An improved complex image combination algorithm for SEMAC

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Target audience : MR engineers and physicists interested in image reconstruction for MR imaging near metallic implants

Purpose

A novel post-processing method to improve SNR of MR images acquired with Slice Encoding for Metal Artifact Correction (SEMAC) sequence [1] is presented. Recently, a few multi-spectral imaging (MSI) methods [1-2], have been presented to correct for severe off-resonance artifacts around metallic implants. All of them are based on multiple spectral acquisitions of the target imaging volume to limit the spectral range of excited spins such that in-plane displacement artifact is restricted within about a voxel. The individual spectral images are later combined to form a final composite image, where the complex summation method suffers from a serious SNR drop even though it preserves sharpness better than other methods such as sum-of-square method. The SNR drop stems from the fact that only a few spectral images contain actual signals for a given local volume while other spectral images add only ringing artifacts and noise. In this abstract, we propose a novel post-processing algorithm for complex summation to detect and combine valid spectral contributions for each voxel while unwanted noise and ringing artifacts are excluded. Our phantom experiment shows significantly improved SNR over the conventional complex summation method.

Theory

Our proposed method is composed of two sequential procedures: peak detection and weighted summation. In the first step, the slice (z) profile at each in-plane (x,y) location of each spectral image is processed to remove ringing artifacts and noise, leaving only valid signal peaks. Noise is removed with simple magnitude thresholding while the ringing artifacts are discarded by removing signals with rapid phase alternation. In the second step, the amplitudes of previously detected peaks are reweighted and finally the complex summation of processed spectral images is performed. This amplitude reweighting is for the peaks excited at off-slice-center locations because their amplitudes are often overestimated due to insufficient image resolution. For example, if a peak is shifted by half a voxel, it is split into two contiguous peaks with 70% amplitude of the original amplitude, not 50% when image resolution is same as slice thickness. When these two split peaks are summed with signals from other spectral images, it can cause overestimation of the original signal. The amplitude reweighting is performed with a lookup table that stores different peak shapes for a range of shifts. Once the closest match for the measured peak shape is found, the associated weights stored in the table are used to multiply the measured peak amplitudes.

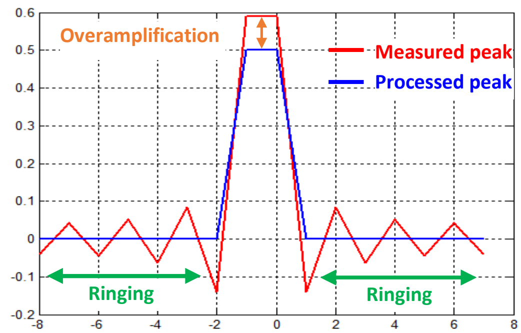

Fig.1. A peak after ringing removal and amplitude reweighting (in blue). Here, half a voxel shift caused much elongated tail and overly amplified peak amplitude for the original peak (in red).

Experiment

To test the proposed method, an agar gel phantom with titanium shoulder prosthesis was scanned with a SEMAC sequence in GE 3T Discovery 750 scanner. TE/TR:5.5ms/3sec, 256x192x16 matrix over 24cm x 18cm x 4.8cm SEMAC slice FOV, 24 SEMAC slices, 2ms Windowed-SINC pulse with TBW = 4 for 3mm slice-thickness, ETL = 8. Noise variance, σ, was estimated from a slice that did not contain any signals from the phantom, and about 4σ was used as a magnitude threshold to detect a peak.

Results & Discussion

Figure 1 demonstrates an example of a peak shifted by half a voxel due to off-resonance and its final shape after our proposed processing. Its original profile shows a very elongated tail from ringing artifact, which cannot be easily removed with previously introduced magnitude soft-thresholding [3]. Figure 2 illustrates final composite slice images of the phantom with the denoised complex summation using soft-thresholding [3] and our proposed method. Our method generally shows much smoother surface than the conventional soft-thresholding. Note that this is not achieved by spatial smoothing, which sacrifices image resolution. SNR comparison between different methods at regions near metal (red box), and at regions far from metal (green box) showed about 59% and 51% increase respectively with our proposed method. We have observed occasional intensity irregularity around the metal implant, which is to be addressed in a future study.

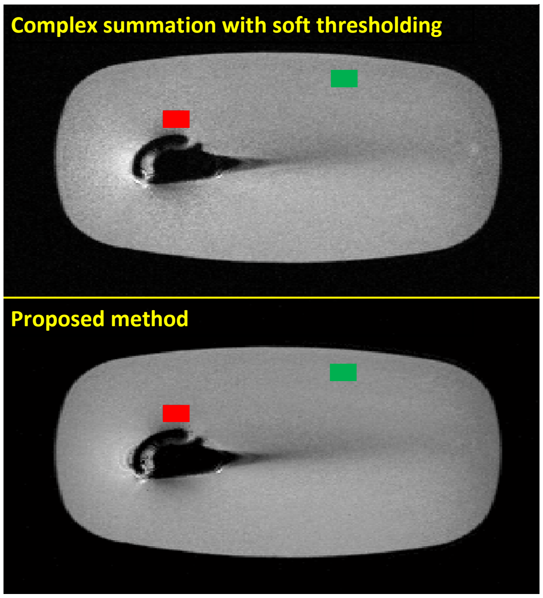

Fig.2. Comparison between the composite image from complex summation with soft-thresholding (top row) and the composite image from our proposed method (bottom row) shows much improved SNR for our method.

Conclusion

A novel post-processing method to improve SNR for complex-sum-combination SEMAC was introduced. A phantom study demonstrates that our proposed method significantly improved SNR over the conventional complex summation method by effectively choosing the appropriate spectral components excluding ringing and noise.

References [1] Lu, MRM, 2009;62:66-76 [2] Koch, MRM 2011;65:71-82 [3] Lu, MRM, 2011;65:1352-1357

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