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Abstract

3D printed coil array for spherical harmonic spatial encoding in magnetic particle imaging

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Magnetic particle imaging is a promising method of noninvasive diagnostics that is being consistently developed for future implementation in clinical routine [1]. The method is based on measuring the magnetic response of superparamagnetic nanoparticles using a set of drive, gradient, and receive coils. One of the major technical obstacles to translating the method to the human scale is the large amount of energy required to establish gradient fields of sufficient levels. In most electromagnet-based MPI scanners presented so far, the selection field gradient system is the main power consumer.

In this work, we propose a novel approach to spatial encoding of the volumetric distribution of superparamagnetic nanoparticles by using only a drive field and an array of receive coils. This could significantly reduce the amount of energy required for the MPI system to operate and make it easier to scale it for clinical applications. Each coil in the array has a unique volumetric spatial sensitivity pattern representing mathematical functions describing spatial variations on a spherical surface, or spherical harmonics [2]. The combination of signals from this array permits us to reconstruct the nanoparticle distribution in space without the use of gradient fields.

To test our approach, we assembled a 3D-printed prototype consisting of 15 receive coils and one drive field coil. Each receive coil was numerically synthesized using the CoilGen software [3] to obtain a specific sensitivity pattern. Coil winding holders were printed using a Formiga P100 laser-sintering system. We tested our setup with a drive field amplitude of 6 mT and measured signals from all receive channels. Small vessels with undiluted Resotran® (28 mg/ml) were used as static imaging objects. Our prototype, consisting of 15 uniquely patterned receive coils and one drive coil, successfully localized nanoparticle distributions within a defined volume using only drive-field excitation. The resulting images allow visualization of the sector of the sphere in which the nanoparticles are located with an angular resolution of at least 65 degrees, without providing any depth information, making the method not truly three-dimensional. Although initial localization has been achieved, future work needs to address current resolution limitations and lack of depth encoding to move towards clinical scale imaging.

AUTHOR'S STATEMENT

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