Ripple Detection using Frequency Modulation

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In the rat hippocampus, high frequency oscillations in the range of 100-200Hz, termed “ripples”, can be found in slow wave sleep and awake immobility. Recent evidence suggests that ripples are an extracellular signature for a process called “replay”, whereby encodings of recent experience are rapidly transferred between the hippocampus and cortex. Although the functional properties of ripples have received considerable attention, the problem of ripple event detection has been understated. Like the multi-unit spike classification problem, errors in ripple detection may lead to erroneous results.

Currently, ripple detection is based on the assumption that ripple amplitude will exceed the amplitude of the background noise. With this definition there is no robust criterion to reject high-frequency, high-amplitude noise (type I error) and there is no chance of detecting ripple events with amplitudes below the noise threshold (type II error). Using a Kalman filter for tracking sinusoids in noise, we found that ripple events contain a stereotypic frequency modulation profile. Although this characteristic can be seen by eye, spectral methods such as FFT and multi-taper analysis do not have the temporal and spectral resolution to resolve such abrupt modulations in frequency. In our analyses, we have used this frequency information to successfully identify small amplitude ripples that are usually missed, count the number of ripples in a burst of overlapping ripples, and reject noise events. Hence, our adaptive filter provides useful frequency information that can be used to lower the rate of type I and type II errors in the problem of ripple detection.