Issues and Artifacts in Intermolecular Double Quantum Imaging

D. F. Gochberg[1,2], A. S. Kussainov[2], J. C. Gore[1,2]
[1]Radiology and Radiological Sciences, VUIIS, Vanderbilt University, Nashville, TN, United States, [2]Physics, VUIIS, Vanderbilt University, Nashville, TN, United States

Introduction

Intermolecular multiple quantum coherences (iMQC) in water were discovered recently and have attracted growing interest from the medical imaging community. A feature of interest for medical imaging is the possibility of manipulating the image contrast to be sensitive to structures on a controllable length scale of 10's to 100's of micrometers. However, there have been few reports of practical biological and medical applications of iMQC imaging. A primary explanation is the difficulty in acquiring images free of artifacts. This work examines the causes of two common artifacts in iMQC imaging and presents simple solutions derived by considering their physical origins.

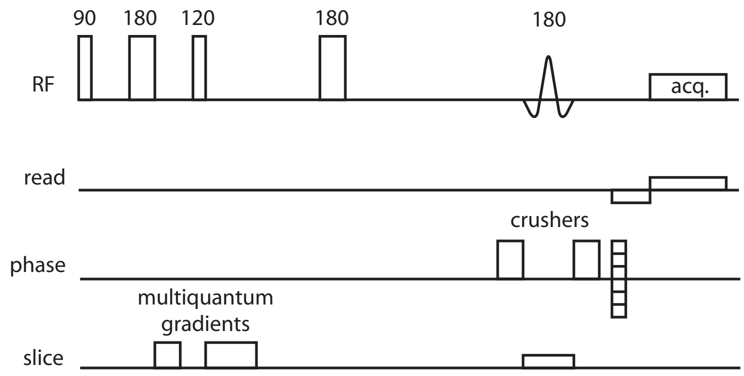

Figure 1: pulse sequence.

An Example

Figure 1 is a variant on the iMQC sequence of Bowtell et al [1], where we have added an additional 180° pulse between the 90° and 120° pulses, removed the crushers around the second 180°, and used a 120° instead of a 60° pulse. Bowtell et al demonstrated the structural sensitivity of this sequence by taking an axial slice across a long cylinder and showing that the signal dropped near the edge of the sample, and that the rate of this drop was dependent on the dictated length scale. We perform a similar experiment on water doped with 1g/l $CuSO_4 \cdot 5H_2O$, but under conditions that reveal sequence sensitivities to artifacts.

Results and Discussion

Figure 2 gives results under six conditions. Controlling the coherence pathway is the key to eliminating many of the artifacts in iMQC imaging. In the example, an undesired coherence pathway arises from the slice profile effects of the slice selective pulse (Fig 2a,b). This pathway (and the corresponding artifact) are eliminated by either crusher gradients (Fig 2c) or expanded phase cycling (Fig 2d). (The expanded phase cycling is x,y,-x,-y, … on the first pulse, x,x,x,x,y,y,y,y,-x,-x,-x,-x,-y,-y,-y,-y on the last pulse, and x,-x,x,-x,-x,x,-x,x,x,-x,x,-x,-x,x,-x,x on the receiver.)

A different artifact arises when an inhomogeneous field is not refocused during the double quantum evolution time (Fig 2e,f). Applying an inversion pulse between the 90° and 120° pulses eliminates this artifact.

1. Bowtell, R., S. Gutteridge, and C. Ramanathan, *Imaging the long-range dipolar field in structured liquid state samples*. Journal of Magnetic Resonance, 2001. **150**(2): p. 147-155.

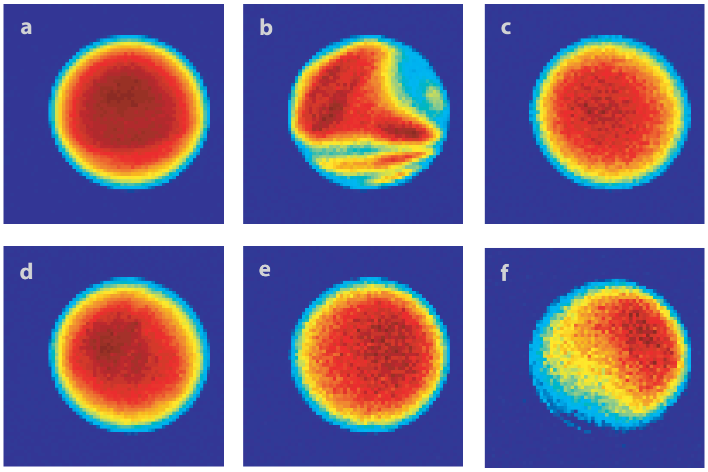

Figure 2: An axial slice through a 10 mm tube with a multiple quantum gradient of 0.265 G/cm and 2 ms. a) with no slice selection gradients. b) a 4mm slice. c) a 4mm slice with crusher gradients around the last 180° pulse. d) a 4mm slice with 16 part phase cycling replacing the standard 4 part cycling. e) a 4mm slice with crusher gradients in the presence of an intentionally poor shim. f) a 4mm slice with crusher gradients and a bad shim, but no inversion pulse between the 90° and 120° pulses.