Adaptive Slice Encoding for Metal Artifact Correction

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Introduction: Metallic implants can cause moderate or severe distortion artifacts in MR images depending on the shape, size, composition and orientation of the implant. Recently-proposed methods correct image distortion due to susceptibility shifts near metallic implants by using excitation of limited bandwidths [1] or limited spatial slices [2], both followed by 3D imaging. Here we demonstrate "adaptive SEMAC," where the acquisition is adaptively prescribed based on the extent of metal-induced frequency shifts, greatly improving acquisition efficiency.

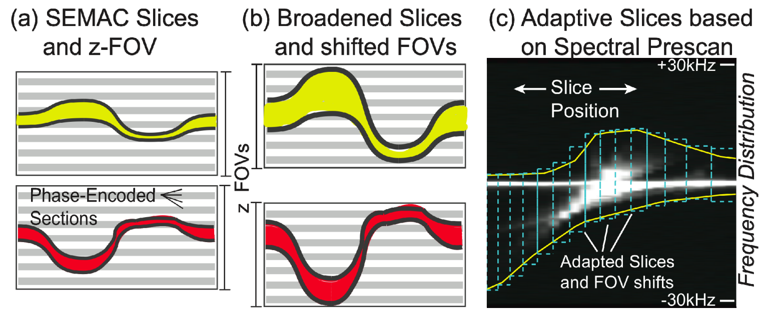

Figure 1: (a) standard SEMAC excitation, z phase-encoded sections and FOV for two differently distorted slices. (b) Objective for adaptively chosen slice width and FOV. (c) Spectral prescan showing operator-selected boundary (yellow) and resulting adaptive slice widths (dashed boxes).

Methods: For any selective RF pulse, spatial distortion due to frequency shifts is proportional to both the slice width and the frequency shift. Slice encoding for metal artifact correction (SEMAC) [2] uses a 2D excitation with constant slice width, followed by 3D phase-encoding with a z FOV centered on the slice to resolve the distortion of each excited slice (Fig. 1a). By repeating this process for all (nominal) slices, each spin is ideally excited and resolved exactly once. SEMAC also uses view-angle tilting (VAT) to correct in-plane distortion [3]. To improve the efficiency of SEMAC, the width of each excited slice and location of the phase-encoded FOV can be adapted to fit the expected distortion (Fig. 1b), which reduces the total number of excited slices. The z phase encode resolution is kept constant for all slices, as this determines the ultimate through-slice image resolution in SEMAC.

To select the appropriate slice widths, we perform a spectral prescan (several seconds), where all 2D slices are excited and imaged with readout and phase-encode gradients off to provide a frequency-slice distribution (Fig. 1c). The operator uses a simple interface to select the region containing signal (yellow lines in Fig 1c). An algorithm then adaptively places slices of different widths to encompass the total region (boxes in Fig 1c). Since the extent of the slice distortion is proportional to slice thickness and range of frequencies excited, the algorithm simply keeps the product of these constant (the area of each box in Fig. 1c). The z FOV is shifted according to the off-center frequency distribution in the box. The distribution in Fig. 1c was obtained from coronal slices covering a 17 cm-thick volume in a patient with a total hip replacement and stainless steel screws.

We demonstrated the adaptive SEMAC scan in a gel phantom with a titanium/cobalt-chromium shoulder implant at 1.5T, comparing it to 2D spin echo with VAT and standard SEMAC. All scans used a 22x16 cm FOV, with 256x96 matrix and 2x parallel imaging, with 1 kHz RF pulses. The 2D and SEMAC scans used 32 slices, each 1.5 mm thick, and TR/TE=460/10ms. The SEMAC and adaptive SEMAC scans used 16 z phase encodes for each excited slice, with through-plane resolution of 1.5 mm. The adaptive method used a total of 16 slices of widths varying between 2.1 and 4.8 mm, and 2 interleaved acquisitions to allow some slice overlap [1], with TR/TE=140/10 ms. (TR was increased slightly to improve SNR.)

Results: The in-plane and reformatted images are shown in Fig. 2 for the three methods. Both SEMAC and adaptive SEMAC resolve the distortions very well compared with the 2D VAT spin echo acquisition. The adaptive SEMAC acquisition shows a minor slice boundary artifact (away from the implant head) that tends to be blurred out in the SEMAC acquisition, and also has reduced SNR due to shorter TR and scan time.

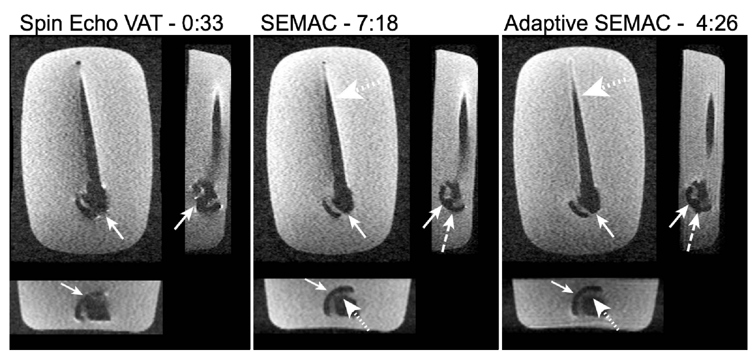

***Figure 2:** Comparison of 3-axis reformatted images for 2D spin echo VAT, standard SEMAC, and SEMAC with adaptive slice widths. Implant detail is clearly seen in both SEMAC methods (solid arrows). In some areas, the adaptive method is slightly better (dotted arrows) or slightly worse (dashed arrows) than standard SEMAC. However, the adaptive SEMAC method is 40% faster.*

Discussion: We have demonstrated that the slab widths in SEMAC can be adaptively set based on a fast spectral prescan, resulting in a 40% scan time reduction. In typical patient scans, the volume extends far beyond the implant, and we expect this reduction to be around 2-3x. Using overlapping slice profiles [1] reduces slice boundary artifacts, and longer echo trains will allow a more efficient acquisition with the reduced number of slices.

Conclusion: Using a very fast spectral prescan and operator-selected volume, the slice widths in SEMAC can be adapted to the actual frequency distribution, which can vary widely with implant composition, size and orientation. Adaptive SEMAC results in a more efficient acquisition, while maintaining distortion correction.

References: [1] Koch KM, et al. MRM 2009; 61:381–390 [2] Lu W, et al. MRM 2009; ; 62:66–76. [3] Cho ZH, et al. 6th SMRM 1987, p.912.
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