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Preclinical Open-Sided Magnetic Particle Imaging Scanner

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Abstract

Preclinical magnetic particle imaging (MPI) plays a crucial role in advancing biomedical research through *in vivo* studies and helps with the translation into clinical systems. Our previously developed open-sided MPI system was capable of electronic rotation and translation of the field-free line (FFL) in three dimensions. However, the field of view (FOV) was limited to 34 × 18 × 12 mm^3 due to restrictions of the drive and receive coils. Here we introduce, a preclinical MPI system with a FOV of 100 × 50 × 25 mm^3, which is suitable for tumor imaging in small mice. We present the imaging system design and 2D imaging results of the phantom obtained using the developed scanner.

I. Introduction

Magnetic particle imaging (MPI) is a non-invasive, non-ionising imaging technique with great potential in both medical diagnosis and therapy [1]. Preclinical MPI holds importance, as it enables biomedical research for *in vivo* studies and provides valuable insights for translating to clinical systems.

Our in-house MPI system [2] has an open-sided configuration and is capable of electronic rotation and translation of the field-free-line (FFL) in three dimensions. The scanner is free of gradient degradation effects and features single-axis drive, focus, and receive coils for tomographic imaging. The performance of the imaging system was evaluated in detail through numerical simulations and experimental studies [2–4]. In previous experiments, a field of view (FOV) of 34 × 18 × 12 mm^3 was scanned in the central plane ($z = 0$) with a gradient field of 0.6 T/m and 2D phantom imaging was performed. In these studies, only the drive field was used for the translation of FFL, and the FOV size was limited due to the constraints of the drive and receive coil design.

In this study, we present, for the first time, an open-sided FFL scanner configuration suitable for preclinical studies, specifically for tumor imaging in BALB/c mice. A focus coil has been added to the previous system, and the design of the drive and receive coils has been revised. In its updated form, the imaging system has 0.35 T/m gradient, and a FOV of 100 mm × 50 mm in the horizontal plane, with a 30 mm opening in the z-direction. Here, we present the scanner configuration and 2D phantom imaging result obtained using the developed scanner.

II. Methods and Materials

In the current configuration of our in-house MPI system, the selection field (SF) with FFL is generated using a bi-planar gradient coil configuration (see Figure 1). FFL in the x- and y-axis is generated using C_x and C_y coils, respectively. For both coil groups, the SF is in the z-direction and FFL is rotated by adjusting the currents of the C_x and C_y coils [2]. A focus field coil was designed in Helmholtz configuration, with a magnetic field in the z-direction, to translate the FFL in the imaging plane. The

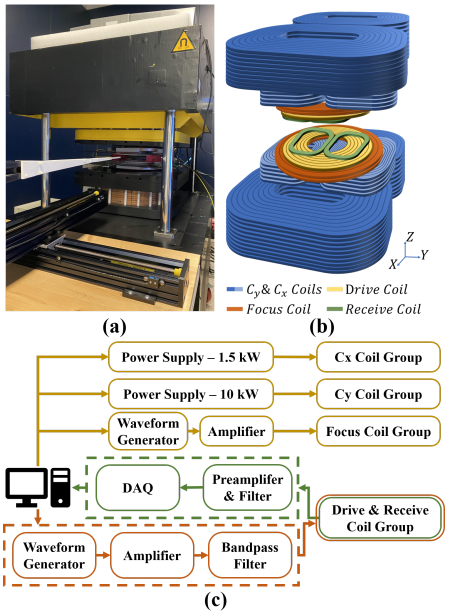

Figure 1: (a) Open sided ASELSAN MPI system. (b) Coil configuration. (c) Schematic diagram showing the overall system setup and connections.

manufactured focus coil (Tesla Engineering Ltd., UK) has an inner radius (r_i) of 120 mm, an outer radius (r_o) of 260 mm, and a thickness (t) of 15 mm. Hollow conductors with a rectangular cross section of 5 mm × 5 mm were used for water cooling. The number of turns is 42, with 14 horizontal (H) and 3 vertical (V) turns. A drive coil ($r_i = 30$ mm, $r_o = 110$ mm, $t = 4.5$ mm, turn number = H : 54 × V : 3) was designed in Helmholtz configuration and wound using a 200-strand AWG 41 litz wire (Pack, Germany). The receive coil consists of two rectangular Helmholtz coils in a gradiometer configuration. Each section has 36 turns and was wounded using a 75-strand AWG 46 litz wire. Copper plates ($t = 2$ mm) were inserted between the focus and drive coils to minimize coupling. SF and focus coils have been cooled with a water cooling system. The schematic of the MPI scanner is shown in Figure 1.

For imaging, FFL was translated to the desired location using the focus field and swept rapidly using the drive field (3.5 mT-peak, 24.3 kHz). The focus field was applied as a stepped waveform, with 50% overlap. The magnetic field gradient was 0.35 T/m, and the FFL was rotated from 0 to 174 degrees with 6 degree steps. The image reconstruction was performed using the system-matrix (SM) based approach with Kaczmarz algorithm. SM was obtained by scanning an undiluted 125 μl MNP sample (Perimag, Micromod, Germany) inside a 4-mm diameter PCR tube within an 80 mm × 40 mm FOV, and was interpolated to 4 × 4 for higher resolution. For imaging experiments, a phantom was used, which consists of a V-shaped tube and a large PCR tube (see Figure 2).

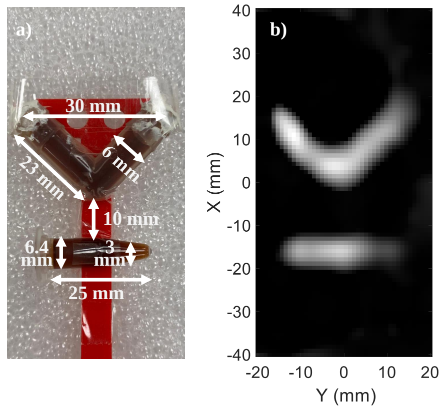

Figure 2: (a) Phantom geometry (b) Reconstructed image.

III. Results and Discussion

The reconstruction result of the imaged phantom is shown in Figure 2. Both the V-shape and PCR tube regions are visually recognizable. The results demonstrate that the developed system can translate and rotate the FFL electronically in the whole imaging FOV for required preclinical scanning experiments.

IV. Conclusion

In this study, initial results obtained with an open-sided MPI scanner with a FOV suitable for preclinical studies are presented. The results suggest that the developed system has potential for use in preclinical applications. Future studies will focus on conducting sensitivity and resolution analyses, and performing 3D imaging.

Author's statement

Authors state no conflict of interest.

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