University PhD Dissertation Defense
Department of Electrical Engineering
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Computational Methods for MRI Under Extreme Field Inhomogeneity
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Static magnetic field inhomogeneity is a fundamental obstacle for spatial encoding in magnetic resonance imaging (MRI), degrading images through intensity artifacts, geometric distortion, blurring, and signal loss. The problem is most severe near metallic orthopedic implants, where susceptibility differences perturb the field by hundreds of parts per million. This dissertation develops computational methods that progressively confront this challenge: measuring the image-quality degradation, managing its tradeoffs, and ultimately encoding the field inhomogeneity itself to eliminate artifacts.

First, I present TONIQ (Toolbox for Non-uniform Image Quality), an ensemble of phantom-design and image-analysis methods for benchmarking MRI techniques. TONIQ enables joint, voxel-wise mapping of several image-quality factors – one novel resolution-mapping approach based on local point-spread-function estimation is highlighted. Second, I present SCORE (Shear Correction of Off-Resonance), a generalization of View-Angle Tilting for correcting bulk displacement artifacts in 3D acquisitions. By synthesizing images both with and without VAT correction from a single acquisition rather than two, SCORE makes the blurring-distortion tradeoff inherent to VAT manageable in post-processing. Finally, I present HIFI (Hyperslabsupported
Image-Field Inversion), a new imaging paradigm based on a convex
relaxation of the joint image-field estimation problem. HIFI lifts the problem to a higher-dimensional (4D) space to yield a linear reconstruction that eliminates residual intensity artifacts close to metal. Together, these methods advance spatial encoding under extreme field inhomogeneity, with applications in musculoskeletal and interventional imaging, and the potential to support next-generation low-field MRI.