through high pass IIR (chebyshev) filter for the removal of the low frequency oscillations or the fluctuations present in the baseline of EMG signal. This technique can easily remove the low frequency oscillations or noise presents in the baseline of EMG signal and thus it may enhance the quality of EMG signal. It is generally based on the threshold values, which can be calculated by a simple algorithm. This technique is comprised the following steps.

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- Calculation of threshold
- Segmentation of EMG signal
- Interpolation of baseline points
- Analysis of power density spectrum
- Filter designing & filtering of raw EMG signal

Step 1: Calculation of threshold:
The number of motor unit action potentials (MUAPs) present in an EMG signal recording depends on the degree of contraction of the muscle. The contraction force increases, then level of EMG activity increases, more MUs are recruited and the number of peaks in the EMG signals increases, and MUAP-free segments become less frequent and shorter.

To characterize the baseline fluctuation, MUAP free segments or the baseline segment (BLS) must be distinguished from MUAP segments of the Electromyography (EMG) signal. It can be able that the threshold calculation is the most significant part in the cancellation of BLF of EMG signal in the digital filter design technique. The threshold is used in the activity level of the EMG signal activity, segmentation and classification of whole EMG signal. The value of threshold is calculated on the base of mean absolute value of each samples present in the EMG signal X (t).
A simple algorithm used for the calculation of threshold T is given as
If maximum X (t)>30* mean (abs X (t))
Then
Threshold = 5 * mean (abs X (t))
Else
Threshold =maximum X (t)/5
The value of threshold will be changeable for different EMG signal.

Step 2: Segmentation of EMG signal:
Electromyography (EMG) signal is the superposition of the electrical activities of a number of motor units (MUs). The segmentation of EMG signal is needed to identify with the mechanisms related to muscle and nerve control.

The aim of the segmentation is the process to cut the EMG signals into segment of possible inactive segments and active segments. Segmentation of EMG signal can be performed with the help of discrete wavelet transform. The discrete wavelet transform (DWT) decomposed the EMG signal into active segment and baseline segment with the help of defined algorithm. This segmentation algorithm calculates a threshold depending on the maximum value max X (t) and the mean absolute value of the whole EMG signal. In this paper, segmentation is performed into two steps. In first step active segment (AS) are obtained and in second step BLS is obtained. In the first step segmentation algorithm calculates the threshold and peaks over the calculated threshold are considered as candidate motor unit action potentials (MUAPs). Now taken a window of constant width of 120 samples is applied centered at the identified peak. If a larger peak is found in the window then the window is centered at the greater peak or else the 120 samples are saved as a candidate motor unit action potential (MUAP) waveform [10]. In next step to obtain the baseline segment (BLS) of EMG signal, second threshold, called T1 is also calculated. This step a windows of constant width of 30 samples is taken and calculates T1 and then selects the next window of 30 samples and calculates the value of T1 again. Thus the complete length of the EMG signal is divided into the window of 30 samples and threshold is calculated each time. The value of threshold (T1) is varying for every next window. The threshold T1 is also calculated on the basis of mean absolute value of complete samples present in a window of 30 samples. Now the BLS is performed by the comparison of this threshold T1 with first threshold T, which has been calculated in last section. If threshold T1 is greater than the threshold T then the samples is again considered as the candidate of MUAPs waveform that is to say the active segment, if not the segment is baseline segment. The value of second threshold T1 is calculated as
*T1=mean [abs(X (w))]*

Step 3: Interpolation of baseline points:
The process of increasing the sampling rate of EMG signal is interpolation (sampling rate expansion). Interpolations are based on polynomial. Interpolation is the process of evaluation of values between the data points. The previous to averaged samples are interpolated with the help of means of cubic splines, which closely follow the baseline (BL)

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through its fluctuations. The cubic spline interpolation is used to obtain the smooth baseline segment. At the present a peak of the amplitude of threshold T1 is marked at the centre of the window of 30 points in the baseline segments (BLS) of the EMG signal, the whole baseline segment of the EMG signal are centered with the peaks of respective threshold T1. Later than obtaining these peaks the interpolation technique is applied to all peaks of baseline segments (BLs). The cubic splines technique interpolates signal points through of concatenated cubic polynomials such that the obtained interpolation curve and its time derivative are both continuous throughout the whole time span. The signal points to be interpolated are accurately on the curve Figure 2.

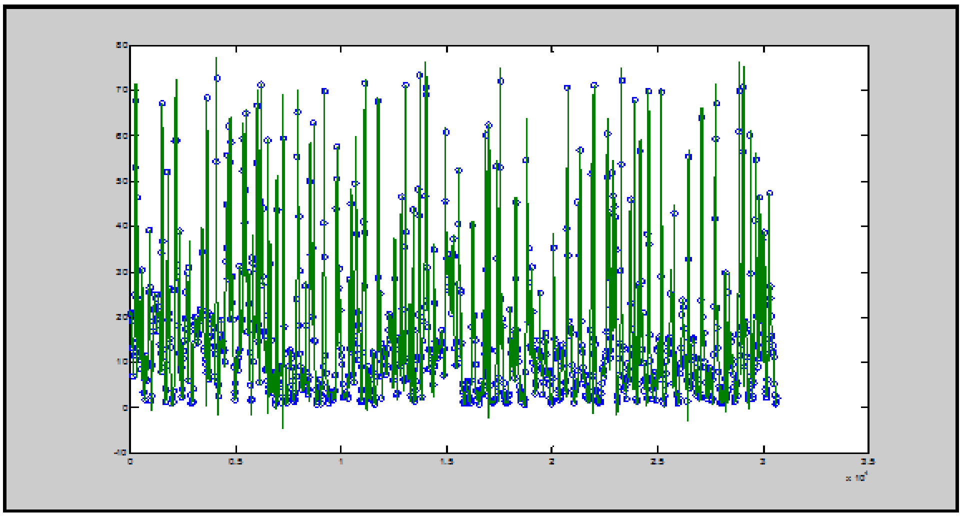

Fig.2. interpolated baseline segment

Step 4: Analysis of power density spectrum:

The signal processing techniques which characteristics the frequency content of a signal corresponds to spectral analysis. In general there is several relation of proportionality between measure of the squared amplitude of the function and a measure of the amplitude of the power spectrum density (PSD).

The power spectrum density of the interpolated baseline segments will be obtained to calculate the frequency range of the baseline of EMG signal so that the filter would be designed for the specified cut off frequency for EMG signal. An estimate of the autocorrelation of the observed data is obtained first and then the AR spectral is calculated. AR spectral estimation can also be used on the interpolated signal to obtain a smooth and high resolution power spectral density. Discrete Fourier transforms and Fast Fourier transform are also the efficient and simplest methods of power density spectral analysis. The fast Fourier transform is an algorithm that efficiently computes the discrete Fourier transform (DFT) so in this present paper Fast Fourier transform is used to obtain the Power density spectrum of interpolated baseline segment. From the PDS analysis, the cut off frequency of the BLS is 15Hz for filter.

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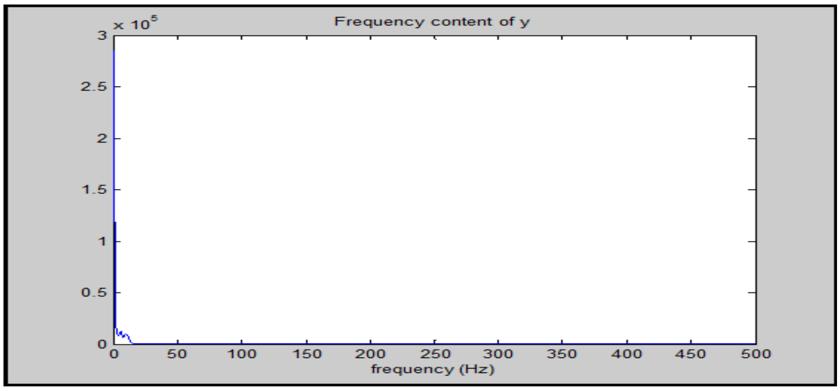


Fig.3. PSD of BLS

Power spectrum density using the FFT:

Designed for a wide-sense stationary (WSS) process of signal X (n), the power spectral density (PSD), $S_{xx}(f)$, is the Fourier transform of the autocorrelation function $r_{xx}(k)$ (Wiener-Khintchine) detail in [7]. The Wiener-Khintchine relation is of fundamental value in analyzing random signals, it provides a relation between the time domain and the frequency domain .The power spectral density, $S_{xx}(f)$ is a real and non negative function then variance of signal is

$$\sigma^2 = r_{xx}(0) = \int s_{xx}(f)df$$

Periodogram:

The power spectral density estimate $S_{xx}(f)$ is the discrete Fourier transform of the autocorrelation estimate $r_{xx}(k)$. Given a signal is finite sequence x[n] and length N then autocorrelation function can be estimated by

$$r_{xx}(k) = \frac{1}{N}\sum_{n=0}^{N-k-1} x(n)x*(n+k)$$

Taking both sides of the Fourier transform and making some mathematical operation and we get the periodgram estimate of power density spectrum.

$$s_{xx}^{PER}(F) = \frac{1}{N}X(f)X^*(f) = \frac{1}{N}|X(f)|$$

Two properties of periodogram estimate are:

- Asymptotically unbiased estimate:

The variance value becomes zero then $r_{xx}(k)$ is an asymptotically unbiased estimate.

$$E[S_{xx}(f)] = w_B(f)^* S_{xx}(f)$$

$W_B(f)$ is the frequency domain representation of the Bartlett window.

- Not consistent:

The estimated autocorrelation is a consistent estimate, but its Fourier transform (PSD) is not a consistent estimate.

$$\text{var}[S_{xx}^{PER}(f)] = S_{xx}^2(f)$$

Therefore the variance does not go to zero as $N \to \infty$.The periodogram is not a consistent estimate of the power spectrum density.

Bartlett estimate:

The variance of the periodogram can be reduced, Bartlett's estimate of periodogram averaging produces a consistent estimate of the power spectrum.

- Divided the sequence x(n) into k non overlap segments.
- Find the periodogram for each segment.
- Calculate the periodogram from k segments periodogram.

The result is the spectral width is increased by a factor k and the frequency resolution by a factor k.

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Welch estimate:
Two changes in the periodogram and Bartlett estimates.

- The segments of x(n) are allowed to overlap.
- A data window w(n) is applied to each segment in computing the periodogram.

Blackman and Tukey estimates:

Smoothing the periodogram estimate was proposed by Blackman and Tukey estimates. The autocorrelation sequence is windowed before calculating the power spectrum density. Windowing is used because if the value is large, only minimum data enter in the estimation.

- Estimate the autocorrelation function.
- Window $r_{xx}(k)$ with lag window.
- Calculate the Fourier transform.

Step 5: Filter designing & filtering of raw EMG signal:

A high pass Chebyshev filter of 3 db cut off frequency with stop band of 15 Hz is designed. Bilinear transformation can be followed for designing the IIR Chebyshev filter. Chebyshev filters are used to separate one band of frequencies from another band of frequency. The Chebyshev response is a mathematical approach for achieving a faster roll off by allowing ripple in the frequency response. Analog and digital filters that use this approach are called Chebyshev filters. To remove of noise present in the baseline of the EMG signal is filtered out by the above designed high pass Chebyshev filter. The low frequency or oscillation and BLF are filtered out from the EMG signal and the active segment of high frequency pass through the filter thus it will remain same throughout the whole filtering process, almost linear phase characteristic of the Chebyshev filter certification the preservation of MUAP shape.
Let H (z) =B (z)/A (z) denote the transfer function of a digital filter. The degree on B (z) will be denoted by L+M, where L is the number of zeroes at z =-1and M is the number of remaining zeroes. The magnitude frequency response of chebyshev filter is

$$|H(j\Omega)|^2 = \frac{1}{1+\in^2 C_N^2(\frac{\Omega}{\Omega_P})}$$

The BLF filtering method using FFT spectral estimation followed by high pass Chebyshev filter is found to be the best approach for baseline fluctuation filtering. An EMG signal without baseline fluctuation is Figure 4.

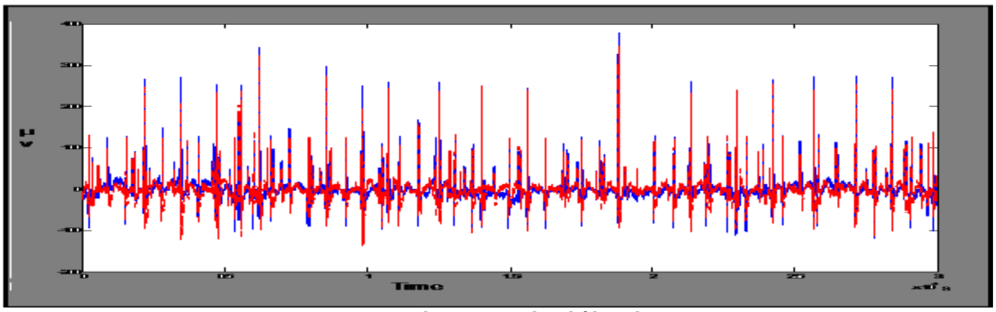

Fig.4. Original EMG signal and filtered BLF

## IV. RESULTS

### A. *Quantitative analysis:*

Quantitative evaluation is required to compare baseline fluctuation (BLF) removal methods. BLF raises or lowers the mean level of a portion of a potential so the degree of waveform variation in the discharges in a MUAP train is increased accurately by the BLF.
Two quantities (F and N) are measuring the degree of BLF. They are calculated as follows.

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1. All the single potential are manually selected and classified, by eye, on the basis of wave shape into several classes corresponding to different MUAP trains.
2. For each MUAP train, the corresponding discharges are time aligned so that correlation between them is maximized.

Let $Y_k = \{ y_k(1), y_k(2)......... ....y_k(n_k )\}$ be the discharge number k of the set of m discharges of a certain MUAP train, where $y_k\ (t)$ is the t sample of $Y_k$ . Discharge in $Y_k$ are normalized dividing their samples values by the maximum absolute value in the whole set. The two proposed quantities are defined below.

$F = S.D_k\,(mean_t( Y1)......... .........mean(Ym )) \; Y$ (4.1)

First the temporal mean of every discharge is calculated; then standard deviation of all these means is computed.

$N = mean_k\,(s.d_k\,(y_k(t)................. y_k(t))$ (4.2)

The standard deviation across different discharges is calculated for every sample time; the resulting set of values is then averaged.

F and N values will be in the range 0-1. F measures the variability of the mean of the different discharges pertaining to the same MU along the EMG signal. Ideally, if low frequency oscillation or baseline fluctuation were not present and if all discharges from the same motor unit were the same then F would be zero. When there is BLF, some discharges appear higher than others and the value of F increases as a result. Other hand, N measures the variability of amplitude values of amplitude values of a MUAP waveform throughout a MUAP train. N will be zero if no BLF is present in the signal and the discharges do not differ from each other. If the BL fluctuates, the amplitude of MUAP samples will vary from one discharge to another and N will increase according to this variation.

Thus the degree of BLF cancellation provided by a given method on a certain EMG signal can be measured indirectly by looking at the decrement in the signal's F and N values. BLF elimination techniques can be compared by direct computation of F and N factors in the processed signal. For lower the F and N values, the lower the remaining BLF, and better the performance of method. The values of F and N are calculated here for method.

Table 1: Values of F and N of Raw EMG signal

| MUs | Value of F for Raw EMG signal | Value of N for Raw signal |
|---|---|---|
| MU1 | 0.0257 | 0.207 |
| MU2 | 0.0337 | 0.205 |
| MU3 | 0.0388 | 0.1768 |

Table 2: Values of F and N without BLF, using Digital filter

| MUs | Value of F for filtered EMG signal | Value of N for filtered EMG signal |
|---|---|---|
| MU1 | 0.0203 | 0.203 |
| MU2 | 0.0230 | 0.2002 |
| MU3 | 0.0320 | 0.1711 |

## V. CONCLUSION

The method has been devised for elimination of BLF named as digital filter designing. This makes use several signal processing, statistical and mathematical techniques in a sequential approach. Two merit figures have been devised to

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find out the degree of BLF present in an EMG signal. In digital filter designing technique of BLF elimination the high pass IIR chebyshev filter has been designed. Digital filter designing approach is efficient and reliable. Tests with real and simulated signals show the validity of these merit figures and demonstrate that they are sensitive to variations in BLF amplitude and less sensitive to the BLF frequency distribution. To measure the activity level, segmentation and classification of EMG signal into the AS and BLS and threshold has been calculated based on mean absolute value of entire EMG signal. The degree of BLF cancellation provided by a given method on a certain EMG signal can be measured indirectly by looking at the decrement in the signal's F and N values. We can also examine disease and neuromuscular disorders with the help of EMG signal.

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