Detection of local anisotropy using double-PGSE filtered imaging

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**Introduction:** The use of multiple scattering techniques to detect local microscopic anisotropy in macroscopically isotropic samples is growing in disciplines ranging from material sciences to medical research[1-3]. In many such systems, one observes microscopic anisotropy by looking at differences between echo attenuations when scattering vectors are applied along different directions, for example between collinear and orthogonal directions. Gray matter in the brain is locally anisotropic but macroscopically isotropic. We propose using an NMR multiple scattering experiment as a filter to an imaging sequence in order to locate and to extract the features of diffusion anisotropy from different brain regions. Previously, we presented spectroscopic results that detect local anisotropic motion in a microscopically anisotropic, macroscopically isotropic phantom and in fixed cortical tissue of a rhesus monkey[4]. Here we extend the measurements to detect the anisotropic water motion in the phantom using a double-PGSE filtered imaging sequence (fig.1).

**Material and Methods:** The microscopically anisotropic, macroscopically isotropic phantom consisted of 0.5 mm long glass tubes (20um inner diameter (ID) and 90um outer diameter (OD)) filled with water and randomly dispersed in deuterated dichloro-benzene. 5 Centistokes PDMS was used as an isotropic sample, to calibrate the experiment. The sequence was repeated in three co-linear and six orthogonal directions to assess variability between deferent gradient directions. All experiments were done on a 7T vertical bore Bruker AVANCE system.

**Results and Discussion:** We used d-PGSE *filtered* imaging instead of the more straightforward choice of double-PGSE imaging (where the diffusion pulse pairs are incorporated within the imaging sequence). While the gain in signal to noise of the latter sequence is substantial, so is the complexity of post processing, owing to the need to include all imaging gradients in the calculation of the signal attenuation. Separating the double-PGSE blocks and the imaging sequence obviate this.

All nine curves of the PDMS d-PGSE experiment (fig. 2a) collapse onto one curve, indicating no observable software and hardware artifacts. The difference in the resulting collinear and orthogonal curves from phantom experiments (fig. 2b) demonstrates local anisotropic water diffusion inside the tubes. Note that the gradient values that were used in the experiment were low, while the largest difference was achieved for gradients value of 125 mT/m and $\delta$=3ms. The d-PGSE imaging experiment can reveal anisotropic diffusion occurring at a microscopic length scale, which the standard PGSE imaging sequence cannot, providing a new potential source of image contrast for applications in materials sciences, medicine and biology.

**References**: 1. P. T. Callaghan, *et al*. *Magn. Reson. Chem*. **40**, S15 (2002) 2. Y. Cheng, D. G. Cory *J. Am. Chem. Soc*. **121**, 7935 (1999) 3. P. T. Callaghan, *et al*. *J. Chem. Phys*. **120** 4032 (2004) 4. M. E. Komlosh, *et al. ENC* P01-003 (2005)

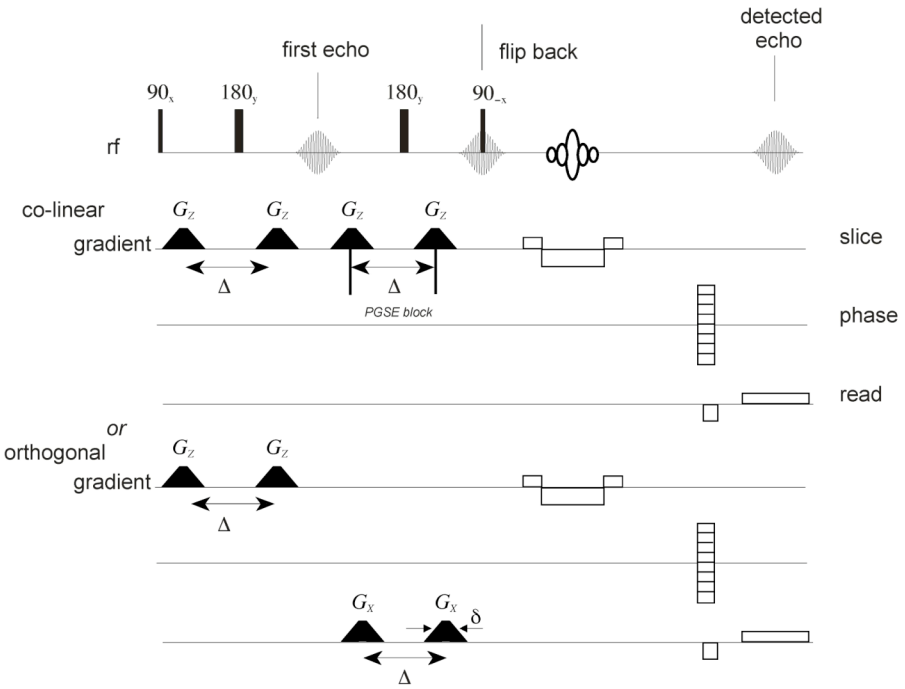


Figure 1:Double PGSE filtered imaging pulse sequence

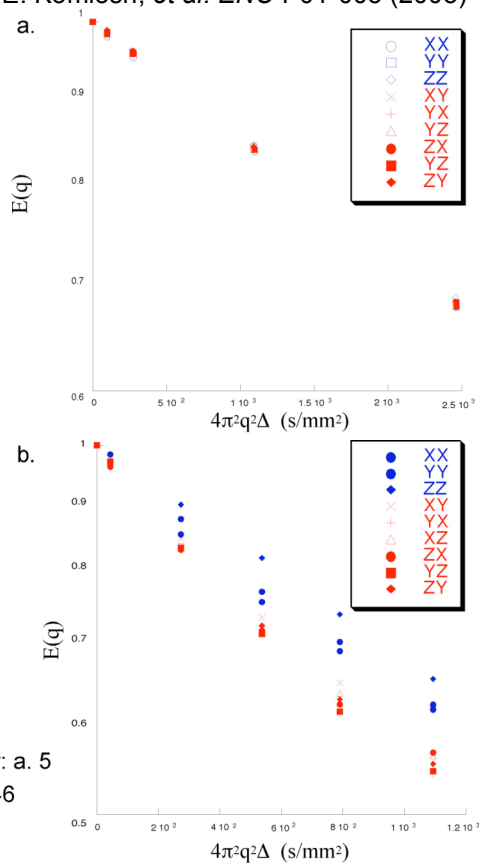


Figure 2:double-PGSE filtered imaging echo attenuation *vs.* $q=(1/2\pi)\gamma\delta G$ for: a. 5 centistokes PDMS. G=220 mTm$^{-1}$, $\Delta$=40 ms and $\delta$=3 ms. b. phantom. G=146 mTm$^{-1}$, $\Delta$=40 ms and $\delta$=3 ms.