A Shim Mapping Method for Spectroscopic Imaging of the Mouse Brain at 9.4T

N. Miyasaka[1], K. Takahashi[2], J. W. Pan[2], H. P. Hetherington[1]

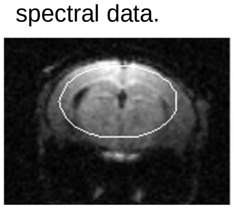
[1]Radiology, Albert Einstein College of Medicine, Bronx, New York, United States, [2]Neurology, Albert Einstein College of Medicine, Bronx, New York, United States

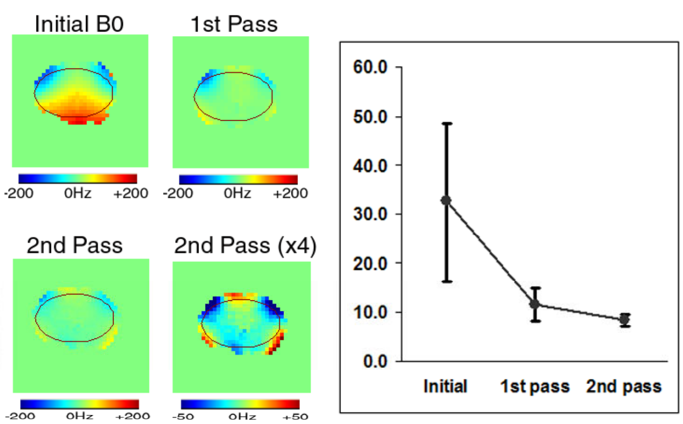
Introduction: Although spectroscopic imaging (SI) of the human brain is relatively common, to date most ^{1}H spectroscopy studies of the mouse brain have been performed using single voxel methods. Due to the small size of the mouse brain and strong susceptibility gradients arising from the posterior and inferior portions of the brain, reliably obtaining a sufficient homogeneity over large ROIs is difficult. Although projection based shim algorithms are useful for small volumes, they often fail for SI studies in relatively inhomogeneous regions where high order (3rd order or greater) inhomogeneities exceed the order of the fit. We have developed an automated multi-slice B0 mapping method to provide rapid, reproducible and robust shimming of the mouse brain. We have characterized the necessary shim order and strength to achieve good homogeneity and acquired 1ul ^{1}H SI studies of the mouse brain at 9.4T.

Methods: All data were acquired on a Varian INOVA 9.4T system using an actively detuneable birdcage transmit coil and an 8x12mm elliptical surface coil for reception. B0 maps were obtained using a multi-slice (11 slices, 0.25mm thick/0.125mm gap) gradient echo imaging sequence (64x64 resolution, FOV 24x24mm) with 6 B0 evolution delays (0,0.5,1,2,4 and 8ms) with a total acquisition time of 96s. The B0 map was calculated by using each evolution delay to correct for phase wrapping in the image of the next longest evolution time. This allows the calculated B0 map to have the frequency range of the shortest evolution time (0.5ms, ±1000Hz) and the accuracy of the longest evolution time 8ms (~0.3Hz/degree). This maximizes the accuracy of the maps and minimizes the number of iterations required. To conform to the brain, an elliptical ROI (3 slices, ~800 pixels, Figure 1) was selected and the data was fit using 2nd order spherical harmonics. To quantitatively assess the achieved homogeneity we calculated the SD of the B0 variation in the ROI. Finally we also analyzed the data using 3rd order spherical harmonics to assess the possible improvement and necessary strengths required. Spectroscopic images of the mouse brain were acquired using a modified LASER sequence with a 1mm slice thickness a FOV of 24x24mm with 24x24 encodes and two averages (38 min).

Results: Displayed in Fig 2 are representative B0 images acquired prior to shimming and after the first and second iteration and the average data for 8 mouse studies. Despite the relatively poor initial homogeneity there is rapid convergence (~1/2 require only a single iteration) of the shim solution and the achieved homogeneity is highly reproducible across the 8 mice. The mean, standard deviation and maximum shim strengths used for the 8 mice are listed in Table 1. As seen in Fig 2, the residual inhomogeneity is strongly third order. Use of third order shims could provide an improvement of 2.6Hz (~31% improvement), however the required strengths are quite large, up to 2.5Hz/mm^3. Displayed in Fig. 3 are spectra spanning the selected ROI showing the uniformity in homogeneity and quality of the 1ul voxels.

Fig. 1: (below) Scout image and ROI for shimming. **Fig. 2:** (right) B0 maps and summary data, 8 mice. **Fig. 3** (far right) SI spectral data.





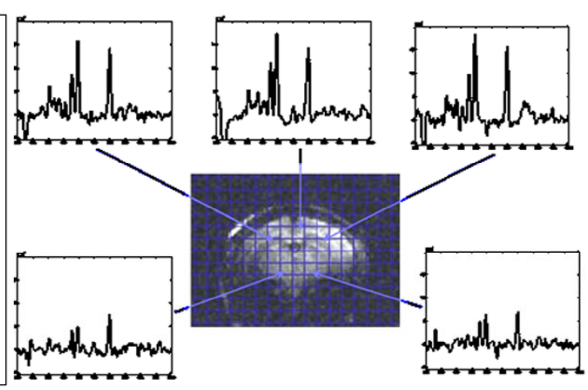


Table 1

	Hz/mm or Hz/mm^2 (n=8 Mice)							
	x	**y**	**z**	**zx**	**zy**	**xy**	**x2y2**	**z2**
Mean	10.4	31.6	51.1	0.9	10.3	1.7	3.1	1.4
SD	2.2	13.9	32.8	3.1	5.9	2.0	1.9	3.4
Maximum	14.1	55.1	106.0	4.5	15.7	4.2	5.9	7.5

Conclusions: Using the automated shim mapping, good homogeneity, ~8.5Hz is routinely and consistently achievable using only second order shims and a maximum of two iterations. Significant improvements (~31% reduction in B0 variation) can be obtained if third order shims with strengths up to 2.5Hz/mm^3 are available.