NMR signal acquisition in the Doubly Tilted Rotating Frame

Denis Grenier[1], Anne-Laure Perrier[1], Hervé Saint-Jalmes[2], and Olivier Beuf[1]
[1]*CREATIS, CNRS UMR 5220, INSERM U1044, INSA-Lyon, Université de Lyon, Villeurbanne, France,* [2]*PRISM, LTSI, INSERM U1099, Université Rennes 1, Rennes, France*

Target audience

The work presented here is intended for NMR physicists. It presents some new concepts which could enable in vivo solid state NMR spectroscopy and imaging.

Purpose

The main effect of dipolar interaction is to destroy the macroscopic NMR signal and prevent solid state NMR/MRI. In this work we propose to acquire the magnetization of a sample in the Doubly Tilted Rotating Frame (DTRF), which enables the averaging of dipolar interactions without any physical rotation. Our objective is to open the way to a new class of solid state NMR experiments which could be used *in vivo*.

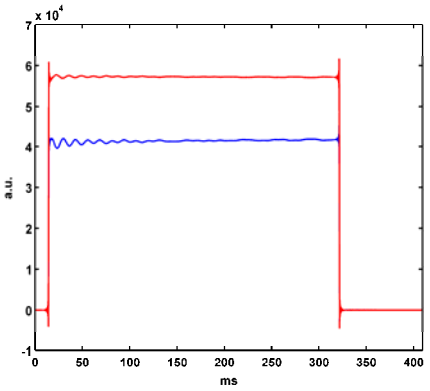

Fig 2: Temporal signal acquired on a PVA sample before, during and after an on-resonant RF irradiation of 5.8µT

Methods

In 1955 Redfield demonstrate that a dipolar interaction averaging effect can occur while the sample is subject to a « strong » RF irradiation [1]. Numerous work has been achieved along this path with the development of techniques relying on irradiation periods followed by signal acquisition periods [2-4]. One drawback of these techniques is that a strong RF has to be periodically switched on and off on a µ-second scale. Instead of placing the system in the DTRF then putting it back periodically to the laboratory frame for the signal acquisition, we have chosen to keep it in the DTRF during the whole process [5] (Fig.1). Acquiring the signal during a strong RF irradiation is challenging. It require a strong decoupling between the emission and reception coils. Furthermore, to avoid saturation of the ADC converter, in this preliminary experiments, the preamplifier of the MRI system was bypassed, thus limiting the dynamic of the signal of interest.

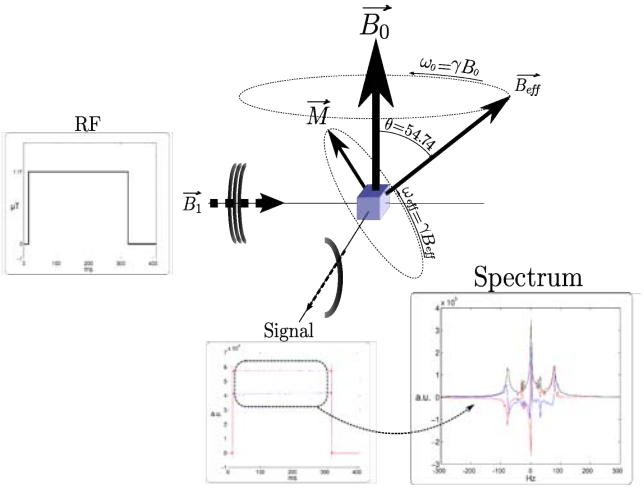

Fig 1: Principle of a dipolar-free signal acquisition in the DTRF

Results

Using a purely geometrical decoupling technique we were able to achieve an Emission-Reception decoupling above 30dB. On our 4.7T Bruker AVANCE1 Biospec hardware, without saturating the ADC dynamic. This decoupling was good enough to allow signal acquisition during an RF irradiation up to 23µT. A signal of 8k complex points was acquired during 409.6ms on a polyvinyl-alcohol (PVA) gel during and after an on-resonance RF of 5.8µT (Fig.2). We also acquired under similar conditions a signal from a 50% water/ethanol mix (Fig.3).

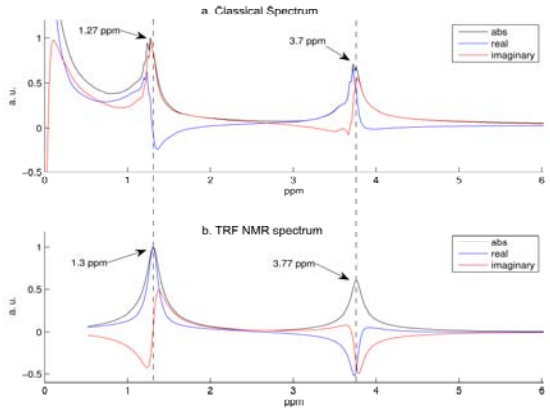

Fig 3: Ethanol spectra obtained from: (a) a classical FID ; (b) a post-processed DTRF-FID

Discussion

Figure 2 shows that the signal exhibit a DTRF free induction signal (DTRF-FID) and we demonstrated that while the T_2^* of the PVA sample used was 2±1ms in the laboratory frame, it was extended to 23±6ms in the DTRF. Fig 3 shows that it is possible to accurately achieve an MRS experiment in the DTRF. Still, to compare the spectra acquired in the laboratory frame and DTRF, we had to preprocess the DTRF-FID to remove the residual baseline emission signal clearly seen as an offset in Fig 2.

Conclusion

It is possible to acquire a NMR signal during an RF irradiation. The chemical shift properties of the sample are kept in the DTRF and the T_2^* range of the sample in the laboratory and DTR frames clearly shows that even using a small RF amplitude of just 5.8µT, we can achieve a 10-fold increase of signal life. These two points demonstrates the potential of this technique that could be further extended for short T_2 tissues investigation.

References

[1] Redfield AG, Nuclear magnetic resonance saturation and rotary saturation in solids, *Phys. Rev.*,**98**(1955) 1787-1809.
[2] Lee M, Goldburg WI. Nuclear-magnetic-resonance line narrowing by a rotating RF field. *Phys. Rev. A*,**140** (1965), p. 1261.
[3] Matsui S et al, Improved Resolution in Solid-State NMR Imaging by Self-Phase Encoding, *J. Magn. Reson.*,**112**(1995) 130-133.
[4] Grenier D et al, Dipolar contrast for dense tissues imaging, *J. Magn. Reson.*,**147**(2000) 353–356.
[5] Grenier D, Saint-Jalmes H. *Patent, PCT EP2011/071960*, (December 6, 2011).

Acknowledgments

This work was performed within the framework of the LABEX PRIMES (ANR-11-LABX-0063) of Université de Lyon, within the program "Investissements d'Avenir" (ANR-11-IDEX-0007).