AUTO-SMASH, a self-calibrating technique for SMASH Imaging

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Introduction: Recently a new fast MR imaging strategy, SMASH (SiMultaneous Acquisition of Spatial Harmonics), based on partially parallel imaging with radiofrequency coil arrays has been described and *in vivo* imaging with this approach has been demonstrated (1). Accurate SMASH reconstructions rely upon an accurate estimate of the sensitivity functions of individual coils in the array used for imaging, and this reliance is one of the greatest constraints of the SMASH imaging technique. *In vitro* or *in vivo* coil sensitivity calibrations can be problematic in many cases, since
(i) coil loading and/or coil position may change significantly from subject to subject,
(ii) in vivo sensitivity measurements require regions of nearly uniform spin density for perfect calibration, or else require the acquisition of multiple reference images,
(iii) $B0$ and $B1$ magnetic field inhomogeneities may distort the true coil sensitivity profiles depending on the imaging technique used,
(iv) sensitivity calibration must be performed for each slice-of-interest, which can be very time consuming.
In order to remove these practical limitations, we have developed a new internal sensitivity calibration technique for SMASH imaging, called *AUTO-SMASH*.

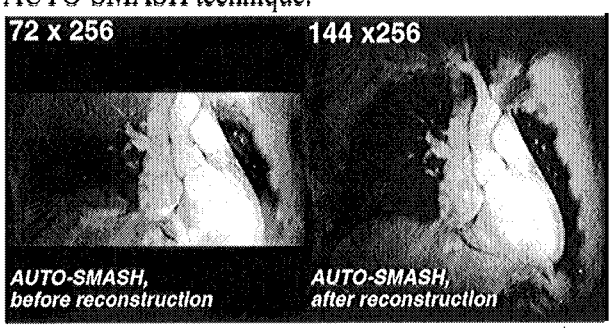
Theory: SMASH reconstructions normally require that component coil sensitivity functions be fitted to sinusoidaly varying spatial harmonic functions in order to generate shifted *k*-space lines that take the place of omitted phase encoding steps (1).

AUTO-SMASH is based on the acquisition of a small number of additional *k*-space lines which serve as reference for internal sensitivity calibration. These extra auto-calibration signals $S^{ACS}_{(k_y - m\Delta k_y)}$ are acquired in conjunction with the normal SMASH signals S_{k_y}, and the relations between the ACS and the normal lines determine signal correlations among the various component coils in the coil array. These signal correlations are then used as the basis for the SMASH image reconstructions. If extra ACS lines with appropriate *k*-space shifts are acquired during a SMASH acquisition, a small subset of SMASH signals may be fitted directly to these reference ACS lines in *k*-space. The resulting coil weighting factors may be used to fill in the remaining portions of *k*-space, without requiring the intermediate of spatial harmonic generation.

Methods: The raw data for the AUTO-SMASH images were generated on a Siemens Vision 1.5 Tesla whole body clinical MR scanner. A home-build 4-element cardiac array coil was used for all studies (2).

In general for AUTO-SMASH, the pulse sequence and gradient phase encoding tables have to be modified, so that for every desired spatial harmonic function *m*, an additional signal $S^{ACS}_{(k_y - m\Delta k_y)}$ is acquired along the $k_y - m\Delta k_y$ position in *k*-space during the actual scan. Thus, for every spatial harmonic, an ACS-line of data is acquired, which results in a ((M-1)x TR/T_{INTER}) increase in scanning time, where M is the number of spatial harmonics used.
In order to validate the auto-calibration scheme a number of cardiac imaging experiments were performed in healthy volunteers. Cardiac experiments are a good test because the thorax has a highly inhomogeneous spin density.

Results: The AUTO-SMASH experiments gave consistently good image reconstructions and AUTO-SMASH calibration is used now routinely in combination with SMASH. As an example the images in the figure below demonstrate a successful *in vivo* application of the AUTO-SMASH imaging technique with M=2 spatial harmonics. Left: two-fold aliased image obtained in half the conventional imaging time, Right: image reconstructed with the AUTO-SMASH technique.



Conclusion: In summary, the AUTO-SMASH self calibration procedure replaces an experimentally cumbersome and potentially inaccurate coil sensitivity measurement with a targeted acquisition of a few extra lines of MR signal data. AUTO-SMASH may be used even in markedly inhomogeneous regions. This auto-calibrating approach can be easily implemented with only a small sacrifice of the overall time savings afforded by SMASH imaging. The results obtained from *in vivo* studies indicate that the self-calibrating SMASH approach is an effective method for extracting coil sensitivity information.

Reference:

(1) D. K. SODICKSON, W. J. MANNING, Simultaneous Acquisition of Spatial Harmonics (SMASH): Fast Imaging with Radiofrequency Coil Arrays. *MRM* 38:591-603, (1997)
(2) M. A. GRISWOLD et al., submitted to the 6th Annual Meeting of the ISMRM