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Optimal Adaptive Filter Design of M-wave Elimination for Treating Tooth Grinding

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Abstract

When tooth grinding occurs, electrical stimulation is given at the same time, and tooth grinding stops on such stimulation. Electromyography signals are used as control signals of electrical stimulation to disturb tooth grinding. However because of the electrical stimulation, the M-waves are generated and mixed with spontaneous electromyogram.

In this study, we designed an optimal filter to remove M-wave and conserve spontaneous electromyogram simultaneously. The inverse power method (IPM) showed that the optimal filter coefficient is the eigenvector corresponding to the minimum eigenvalue of the input covariance matrix. In order to evaluate the performance of the optimal filter, we compared using a conventional band pass filter and adaptive filter using least mean square algorithm. The experimental results show that the optimal filter can effectively remove the M-wave compared to the previously studied prediction error filter

Key words: *Tooth grinding, Electromyogram, Eigen filter*

1. Introduction

It is a parafunctional activity that includes grinding, gnashing, and clenching, and includes both daytime and nighttime extensively. However, in general, it is often referred to as the discomfort that occurs during sleep. It can be classified into awake bruxism that occurs during awake and sleep bruxism that occurs during sleep. The phasic or eccentric bruxism, which produces an uncomfortable sound to the sleeping person, is shown by moving the jaw to the left or to the right according to the aspect of the jaw muscle activity, and the eccentric bruxism. There is also a mixed bruxism in which these two appear together. In the case of arousal bruxism, tautness is the predominant mode of torticollis, which usually occurs when you focus on something [1]. Electromyography or polysomnography should be used to accurately diagnose dryness, but it is practically difficult to use it in practice because of cost and difficulties in the examination method. We can define the EMG signal generated at the beginning of ejaculation as a voluntary EMG signal. There is a

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method of detecting the spontaneous EMG signal and suppressing the patient's irritation by applying electrical stimulation while the signal is continued. This method calculates the intensity required for the stimulation according to the magnitude of the spontaneous EMG obtained from the electrode, and then applies electrical stimulation to the muscle. In the case of such electromyographic control electrical stimulation, two problems arise. The first problem is stimulation artifacts that appear to be saturated in the electromyographic amplifier stage by a large electric stimulus of about 30V to 50V. However, the stimulation noise can be easily solved by using a blanking circuit because the existence interval is short. Another problem is the M-wave signal caused by the simultaneous activation of many motor units by electrical stimulation. Since the magnitude of this signal is generally more than 20dB compared to the spontaneous EMG signal, most of the signals obtained from the EMG amplifier and cannot be removed by band-limiting filters because the frequency band overlaps with the spontaneous EMG signal.

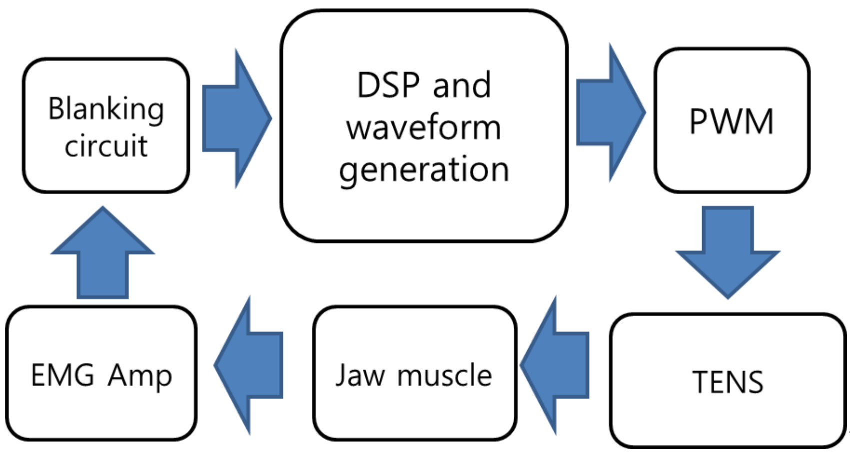

Figure 1. Block diagram of whole system

For effective EMG-controlled FES, a signal processing technique for extracting only spontaneous EMG mixed with M-wave is required. The simplest method that can be used for this is the comb filter [2]. The comb filter is a simple and real-time processing method that can be used under the assumption that the M-wave is a periodic signal generated by periodic stimulation and that the characteristics of the signal are kept constant for a long time. However, since the M-wave is not a signal whose size or shape is constant with time, the m-wave removal method using a comb filter has a limitation in performance. The proposed method is based on the adaptive filter [3], considering that the M-wave changes its statistical properties with time. The adaptive filter has the advantage of adaptively estimating and removing the characteristic of the M-wave that changes with time. When an adaptive prediction error filter (adaptive PEF) is used to remove M-waves, although the magnitude of the M-wave is variable depending on the stimulus period, and the spontaneous EMG signal has a low correlation to the stimulation cycle and can very effectively remove the M-wave. In this study, we design an optimal filter to satisfy two constraints that minimize the output while maintaining spontaneous EMG signals. It is shown that the optimization process with two constraints is the same as that of a typical eigenfilter design. Finally, the optimal filter has an eigenvector corresponding to the minimum eigenvalue of the input covariance matrix as a coefficient. We also propose a method for adaptively implementing the proposed optimal filter using inverse power method (IPM). And we verify the optimization of the proposed method through experimental process using simulation data.

2. Methods

Since the performance of the filter can be changed according to the relative size and the change of the M-wave and the spontaneous EMG signal, the filter performance is objectively evaluated by using the simulation data rather than comparing the filter performance with the actual patient's EMG data.

A nonstationary variation of an M-wave can be represented by changes in size and shape. The M-wave can be adjusted to the size and shape of the M-wave by varying the size and time constant, assuming it is an exponentially decaying sine wave.

$$s_j(i) = a_j e^{-i/\tau_j} \sin(2\pi 3i/N) + v(i), i = 0 \cdots N-1$$

$a_j e^{-i/\tau_j} \sin(2\pi 3i/N)$: *i*-th M-wave, a_j : a scaling parameter determining the amplitude of the *j*-th M-wave,

τ_j : a parameter determining the shape, $v(i)$: *i*-th voluntary EMG as band-limited Gaussian noise.

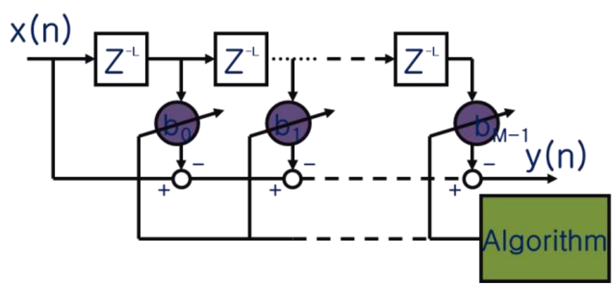

Figure 2. Optimum filter with algorithm,
$b=-R^{-1}_{MxM}P$, b: weight vector , R: auto-correlation matrix , P: cross-correlation vector.
We show the matlab code of optimum filter as below.

```
% y =    input signal vector
% M = filter order ADF
% N = period of the M response
% L = number of M responses to be processed
% iter = number of IPM iteration

Sj=[];                                % make (Nx(M+1)) reference data matrix
    for ii=1:M+1
        Sj=[Sj y((loop-ii)*N+1:(loop-ii+1)*N)'];
    end

    Phi = Sj'*Sj;                 %% (M+1)x(M+1) correlation matrix
    PhiS=PhiS+Phi;
    IPhi=inv(Phi);

    %%% Using EVD
    [E,V]=eig(Phi);      %% compute ((M+1)x1) LS weight vector
    br=E(:,1);
    lbr=norm(br);
```

```
%       diag(V),pause
        vx=vx+diag(V);

        %%% Using iterative EVD
        b=[1 zeros(1,M)]';

        for jj=1:Max_iter
                bh=b'*IPhi;
                b=bh'/norm(bh);
                T(jj)=T(jj)+abs(b'*br)/lbr;
        end
```

3. Results

Finally, the performance of the filter is determined by whether or not the spontaneous EMG is maintained. Figure 3 (a) shows the mixed signal of M-wave and EMG and figure 3 (b) shows the first output of optimal filter. Figure 3(c) is the third-order output of the optimal filter, but the peak components are intermittently removed, and the 6th-order output of figure 3 (d) Intermittent peaks are not observed, and the magnitude of the output maintains the magnitude of the input EMG as the M-wave is completely removed.

(a)

(b)

(c)

(d)

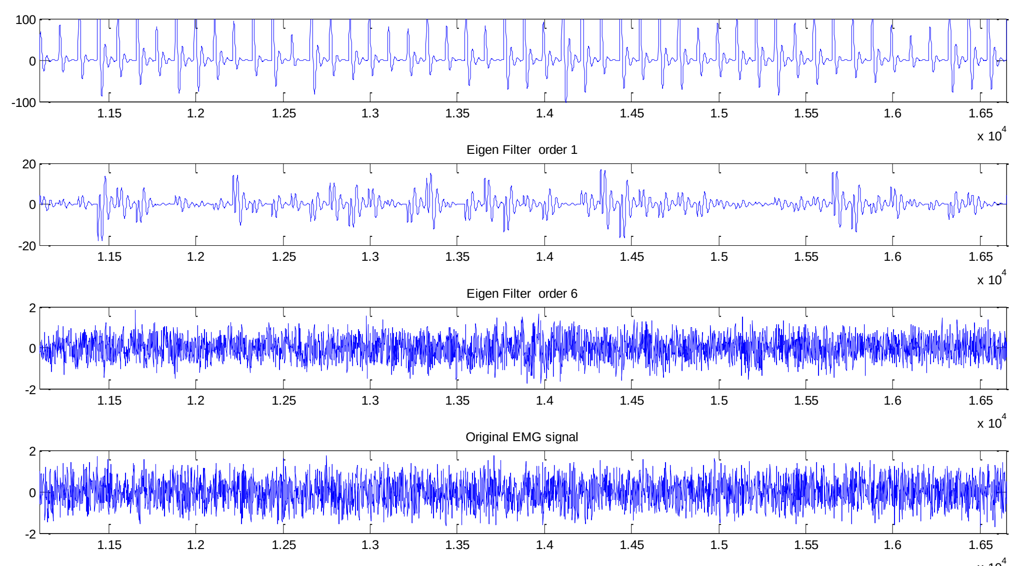

Figure 3. Optimal filtering results with simulated EMG and M-wave data

4. Discussion

In this study, the optimal filter was derived with the limitation of maintaining the spontaneous EMG while minimizing the output size in order to remove the M-wave. In order to evaluate the performance of the designed filter, we experimented with the mathematical modeling of the M-wave and spontaneous EMG and the actual patient data.

References

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