Magnetic Resonance Imaging at the boundary of Quasi-Static to Far-Field RF Regime

Andrew J. M. Kiruluta[1], Patrick Bluem[2], Zoya Popovic[2], Pierre-Francois Van de Moortele[4] and Branislav M. Notaroš[3]
[1]Department of Physics, Harvard University, Cambridge MA, USA, ECE Dept, University of Colorado, [3]Electrical & Computer Engineering Department, Colorado State University, Fort Collins, CO
(4) Department of Radiology, University of Minnesota, Minneapolis, MN

Since its inception, magnetic resonance (MR) imaging has operated in the long wavelength regime where far field electrodynamic effects are negligible. With the use of high field strength imagers (>7T, 300 MHz proton resonance), on large samples such as a human head, and coupled with the high dielectric constant of tissue (>80), the excitation wavelength becomes on the order of or smaller than the imaging sample. Under these conditions, new phenomena previously unknown in MR, arising from the spatial and spectral interference of quasi-static RF excitation fields start to emerge. It has become possible to record these spatial-spectral interference patterns in an MR excited medium. The spectral grating component has always been part of conventional MR. It arises naturally from either the intrinsic chemical shift anisotropy of the spin system or the field inhomogeneity due to the application of spatial encoding field gradients. The spatial grating component is new and is due to the emergence of the propagating wave vector with quasi-static excitation fields. Quasi-static field interference phenomena such as spatial-spectral holographic properties of storage, programmable time-delay, phase conjugation or time-reversal and Bragg selectivity are experimentally demonstrated for the first time in an MR sample. These ideas are shown to be extendable to complex holographic signal processing functions such as recognition, correlations and triple products. This approach has potential for new spatial localization techniques using quasi-optical techniques for focusing excitation fields, slice selection through volume Bragg selectivity, phase conjugate distortion free imaging as well as higher resolution encoding limited only by the spacing of spatial interference fringes and T2.

We have previously presented work on the helical antenna concept as well as patch probes to couple quasi-static RF power to a sample in an MR field at 7T, 10.5T and 16.4T field systems. In this work, we will discuss implications of this interpretation to the design of RF probes for exciting RF modes in the MR sample and detecting the resultant signal. We will present several innovative ideas for extending the RF design of a typical MR coil for uniform coverage of the imaging volume under these quasi-static to far field conditions. These include dipole helix arrays as well as leaky waveguides for increased mode coupling to the sample.