Localized Spectroscopy with Intermolecular Zero Quantum Coherences: Phantom Results

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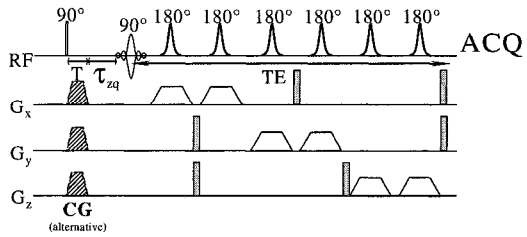
Introduction

Multiple-quantum coherences (MQCs) are part of the standard repertoire of NMR spectroscopists. As detectable magnetization corresponds to single-spin, single-quantum coherences, MQCs have no exact classical analogue. Loosely speaking, they connect states that are separated by more than one spin flip. These coherences can evolve silently and then be transformed into magnetization by an appropriate pulse sequence element **in the presence of coupling** between the spins involved. Previously it was thought that there is no net coupling between spins in different molecules; hence coherences involving such spins were thought to never become observable. However, it was recently found that, in the presence of gradients, long-range dipolar couplings between nuclei can reappear because of incomplete spatial averaging.[1] Hence such couplings can provide a pathway to make **inter**molecular multiple-quantum coherences visible. Furthermore, the 'correlation distance' (i.e., the distance between the spins whose mutual correlation eventually becomes visible) is a linear function of the area under the correlation gradient producing the dipolar couplings. Hence we can select the desired interaction distance through experimental parameters; in practice, this distance ranges from tens to hundreds of micrometers.

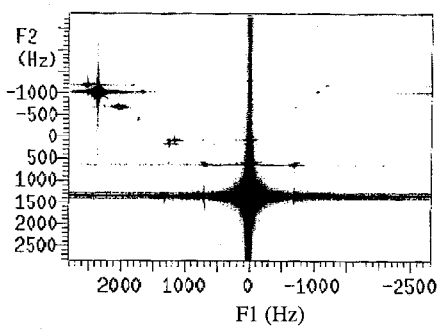
Intermolecular **zero**-quantum coherences (iZQCs) involving two spins are prime candidates for useful applications. Such coherences, again loosely speaking, correspond to the simultaneous flipping of two spins in opposite directions. The iZQC evolution frequency is the difference of the resonance frequencies of the two spins which are involved. This means that this evolution frequency is a measure of the local inhomogeneity of the magnetic field, on a distance scale selected by the experimenter. Importantly, this distance scale is smaller than a typical voxel in an imaging experiment, and can be smaller than the anatomical detail which gives rise to wide lines in vivo. For example, the overall linewidth of water or metabolites in a volume of tissue may be large because of susceptibility variations over the volume of interest, but, on a short distance scale, the field inside the tissue can be quite homogeneous. Hence iZQCs can in principle be used to separate lines that would overlap in a conventional NMR experiment. This has been demonstrated in an NMR sample for a simple molecule and without localization.[2] In order to make this feasible for in vivo studies, the iZQC method must be integrated with volume localization. Here we show that it is possible to obtain a localized spectrum of a complex mixture of molecules with narrow lines in the presence of gross inhomogeneities.



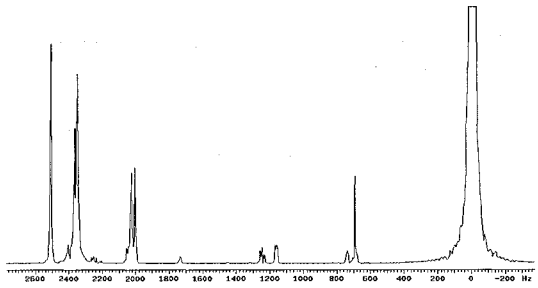
Method

Localized iZQC spectra were obtained from a 9.4 Tesla horizontal bore imaging system (Magnex/Varian) with a gradient insert (11 cm i.d.). The sample was a glass sphere (2.1 cm diameter) containing a mixture of benzene and olive oil (approximately 4:1 by volume). Benzene yields a single NMR peak and serves here as one partner for the intermolecular couplings; in vivo, this role is played by water. The pulse sequence used is shown in the figure above. The initial excitation pulse and correlation gradient are followed by the incremented time τ_{zq}. Then, volume localization is performed in a variant of the LASER method.[3]

Results and Discussion



Shown above is the resulting 2-D spectrum. The large peak at F1=0 is the zero-quantum cross peak between two benzene molecules. The peaks in the upper left quadrant are cross peaks between the olive oil protons and benzene; as discussed above, these peaks come at the difference of the two directly detected frequencies (for example, the large peak at F1=2300 originates from benzene (F2=1300) and a proton in olive oil (F2=-1000).



This figure shows the one-dimensional projection of the pseudodiagonal of cross peaks (F1=F2-1300). This spectrum has relatively sharp lines; quantitative analysis shows that the linewidth is reduced approximately by a factor of two from the one-dimensional linewidth of the sample (30 Hz).

Hence we have shown that the iZQC method can produce sharp lines in inhomogenous samples with simultaneous volume selection. This paves the way for in vivo applications.

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References

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3. DelaBarre, L., Garwood, M., Proc. ISMRM, 358 (1998).