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Advancements in the imaging of magnetic nanoparticles using magnetorelaxometry with sequential activation of inhomogeneous excitation fields

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Introduction

Magnetic nanoparticles offer a large variety of promising applications in medicine thanks to their exciting physical properties. However, an imaging technique capable of the non-invasive, sensitive, specific and in particular quantitative detection of these particles is not available at present. A promising approach is the determination of the distributions from multichannel magnetorelaxometry measurements by solving an inverse problem, e.g. by minimum norm estimation techniques. In first simulation and measurement studies, homogeneous excitation fields were employed. However, this determination is considerably ill-posed, resulting in a limited spatial resolution [1].

Methods

A promising idea for improving the reconstruction quality and increasing the spatial resolution is the employment of three-dimensional coil arrays generating inhomogeneous excitation fields [2]. These fields are sequentially applied and the respective measurement results are combined.
In this contribution, the reconstruction quality for homogeneous and inhomogeneous excitation as well as the use of sequential activation using an excitation coil array is compared. For this purpose, computer simulations involving three-dimensional sources and real sensor geometries were performed. Furthermore, we present a strategy for adapting the inhomogeneous field sequences with respect to an improved and uniform sensitivity.

Results

Imaging results obtained with the different excitation schemes were computed and compared. The visual and quantitative reconstruction quality is improved when employing sequential activation of homogeneous fields with different orientations. However, visually best results are gained with inhomogeneous field sequences. This activation results in a more homogeneous distribution of the spatial lead field sensitivity, which is a measure for the impact of nanoparticles in a certain voxel to the sensor positions of the measurement system.

Conclusion

Our results show that the sequential employment of inhomogeneous magnetization fields leads to a better quantification of the magnetic nanoparticle distributions. In future work, we will investigate optimization strategies for the excitation coil arrangements.

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