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Initial MRI Results Using Open-Sided Hybrid MPI and Low-Field MRI Scanner

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Abstract

Magnetic particle imaging (MPI) offers high contrast and sensitivity in imaging the spatial distribution of the magnetic nanoparticles (MNPs), since only the MNPs contribute to the signal and the human tissue does not. In return, MPI lacks anatomical information, which needs to be provided by another imaging modality such as magnetic resonance imaging (MRI). Recently, we presented a preclinical-size open-sided hybrid MPI and low-field MRI (LF-MRI) scanner, in which the coils are used interchangeably between the two modalities. In this study, the transmit/receive chain, exclusively dedicated to the LF-MRI mode, is integrated into the hybrid system, and its LF-MRI performance is demonstrated with imaging experiments at B_0 field of 50 mT.

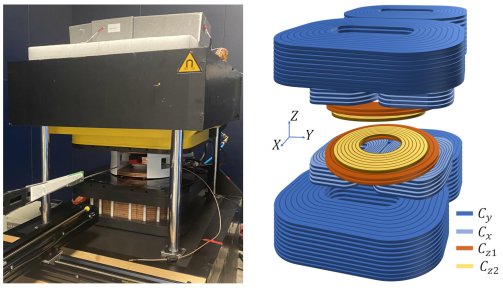
I. Introduction

The signal in magnetic particle imaging (MPI) stems from the non-linear magnetization response of magnetic nanoparticles (MNPs) [1]. Since the human tissue does not exhibit such a response, MNPs are the only source of the signal, providing MPI with high contrast and sensitivity. In return, the lacking anatomical information needs to be acquired via a complementary imaging modality. Among the possible options, magnetic resonance imaging (MRI) offers unique advantages due to its non-ionizing nature and the potential compatibilities among the required magnetic fields [2].

Based on our in-house prototype MPI system [3], we recently presented a preclinical-size open-sided hybrid MPI and low-field MRI (LF-MRI) scanner that features interchangeable use of coil groups between MPI and MRI modes [4]. The performance of this hybrid system was analyzed via simulation studies, revealing promising capabilities. In this work, we present the initial experimental results of the LF-MRI mode with 50 mT B_0 field, demonstrating the imaging performance of the hybrid scanner.

II. Methods

Figure 1(a)-(c) shows the prototype open-sided hybrid system and its interchangeable use of coil topologies. The signal flowchart for the LF-MRI mode including the transmit/receive (Tx/Rx) chain is shown in Figure 1(d). For the Tx/Rx chain, a single solenoid coil (Pure Devices GmbH, Germany) was employed, serving dual purposes for transmission and signal reception. This Tx/Rx chain was facilitated by a customized switch operating around 2.1 MHz, corresponding to the Larmor frequency for $B_0 = 50$ mT. In addition, we employed a control unit (drive-l, Pure Devices GmbH, Germany) incorporating an RF waveform generator, preamplifier, and data acquisition card (DAQ), along with an RF amplifier (RF-200, Pure Devices GmbH, Germany). This chain enabled suc-



Coil Group	Magnetic Particle Imaging	Magnetic Resonance Imaging
C_x & C_y	Selection Field	Gradient Field (Y & X)
C_{z1}	Focus Field	Main Static Field
C_{z2}	Drive Field	Gradient Field (Z)

(c)

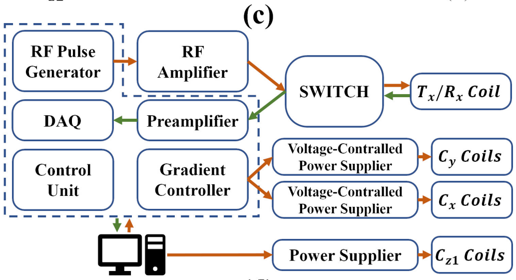


Figure 1: (a) Prototype ASELSAN open-sided hybrid system. (b) The coil topology and (c) functions of each coil group in MPI and MRI modes (interchangeable coils only). (d) Signal flowchart for the LF-MRI mode.

cessful RF pulse transmission and signal reception.

The timings of the pulse sequence were regulated by the control unit. For the gradient coils, 1.5 kW bipolar power supplies (FAST–PS-1K5, Caen Els S.R.L., Italy) were employed in analog input mode. A 10 kW power supply (NGPS, Caen Els S.R.L., Italy) was used to generate a B_0 field of 50 mT. Pulse sequences were implemented and executed via a custom MATLAB script.

A spin echo pulse sequence was employed with a TR of 500 ms and a TE of 14 ms. Imaging was performed over a field-of-view (FOV) of 34×32 mm^2 with an acquisition matrix size of 62×30, corresponding to a resolution of 0.55×1.05 mm^2. Slice selection was not applied, resulting in projection imaging. A readout bandwidth (BW) of 65 kHz was utilized. To enhance the signal quality, 72 averages were acquired, resulting in a total scan time of 18 minutes. For image reconstruction, apodization and zero-padding were applied to the raw k-space data, followed by 2D inverse Fourier transformation.

III. Results and Discussion

Figure 2 shows the experimental LF-MRI image acquired on the hybrid system, demonstrating accurate reconstruction of the phantom geometry. The warping seen

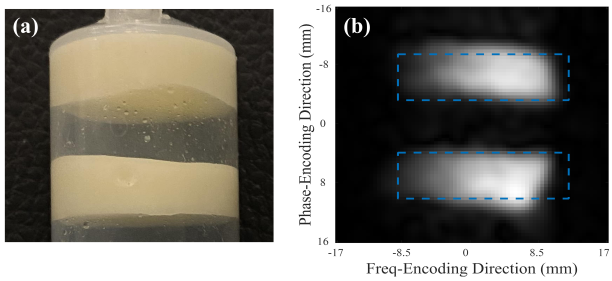


Figure 2: (a) Tissue-like phantom consisting of water, oil, and gelatin and (b) its experimental LF-MRI image. The blue dashed lines indicate the approximate shape, position, and size of the phantom.

along the frequency-encoding direction is caused by the off-resonance effects due to approximately 2000 ppm B_0 field inhomogeneity within the imaged FOV. The level of warping is more pronounced in the outer regions of the FOV, where the B_0 field inhomogeneity is larger. This warping can be mitigated by using a higher readout BW or corrected via an unwarping algorithm [5].

IV. Conclusion

In this work, initial LF-MRI results for open-sided hybrid MPI and low-field MRI system is presented. Experimental results demonstrate that the LF-MRI mode accurately captures the phantom geometry, demonstrating the LF-MRI capability of the hybrid system.

Author's statement

Conflict of interest: EUS states no conflict of interest. SK, DAS, and CBT are employees of Aselsan A.Ş.

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