3D - MR Microscopy of the Mouse Brain with Intermolecular Zero and Double Quantum Coherences at 11.7T

P.T. Narasimhan, S. Sendhil Velan and Russell E. Jacobs
Beckman Institute, Division of Biology, California Institute of Technology, Pasadena, CA 91125

Introduction

MR image contrast based on intermolecular zero and multiple quantum coherences (i-MQC's) has been experimentally investigated recently by various groups [1-3]. In these investigations slice excitation is employed and voxel dimensions are large in comparison with the magnetization pitch generated by the coherence gradients. We have employed whole volume excitation and 3D encoding (two phase encodes and one frequency encode) to obtain good quality i-ZQC and i-DQC images of an excised mouse brain with a voxel size of 98μm x 98μm x 390μm. The dipolar demagnetizing field arising from nuclear dipoles within a sample plays an important role in generating contrast. The ability to alter the distance over which the dipolar demagnetizing field is effective by altering the coherence gradient makes i-MQC methods attractive from the point of view of biological imaging.

Materials and Methods

All images were obtained on a Bruker AMX 500 MHz (11.7T) system equipped with actively shielded gradients and 10mm birdcage resonator. The 3D images of mouse brain maintained at 288k were obtained with a dimension of 256 x 128 x 64 along Y, X and Z directions respectively with an FOV of 1.25cm x 1.25cm x 2.5 cm. The i-ZQC images were obtained with the sequence:

$90°_x$ - G_c - t - $45°_x$ [$135°_{-x}$]- TE/4 - $180°_x$ - TE/2 - $180°_x$ - TE/4 - AQ

where 45_x [135_{-x}] denotes the application of a 45 x pulse for the first scan and 135-x replacing the 45x pulse in the next scan. The first 90 pulse was phase alternated. Values of t and TE were optimized for both signal intensity and contrast. The duration of G_c, the coherence gradient was 2ms and was applied along Z axis.

The i-DQC images were obtained with the following sequence:

$90°$- G_1- t_1 - $90°$- G_2 - t_2 - $180°$- TE/2 - $180°$ - TE/4 - AQ

The coherence selection gradients G_1 and G_2 were varied such that their values were always in the ratio 1:2. The i-DQC echo signal intensity was found to be very sensitive to quite small deviations from this ratio. These gradients were also along the Z axis and had duration of 2ms. The 90° pulses were phase cycled according to the scheme recently proposed by Minot et al [4]. The experiments were done with 4 averages and a repetition time of 1.5s, necessitating 13.5 hours for each experiment.

Results and Discussion

Figure 1

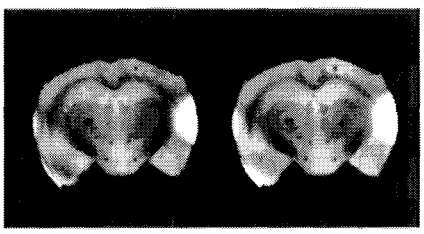

Fig. 1 compares i-ZQC images of the same coronal slice of an excised mouse brain. Slices were taken from 3D data sets with G_c=2.8G/cm (left image) and 3.7G/cm (right image), both along Z. These two Gc values correspond to a magnetization pitch value of 420μ and 320μ respectively along the Z direction. Thus the magnetization pitch is comparable to slice thickness of 390μ along Z.

The areas of hyperintensity presumably arise from pulse imbalances and extended phase cycling may alleviate this problem. Apart from the hyperintense areas, differences in details are noticeable in the two i-ZQC images of Fig. 1. These can be attributed to the local field inhomogeneities arising from susceptibility differences as well as diffusion effects.

Figure 2

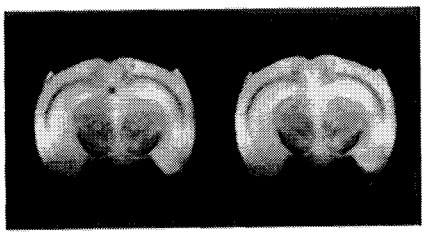

Fig. 2 shows two i-DQC coronal sections of the same mouse brain as used for i-ZQC images. These were obtained with G_1=2.8 G/cm, G_2=5.6G/cm for the left image and G_1=3.7G/cm, G_2=7.4G/cm for the right image. The i-DQC images are of surprisingly good quality, especially comparing our images with that of Mori, et al [3]. These images were obtained at a field almost three times that used by these authors. The four step phase cycle [4] used in the present work results in better DQC filtering.

i-MQC signals are in general weaker than conventional echo signals. Application of larger coherence gradients results in further losses due to diffusion effects. It is therefore not surprising that the imaging time is lengthened for i-MQC imaging in comparison with conventional methods. From the point of view of MR microscopy i-MQC imaging of biological samples appears to be worth exploring further.

References

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