Generalized Reconstruction of Multi-Spectral MR Acquisitions for Imaging Near Metal Implants

D. Hernando\textsuperscript{1}, K. M. Koch\textsuperscript{2}, K. F. King\textsuperscript{3}, and Z-P. Liang\textsuperscript{4}

\textsuperscript{1}Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, United States, \textsuperscript{2}Applied Science Laboratory, General Electric Healthcare, Waukesha, WI, United States

Introduction
MR imaging near metal implants is a challenging problem due to the presence of very large induced $B_0$ field distortions (~20 kHz). Several techniques have been recently developed, that effectively divide the large spectral range into smaller bins, dramatically reducing $B_0$-related distortions [1,2,3]. The MAVRIC technique [1,2] acquires several 3D datasets using different transmit/receive frequencies (with each dataset covering a narrow spectral band). These datasets are then independently reconstructed, and combined using sum-of-squares (SOS). One of the main limitations of this reconstruction is the presence of residual image intensity distortions in regions of rapid field variation, which can produce both characteristic signal pile-up and intensity attenuation artifacts. In this work, we develop a generalized reconstruction method for multi-spectral acquisitions, where the true image and $B_0$ field map are directly estimated by solving the corresponding inverse problem.

Methods
For a 3D acquisition without slab selection gradients, the signal obtained using each transmit/receive frequency $\nu^RT_0$ can be modeled as:

$$s(k_x, k_y, k_z, \nu^RT_0) \propto \int_{\mathbb{R}^3} \rho(x, y, z) \rho(\nu_0(x, y, z) - \nu^RT_0) e^{i2\pi \left[k_x(x + \nu_0(x, y, z) - \nu^RT_0) + k_y y + k_z z\right]} dx \, dy \, dz \quad (1)$$

where $k_x$ is the readout dimension and $k_y$, $k_z$ are the phase-encoding dimensions, $\rho_0$ is the amplitude of the readout gradient, $\rho(\cdot)$ is the excitation/refocusing spectral profile, $\rho(x, y, z)$ is the desired image and $\nu_0(x, y, z)$ is the frequency offset due to $B_0$ inhomogeneity. The spectral profile $p(\cdot)$ is assumed known or calibrated from the data (in this work it is modeled as a Gaussian with FWHM ~2 kHz and linear phase). Therefore, the only unknown parameters in the signal model are $\rho(x, y, z)$ and $\nu_0(x, y, z)$. These parameters are estimated using a nonlinear least-squares (NLLS) fitting procedure [4] after discretizing Eq. (1). We include regularization of $\rho(x, y, z)$ and $\nu_0(x, y, z)$ in the NLLS procedure to prevent excessive noise amplification in regions of rapid field variation (where the conditioning is worst).

Data acquisition: Data were obtained on a phantom containing a cobalt-chromium component of a total knee replacement as well as a plastic replica, using a standard MAVRIC acquisition, with $\nu^RT_0$ separation of 1 kHz between consecutive spectral bands, 256 readout points and readout bandwidth of +/-125 kHz. An in vivo acquisition with similar parameters was performed on a human subject with total knee replacement.

Results and Discussion
Results from the proposed method are shown in Figs. 1 and 2 (phantom and in vivo results, respectively).

Conclusions
This abstract presents a novel method for the reconstruction of multi-spectral acquisitions such as MAVRIC, based on estimating the image and field map directly from the data. The proposed method overcomes important limitations of current reconstruction methods.