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Direct Detection of Neural Magnetic Fields with Fast-Temporal Resolution Magnetic Resonance Spectroscopy

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B.S., University of Pittsburgh, 2004

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**ABSTRACT**

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By Alexander John Poplawsky

Functional magnetic resonance imaging (fMRI) indirectly detects brain activation by measuring the hemodynamic response to increased energy demand. The detection of neural magnetic fields (NMFs) with MRI seeks to improve the temporal and spatial accuracy of fMRI by directly measuring the electrical responses of the brain. *In vivo* studies of the human brain provide conflicting results for the true detection of NMFs and are hypothesized to be contaminated by signal changes originating from the blood. Our experiments are the first to measure axonal NMFs by examining the free-induction decay (FID) at a sub-millisecond temporal resolution. Two *in vitro* preparations were chosen to eliminate confounding signal changes attributed to the vasculature and simultaneous field potential recording was used to time-lock neural activity to the onset of the FID. In the first study, we experimentally measured an FID phase change associated with a single evoked action potential from the earthworm giant axon system. A maximum phase change of [-1.2 ± 0.3] x 10-5 radians was observed in the background-subtracted FID. In addition, the experimental phase time course correlated well with a theoretical phase time course in both amplitude and temporal characteristics. In this way, this study provides the first evidence for the direct detection of a magnetic field from an evoked action potential using magnetic resonance technology. In the second study, we determined that the signal changes associated with evoked CA1 neurons of the rat hippocampal slice were 25 to 100 times below our detection limits. Theoretical simulations and experimental measurements support that our methods are sensitive to axonal components of the evoked NMF and insensitive to dendritic components. In this way, our technique measures signal changes originating from the white matter, unlike current fMRI techniques that measure signal changes originating from the gray matter.

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