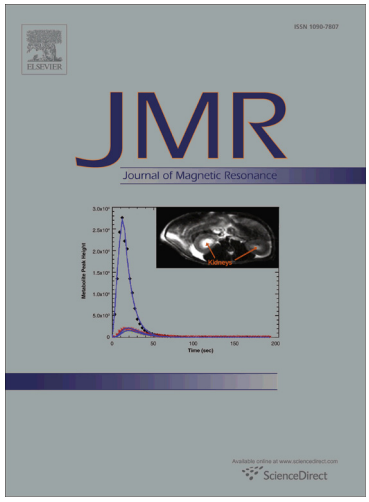

Improving the resolution in proton-detected through-space heteronuclear multiple quantum correlation NMR spectroscopy

M. Shen, J. Trébosc, O. Lafon, F. Pourpoint, B. Hu, Q. Chen, J.-P. Amoureux

PII: S1090-7807(14)00141-4
DOI: http://dx.doi.org/10.1016/j.jmr.2014.05.006
Reference: YJMRE 5442

To appear in: *Journal of Magnetic Resonance*

Received Date: 21 March 2014
Revised Date: 2 May 2014

Please cite this article as: M. Shen, J. Trébosc, O. Lafon, F. Pourpoint, B. Hu, Q. Chen, J.-P. Amoureux, Improving the resolution in proton-detected through-space heteronuclear multiple quantum correlation NMR spectroscopy, *Journal of Magnetic Resonance* (2014), doi: http://dx.doi.org/10.1016/j.jmr.2014.05.006

Improving the resolution in proton-detected through-space heteronuclear multiple quantum correlation NMR spectroscopy

M. Shen,[a,b] J. Trébosc,[b*] O. Lafon,[b*] F. Pourpoint,[b] B. Hu,[a] Q. Chen,[a] J.-P. Amoureux,[a,b*]

[a] Physics Department & Shanghai Key Laboratory of Magnetic Resonance, East China Normal University, Shanghai 200062, China.

[b] UCCS, University Lille North of France, Villeneuve d'Ascq 59652, France.

Jean-paul.amoureux@univ-lille1.fr tel (33) 3.20.43.41.43, Fax (33) 3.20.43.68.14

Abstract. Connectivities and proximities between protons and low-gamma nuclei can be probed in solid-state NMR spectroscopy using two-dimensional (2D) proton-detected heteronuclear correlation, through Heteronuclear Multiple Quantum Correlation (HMQC) pulse sequence. The indirect detection via protons dramatically enhances the sensitivity. However, the spectra are often broadened along the indirect F_1 dimension by the decay of heteronuclear multiple-quantum coherences under the strong ^{1}H-^{1}H dipolar couplings. This work presents a systematic comparison of the performances of various decoupling schemes during the indirect t_1 evolution period of dipolar-mediated HMQC (*D*-HMQC) experiment. We demonstrate that ^{1}H-^{1}H dipolar decoupling sequences during t_1, such as symmetry-based schemes, phase-modulated Lee-Goldburg (PMLG) and Decoupling Using Mind-Boggling Optimization (DUMBO), provide better resolution than continuous wave ^{1}H irradiation. We also report that high resolution requires the preservation of ^{1}H isotropic chemical shifts during the decoupling sequences. When observing indirectly broad spectra presenting numerous spinning sidebands, the *D*-HMQC sequence must be fully rotor-synchronized owing to the rotor-synchronized indirect sampling and dipolar recoupling sequence employed. In this case, we propose a solution to reduce artefact sidebands caused by the modulation of window delays before and after the decoupling application during the t_1 period. Moreover, we show that ^{1}H-^{1}H dipolar decoupling sequence using Smooth Amplitude Modulation (SAM) minimizes the t_1-noise. The performances of the various decoupling schemes are assessed via numerical simulations and compared to 2D ^{1}H-{^{13}C} *D*-HMQC experiments on [U-^{13}C]-L-histidine.HCl.H_2O at various magnetic fields and Magic Angle spinning (MAS) frequencies. Great resolution and sensitivity enhancements resulting from decoupling during t_1 period enable the detection of heteronuclear correlation between aliphatic protons and ammonium ^{14}N sites in L-histidine.HCl.H_2O.

I. Introduction

Two-dimensional (2D) heteronuclear correlation (HETCOR) experiments are key tools of solid-state NMR spectroscopy to probe through-bond connectivities or through-space proximities between distinct isotopes.[1–4] The connectivities and the proximities are revealed through coherence transfers via *J*- or dipolar couplings, respectively. When the one-dimensional (1D) NMR spectra of both correlated isotopes contain several signals, the 2D HETCOR experiments are especially efficient since they allow unambiguous observation of connectivities or proximities between specific sites.

We focus here on 2D HETCOR experiments between protons and another isotope. In solution, the sensitivity of HETCOR experiments can be dramatically enhanced by indirect detection through ^{1}H signals using Heteronuclear Single-Quantum Coherence (HSQC) and Heteronuclear Multiple-Quantum Coherence (HMQC) sequences.[5–7] These methods have been routinely employed for the last three decades in solutions. In solids, it is well-established that effectiveness of indirect ^{1}H detection requires low ^{1}H concentration and/or high MAS frequencies, $\nu_R \geq 30$ kHz, since broad ^{1}H signal can negate sensitivity enhancement.[8–40] One method to correlate ^{1}H and another spin-1/2 nuclei, such as ^{13}C or ^{15}N, is the double cross-polarization (CP) transfer.[8,9] This method has notably permitted the acquisition of ^{1}H-{^{13}C} and ^{1}H-{^{15}N} 2D HETCOR spectra, with ^{13}C and ^{15}N natural