Microtesla MRI of the human brain with simultaneous MEG

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Magnetic resonance imaging at ultra-low fields (ULF MRI) is a promising new imaging method [1] that uses measurement fields in the microtesla range. In this method, sample magnetization is enhanced by a pre-polarization field substantially larger than the measurement field, and MRI signals are subsequently measured at an ultra-low field using SQUIDs (superconducting quantum interference devices) – the most sensitive detectors of magnetic flux. Unlike conventional high-field imaging, ULF MRI is compatible with SQUID-based techniques for biomagnetic measurements, such as magnetoencephalography (MEG) [2]. The combination of MEG and ULF MRI capabilities in one multi-channel instrument would eliminate the MEG/MRI co-registration errors and allow simultaneous functional (MEG) and anatomical (ULF MRI) imaging of the human brain.

Recently, we reported the first multi-channel SQUID system specially designed for both ULF MRI and MEG [3,4]. The seven 37 mm diameter second-order SQUID gradiometers have magnetic field resolutions of 1.2 to 2.8 fT/√Hz. Five sets of magnetic field and gradient coils are used for 3D Fourier imaging using pre-polarization. The system was used to acquire ULF images of a human hand and record auditory MEG [3]. It was also used to demonstrate benefits of multi-channel imaging at ULF, including imaging acceleration with the sensor array [5].

In this work, we report the first MR images of the human head acquired at an ultra-low (46 microtesla) measurement field (Figure 1). The subject's head was placed under the bottom of the cryostat. A pre-polarization field of 30 mT was applied for 1 sec prior to each imaging step. The image was acquired at 46 µT field according to 3D Fourier protocol with 3 mm × 3 mm × 6 mm resolution. A multiple-echo technique was used, and three echoes with echo tops at 65 ms, 137 ms, and 210 ms were recorded. The images in Figure 1 are composite seven-channel T_2 weighted images corresponding to the first echo. They were obtained by averaging six consecutive scans with 81×61×11 image matrix size. Only four horizontal layers of the 3D image (out of 11 acquired) are shown in the figure. The images corresponding to the second and third echoes (not shown) exhibit stronger T_2 contrast. Using the multiple-echo data, we were able to estimate values of the transverse relaxation time T_2 for different parts of the human head at ULF for the first time.

Immediately following the ULF MRI experiment, and without removing the human subject from inside the system, we also performed auditory MEG measurements.

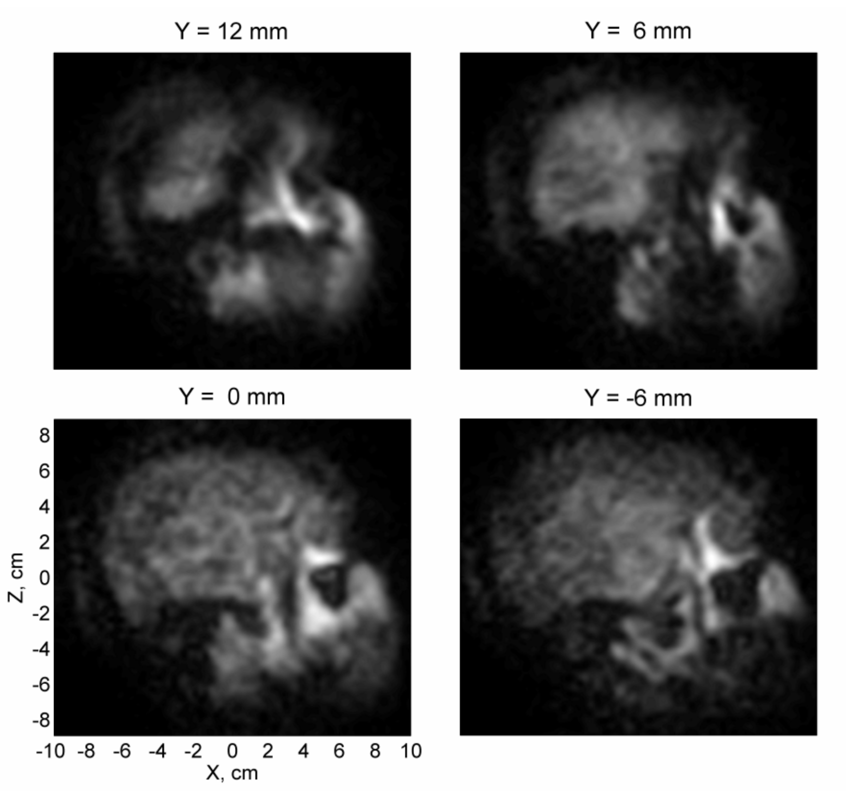

Figure 1. The first 3D ULF MRI image of the human head (46 µT field).

Our results demonstrate feasibility and potential of the human brain imaging at microtesla magnetic fields. They also show that SQUID-based instrumentation combining MEG and ULF MRI for advanced brain studies is practical.

References:

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