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Estimating the spatial range of local field potentials in a cortical population model

Henrik Lindén*[1], Klas H Pettersen[1], Tom Tetzlaff[1], Tobias Potjans[2], Michael Denker[2], Markus Diesmann[2], Sonja Grün[2] and Gaute T Einevoll[1]

Address: [1]Department of Mathematical Sciences and Technology, Norwegian University of Life Sciences, Norway and [2]Theoretical Neuroscience Group, RIKEN Brain Science Institute, Hirosawa, Japan

Email: Henrik Lindén* - henrik.linden@umb.no

* Corresponding author

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Joint extracellular recordings of cortical spiking activity and mesoscopic population signals, such as the local field potential (LFP), are becoming increasingly popular as a tool for measuring cortical activity. The LFP, the low-frequency part of extracellular potentials, is thought to mainly reflect dendritic transmembrane currents following synaptic activity in the vicinity of the recording electrode. As the LFP signal stems from the population activity of a large number of cells, it represents a more robust measure of the network dynamics than single cell recordings. However, despite recent modeling [1] and experimental [2-4] studies on the origin of the LFP, much of the nature of this signal still remains to be understood. In particular, the literature has contradicting reports on how large the cortical area represented in the signal from an LFP electrode is. While some studies claim a spatial range as large as several millimeters [4], others suggest a much more local origin of LFP fluctuations [2]. A possible reason for this apparent discrepancy is that, in real brain measurements, is difficult to disentangle LFP correlations between nearby recording sites due to signal conduction from intrinsic correlations in the generators of the signal.

Here we address the question using a forward-modeling approach [1]. We simulate populations of up to several thousand neurons of morphologically reconstructed layer-5 pyramidal cells receiving synaptic input and calculate the resulting LFP generated by all transmembrane currents in the population. The neuronal population is considered to be in a cylindrical cortical column with realistic cell density and geometric arrangement, and the contributions to the LFP from cells at different distances to the electrode are evaluated. Each neuron receives numerous synaptic inputs with tailored presynaptic spike-train patterns. This enables us to investigate how (1) the population geometry and (2) the statistics of the presynaptic spike trains such as spike-train correlations, common-input correlations, and spectral properties determine the spatial range of the LFP.

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