Observation of signal dips in iMQC study

Z. Chen[1], S. Zhang[1], and S. Cai[1]

[1]Physics, Xiamen University, Xiamen, Fujian, China, People's Republic of

Introduction

Intermolecular multiple-quantum coherences (iMQCs) have generated much interest and controversy over past decades. One of the fierce controversies arises from so called correlation distance, defined as $\pi/\gamma G\delta$. Capuani and co-workers have done a lot of work on this aspect [1], and suggested that when the correlation distance was comparable to the averaged length-scale of sample heterogeneity, a signal dip would appear, thus it could be applied to the study of porous micro-structured materials. However, this phenomenon was not always observable [2]. Recently, Warren and co-workers noted a signal dip with a processed trabecular bone from human distal tibia. Since the position of the dip would shift with evolution time, they believed that it was resulted from the complex effect of the inner field, and could not be attributed to any physical features [3]. In this abstract, the CRAZED-like sequences were qualitatively investigated with the strength of the coherence selection gradients (CSGs) ranging from a very small value to a large value. The results demonstrated that the existence of signal dip was a synergistic effect of CSG, sample geometry and inhomogeneous field. It may be utilized to explore the structural feature of the sample in MRI applications.

Methods

All measurements were carried out on a 500 MHz Varian spectrometer equipped with a 5 mm ID probe, which has a self-shielded x, y, z gradient coil. The pulse sequences used are shown in Fig. 1. The influence of magnetic field inhomogeneity during the evolution period is included using the pulse sequence shown in Fig. 1a (defined as scheme $1^{\#}$) and eliminated using the pulse sequence shown in Fig. 1b (defined as scheme $2^{\#}$). All the CSGs were applied along z-direction, with durations of 1 ms and various strengths. The pulse flip angles were $\alpha = \pi/2$, $\beta = 2\pi/3$, and the other parameters used were TR = 6s, τ = 17 ms, TE = 40 ms. In all experiments a four-step phase-cycling scheme of α (x, -x, y, -y) and receiver (x, x, -x, -x) was employed to select iDQC signal and suppress other undesired echoes from unexpected coherence pathways. 1% agar-gel samples were used for investigation.

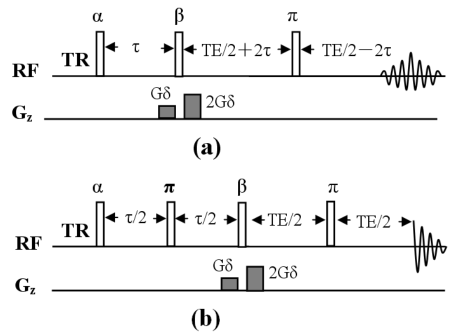

Fig. 1 Pulse sequences used in this study.

Results and Discussion

A series of CSG strengths were used, with k ($k = \gamma G\delta$) values of 0.005, 0.05, 0.16, 0.27, 0.53, 1.1, 1.6, 2.7, 5.3, 11, 21, 42 and 63 mm^{-1}. When the magnetic field was well shimmed (the calculated residual inhomogeneity was about 3 Hz), an obvious signal dip was observed at about k = 0.43 mm^{-1}, as shown in Fig. 2. Since the dip still appeared at exactly the same position even when the pre-delay was set to 15 s (results not shown), we cannot attribute it to stimulated echo [3]. A similar phenomenon was observed in our previous study, which was attributed to the "analogous magic angle" effect [4]. However, in the present case, the residual field inhomogeneity was very small, and the condition for "analogous magic angle" was no longer satisfied, so the observation could not be attributed to the same effect. The position of the dip shifted with the variation of inhomogeneous field, but the dip still existed even when the influence of field inhomogeneity was eliminated (Table 1). Thus it could not be fully attributed to the reason proposed by Warren et al. Our observation seemed consistent with Capuani's result, though the position of the dip did not fully obey the proposed relation (in our cases, the correlation distance at the dip was about twice the sample tube size when the field inhomogeneity was eliminated). Theoretically, when the correlation distance is set to the sample size, the distribution of the residual distant dipolar interactions within the correlation distance is similar to that in a spherical sample, thus the distant dipolar field would vanish. However, for an infinitely long cylindrical sample, a series of "spherical samples" exist instead of a single "spherical sample". Since the influence from other "spherical samples" cannot be ignored, the net dipolar interaction is not averaged out within the correlation distance, but within a distance more or less deviated from the correlation distance. When the influence of the inhomogeneous field cannot be neglected, this distance would be further shifted. From Table 1 we note that the position of the dip also shifts with sample tube size. So we believe that the existence of the dip is a complex effect of CSG, residual inhomogeneous field and sample geometry. In addition, Fig. 2 shows that the iDQC signal obtained with weak CSG is much stronger than that obtained with strong CSG. Detailed investigation on this phenomenon is in progress.

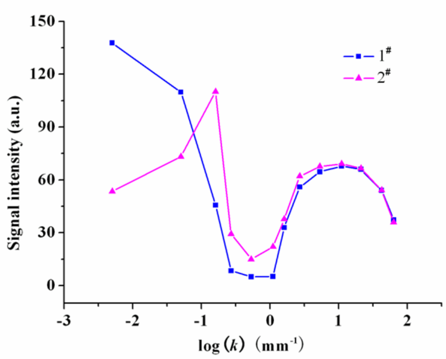

Fig. 2 Variation of the iDQC signal intensity with CSG strength.

Table 1 Positions of the signal dips observed from different sample tubes. Different inhomogeneous fields were created by adjusting shim coils.

Size of the inner diameter of the tubes (mm)		4.3			2.5	1.3
Residual field inhomogeneities (Hz)		3	42	100	3	3
Duration of τ (ms)		17	17	17	17	17
k value at position of dip (mm^{-1})	Scheme $1^{\#}$	0.43	1.34	2.69	1.0	1.86
	Scheme $2^{\#}$	0.43	0.43	0.53	1.0	1.86

Acknowledgments

This work was partially supported by the NNSF of China under Grant 20573084.

References

[1] Capuani S, et al. Magn. Reson. Med. 46 (2001) 683.
[2] Charles-Edwards GD, et al. J. Magn. Reson. 166 (2004) 215.
[3] Bouchard LS, et al. J. Magn. Reson. 176 (2005) 27.
[4] Cai CB, et al. J. Magn. Reson. 193 (2008) 94.