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Analysis of the power spectra, autocorrelation function and EEG time-series signal of a network of leaky integrate-and-fire neurons with conductance-based synapses

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Introduction

Focal epilepsy is characterized by the spread of seizure activity from pathological cortical tissue (focus) to other parts of the surrounding cortex and is typically diagnosed via the EEG [1]. The research described below will form the basis of a mathematical description of a mesoscopic network of cortical columns where the network dynamics will be examined as seizure-like behaviour spreads from a focal (pathological) column to other columns. In particular, the emphasis will be on how the local dynamics, network topology and physiological regulatory (control) mechanisms influence the overall global dynamics of the seizure spread. This study examines the dynamics of a network of neurons that approximate a single cortical column. Both the time series and power spectrum of the network are calculated and used to approximate the EEG signal of a cortical column.

Methods

The power spectrum is calculated from the autocorrelation function of a network of leaky integrate-and-fire neurons with conductance-based synapses that receive Poisson distributed synaptic input [2]. This is then generalized to a mean-field network approximation that includes both excitatory and inhibitory neurons [3]. This requires the calculation of the first passage time density, which is found numerically by solving a nonlinear Volterra integral of the first kind using Fourier transform methods. This also yields the EEG time-series resulting from the spikes generated by the network.

Results

The analytical results of the power spectra, autocorrelation function, first-passage time density and EEG time series are compared with network simulation results. Results were obtained using parameter values that represent typical cortical *in vivo* neurons [4].

Discussion

This work is the first stage necessary for constructing a physiologically plausible mathematical model of a mesoscopic network of cortical columns. The results presented here will be used as a mathematical approximation of a single cortical column and be generalized into a nonlinear network of columns. Future research will be directed toward incorporating an epileptic focus into a network of columns to investigate seizure propagation dynamics as described in the introduction.

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