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Asymmetric cancellation coil array for surface receiver coils in open-sided FFL MPI

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Abstract

Magnetic particle imaging (MPI), as an emerging non-invasive molecular imaging technology, utilizes the nonlinear magnetic response properties of superparamagnetic iron oxide nanoparticles for imaging. Compared to body coils, surface coils provide higher filling factor, which is promising to enhance the receiving sensitivity. The field-free line MPI (FFL MPI) is rotated at multiple angles for reconstructing particle concentration images. Single cancellation coil for surface coil may be reduced in accuracy at different angles due to imperfections in the magnetic field or mechanical errors. In this paper we design an asymmetric cancellation array based on an open-sided FFL MPI system for improving the cancellation failure problem at different angles. The results show that the array cancellation is superior to the individual cancellation.

I. Introduction

MPI is a non-invasive imaging technology that uses the nonlinear magnetic response of superparamagnetic iron oxide nanoparticles for concentration distribution imaging [1]. Typical receiver coils are body coils that can cover the field of view (FOV), while surface coils can improve imaging sensitivity due to closer proximity to the object with a larger fill factor [2]. Meanwhile, cancellation coils are employed to reject direct feed-through, harmonic disturbance and space electromagnetic interference. Thus optimizing the design of the cancellation coils is essential to maintain the signal quality, especially in the case of rotational inconsistencies in the magnetic field. In FFL MPI, the scanner is rotated to decouple the magnetic particle signal, but magnetic field defects or mechanical errors can lead to rotational inconsistencies. Optimiza-

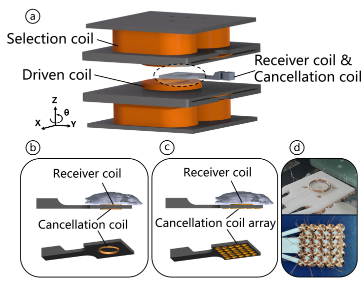

Figure 1: a is Open-sided FFL MPI System with receiver cancellation Coil Design Solution; b is the symmetric single cancellation coil (R&C 1); c is the asymmetric cancellation coil array (R&C 2); d is the photograph of the array cancellation scheme (R&C 2). The R&C in figure is at θ=0°, is along the y-axis.

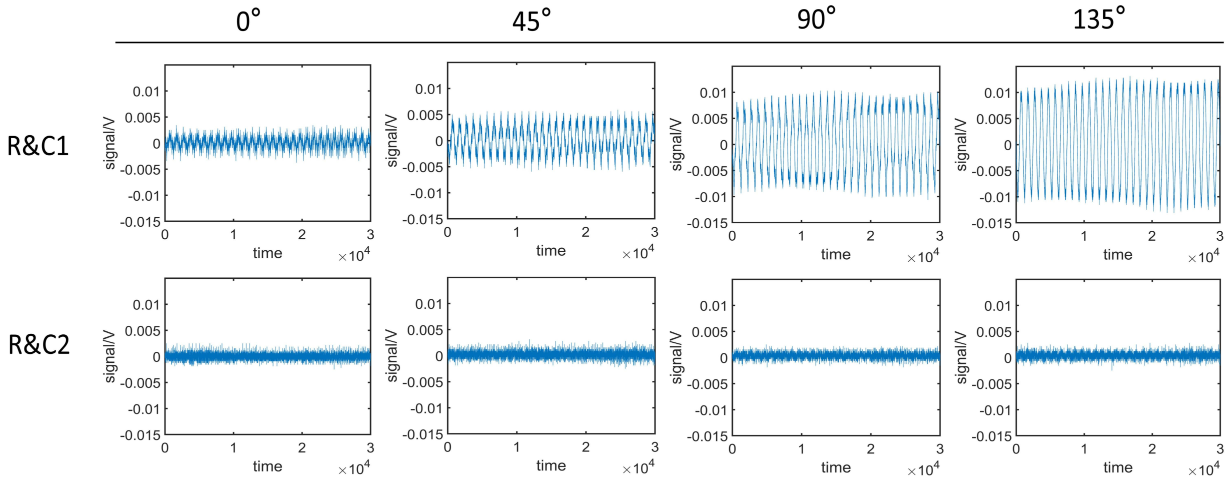

Figure 2: Comparison of time-domain signals for the two cancellation schemes at different angles.

tion of the cancellation coil is essential to compensate for these defects. In this paper, two designs of cancellation coils for open FFL MPI devices are considered: cancellation scheme 1 is a single cancellation coil (R&C 1) and scheme 2 is an asymmetric cancellation array (R&C 2). Both designs are tested at multiple angles to assess their effectiveness in improving imaging performance.

II. Methods and materials

The hardware device used is an open-sided FFL MPI scanner. The selection and driven coils are shown in Fig. 1. a, with parameters detailed in [3]. The experimental parameters are the drive field excitation frequency of 3000Hz, excitation amplitude of 2.4A, drive field strength of 4.62mT; the focus field frequency of 10Hz, focus field amplitude of 0.223A and focus field strength of 15mT. We used a localized surface coil as a receiver coil in this work instead of the classical body coil. The details of the surface receiver coil and the cancellation coil used are as follows:

1. Surface Receiver Coil: Copper, 0.2mm wire, 34mm diameter, 250µH, placed above the carrier table, centered in the FOV.
2. R&C 1 Cancellation Coil: Single coil with the same parameters as the surface receiver coil, placed below the carrier platform, 5mm from the receiver coil in the z-direction (i.e., carrier thickness).
3. R&C 2 Cancellation Array: 25 coils (10µH, 0.3mm wire, 10mm diameter) connected in series, placed below the carrier platform.

After setup, background tests were conducted at 0°, 45°, 90°, and 135° angles. Comparison of direct feed-through time-domain signals at different angles.

III. Results

The experimental results are shown in Fig. 2. The time-domain background signal measurements of the R&C 1 and R&C 2 cancellation schemes at 0°, 45°, 90°, and 135° are presented in Fig. 2. The main components of the background signal are direct feed-through and noise interference. The direct feed-through interference is increased as the rotation angle was increased in the R&C 1 scheme. However, in the R&C 2 scheme, the background signal remains stable at different angles. This indicates that the R&C 1 design is not able to effectively suppress the direct feed-through after rotating the magnetic field, but the R&C 2 is designed with an array of cancellation coil units to cover the full range of rotation, which reduces the cancellation error caused by rotation.

IV. Conclusions

This work presents a new cancellation scheme for surface coils in open-sided FFL MPI scanners designed with asymmetric cancellation arrays. Facing magnetic field inconsistencies in FFL MPI scanners during magnet rotation, the array design exhibits superior cancellation stability compared to individual cancellation coils. This study has the potential to further improve the signal stability of the imaging system and support the reconstruction of higher quality images.

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Author's statement

Conflict of interest: Authors state no conflict of interest.

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