Fast 2D Imaging for Distortion Correction Near Metal Implants

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Target Audience: Scientists and clinicians interested in applications demanding relatively fast imaging near metal devices or implants.

Purpose: Multispectral imaging (MSI) approaches such as SEMAC, MAVRIC, MAVRIC-SL and others have shown promise for artifact-reduced imaging near metal [1-3]. These methods all combine multiple 3D images, each from a separately excited region (frequency bands in MAVRIC, distorted slices in SEMAC). The longer scan times of these approaches can be mitigated using reduced-excitation-region approaches using varied 90°/180° pulse bandwidths in combination with SEMAC or MAVRIC [4,5]. Here we investigate a fast, distortion-free 2D imaging alternative that offers considerable flexibility when the number of slices is limited (e.g. for localization), or when off-resonance variation is small (near smaller devices).

Methods: Reversing the selection gradient between excitation and refocusing pulses excites finite spectral (f) and spatial (z) regions (“bins”), where frequency modulation of each pulse allows arbitrary positioning of regions (Fig. 1) [6]. Using a high readout bandwidth (BW) limits distortion to within about a pixel (slice BW/pixel BW ratio), like MSI sequences. Multiple bands at a location can be combined with a complex sum or square-root-sum-of-squares approach as with other MSI methods. In all cases we image at TR/TE=3000/12 ms, 2mm-thick slices, 384x120 matrix over 24x18cm FOV with ±125 kHz receive bandwidth, 1.3 kHz RF bandwidth, ETL=8, half-Fourier and no parallel imaging. We demonstrate several aspects of this method in a phantom with a titanium shaft / cobalt-chromium head shoulder replacement:

a) Single-slice imaging with 24 frequency bins in 32 sec, compared to a 24-slice fast spin echo (FSE) scan.
b) Distortion free imaging by exciting 24 frequency bins for each one of 24 slices (12:48) compared to a SEMAC scan with 24 slices and 24 z phase encodes in 9:22 (25% speedup using elliptical k-space sampling).
c) Using one y-projection image (Fourier transformed k_y=0 line) for each bin to determine the signal in that bin to rapidly map where signal occurs [7]. Automated selection of bins to include is done retrospectively using a threshold of 1% of the maximum bin signal. This selection could be prospective under the assumption that the excitation regions can be efficiently interleaved, resulting in a substantial scan time decrease.

Results: Fig. 2 shows the maximum intensity along the y-projection for each excited bin. Fig. 3 compares standard FSE, SEMAC, a full acquisition with the proposed approach, and the reduced acquisition concept with retrospective discarding of bins below the 1% threshold. Obvious distortion and pile-up artifacts in FSE are corrected by the other methods. The proposed method has comparable artifact correction to SEMAC, but lower SNR due to the 2D approach. Using bins above 1% gives about a 60% scan time reduction, and actually reduces noise added from zero-signal bins. The benefit of the localizer would likely be much greater near smaller devices such as surgical clips, dental fillings or titanium screws. Like other MSI methods, residual artifacts from background gradients also exist [8].

Discussion: We have demonstrated a “multi-frequency” 2D imaging approach for artifact correction near metallic implants. This is essentially a 2D version of MAVRIC [1], and similar to a proposed spiral off-resonance correction method [9]. Regions are excited using a well-known gradient reversal between excitation and refocusing [6], though other excitation options can be used [4,5]. Current MSI methods (including [4,5]) use 3D phase encoding, which is slow, inflexible, and can induce ringing artifacts with low numbers of phase encodes. Instead, the proposed approach directly excites and images frequency bands without 3D phase encoding, offering much faster imaging for limited numbers of slices or limited off-resonance. Further advantages are the lack of need for view-angle-tilting and the ability to acquire selected bins with reduced excite/receive bandwidth, perhaps to improve SNR for the “on-resonance” bin, which typically contains most of the signal. Drawbacks include a lower SNR efficiency with respect to 3D sequences and the need for intelligent interleaving, especially when reduced bin sets are used. Acceleration with parallel imaging, multiband or Hadamard encoding, along with different bin combination methods are all straightforward variations. Overall this approach offers a much faster alternative to 3D MSI sequences, with comparable artifact suppression, for many applications of imaging near metal.