Localized Single Scan 2D NMR

Bruno Vitorge[a], Philippe Pelupessy[a], Andreas Volk[b], Geoffrey Bodenhausen[a,c]

a) Département de chimie, associé au CNRS UMR 7203 et à l'Université Pierre et Marie Curie, Ecole Normale Supérieure 24 rue Lhomond, 75231 Paris Cedex 05, France.
b) U759 INSERM/ Institut Curie centre de recherche, Bâtiment 112 91405 Orsay, France
c) Institut de Sciences et Ingénierie Chimiques, Ecole Polytechnique Fédérale de Lausanne, Batochime, 1015 Lausanne, Switzerland.

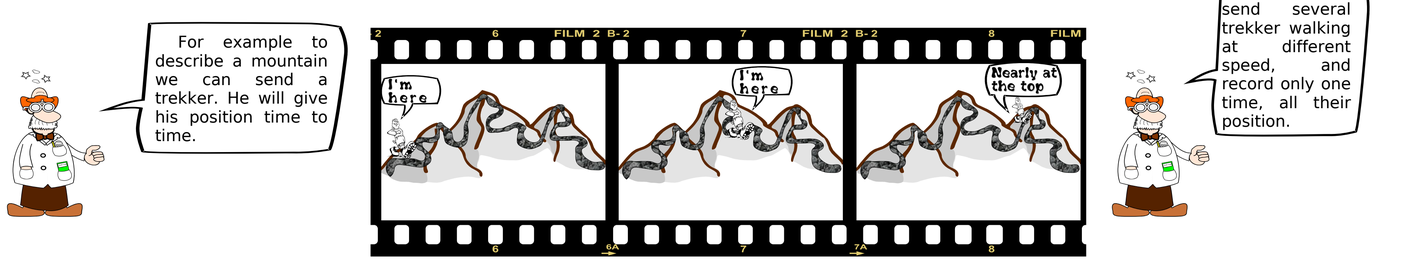
bruno.vitorge@ens.fr

Single scan

To sample a space, we can imagine at least two different solutions.

The first one involve a unique reporter giving his state at different time, a series of time dependant experiments is then needed to characterized the full space.

A faster solution would be to excite simultaneously several reporters with different evolution rates. Then the full space can be characterised in one experiment.

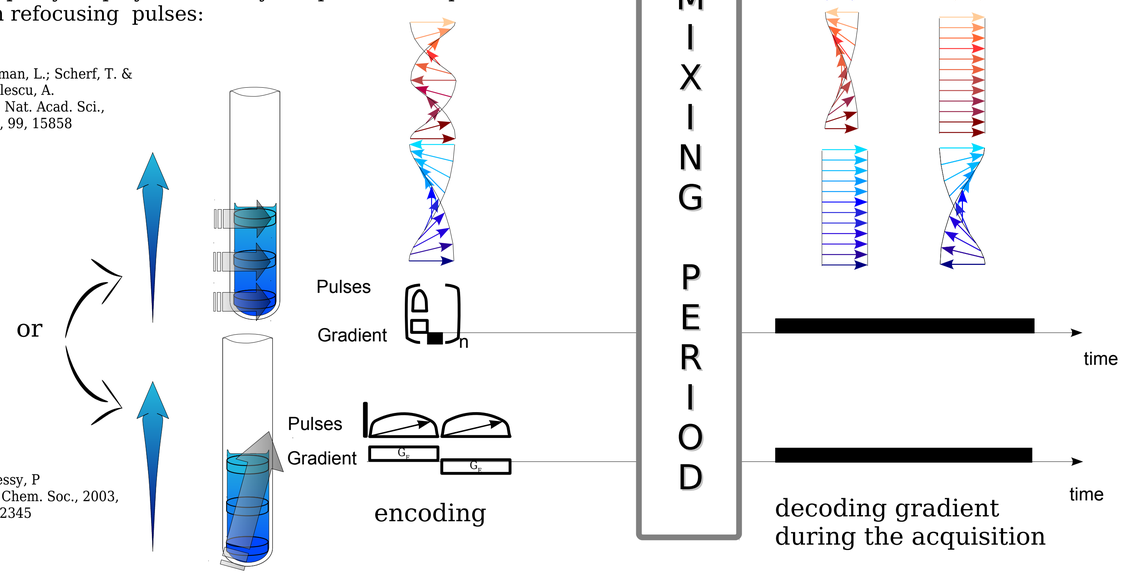


Creation of Multiple reporters

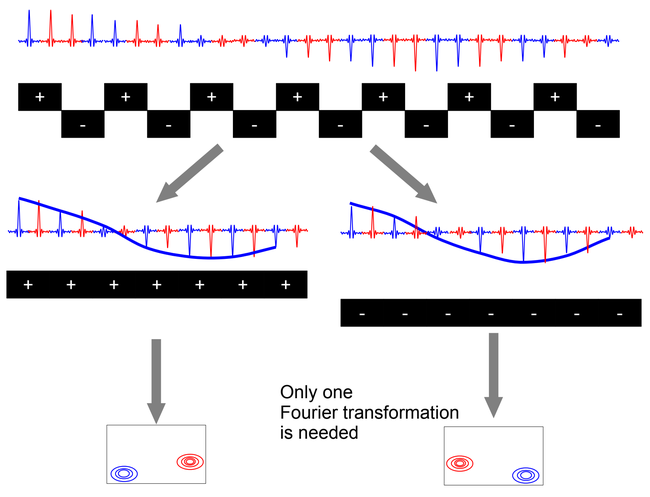
Frydman proposed to use a series of selective pulses.
Pelupessy employed linearly swept adiabatic pair of spin refocusing pulses:

Frydman, L.; Scherf, T. & Lupulescu, A.
Proc. Nat. Acad. Sci., 2002, 99, 15858

Pelupessy, P
J. Am. Chem. Soc., 2003, 125, 12345



Getting the second dimension



Schematic representation of the acquisition used for single scan experiment. It is inspired by echo planar imaging. During the first part of the positive gradient the blue helix is unwrapped giving an echo, then the red one.

At the end of the first positive gradient the helices have been wrapped again with an opposite turn.

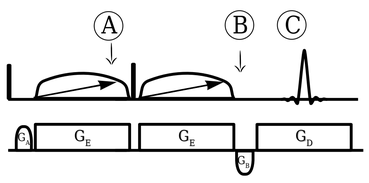
The application of a negative gradient permit to record a second series of echo. The scheme is extended to record the desired number of point.

The echoes are sorted depending on the sign of the gradient. A Fourier transformation is apply to obtain the frequencies of the evolution during the gradients.

Overcoming inhomogeneous field

Single scan SECSY

Vathyam has shown in 1996[1] that a SECSY[2] experiment can be used to record highly resolved spectra in inhomogeneous magnetic field. Peluppesy[3] proposed a single scan version of the SECSY experiment. In this kind of experiment the inhomogeneities are coded in a first part of the sequence. The carrier nuclei can be the solvent[1] or one of the molecule of interest. In the second part, the magnetization is transferred to an other nuclei with a coherence order p=-1, thus removing inhomogeneity component.



Pulse sequence to obtain high-resolution spectra in a single scan in arbitrarily inhomogeneous, magnetic fields with unknown spatiotemporal distributions. The shape with sloping arrow indicates adiabatic frequency-swept refocusing pulses.
G_E and G_D are encoding and decoding gradients.
The gradients G_A and G_B of equal area serve to select the desired coherence pathway.

Phase at points A, B, C of the sequence, the color represent the different contribution.

field inhomogeneities, chemical shift, gradient

Ⓐ $\varphi = \alpha\{\Omega_s+\delta\omega(r)+\Gamma_E(r)\}^2$

Ⓑ $\varphi = \alpha\{\Omega_s+\delta\omega(r)+\Gamma_E(r)\}^2 - \alpha\{\Omega_I+\delta\omega(r)+\Gamma_E(r)\}^2$

$\varphi = \alpha(\Omega_s^2-\Omega_I^2)+2\alpha(\Omega_s-\Omega_I)\{\delta\omega(r)+\Gamma_E(r)\}$

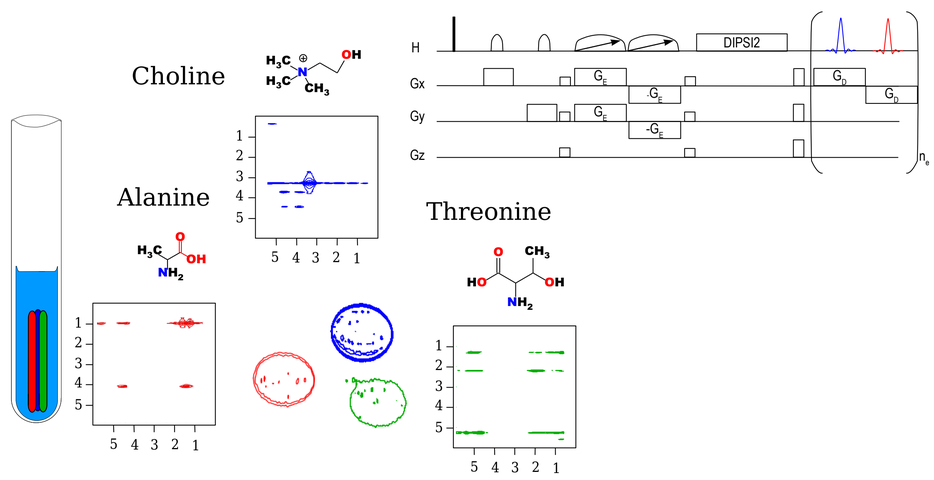
Ⓒ $\varphi(t_D) = \alpha(\Omega_s^2-\Omega_I^2) + 2\alpha(\Omega_s-\Omega_I)\{\delta\omega(r)+\Gamma_E(r)\} - t_D\{\Omega_I+\delta\omega(r)+\Gamma_E(r)\}$

when $t_D=2\alpha(\Omega_s-\Omega_I)$ the phase is given by $\varphi(t_D) = \alpha(\Omega-\Omega)^2$ there is no more field dependencies

Localised single scan

TOCSY

Single scan scheme can be used for localized spectroscopy. The volume selection can be done using selective pulses during gradients along each axis (STEAM or PRESS for example).
Below three localized single scan TOCSY spectra obtained from a sample containing three tubes with different compounds.

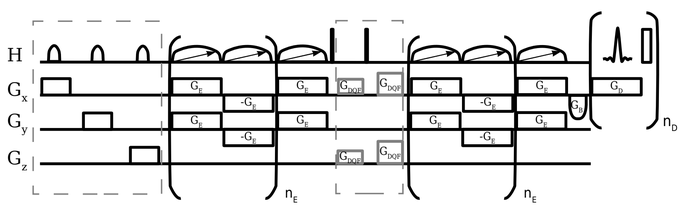


1- Vathyam, S.; Lee, S. & Warren, W. S. *Science*, **1996**, 272, 92-96

2- Nagayama, K.; Wüthrich, K. & Ernst, R. R. *Biochem. Biophys. Res. Commun.*, **1979**, 90, 305-311

3- Pelupessy, P.; Rennella, E. & Bodenhausen, G. Science, 2009, 324, 1693-1697

Localised single scan SECSY

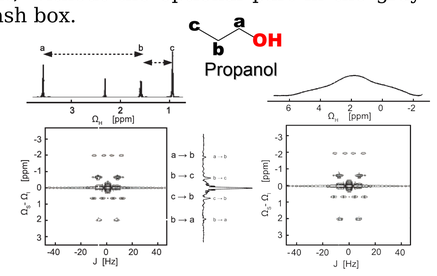


STEAM

Double Quata Filter (DQF)

A STEAM scheme for voxel selection has been added to the sequence above. To reduce the non transferred signal, a double quanta filter can be added. The filter may be obtained using proper gradient proportion, or by phase cycling if several scan are required to increase signal to noise. The two parts in parenthesis are optional, and may be used to increase the resolution

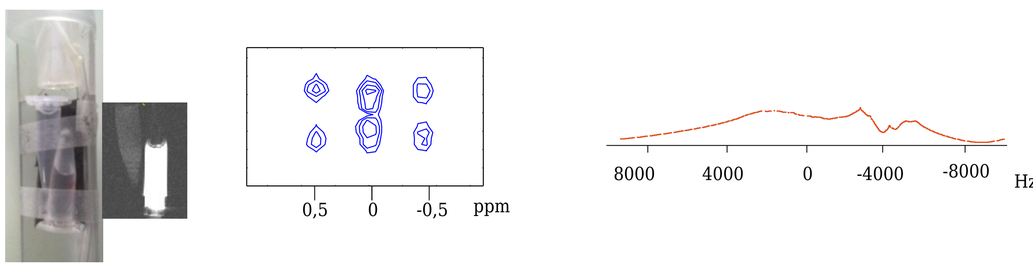
Two-dimensional spectra, plotted in absolute-value mode, of propanol $CH3^cCH2^bCH2^aOH$ taken in ~500 ms with the single-scan sequence presented on the left, without the optional part in the gray dash box.



Pelupessy, P.; Rennella, E. & Bodenhausen, G.
Science, 2009, 324, 1693

On the way to in-vivo

2D Spectrum obtained with the localized, DQF (using gradients) sequence presented on the left. The sample consist of two eppendorfs placed in the mouse holder. The left one contained 10mM of Choline in D_2O (MRI image is pale), the right one contained 10mM of Alanine in water. In orange 1D ^1H spectrum of choline showing the inhomogeneity of the magnetic field



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