# Modelling of Compound Nerve Action Potentials in Health and Disease

BUDAGAVI MADHUKAR, I. S. N. MURTHY AND A. G. RAMAKRISHNAN

Department of Elec. Engg., Indian Institute of Science, Bangalore - 560 012, India

**Abstract-This paper reports the results of application *of* Murthy-Prasad technique in extracting the principal component from compound nerve action potentials (CNAP). The DCT of the CNAP is pole Zero modelled using the Steiglitz-McBride method. This model is expanded into a set of partial fractions eachof order (2,2). The sum of the monophasic functions recovered from the relevant fractions in the inverse process gives the major potential in the response. In the case of patients' responses, this improvesthe main component by rejecting the smaller peaks due to dispersion by demyelination. The technique works well in waveforms deformed moderately. The improved waveshape is extremely useful in cases where the original waveshape prevents the exact location of arrival of nerve impulse.**

## I. INTRODUCTION

The study of compound nerve action potentials (CNAP) is extremely useful in the diagnosis and assessment of neurological disorders. The typical response consists of the integrated potential due to all the fast conducting A fibres. In healthy individuals, it is easy to identify the onset of the main potential and measure the nerve conduction time accurately. In the case of patients with demyelinating neuropathies, different nerve fibres conduct at different velocities and there is dispersion of the CNAP. Hence, there is uncertainty in locating the time of arrival of the nerve impulse. Based on the model proposed in [1] for ECGs, we present a technique in this paper, which delineates the different components of the waveform and thus helps to separate the main potential from other peaks, artifacts or otherwise. The latencies of all the peaks are also obtained from the model.

## II. THEORY

The CNAP is approximated as a sum of m number of monophasic components :

$$x(n) = \Sigma\, x_i(n), \quad i = 1,2, \ldots, m \qquad (1)$$

where each $x_i(n)$ is a monophasic wave. A subset of these components add upto p(n), the principal part of the CNAP and r(n) is the ensemble of all the remaining components. Thus,

$$x(n) = p(n) + r(n) = \Sigma^{*} x_p(n) + \Sigma\, x_r(n)$$

where $n_p$ is the number of monophasic components in the main response (not necessarily the first $n_p$ components of x(n)) and $n_p + n_r = m$. The delineation of the principal response is achieved using the following principle, proved in [2]: The discrete cosine transform (DCT) of a bell shaped monophasic wave can be approximated as the impulse response of a system function with 2 poles and 2 zeros, ie., of order (2,2).

Let X(k), $k = 0,1,\ldots(N-1)$ be the DCT of the signal x(n). X(k) is approximated as the impulse response of a system, X(z), of order (2m,2m). X(z) is given by the rational transfer function,

$$X(z) = \frac{B_0 + B_1 z^{-1} + \ldots + B_{2m} z^{-2m}}{1 + A_1 z^{-1} + \ldots + A_{2m} z^{-2m}} \qquad (3)$$

where the coefficients $A_i$'s and $B_i$'s are estimated using the Steiglitz-McBride method [3]. This model is expanded into a unique set of partial fractions (PF) each of order (2,2) and a monophasic function is recovered from each one of these fractions in the inverse process. The PF expansion of (3) is given by

$$X(z) = \sum_{i=1}^{m} \left\{ c_i + \frac{(a_i + b_i z^{-1})}{1 - 2r_i \cos\theta_i z^{-1} + r^2 z^{-2}} \right\} \qquad (4)$$

where $\Sigma\, c_i = B_{2m}/A_{2m}$. The constants $c_i$ are determined as

$$c_i = -x_i(0)\sqrt{N}, \quad i = 1,2,\ldots,m \qquad (5)$$

The sum of all the above m component waves gives the complete signal x(n). The selection of the relevant $n_p$ fractions making up p(n) is based on the fact that the, pole nearest to the unit circle corresponds to the peak due to the principal component. Thus the components corresponding to

the cluster formed by the pole angle $\theta_i$ (i = 1,2,...,$n_p$) are selected such that they lie within the angular region $(\theta_p-\theta_w/2) < \theta_i < (\theta_p+\theta_w/2)$ where $\theta_p$ is the angle corresponding to the pole nearest to the unit circle and $\theta_w$ is the maximum angular width. A value for $\theta_w$ is chosen depending upon the duration of the principal potential, the sampling frequency and the total number of samples in the input signal.

Median nerves of 5 normal subjects and 5 leprosy patients were electrically stimulated and CNAPs were recorded just above the elbow, medial to the brachial artery. These potentials were represented using the above model and the main responses of the A fibres were extracted.

## III. Results

A system of order (6,6) or (8,8) was found to be adequate to model all the data. Fig. 1a shows the CNAP from a normal subject and the corresponding reconstructed model output. Figs. 1b and 1c show the separated monophasic components and the extracted principal potential obtained by regrouping the pertinent fractions. Fig. 2a shows the CNAP from a leprosy patient and the corresponding model output. Fig. 2b gives the reconstructed principal response for the patient. The main potential usually requires 2 or at most 3 monophasic functions. A one to one relationship is found to exist between the pole pattern in the z-plane and component wave pattern in the time signal. The latency of the peaks can be easily obtained from the model since a pole angle $\theta$ is directly related to the peak sample number of that component.

## IV. Conclusion

The method is general and provides a way to develop efficient models to waveforms with well defined peaks. The technique can be successfully used to separate H-reflex, F response, etc. from the direct M-potentials in the case of stimulation of motor nerve trunks. Similarly the different waves in the auditory brainstem evoked response (ABER) attributed to specific structures in the ascending auditory pathway can be singled out. This could have potential applications in neurology.

## References


[1] I. S. N. Murthyand G. S. S. D. Prasad, "Analysis of ECG from pole-zero models," *IEEE Trans. Biomed Eng.* , in press.

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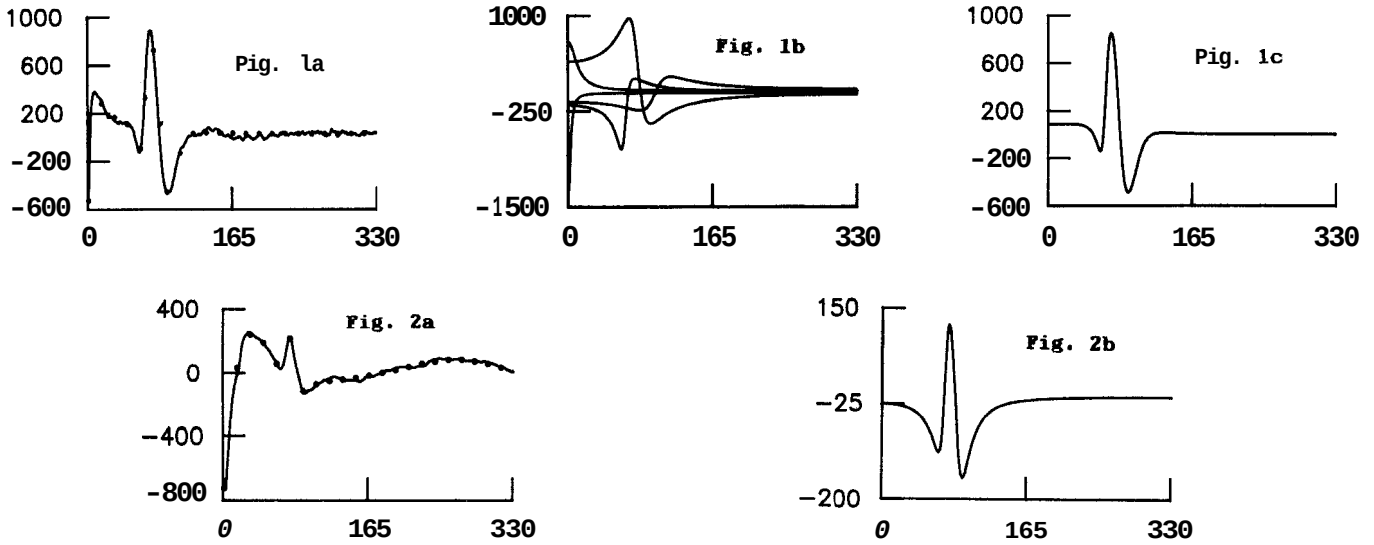
[3] K. Steiglitz and L. E. McBride, "A technique for the identification of linear systems," *IEEE Trans Automat. Contr.* Vol. 10, pp. 461-464, Oct. 1965.


Pig. la. Original ( ——— ) and the reconstructed ( ... ) CNAP from a normal. lb. The separated fractional components. 1c. The extracted principal potential. 2a. Original ( —— ) and the reconstructed ( ... ) CNAP from a patient. 2b. The extracted principal potential.
For all the figures, x-axis is sample no. and y-axis is arbitrary amplitude.