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A first approach to denoising CMAPs in a large animal model

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***Abstract*— Acquisition of high signal-to-noise (SNR) electrically-evoked Compound Muscle Action Potentials (CMAP) during acute, invasive experiments can be a challenge due to motion and stimulation artifacts in addition to biological noise contamination, and electromagnetic interferences. This study compares the gold-standard bandwidth limit filter (4th order Bandpass Butterworth) against a combined strategy using an adaptive filter with a wavelet denoising approach to process electromyographic (EMG) signals, extracting their CMAPs from a dataset of Pelvic floor muscle (PFM) muscle contraction evoked via electrical stimulation in a rabbit.**

I. INTRODUCTION

Compound Muscle Action Potentials (CMAPs) represent the summation of simultaneous action potentials of muscle fibers in the same area (synchronization) due to electrical stimulation of motor nerves. [1]. Adaptive filtering can provide a robust alternative to deal with baseline interference [2] in EMG signals, additionally recent filtering strategies for CMAP and electromyographic signals involve the use of Wavelet-based denoising techniques [3]. We assess two different approaches to filter noisy CMAPs obtained in an invasive protocol of muscle stimulated to evoke contraction in a rabbit, implementing an adaptive filter and wavelet-based filtering.

II. METHODOLOGY

The electromyographic signals CMAPs sets were provided by the University of Texas at Dallas from rabbits that received electrical stimulation to the PFM while simultaneously recording their electromyographic activity at 30 kHz (Neuronexus SmartBox), obtaining a total of 428 CMAPs. The filtering of the raw CMAP data sets (M_n) consists of a digital limit bandwidth filter (Butterworth $4th$ order configuration), resulting in the $F_{BW}(M_n)$ filtered signal. After this stage a digital adaptive filter is implemented considering two different references; the first one is the moving average filter of the raw signal, called *Artificial noise*) and the second one is a muscle signal (active electrode). Two additional approaches were considered a) a bandwidth limit filter (Butterworth 4th) and b) a wavelet denoise approach (4 levels, family Sym 4 and db comparison). The signal-to-noise ratio (SNR) after each experiment was calculated and compared.

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III. RESULTS

After the adaptative filter the width of the stimulus reduced from the original one by 52% or 0.334 ms and the amplitude of the stimulation peak increased from 5.9945 mV to 7.3375 mV (SNR 0.2229 dB) Figure 1b. The Symlet showed a better performance based on the SNR reduction to 0.2020 dB. Because noise was still present after the adaptative filter, fourth order pass-band Butterworth filter was applied with a low cut frequency of 250 Hz and a high cut frequency of 3 kHz. The SNR was measured and compared against other signal which was 0.0088 dB Figure 1c.

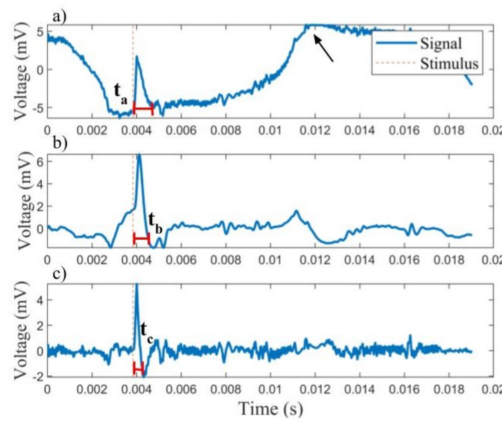

Fig. 1: Example of a CMAP filtering in the register a) Original EMG after stimulus (red dotted line). Signaled by the arrow is the carrier signal which needs to be eliminated. Time t_a is the duration of the CMAP which is of 830 μs.b) Stimulus after Butterworth filter.Time t_b equals 760 μs. c) Stimulus after the adaptative filter, where t_c equals 430 μs.

IV. DISCUSSION & CONCLUSION

The wavelet denoising or pass-band Butterworth, preceded by adaptive filtering resulted in successful extraction of CMAPs in this first approach, the smallest SNR comes from applying an adaptive filter followed by a Butterworth passband filter. At the same time, the biggest one belongs to the adaptive filter alone. Nonlinear filtering approach will be implemented as next step of comparison.

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