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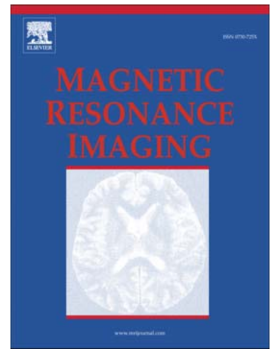

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A study of MRI gradient echo signals from discrete magnetic particles with considerations of several parameters in simulations

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Abstract

Modeling MRI signal behaviors in the presence of discrete magnetic particles is important, as magnetic particles appear in nanoparticle labeled cells, contrast agents, and other biological forms of iron. Currently, many models that take into account the discrete particle nature in a system have been used to predict magnitude signal decays in the form of R2* or R2' from one single voxel. Little work has been done for predicting phase signals. In addition, most calculations of phase signals rely on the assumption that a system containing discrete particles behaves as a continuous medium. In this work, numerical simulations are used to investigate MRI magnitude and phase signals from discrete particles, without diffusion effects. Factors such as particle size, number density, susceptibility, volume fraction, particle arrangements for their randomness, and field of view have been considered in simulations. The results are compared to either a ground truth model, theoretical work based on continuous mediums, or previous literature. Suitable parameters used to model particles in several voxels that lead to acceptable magnetic field distributions around particle surfaces and accurate MR signals are identified. The phase values as a function of echo time from a central voxel filled by particles can be significantly different from those of a continuous cubic medium. However, a completely random distribution of particles can lead to an R2' value which agrees with the prediction from the static dephasing theory. A sphere with a radius of at least 4 grid points used in simulations is found to be acceptable to generate MR signals equivalent from a larger sphere. Increasing number of particles with a fixed volume fraction in simulations reduces the resulting variance in the phase behavior, and converges to almost the same phase value for different particle numbers at each echo time. The variance of phase values is also reduced when increasing the number of particles in a fixed voxel. These results indicate that MRI signals from voxels containing discrete particles, even with a sufficient number of particles per voxel, cannot be properly modeled by a continuous medium with an equivalent susceptibility value in the voxel.

Keywords: Simulation, Static Dephasing Regime, Density of States, MRI, Susceptibility

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