Abstract

In this chapter, well-known solutions that utilize a Fourier transform method for determining the extracellular, volume-conductor potential distribution surrounding elongated excitable cells of cylindrical geometry are reformulated as a discrete Fourier transform (DFT) problem, which subsequently permits the volume-conductor problem to be viewed as an equivalent linear-filtering problem. This DFT formulation is fast and computationally efficient. In addition, it lends itself to the application of some rather well-known techniques in linear systems theory (e.g., the DFT for convolution and least mean-square (Wiener) filtering for optimal prediction of a signal in random noise). Two specific examples are employed to demonstrate the utility of this discrete Fourier method: (1) the single, isolated, active nerve fiber in an essentially infinite volume conductor and (2) the isolated, active nerve trunk in a similar type of extracellular medium. In each of these, our DFT method is employed to obtain both the classical "forward" and "inverse" potential solutions for each volume conductor problem. In the case where the single, active nerve fiber is the bioelectric source in the volume conductor, simulated action-potential data from an invertebrate giant axon is utilized, and potentials at various points in the extracellular medium are calculated. The calculated potential distributions in axial distance z, at various radial distances r, are consistent with well-known experimental fact. When the active nerve trunk acts as the bioelectric source, the DFT method provides calculated potential distributions that are fairly consistent with experimental data under a variety of experimental conditions. For example, in these experiments, a special, isolated frog spinal cord preparation is used that permits separate or combined stimulation of the motor and sensory nerve fiber components of the attached sciatic nerve trunk. By manipulating the stimulus intensity applied to the motor (ventral) or appropriate sensory (dorsal) roots of the spinal cord, a variety of multiphasic extracellular volume-conductor potentials can be recorded from the sciatic nerve. The excellent agreement of model-generated and experimental data, regardless of the complexity of surface potential waveform, tends to validate the modeling assumptions and offer encouragement that this computationally efficient DFT method may be usefully employed in volume-conductor problems where both the bioelectric source, and the surrounding volume conductor, are of a much more complicated nature.

Citation

J. W. Clark, E. C. Greco and T. L. Harman, "Experience with a Fourier Method for Determining the Extracellular Potential Fields of Excitable Cells with Cylindrical Geometry," Critical Reviews in Bioengineering, CRC Press, Inc., 1978.