

Investigations on Imaging Near Metal with Combined 3D UTE-MAVRIC

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Introduction: Recently developed sequences such as MAVRIC [1] and SEMAC [2] have enabled the ability to image near embedded metal implants using MR on clinical scanners. Another class of sequences that have gained popularity in recent years is UTE [3], which allows imaging of tissue with very short T2s such as bone. Here, we investigate the potential combination of 3D UTE with MAVRIC to image short T2 tissues surrounding orthopedic implants with reduced susceptibility artifacts.

Theory: UTE: Imaging short T2 tissues with UTE sequences is achieved by acquiring the Free Induction Decay (FID) of the MR signal as soon as possible after RF excitation (which are hard pulses for 3D UTE). This is typically accomplished using radial center-out k-space trajectories and performing data sampling in only a few hundred microseconds. Magnitude images are then reconstructed from the (re-gridded) k-space data.

MAVRIC: In MAVRIC, the wide range of off-resonance frequencies encountered near metal implants is split-up into separate frequency segments, which are independently encoded and acquired. Images obtained at different center frequencies contain signal from different locations of the image and can be added (i.e. sum-of-squares) to obtain the final image. In order to refocus the rapidly dephasing spins near metal implants, spin echo sequences are typically employed.

UTE on the other hand belongs to the class of gradient recalled sequences, but operates at $TE \rightarrow 0$, so that the FID signal is reminiscent of the second half of a spin echo. Fig.1 shows the composite spectral response (sum of squares) resulting from 17 hard RF pulses of duration 500 μ s with spectral separation of 0.8kHz. The spectral response is almost as flat as using Gaussian excitation pulses used in MACRIC [1], and hard pulses have the added benefit that they minimize the time from the center of the excitation pulse to the beginning of readout and hence minimize undesired phase evolution of spins during this time.

Methods: The phantom in our experiments contained a stainless steel plate ($\chi_m \approx 3000-5000\text{ppm}$) immersed in agarose gel (see Fig.3 left) and imaged at 3T. This represents one of the worst-case scenarios for MR imaging near metal implants. Images were obtained with the phantom standing upright using a 3D UTE sequence (BW = 125kHz) at different spectral center frequencies ranging from $\pm 6.4\text{kHz}$. Clinical 2D FSE (BW = 125kHz) images were obtained for comparison.

Results: Fig.2 shows coronal 3D UTE images of the phantom. Several images of the same slice are shown covering a spectral range of $\pm 6.4\text{kHz}$. Fig.3 shows a coronal image using a clinical 2D FSE sequence, an on-resonance image using 3D UTE, and finally the UTE-MAVRIC image of the sum-of-squares combinations of the spectral bins ranging from $\pm 6.4\text{kHz}$ (see Fig.2). A marked reduction in both image artifacts and signal voids near the metal implant can be observed in the 3D UTE-MAVRIC combination.

Conclusion: We have investigated the potential to combine UTE and MAVRIC sequences to image near metal implants at ultrashort TE values. Our initial studies have shown promising results, suggesting that these two techniques may be combined to harvest their respective advantages. In this example, we have shown substantial artifact reduction around stainless steel at 3T. Based on these results, we can expect to have similar or better success when imaging near less susceptible materials such as cobalt-chromium (900 ppm) or titanium (180 ppm) at 3T or 1.5T. We are currently investigating other RF pulse designs to further improve the spectral combinations.

References: [1] Koch et al, MRM 61:381-390 (2009) [2] Lu et al, MRM 62:66-76 (2009) [3] Robson et al, JCAT 27(6): p.825-46 (2003)

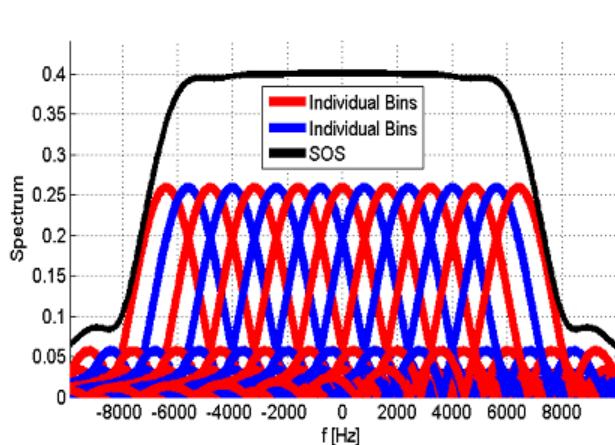


Fig.1: Spectral response of 500 μ s hard RF pulses at different off-resonance frequencies and their sum-of-squares (SOS) combination.

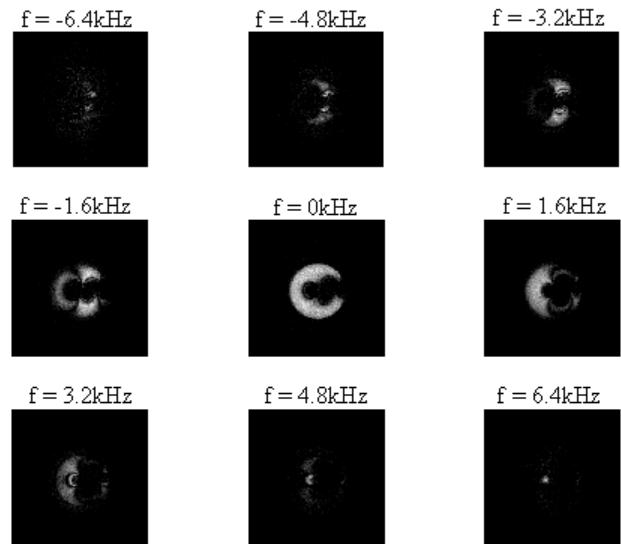


Fig.2: Coronal phantom images at various off-resonance frequencies.

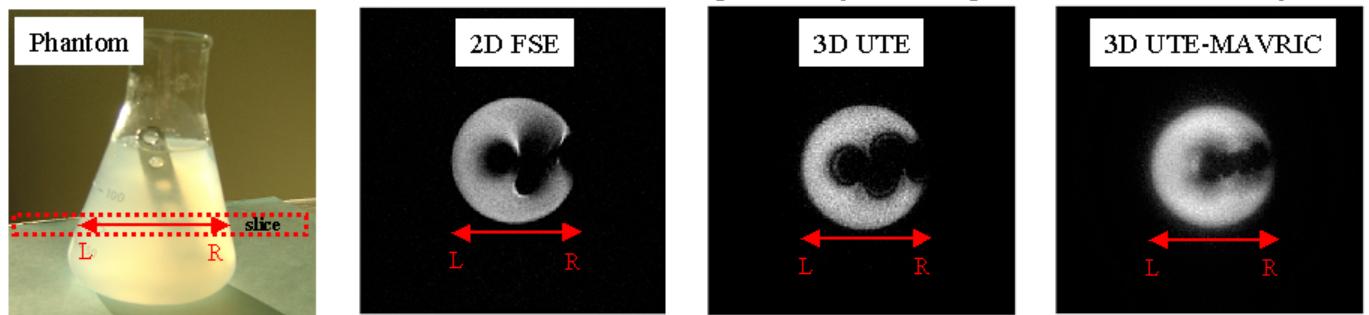


Fig.3: Photograph of experimental phantom setup (left). Coronal 2D FSE image, 3D UTE image (on-resonance), and 3D UTE-MAVRIC image.