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Feature Article: SQUID Applications ･Medical Applications - Ultra-Low Field NMR/MRI

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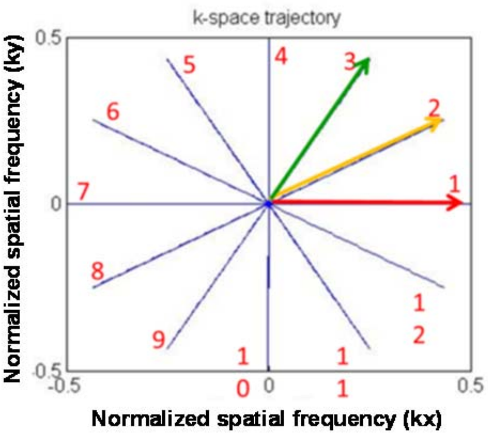
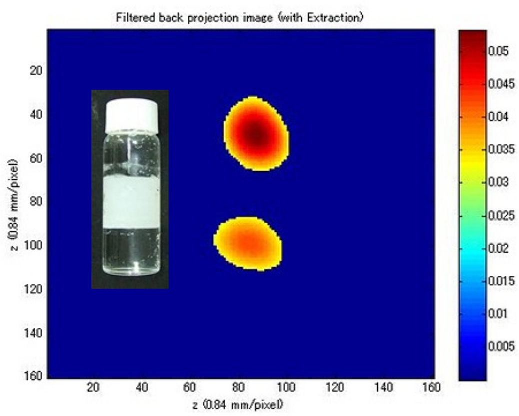
Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) work on the phenomenon that ^{1}H protons either absorb or emit electromagnetic energy exhibiting a specific frequency in the magnetostatic field. Both methods are utilized in many fields that include physics, chemistry and medical science. As conventional NMR/MRI systems utilize strong magnetic fields ranging from a few to several tens of tesla, superconducting magnets cooled using a helium refrigerator are necessary. This incurs high costs required for the construction of large-scale systems, making them complex in their design. In recent years, attention has focused towards ultra-low field NMR/MRI systems that employ highly sensitive SQUID magnetic sensors operating at low frequencies. Such systems do not require superconducting magnets and thus allows compact systems to be constructed at lower costs compared to conventional methods. The weak magnetostatic field generated by ultra-low field NMRs requires polarizing fields (Bp) of between 10-100 mT applied for several seconds to increase the magnitude of the nuclear spin. In a similar way to the strong magnetic fields in NMR, the rapid shut down of Bp causes a procession of the nuclear spin, returning to the original magnetostatic field direction via a free induction decay (FID) mechanism. Dependent on the direction of polarization, 90° or 180° RF pulse is sometimes applied after the shut down of Bp. Since the frequency of the FID signal has the same magnitude as the strength of the magnetostatic field, the ultra-low field NMR/MRI signal of several tens of micro-tesla is of a kHz order low frequency. Hence, sufficient sensitivity cannot be realized using an induction coil. Instead, an ultra-low field NMR/MRI system employing a highly sensitive, high temperature superconducting (HTS) SQUID operating at low frequencies has been developed.



(a) k-space trajectory



(b) 2D-image after reconstruction

Fig. 1 2D-images of divided water samples

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An ultra-low field NMR/MRI system requires an application of large polarizing field (Bp) in order to increase signal-to-noise ratios (SNR). Current investigations have been undertaken for a method to strengthen the polarizing field Bp, and have led to the development of technology that enables polarization using a 1.1 T permanent magnet. Figure 1 shows the results of 2D MRI image of a water bottle, acquired using a back projection method and exploiting the technology developed here. With the application of a rotating magnetic field gradient required for imaging, Figure 1(a) shows the FID signal obtained at 0° (G_y=56 nT/cm、G_z=0 nT/cm) and also at a 30° magnetic field gradient. The data was reconstructed using a Fourier transform, which produced a 2D-image corresponding to a 10 mL water sample volume, separated by silicone rubber, as shown in Figure 1(b). In the future, the author will endeavor to further improve the resolution with elaborate efforts applied in the field gradient.

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