SMASH with Volume TEM Coils at 8T: Feasibility Study and SNR Analysis

P. A. Wassenaar[1], B. D. Clymer[2], P. Schmalbrock[1]

[1]Radiology, The Ohio State University, Columbus, Ohio, United States, [2]Electrical and Computer Engineering, The Ohio State University, Columbus, Ohio, United States

Introduction

Simultaneous Acquisition of Spatial Harmonics (SMASH) [1] has been used with phased array surface coils at 1.5 and 3T to reduce acquisition time for a variety of applications [2,3]. Variable density auto SMASH (VD-AUTO-SMASH) is a more recent implementation [4] that acquires some extra lines around the origin of k-space to automatically find coefficients used in reconstructing the reduced data set. While it was initially assumed that parallel reconstruction requires decoupled receiver channels, more recent work indicates that coupling may have much smaller adverse effects on the ability to unfold images and to retain adequate SNR. This observation is of particular interest for ultra high field MRI, where interactions between coil and sample are significant [5]. This work implements VD-AUTO-SMASH at ultra-high fields (≥7T), where the advantage of high resolution comes at a cost of long acquisition times. This is complicated by the need to use TEM transmit/receive coils, which have coupled channels whose sensitivity regions overlap in the sample space. Our feasibility study shows that SMASH can be used with volume TEM coils without SNR penalty for moderate reduction factors. Furthermore, SMASH preserves phase information, which is a valuable contrast at fields ≥7T.

Method

Images of a homogenous phantom (cylinder filled with 0.125M NaCl and 0.5mM Gd-DTPA) and postmortem in situ human brain were acquired using an 8T whole body magnet, with a 16 strut transverse electromagnetic (TEM) resonator head volume coil with four symmetrically placed excitation ports. During excitation, the RF pulses were shifted by 0°, 90°, 180° and 270° on the respective ports. For this initial proof-of-principle study, full FOV k-space data were acquired, as a pulse sequence for variable density sampling in the inner and outer parts of k-space has not yet been implemented on the BRUKER console. Human post mortem brain images were generated using an axial gradient echo with TR/TE=700/11ms, FOV 20x20cm, 1024x1024 matrix size, and 2.5mm slice thickness. Phantom data were acquired with TR/TE 200/14ms and 512x512 matrix size. The reduced data set for use by VD-AUTO-SMASH was simulated by decimating the full k-space data in the phase encode direction, nominally 2 and 4-fold. For the human data, 128 lines, and for the phantom, 32 lines around the center of k-space were retained as auto calibration signals (ACS) for the algorithm. Analogous to Sodickson et al who evaluated SNR in SMASH reconstructed images from ensembles of repeat images, we determined SNR from ensembles of lines in k-space of noise only images. The legitimacy of this was validated at 1.5T where both approaches were feasible, whereas 8T gradient stability constraints prevented us from direct comparison of repeat acquisitions.

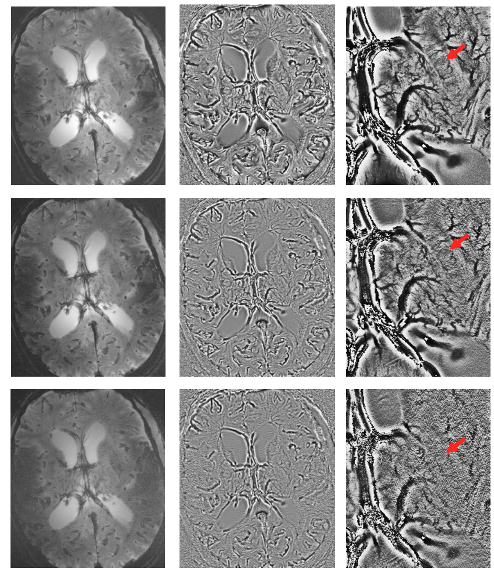

Figure 1, SMASH reconstructed images with outer reduction factors of R=1 (full data set, top row), 2 (middle) and 4 (bottom row). Depicted are magnitude images (left column), phase images (middle) and magnified views of these phase images (right column). Note the improved vessel conspicuity in the phase images in the full (R=1) and R=2 data. There are no reconstruction artifacts in the R=4 data, however, decreased SNR diminishes the quality of microvessel depiction (arrow).

Results

Shown are images of a phantom and postmortem human brain in situ that were acquired in an 8T whole body MRI system using 16-strut, 4-port TEM coils. The raw data were decimated 2 and 4-fold, and reconstructed using VD-AUTO-SMASH. It is shown that the signal-to-noise ratio (SNR) does not change dramatically for a reduction factor of 2 compared to no reduction. In Figure 1, microvasculature can be seen in the image with no reduction and the image with a reduction factor of 2. For a factor 4, it is less noticeable (see arrows).

For the structure phantom, noise-only data were acquired by turning off the rf transmit amplifier. A prediction was made for the noise variance through a slice of a phantom for both a Simple Sum and a SMASH image with a reduction factor 2 [Sodickson, 1999, eq. 27]. The results are shown in the bottom graphs of Figure 2 (solid curve), where also the measured noise variances are shown (dots). The left column displays the results for the Simple Sum image, and the right for the SMASH image (reduction factor R=2). Variance measurements were done for 50 voxels per phase encode location. Also shown are the corresponding images, acquired with the rf amplifiers on.

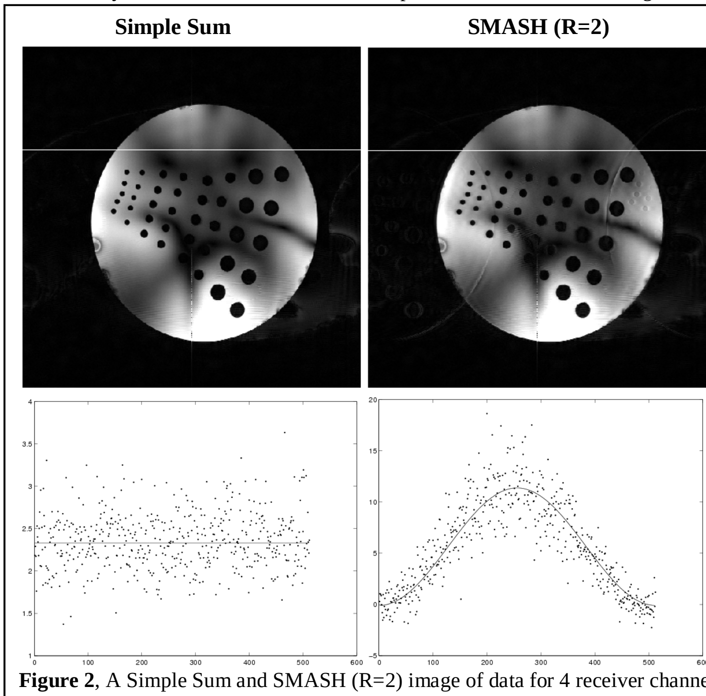

Figure 2, A Simple Sum and SMASH (R=2) image of data for 4 receiver channels (top) and predictions (solid line) and measurements (dots) of noise variance (bottom). The predicted values have been scaled and amplified to match the measurements. Variances are based on 50 voxels per phase encode location. These measurements were performed for noise only data (rf transmit amplifier off).

Conclusion

VD-AUTO-SMASH can be used at 8 Tesla to reconstruct reduced data collected from a transverse electromagnetic (TEM) coil with 4 channels. Coupling between coil and sample does not appear to be detrimental for high field parallel imaging. SNR is retained for moderate reduction factors, and the noise behaves as predicted.

References

[1] Sodickson, Manning, MRM 38: 591-603, 1997
[2] Bankson, Wright, MRM 47(4):777-786, 2002
[3] McKenzie, Yeh, et al, MRM 47(3):529-38, 2002
[4] Heidemann, Griswold, MRM 45: 1066-1074, 2001
[5] Ibrahim, Lee, et al, MRM 19(2): 219-226, 2001
[6] Sodickson, Griswold, et al, MRM 41:1009-1022, 1999