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In Vivo Microtesla Magnetic Resonance Imaging[1]

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We have developed a magnetic resonance imaging (MRI) system which operates at magnetic fields of 132 microtesla, corresponding to proton Larmor frequencies of 5.6 kHz. The main advantages of performing MRI at low magnetic fields (< 10 mT) are the reduced costs compared to conventional high- field MRI, and the reduction of nuclear magnetic resonance line broadening caused by inhomogeneous magnetic fields and susceptibility variations in the sample. Our technique combines prepolarization of the nuclear spins in a magnetic field up to 300 mT and signal detection at 132 microtesla using an untuned superconducting input circuit coupled to a superconducting quantum interference device (SQUID) to achieve a signal amplitude independent of the measurement field. We employ a standard spin-echo pulse sequence to acquire three-dimensional images in less than 6 minutes. Using encoding gradients of about 100 μT/m we obtain images of bell peppers and water phantoms with a resolution of 2 mm x 2 mm x 8 mm. Three- dimensional images of a human forearm were acquired at 132 microtesla with an average prepolarization field of 50 mT showing a signal-to-noise ratio (SNR) of 10 and an in-plane resolution of 3 mm x 3 mm. We have shown that for certain materials the longitudinal relaxation time (T_1) contrast is greatly enhanced at low magnetic fields. This enhancement is expected to lead to novel applications in specialized clinical imaging of human subjects, for example, low-cost tumor screening. To make such applications feasible further improvements of the SNR and resolution of the system are necessary. By employing a SQUID detector with a lower magnetic field noise and by raising the maximum polarizing field, an improvement of the SNR by an order of magnitude should be possible.

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