Spectral fitting using basis set distorted by measured B0 field distribution

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TARGET AUDIENCE: Scientists and clinicians who are interested in studying the brain metabolites and intracellular environment using *in vivo* magnetic resonance spectroscopy (MRS).

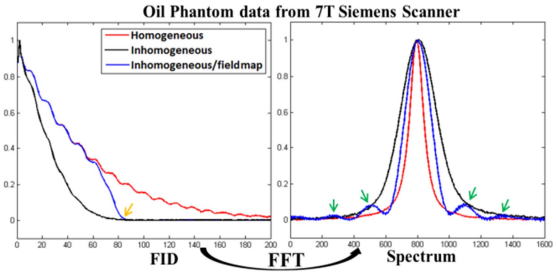

Fig. 1. Left panel: Oil phantom FIDs with homogeneous B0 field (red) and inhomogeneous B0 field (black), the latter is partially restored by complex division (blue). Right panel: corresponding spectra. Green arrows indicate ringing artifacts.

PURPOSE: In spectral fitting, lineshape distortion due to magnetic field inhomogeneity can be corrected by complex division using a reference signal such as the unsuppressed water signal. To prevent noise amplification due to rapid decay of the water reference signal, Tikhonov regularization[1] and Wiener filtering[2] have been introduced to lineshape deconvolution. The purpose of the present study is to demonstrate an alternative approach to spectral fitting that can be used in the presence of large magnetic field distortion. Instead of complex division, we measure magnetic field using standard B0 mapping. Then, we distort the basis set based on measured magnetic field distribution within the MRS voxel and use the distorted basis set to fit the *in vivo* MRS data. This novel approach significantly improves the accuracy and reliability of spectral fitting in the presence of large magnetic field distortion.

Table 1. True and estimated chemical concentration ratios over creatine (Cr).

Chemicals	NAA	NAAG	Glu	Gln	Cho
True	1.30	0.26	1.00	0.15	0.30
Water reference	1.36±	0.21±	0.97±	0.17±	0.34±
Method	0.026	0.017	0.037	0.059	0.007
New Method	1.30±	0.26±	1.01±	0.15±	0.30±
	0.050	0.023	0.031	0.058	0.001

METHODS: Phantom and *in vivo* MRS experiments were performed using PRESS (TR: 2.5s; TE1/TE2: 26/72 ms; voxel size: 2cm isotropic) at 7 Tesla. A double-echo GRE sequence (TR: 700ms; TE: 4.5/9.5ms; Resolution: 3mm isotropic) was used to acquire B0 maps. The local field variations were computed based on the unwrapped phase[3] difference and the time difference between the two echoes. Two sets of phantom MRS data were collected, one with a homogeneous magnetic field, and the other with a manually adjusted inhomogeneous field. Three sets of *in vivo* MRS data were collected, one within the white matter (WM) dominant right frontal cortex, where a homogeneous magnetic field is easy to achieve through shimming techniques. The other two voxels were placed in thalamus and near the frontal sinus. Large field distortions were present in both regions. Monte Carlo simulations were performed to evaluate the accuracy of the field-map-based signal fitting and compare it with a conventional water deconvolution method using Tikhonov regularization[1]. Mean and standard deviations from 100 different noise realizations were calculated.

Table 2. Estimated concentration ratios over Cr in phantom studies.

Chemicals	NAA	Glu	Cho	mI
Homogeneous B0	1.23	1.02	0.27	0.33
Water reference	1.27±	1.12±	0.29±	0.45±
method	0.015	0.015	0.019	0.013
New	1.26±	1.07±	0.28±	0.34±
Method	0.011	0.016	0.018	0.020

RESULTS: Fig. 1 showed the presence of ringing artifacts when metabolite signals decay faster than the FID synthesized from B0 distribution within the MRS voxel. As shown by Fig. 1 left panel, in the presence of large B0 inhomogeneity, dividing a FID signal synthesized from B0 map into the metabolite FID (black) could only restore the metabolite FID signal above the noise level (blue). This partial restoration led to ringing artifacts in the frequency domain (Fig. 1 right panel). Quantifications results from Monte Carlo simulations with known ground truth concentrations are summarized in Table 1. The new method, which was free of statistical bias associated with regularization, yields greatly improved accuracy. Fig. 2 shows phantom spectra. Phantom quantification results are summarized in Table 2. Compared to water reference deconvolution method, the new method yielded results closer to values derived from homogeneous B0 field. Preliminary *in vivo* results acquired from voxels placed at WM, thalamus and near frontal sinus are shown in Fig. 3. In vivo validation of our new method requires comparing metabolite quantification results from the same anatomical location but with different B0 field inhomogeneities. Work along this direction is currently in progress.

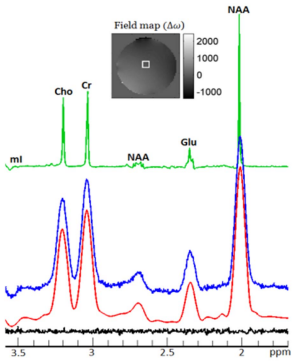

Fig. 2. Phantom spectra acquired from a homogeneous field (green) and an inhomogeneous field (blue), spectrum fitted using field map distorted basis sets (red), and fitting residues (black).

DISCUSSION: This study aims to propose and evaluate a novel approach to quantifying metabolite concentrations through field-map-based signal fitting and compares it with a conventional water deconvolution approach. Since the new method does not require regularization, it does not suffer from inherent statistical bias associated with regularization. In the presence of large magnetic field distortion, the water method is often hampered because water signal decays much faster than metabolite signals. The proposed method calculates the field variations and considers it as a part of the signal model. Therefore it avoids complex division and could easily be applied to regions with large magnetic field distortions. Accurate measurement of field map is a key step in this method. Because B0 distributions are relatively slow-varying within a spectroscopy voxel, image interpolation may be used as an alternative to time-consuming high resolution acquisitions.

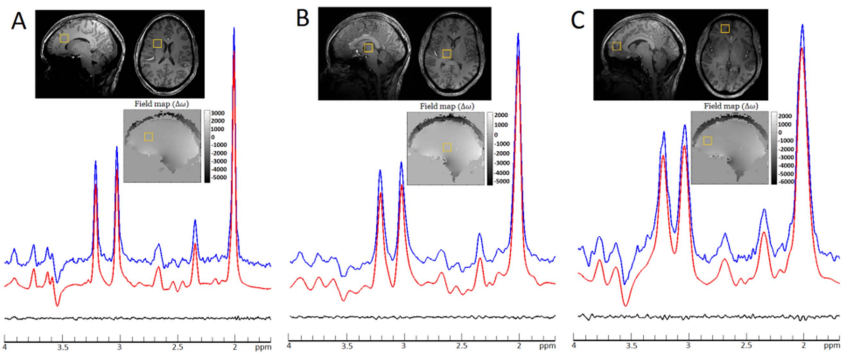

Fig. 3. *In vivo* spectrums (blue) and fitted spectrums (red) from a 2cm isotropic voxel selected in WM (A), thalamus (B) and near the frontal sinus (C). Black lines at the bottom are fitting residuals. Orange boxes within sagittal and axial brain images indicate MRS voxel locations.

CONCLUSION: A novel approach for brain metabolite quantification was developed. It used a signal model distorted by measured B0 field map to fit the observed data. Simulations and experiments showed that the new approach offered more accurate quantification results compared to conventional water reference deconvolution.

References: 1. *Zhang Y, et al.,* Magn Reson Med 2011;66:307-13. 2. *An L, et al.,* Magn Reson Med 2014;72:903-12. 3. *Cusack R, et al.,* NeuroImage 2002;16:754-764.