The Paxon - A Physical Axonal Mimic

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I. Introduction

We describe a physical model of a myelinated axon or "Paxon". Hodgson and Huxley[1] formalized the equations that define an axonal propagating action potential. While many implementations of axon models exist, few can be physically probed. This model enables a comparative study of medical electrodes, for example those used for deep brain stimulation. The Paxon fills the need of a physiologically similar action potential generator (e.g. physical size, rate of propagation, electrical excursions) that can be used to generate an action potential equivalent in a stable repeatable manner.

II. Methods

"A" fibres are the fastest human nerve fibres, propagating signals up to 120 m/s. Our Paxon model mimics these nerves with the following parameters: propagation velocity of 120 m/s, amplitude excursions of 130 mV, internode spacing of 2mm [2], pulse width of 3 ms [3], and rough node of Ranvier dimension of 20 µm. Each of the 40 nodes of Ranvier in the physical construction of our well (Fig. 1) is driven by a single IO line from an Atmel ATXMEGA64A1CPU. This configuration allows for programmability of timing, amplitude and pulse width within the model, although the physical node spacing of 20 µm is fixed. The Paxon is probed using a differential 7 mm diameter electrode pair spaced 21 mm on center, followed by a 750 Hz input filter attached to a data acquisition system (National Inst. NI USB 6251) which is used to record the data events of the action potential. Data are post-processed using MATLAB. The most important model parameters for repeatability are step-to-step time, pulse width, and amplitude excursions, which are statistically compared between multiple runs.

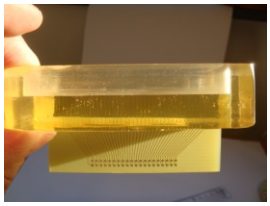

Figure 1, Photo of a PAXON well.

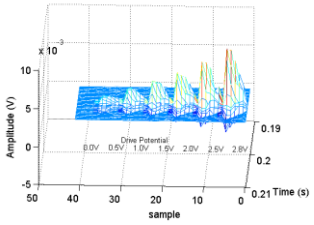

Figure 2, Output varying Drive Amplitude and generated pulse width.

III. Results

Variations in drive amplitude and pulse width result in a variation in detected signal amplitude (Fig. 2) allowing the model to be tuned to physiological signal levels. Fig. 3 shows 50 runs of raw data as well as the averaged offset removed plot in red (above).The stability of the repeated signal is useful when sequential comparisons are performed on multiple electrode types. The averaged amplitude is 1.5 ± 0.055 mV with a peak time variation of 196.4 ± 0.06 ms.

IV. Conclusion

The model generates an acceptable mimic to an action potential. The ability to program amplitude, velocity and width allows for fine tuning of the model, e.g. variability in nerve dimensions the model is mimicking. The model also offers a repeatable, stable and controllable output that can be used as a nerve standard in testing of electrodes for both static and dynamic electric fields without the variability found in live tissues.

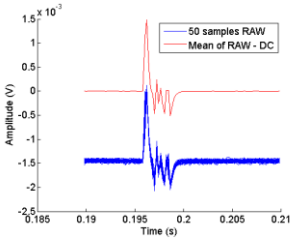

Figure 3, Drive 1V 50 repeated runs raw data and the composite average with offset removed.

References

[1] A. L. Hodgkin and A. F. Huxley, "A quantitative description of membrane current and its application to conduction and excitation in nerve," *J Physiol,* vol. 117, pp. 500-44, Aug 1952.

[2] W. A. H. Rushton, "A theory of the effects of fibre size in medullated nerve," *The Journal of Physiology,* vol. 115, pp. 101-122, 1951.

[3] G. J. Tortora and S. R. Grabowski, *Principles of anatomy and physiology*, 9th ed. San Francisco: Benjamin Cummings, 2000.

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