Real Time Dynamic Shimming for MR Spectroscopy Using 2-dimensional Rf Excitations

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INTRODUCTION

Patient motion compromises the quality and reliability MR spectroscopy (MRS). Several MRS motion-correction methods have recently been shown to improve signal-to-noise ratio (SNR) and spectral reproducibility by updating the voxel position/orientation in real-time. [1] However, even with perfect motion tracking, patient motion can have deleterious effects on the B0 homogeneity (shim) within the voxel. [2] The effects of such motions on the shim are essentially unpredictable, and can potentially lead to poor spectral line-width, inaccurate quantification, and unusable spectra. Therefore, we propose a novel method for using low flip angle, multi-dimensional excitations to measure and apply linear shim corrections in real-time during an MRS acquisition.

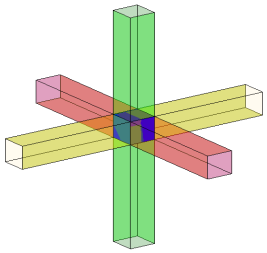

Fig. 1: Column excitations and MRS voxel

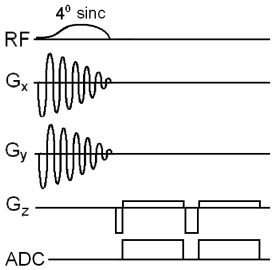

Fig. 2: pulse sequence for one column

METHODS

We added a dynamic shimming module to a standard short-TE point-resolved spectroscopy (PRESS) [3] sequence (TE/TR=35/3000ms, BW=1.0 kHz, 32 averages, 20x20x20mm voxel). The dynamic shimming module was executed immediately prior to water suppression module [4], and consisted of 3 orthogonal, low flip-angle (FA=4°) 2-D RF excitations parallel to the stationary coordinate system. The column profiles were chosen to be 2-D rect functions, and the phase of the excitation pulses was modulated to position the columns to intersect at the MRS voxel (Fig.1). Subsequent to each excitation, two echoes were read out along the direction of the column axes (BW=10kHz, 128 RO pts, FOV=300, Fig.2). The difference in the echo times of the two readouts (ΔTE=13.5ms) enable the calculation of three one-dimensional field maps, each along one of the coordinate directions. The field map voxels that fall within the MRS volume were identified and linear regressions [provided] the necessary corrections. These three linear corrections were fed back to the sequence, where they were applied as shim gradients during the subsequent PRESS acquisition. The entire dynamic shim module takes approximately 124 ms.

We performed experiments both on the phantom and *in vivo* on a Siemens 3T scanner. Prior to scanning, the voxel was placed in the desired location, and the shim was manually optimized. Typical water line widths were 0.01ppm in the phantom and 0.05ppm *in vivo*. In order to test the ability of our sequence to correct sub-optimal shims, we intentionally offset one of the linear shims by a known amount from the ideal value. For phantom experiments, the shim offsets were varied from -20 to 20μT/m in 5 unit increments. In the *in vivo* experiment, the voxel was placed in frontal gray matter and the z-shim was offset by 10 μT/m from its ideal value. Such an offset would be typical for an x-rotation (head nod) of approximately 10°. [2]

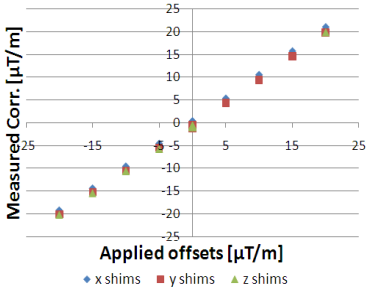

Fig. 3: applied vs. measured B0 offsets

RESULTS

As shown in Fig.3, the applied shim offsets were recovered very well in the phantom (average magnitude error 1.0±0.2 μT/m). *In vivo* spectra are shown in Fig.4. The baseline scan (left, ideal shim) had a line width of 0.029ppm. With the 10 μT/m offset (center), the line width increased to 0.052ppm (Fig.4 center). When the real-time shim corrections were applied (right), the line width was restored (0.029ppm).

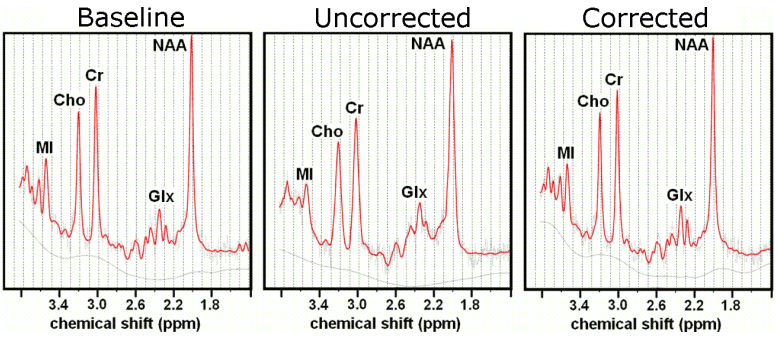

Fig. 4: *In vivo* spectra. Left: good shim, center: 10 unit offset, no correction right: 10 unit offset, with dynamic shimming

DISCUSSION

MRS is uniquely sensitive to shim, particularly if metabolite quantification is desired. The dynamic shimming method described here can correct the linear shim to an accuracy of <1Hz in less than 125ms. The duration of the measurement can be reduced by using a higher bandwidth, at the expense of lower SNR. While 3-D EPI can also be used to construct a field map in real time [4], acquisition is about an order of magnitude slower than the method described here. Further *in vivo* testing is necessary to ensure that the method works well in the presence of off-resonance effects and large susceptibility gradients.

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REFERENCES

1. Keating B, et al. MRM. 64(672), 2010 2. Keating B and Ernst T. ISMRM, 2010 3. Bottomley PA. Ann. NY Acad. Sci. 508(333), 1987
4. Ernst T & Li J. MRM, in revision 5. Hess AT, et al. ISMRM Workshop on Motion Correction, Kitzbühel, Austria, 2010