Development of a compact ultra-low field MRI system

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Magnetic resonance imaging (MRI) around geomagnetic field strength, also referred to as ultra-low field MRI (ULF-MRI), has been expected to be the new application of Biomagnetics. Comparing to conventional MRIs that use a much stronger magnetic field, the benefits of the ULF-MRI include the low cost of the system, more open geometry, decreased susceptibility to artifacts, increased relaxation time contrast, and being combined with biomagnetic "functional" measurements, e.g., magnetoencephalography (MEG).

Existing studies have mainly dealt with developing ULF-MRI systems for human body or head. In contrast, the author's group has conducted extensive studies on measuring biomagnetic signal from small-animals, known as small-animal MEG systems. Therefore, we have been developing a compact ULF-MRI system for small-animals.

Our compact ULF-MRI system consists of a set of five pairs of coils: for a polarizing field, a measurement field, and three dimensional gradient fields[1)]. These coil sets were designed and fabricated to be the desktop size for installation inside a magnetically shielded box. The coil pairs for measurement and gradient fields were optimized by using a target field method, and sufficient area of homogeneity has been obtained for ultra-low field MRI measurements.

In our research, two types of magnetic sensors have been tested to detect the magnetic resonance signal. The first sensor is a superconducting quantum interference device (SQUID) sensor that has extremely high sensitivity in the ultra-low magnetic fields and is commonly used for ULF-MRI measurements. We demonstrated ULF-MRI measurements of water phantoms and a rat head at 33 μT using the SQUID sensor[2)].

However, there are some difficulties with using SQUIDs because of their fragility against larger magnetic fields such as a polarization pulse and necessity of cooling with a cryogen, like liquid nitrogen or helium. We also developed a novel detection unit composed of an induction coil that has been used to detect magnetic resonance signal in a higher magnetic field so far. The induction coil does not need a cryogen and is more robust and easier to handle than SQUIDs. We demonstrated ULF-MRI measurement[3)] and T_1 relaxation time measurement of water and aqueous solutions at 70 μT, as shown in Figs. 1 and 2. The results show the potential of using induction coil detection to realize a compact ULF-MRI system.

In the presentation, we would like to discuss these two detection techniques for ULF-MRI applications.

References

1) J. Hatta et al., *IEEE Tras. Appl. Supercond.*, **21**, 526-529, 2011.
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3) D. Oyama et al., *IEEE Trans. Magn.*, **53**, 5100504, 2017.

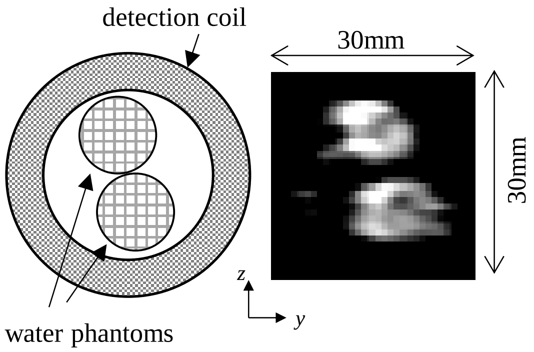

Fig. 1 Magnetic resonance image of water phantoms taken by the detection coil at 70 μT.

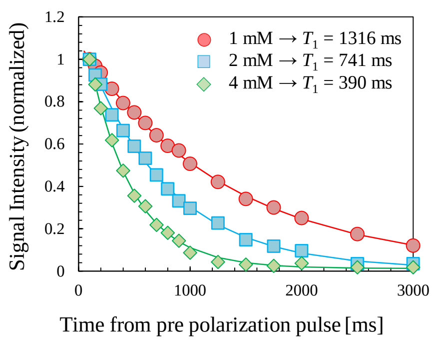

Fig. 2 Measured relaxation curves and calculated relaxation time of $NiCl_2$ aqueous solution phantoms.