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SQUID-detected microtesla MRI[1]

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We have developed a system to detect nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI) signals in magnetic fields of 1-100 microtesla. At such low fields, the very small nuclear polarization and the frequency dependence of conventional Faraday detection would lead to extremely weak signals. To overcome these problems we use a combination of prepolarization and frequency-independent detection with an untuned superconducting gradiometer coupled to a Superconducting Quantum Interference Device (SQUID). We demonstrate narrow linewidths in NMR spectra of nuclei in liquids and in spectra of J-coupled nuclei in molecules. Our MRI system operates at 132 μT (proton Larmor frequency 5.6 kHz), uses a prepolarizing field up to 150 mT and has a magnetic field noise below 1 fT/Hz$^{1/2}$. This system demonstrates submillimeter in-plane resolution of phantoms, and can acquire *in vivo* images of the human forearm, wrist and fingers. In high-field MRI, the susceptibility difference between tissue and, for example, a medical implant, can cause severe image distortion. We show that such artifacts are absent at microtesla fields, so that this technique could enable distortion-free MRI of patients with medical implants. Furthermore, microtesla MRI displays a greatly enhanced T_1-weighted contrast between different concentrations of agarose gel (T_1 is the longitudinal relaxation time). Preliminary experiments on *ex vivo* prostate specimens containing normal and cancerous tissue demonstrate similarly enhanced contrast, suggesting that this technique could be used to image tumors.

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