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Signal-to-noise ratio of the neurophonic potential in the laminar nucleus of the barn owl

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It is a challenge to understand how the brain represents temporal events. One of the most intriguing questions is how sub-millisecond representations can be achieved despite the large temporal variations at all levels of processing. For example, the neurophonic potential, a frequency-following potential occurring in the network formed by nucleus magnocellularis and nucleus laminaris in the brainstem of the bird, has a temporal precision below 100 μs.

Here we address the question of how the neurophonic potential is generated and how its remarkable temporal precision is achieved. The neurophonic potential consists of at least three spectral components [1], and our studies aim at revealing their origin. Our hypothesis is that magnocellular axons are the origin of high-frequency (> 3 kHz) component of the neurophonic. To test this hypothesis, we present an advanced analysis of *in-vivo* data, numerical simulations of the neurophonic potential and analytical results. Describing the neurophonic as an inhomogeneous Poisson process (with periodic rate) that is convolved with a spike kernel, we show how the signal-to-noise ratio (SNR) of this signal depends on the mean rate, the vector strength, and the number of independent sources. Interestingly, the SNR is independent of the spike kernel and subsequent filtering. The SNR of the *in-vivo* neurophonic potential in response to acoustic stimulation with tones then reveals that the number of independent sources contributing to this signal is large. Therefore, action potentials of laminaris neurons cannot be the main source of neurophonic because neurons are sparsely distributed with a mean distance of about 70 μm. Synapses between magnocellular axons and laminaris neurons are assumed to contribute little to the neurophonic because neurons in the high-frequency region of laminaris are nearly spherical with a diameter in the range of 10 μm and they have virtually no dendritic tree. On the other hand, the summed signal from densely packed magnocellular axons can explain the high SNR of the neurophonic. This hypothesis is also supported by our finding that the stimulus frequency at which the maximum SNR is reached is lower than the unit's best frequency (BF), which can be explained by the frequency-tuning properties of the vector strength [2] and the firing rate [3] of magnocellularis neurons.

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