Development of low field MRI system running on the same magnetic circuit used for 750 MHz CW EPR imaging system

Hideo Sato-Akaba[1] and Hiroshi Hirata[2]

[1]*Department of Systems Innovation, Graduate School of Engineering Science, Osaka University, Toyonaka, Osaka, Japan,* [2]*Division of Bioengineering and Bioinformatics, Graduate School of Information Science and Technology, Hokkaido University, Sapporo, Hokkaido, Japan*

Introduction

Electron paramagnetic resonance imaging (EPRI) allows visualizing free radicals in small animals and gives useful information of redox status in various tissues. Recently, reduction of stable nitroxyl radicals injected into a mouse brain has been studied for indicating the redox status in a brain-disease mouse[1]. However, the determination of the position in the brain is difficult due to the lack of anatomical information from the EPRI. So far to solve this problem, co-registration of an EPRI image and a high field MRI image has been applied[2]. However, the cost of the high field MRI system in addition with the EPRI system may be obstacle for many researchers to access this method. The purpose of the present work was developing a compact low field MRI system running on a same magnetic circuit used for a 750 MHz CW EPRI system.

Design of low field MRI system

A developed MRI system was mainly consisted of a 1.2 MHz NMR console, a gradient driver (Fig. 1), a transimit-receive (TR) switch circuit and a commercial magnetic circuit for the static field (~ 27 mT) and gradient field. The NMR console was built from a commercial FPGA developing board (DE0-NANO), a class-D amplifier and an acquisition board made from a post amplifier, a band pass filter and an analog digital converter (ADC). The TR switch circuit containing a trans-impedance pre-amplifier was designed for low impedance transmission and reception[3]. An NMR probe consisted of fixed capacitors, a variable capacitor and a solenoid coil (ø 27.5 mm × 30 mm, L = 40 μH at 1.15 MHz). An NMR signal from the pre-amplifier was fed into the post amplifier and then filtered with the band pass filter before digitizing the signal with the ADC. The sampling frequency was selected as NMR frequency × 4 divided by odd number for digital quadrature detection using band pass sampling[4]. The MRI system was controlled by a laptop PC (MacBook Air) via USB connection. The FPGA hardware program was developed with Quartus II v10. The MRI control software was written by LabVIEW 2012 and Xcode 4.2.1.

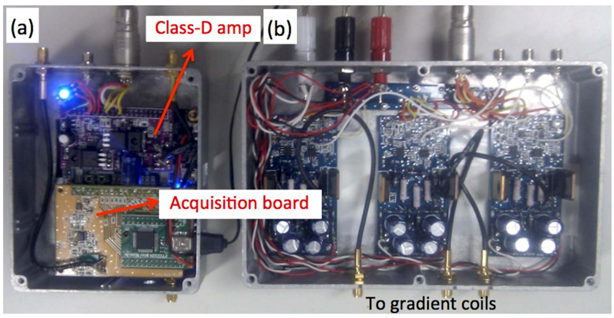

Fig.1 Photograph of (a) the NMR console and (b) the gradient driver.

Evaluation

We prepared a phantom that has five cylindrical cavities (ø4 mm) drilled in a cylindrical plastic (ø17.4 mm x 30 mm) and filled with 380 μL x 5 of 200 mM tempone aqueous solution. The phantom was set in the RF coil. 3D radial projections were collected with gradient echo sequence under the following condition: number of projections 641, number of averages 10, readout field gradient 0.05 mT/cm, TR/TE 106 ms/160 μs, RF pulse width 17 μs, RF frequency 1.15 MHz. The non-gradient signal was used to deconvolute the signal under gradient to compensate the small drift of the static magnetic field during acquisition and inhomogeneity of the static field. The directions of the projections were precalculated from the vertices of a geodesic sphere of an icosahedron[5]. 3D image reconstruction was carried out by the filtered back-projection method. The volume rendered image was shown in Fig. 2. From the visual inspection, the low field MRI image corresponded with the shape of the phantom. The precise comparison and resolution will be discussed in the presentation.

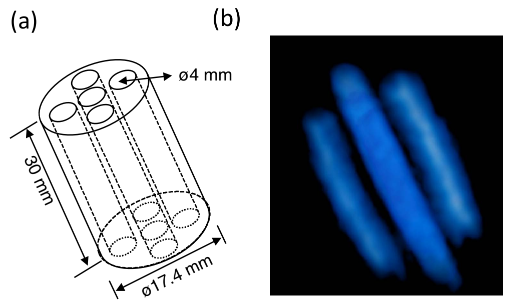

Fig. 2 (a) Schematic of the phantom and (b) the MRI image constructed from the 3D radial gradient echo sequence.

Summary

A low field MRI system using a same magnetic circuit for the 750MHz CW EPRI system was developed and tested using a phantom. The cost of the MRI system was considerably lower than having a high field MRI system since the additional magnetic circuit was not necessary. From the results, the low field MRI system is promising option for the co-registration of the EPRI/MRI image.

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Reference: [1] H. Fujii, et al., Magn. Reson. Med. **65**, 1 , 295-303, 2011. [2] M. Ohfuchi, et al., Concept Magn. Reson. B, **39**B, 4, 180-190, 2011. [3] H. Sato-Akaba, Solid State Nucl. Magn. Reson., in press. [4] R. G. Vaughan, et al., IEEE Trans. Signal Process. **39**, 9, 1973-1984, 1991.[5] H. Sato-Akaba, et al., J. Magn. Reson., **193**, 2, 191-198, 2008.