MRI beyond Fourier encoding: From array detection to higher-order field dynamics

K. P. Pruessmann

Institute for Biomedical Engineering
ETH Zurich and University of Zurich
8092 Zurich, Switzerland
klaas@biomed.ee.ethz.ch

MRI is currently seeing a steady departure from the traditional pure Fourier paradigm of signal encoding and reconstruction. One of the drivers of this development has been parallel imaging with arrays of signal detectors, in which Fourier encoding in the spin domain is complemented by non-Fourier encoding through electrodynamics. The first part of this contribution will be dedicated to a brief review of mathematical aspects and tools that parallel imaging has brought to MRI reconstruction. It will include remarks on the general trade-off between depiction fidelity and signal-to-noise ratio, joint optimization, its generic L_2 formulation, iterative solving, and the extension of this approach to more general encoding models.

The second part of the presentation will discuss the concept of magnetic field monitoring during MRI scans, a recent approach designed to enhance reconstruction results by improving the accuracy of the underlying encoding models. Arrays of miniature NMR probes yield highly sensitive, time-resolved accounts not only of intentional gradient encoding but also of undesired field dynamics. Field perturbations from 0^{th} spatial order (uniform) to very high spatial orders frequently occur in MRI scans due to hardware imperfections, physiological susceptibility effects, and external sources. It is shown that field monitoring permits incorporating such perturbations in a suitable signal model, enabling high-fidelity reconstruction despite experimental imperfections. Special attention will be given to the implications of this approach for image reconstruction, available algorithms, and requirements in terms of computing resources. Current examples include diffusion tensor imaging with 3^{rd}-order image reconstruction, i.e., incorporating measured field dynamics up to 3^{rd} spatial order in terms of spherical harmonics.