Fast SEMAC by separation of on-resonance and off-resonance signals

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Target audience : MR sequence engineers and physicists attempting to perform MR imaging near metallic implants.

Purpose

We present a novel, efficient method to accelerate the Slice Encoding for Metal Artifact Correction (SEMAC) sequence [1] for MR imaging near metallic implants. MR imaging near metallic implants has been a very challenging problem, for the extreme off-resonance around the metallic implants causes huge distortions in both in-plane and slice-select dimensions. SEMAC corrects these severe off-resonance artifacts by employing an additional slice dimensional encoding to resolve the distortions along slice-select dimension, at a cost of increased scan time. In this abstract, we present a simple undersampling scheme exploiting that the support-regions of on-resonance spins and off-resonance spins are limited in slice-select(z) and phase encoding(y) dimension respectively. We also introduce an easy algorithm that reconstructs each area separately from undersampled measurements. Phantom experiments demonstrates that our proposed method alone can accelerate the imaging time more than 50% before applying other acceleration methods such as partial Fourier, parallel imaging, and compressed sensing.

Theory

A typical slice profile distorted near a metallic implant is illustrated as a white band in Figure 1. Here, the excited object signal denoted as X can be decomposed as $X = X_A+X_B$ where X_A is the signal in a green box representing on-resonance spins, and X_B is the signal in a red box for off-resonance spins. Since the support of X_A is limited in slice-select dimension (Z), we can reconstruct it without aliasing from measurements undersampled in kz. Similarly, we can reconstruct X_B from measurements undersampled in ky. However, in reconstructing X_B, the measurements should be offset by the contribution from X_A to avoid aliasing of X_A into the support of X_B. Figure 2 plots an example undersampling pattern on a full K-space sampling grid for a case that X_A and X_B occupy only 1/4 of the full zFOV and 1/3 of the full yFOV respectively. The reconstruction process is summarized as follows.

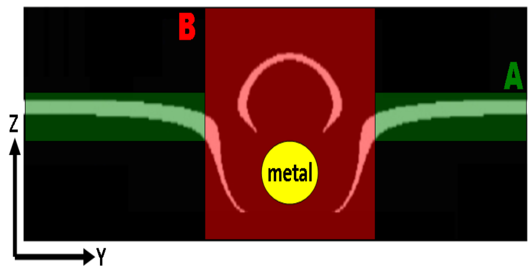

Figure. 1. A typical slice distortion near metal.

i) Reconstruct X_A
- Take the inverse Fourier transform of the measurements at green sampling locations.
- Select the X_A region from the resulting image of Fourier transform.

ii) Remove contributions of X_A from the measurements
- Compute the measurements of X_A at the red locations.
- Subtract them from the original measurements there.

iii) Reconstruct X_B
- Take the inverse Fourier transform of the new measurements at red sampling locations.
- Select the X_B region from the resulting image of Fourier transform.

iv) Combining X_B and X_B leads to the whole image, X

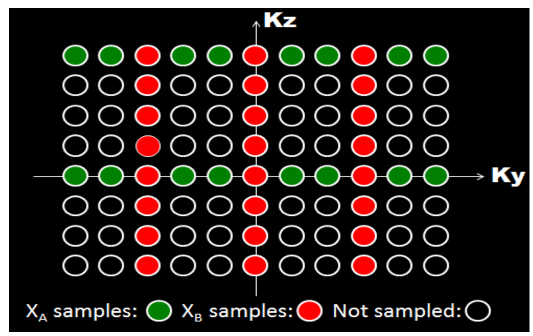

Figure. 2. An example undersampling pattern on a full sampling grid in K-space.

Experiment

We conducted a phantom study to validate our method. An agar gel phantom with titanium shoulder prosthesis was scanned with a SEMAC sequence with following parameters in GE 3T Discovery 750 scanner. TE/TR:5.8ms/3.2sec, 256x192x30 matrix over 24cm x 18cm x 9cm SEMAC slice FOV, 12 SEMAC slices, 2ms Windowed-SINC pulse with TBW = 4 for 6mm slice-thickness, ETL = 16. It was important to set z-resolution high enough to limit the ringing artifact. We assumed that the slice profile information depicted in Figure. 1 was available by a fast spectral localizer suggested in [2], and retrospectively undersampled the fully sampled data to test our method.

Results & Discussion

In our phantom study, the reduction factors of the measurements to reconstruct X_A and X_B were 0.2 and 0.33 respectively, leading to the total reduction factor of 0.2+0.33-0.2*0.33 = 0.46. In Figure 3, reconstruction results with fully sampled data and with 46% of the fully sampled data using our proposed approach are compared. They show comparable quality in off-resonance correction, though our result shows noise amplification in the X_B region because of the propagation of the estimation error of X_A. We expect adopting an additional denoising method could help removing this noise artifact.

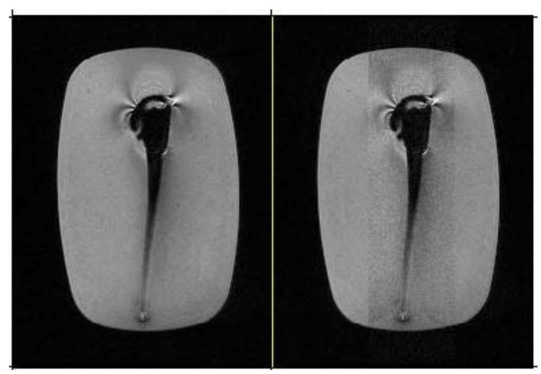

Figure. 3. Reconstructed slices with fully sampled data (left) vs. with 46% data with our scheme (right) in a complex sum of slabs.

Conclusion

In this abstract, we presented a novel, efficient undersampling scheme and a simple reconstruction algorithm for SEMAC sequence to accelerate MR imaging near metallic implants. Successful reconstruction of a phantom with 46% of fully sampled data was demonstrated. Our method can be also easily extended with other acceleration methods such as partial Fourier, parallel imaging, and compressed sensing to further reduce the scan time.

References [1] Lu, MRM, 2009;62:66-76 [2] Hargreaves, ISMRM 2010, p.3083.