Physiological Signal Processing Primer

This document is intended to provide the user with some background information on the methods employed in representing bio-potential signals, such as EMG and EEG. For the purpose of this doc we will focus on an EMG bio-potential signal, as EMG and EEG bio-potential signals are similar. Signal processing is sometimes considered as a speed bump on the road to advance biofeedback, however it shouldn't be viewed as an obstacle. BioGraph Infiniti packages these processes into its channel sets making in-depth comprehensions of the issues optional for effective biofeedback therapy. However if you intend to design channel sets and screens it is essential to be familiar with these techniques.

RAW bio-potential signals

The RAW information from the subject is a collection of positive and negative electrical signals, their frequency (how often they occur), and their amplitude give us information on the contraction or rest state of the muscle. A RAW EMG signal can be seen in fig 1.

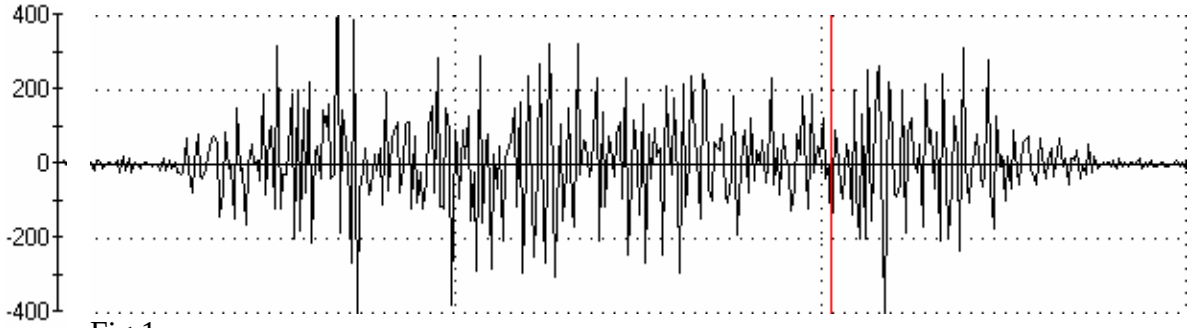
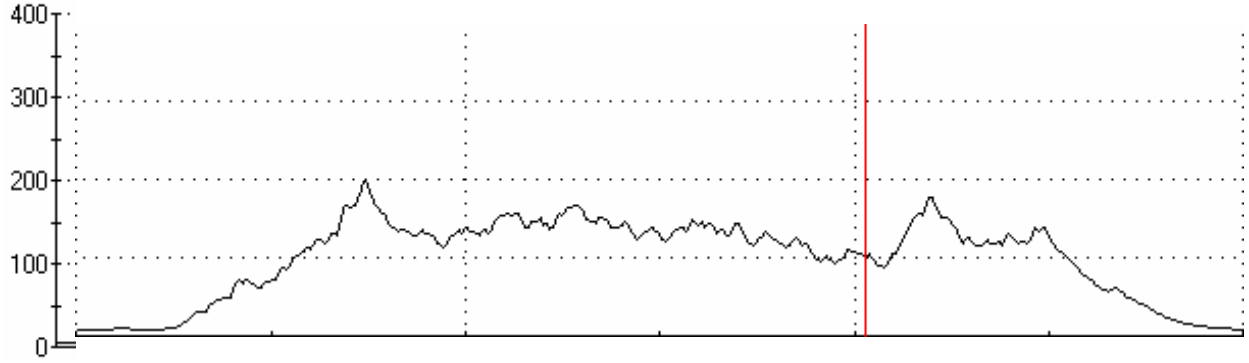


Fig 1.

In the raw graph the X axis displays time and the Y axis displays amplitude in µV(micro-Volts), both positive and negative about the axis which is zero. This 3 second sample of data has an amplitude of 400µV. As the subject contracts the muscle the number and amplitude of the lines increases, as the muscle relaxes it decrease. As the muscle fatigues the number or frequency of the firings will decrease.

RMS

RMS or Root Mean Square is a technique for rectifying the RAW signal and converting it to an amplitude envelope, which is easier to view, to make it easier to view. The rectification process converts all the numbers into positive values rather than positive and negative. The RMS graph of the same 3 seconds of signal is shown below in Fig 2.



Frequency Domain

The signal can also be represented in the frequency domain. The RAW and RMS displays are both representations of the signal in the time domain. The signal is comprised of many electrical firings, these firings occur at different rates, the overall signal that we view in the time domain is a composite of these multiple frequencies. Frequency is measured in Hertz (Hz) and is the number of events (in this case firings) per second.

For EMG for example we are interested in frequencies between 0 – 500Hz, for EEG frequencies from 0 – 60Hz. It is possible to display and represent the signal in its frequency domain by separating out the individual frequencies. The RAW signal is converted into the frequency domain by passing all the data points through a Fast Fourier Transform calculation (FFT), this mathematically isolates each of the frequency bands. The signal that we have viewed in RAW and RMS representations is displayed in fig 3. in the frequency domain.

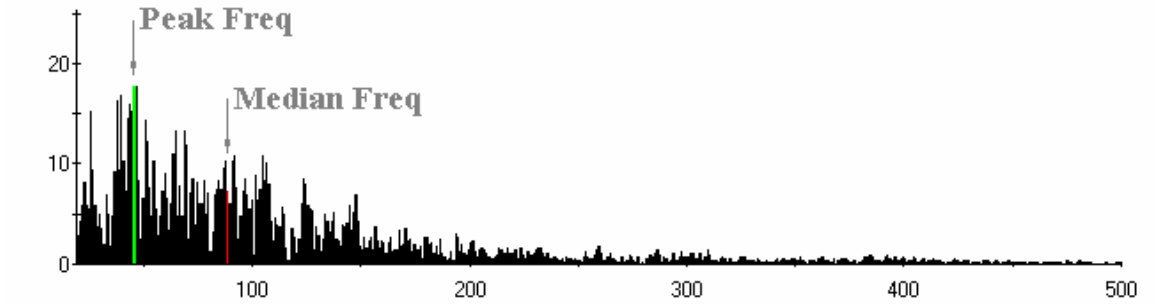


Fig 3

The X axis displays frequency in Hz, the Y axis displays relative amplitude. Different information can be gathered from the frequency domain that is not available as readily from the time domain such as muscle fatigue. As a muscle fatigues the frequency of firings decrease but the total amplitude in the time domain can remain constant. Two important measures are the Peak Frequency displayed in Fig 3 by the green bar, and the Median Frequency denoted by the red bar.

Filtering

Filtering of the signal is important; it is used to focus on a narrow band of electrical energy that is of interest to us rather than all the electrical signals that the sensors will pick up. It enables us to remove noise and artifact such as that commonly found at 50 or 60 Hz that are not relevant to our studies. 50/60Hz energy is used to transport electrical energy and is emitted into the recording environment by devices such as florescent lights , computer power supplies etc. Primarily EMG signals occur within the range of 0 – 500Hz, however artifact can be introduced at the low frequency end of this range by sources such as the heart and electrical equipment. Fig 4. Shows a resting EMG signal being filtered in different ways, displayed in RMS. This EMG signal was measured in close proximity to the heart, the heart's electrical activity can clearly be seen as spikes in activity approximately every second. To remove the artifact from the signal we filter the signal through a band pass filter, in the case of the BioGraph Infiniti software it is an IIR filter algorithm. We set this filter to 'pass' or include the signal between two frequencies also referred to as a band of frequencies. The choice of the band should be a cautious one as it is a trade off between over filtering and under filtering the signal. In Fig 4. the signal without any filtering is affected most by the artifact, and the one filtered from 100 – 500 Hz the least.

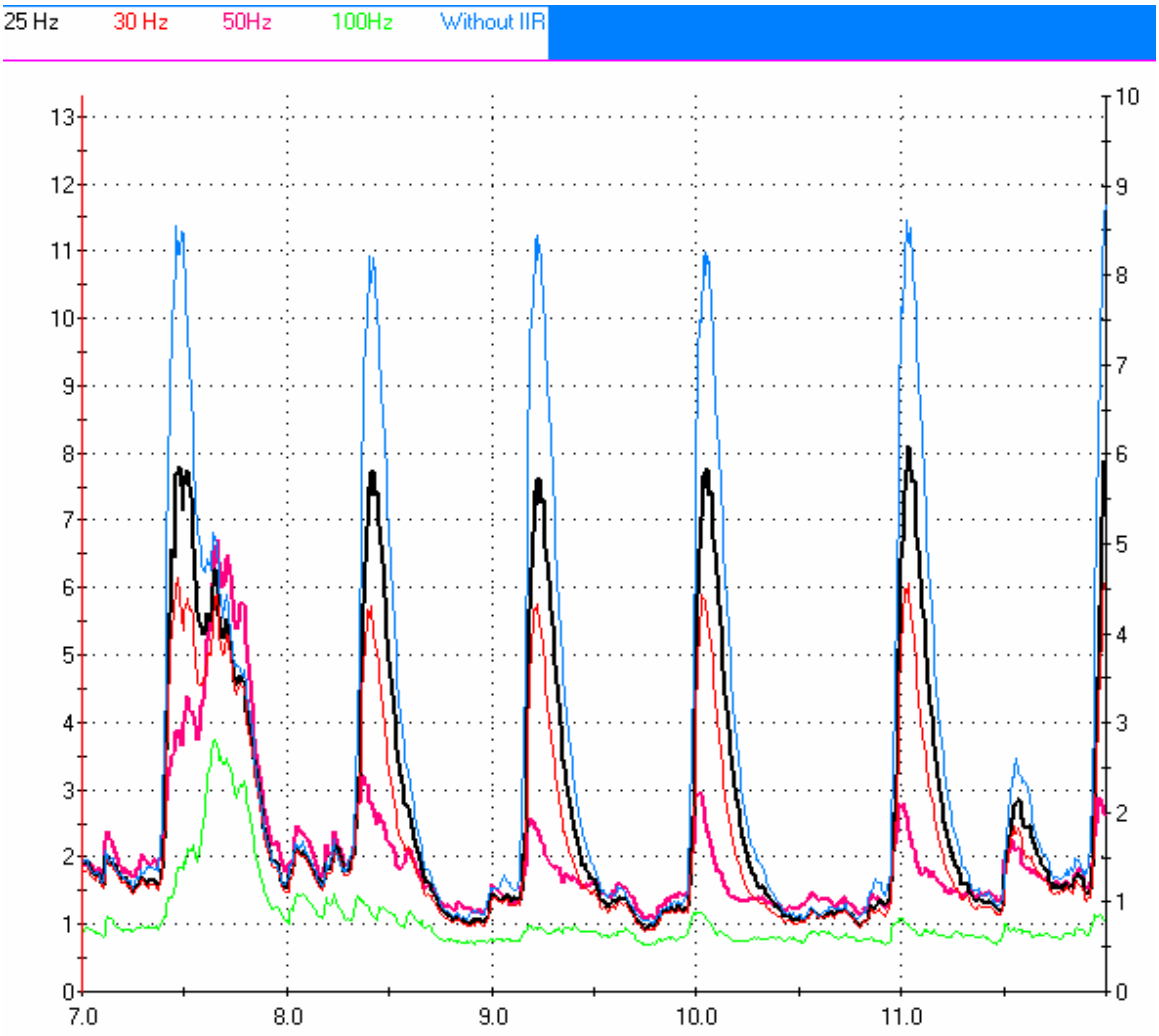


Fig 4.

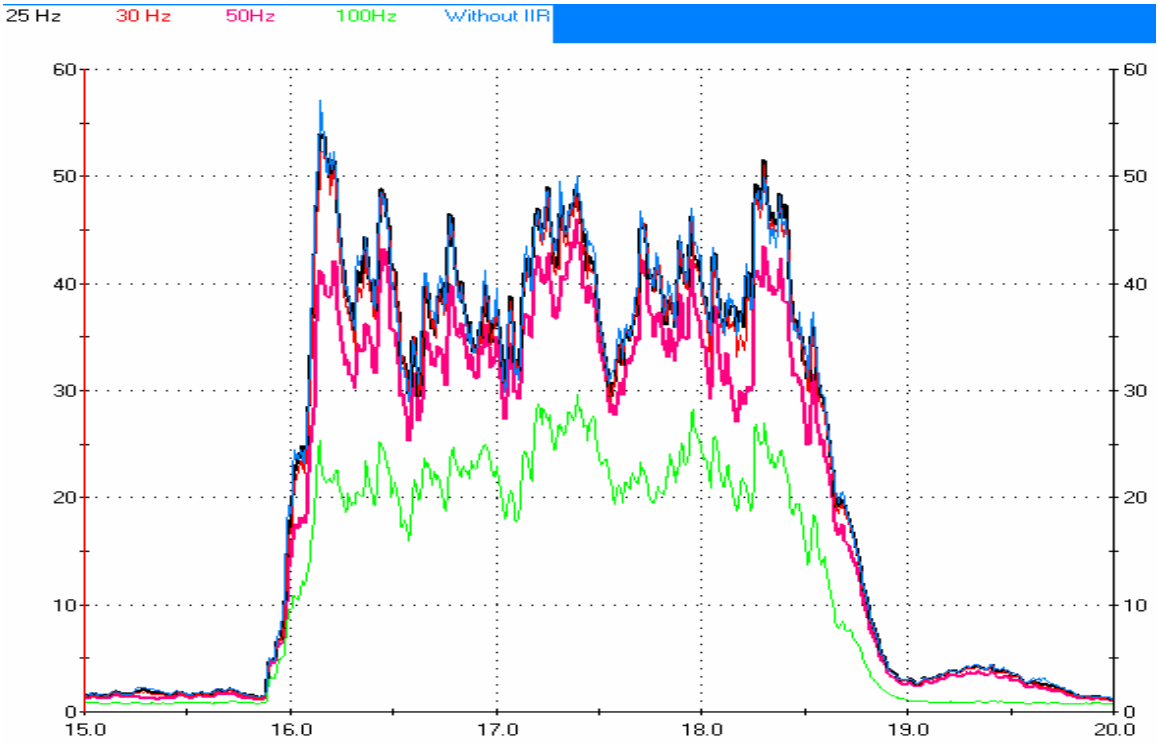


Fig 5.

As we can see from Fig 5. and its accompanying frequency display Fig 6. When muscles contract there are a range of frequencies as can be seen in Fig 6. Some frequencies are more active than others; this can be seen by higher amplitudes in these areas, designated by brighter colors. It is clearly seen that most of the activity is below 100Hz. Above 200Hz there is little activity. This highlights the problem of over filtering the signal to remove all the artifact and noise. As we remove more of the signal at the bottom end we see that our filtered RMS signal decreases in amplitude during the contraction, from 40µV to 20µV. Filtering should be selected based on electrode placement and purpose of the recording.

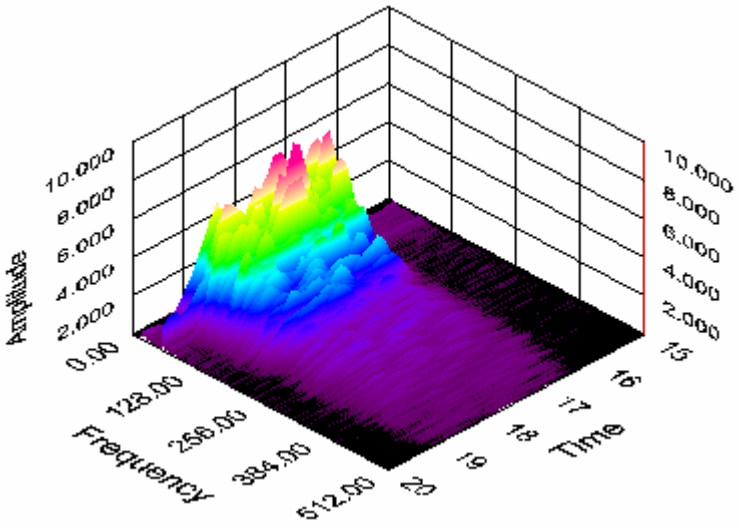


Fig 6.

Glossary

Artifact – Unwanted information contained within a signal
Band pass filter – Filter that excludes signals information below and above specified band of frequencies.
Bio-potential - Electrical signals emitted by the body.
EEG – Electroencephalography, electrical signals emitted by the brain.
EMG - Electromyography, electrical signals emitted by the muscles.
EKG - Electrocardiogram
FFT (Fast Fourier Transform calculation) – Mathematical method of translating a signal from the time to frequency domain.
Frequency – Measured in Hertz (Hz) how often something occurs with in a second.
High pass filter – Filter that excludes signal information below specified frequency.
IIR filter – Infinite Impulse Response filter, configured as a bandpass, highpass or lowpass.
Low pass filter – Filter that excludes signals information above a specified frequency.
Notch filter – A filter that excludes a small band of frequencies.
RAW- A signal in its raw un-rectified state
Rectification – conversion of a bi-polar signal into a uni-polar signal.
RMS or Root Mean Square – A method of rectifying a RAW signal.