Higher Order B0 Shimming of the Human Brain at 7T

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Introduction: With the advent of ultrahigh field systems (7T), significant improvements in spectroscopic imaging (SI) studies of the human brain have been anticipated. Although excellent B_0 homogeneity is a requisite for SI, the hardware requirements in terms of shim strength and shim order necessary for 7T is controversial, with the majority of systems delivered having only 2nd order shims. The goal of this work was to: 1) determine the role of 3rd order shims for SI studies at 7T in two representative regions (the frontal and temporal lobes); 2) characterize the remaining inhomogeneity and 3) demonstrate high resolution spectroscopic imaging in the frontal and temporal lobes.

Methods: All data were acquired with a Varian Direct Drive system and a head only (68cm ID) actively shielded 7T magnet. The gradient system (Magnex Scientific) included a full set of 2nd and 3rd order shims, with each shim driven by two 10A shim power supplies (Resonance Research Inc.). Data from 20 subjects was acquired using an 8 element transceiver array from the frontal lobe at the level of the supplementary motor cortex (n=10) and temporal lobe at the level of the hippocampus (n=10). A non-iterative multi-slice B_0 mapping method (96seconds) was used to set all 1st-3rd order terms. The predicted and measured standard deviation of the B_0 field (σB_0) over the target ROIs (Fig. 1a,1b) varied by less than 1Hz for a single pass. Whole plane spectroscopic imaging data was acquired from all volunteers and patients using either a short TE (15ms) acquisition (frontal lobe) or moderate TE (42ms) acquisition (temporal lobe).

Fig 1a

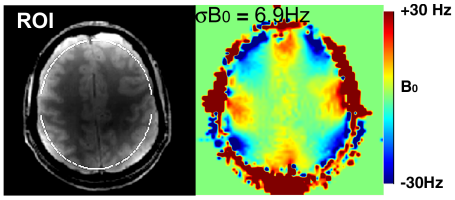
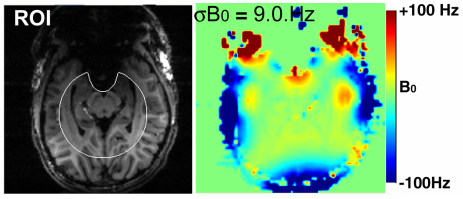


Fig 1b



Results: Displayed in Fig 2 are data summarizing the achieved σB_0 for 1st-3rd order shims with the current shim set along with theoretical values for 4th order shims. Using 1st&2nd order shims σB_0 over the target ROI was 11.4±2.5Hz (frontal) and 15.5±3.0Hz (temporal). When 3rd order shims were added σB_0 improved by 29% and 31% (8.5±2.1Hz and 10.7±2.1Hz). With all third order terms compensated for, the measured residual inhomogeneity across the frontal lobe ROI is clearly 4th order in origin (Fig.1a). Theoretical compensation for the 4th order terms further reduces the σB_0 by 37%. Displayed in Fig 3 are a scout image and SI data (TE=15ms) from tumor patient diagnosed with a recurrent tumor lateral to the resection site demonstrating increased choline and decreased NAA. Displayed in Fig 4 are a scout image and SI data (TE=42ms) from a patient with temporal lobe epilepsy demonstrating reduced NAA/Cr in the ipsilateral anterior hippocampus.

Fig. 2

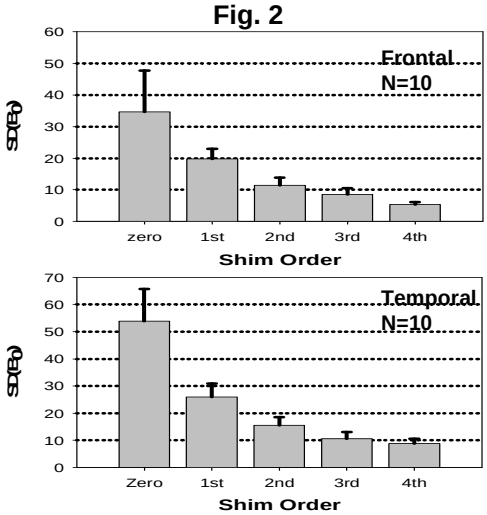


Fig. 3

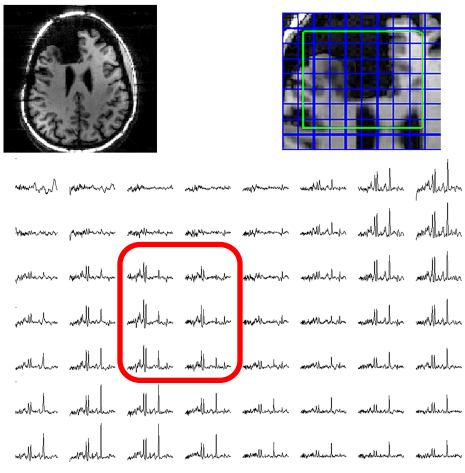
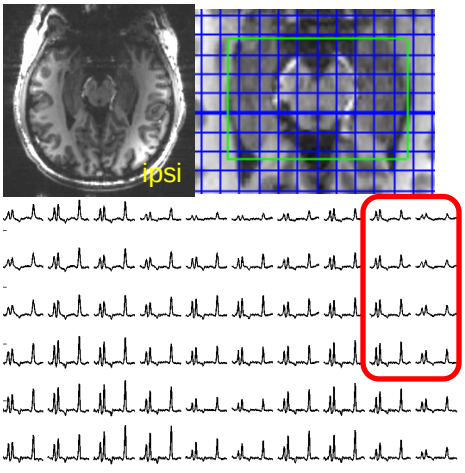


Fig 4



Conclusions: Our data indicates that a 30% improvement in σB_0 can be obtained by the inclusion of third order shims at 7T. The use of third order shims enables high resolution SI data to be acquired from extended regions in the frontal and temporal lobes at 7T. In the frontal lobe our data indicates that 4th order inhomogeneities are present and compensation for a selected set of 4th order shims can provide additional large improvements (37%) in σB_0.