Low-field Magnetic Resonance Fingerprinting

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Introduction

Magnetic Resonance Fingerprinting (MRF) is a novel imaging technique that offers a rapid quantitative approach for magnetic resonance imaging (MRI). We show the adaptation of the MRF for time-domain NMR at low field, with the objective of accelerating NMR multiparametric analysis for a wide range of applications, which at present necessitate the acquisition of multiple NMR sequences. The use of a pseudo-random RF sequence results in the generation of a unique signal, or "fingerprint", for differing NMR parameters (i.e. T_1, T_2). The matching of these fingerprints against a precomputed dictionary of synthetic signals enables MRF to identify the NMR parameters. In order to accomplish this task and ensure the robustness of the data analysis, RF pulse sequences can be customized for use with laboratory instrumentation.

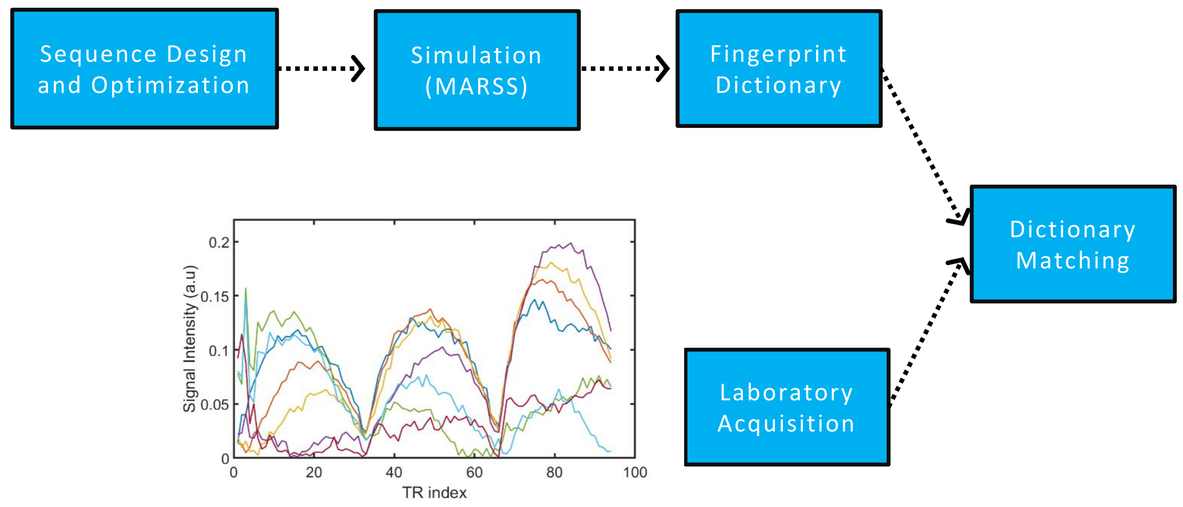


Figure 1: *Framework of the method*

Materials and methods

Acquisitions

The acquisition apparatus consisted of a Stelar NMR console connected to a 0.5 T permanent magnet, using 10 ml of 2 mM $MnCl_2$ as sample. Standard CPMG and IR sequences for ground-truth T_1 and T_2 and a 2D-ANGLE-FID sequence for B_0-B_1 characterization (Figure 2) were performed.
The MRF sequence implemented in this stud y was based on an bSSFP scheme (269 RF pulses, flip angle pattern as described in [1], pulse spacing TR = 1 ms, repetition time = 4 s, 16 scans).

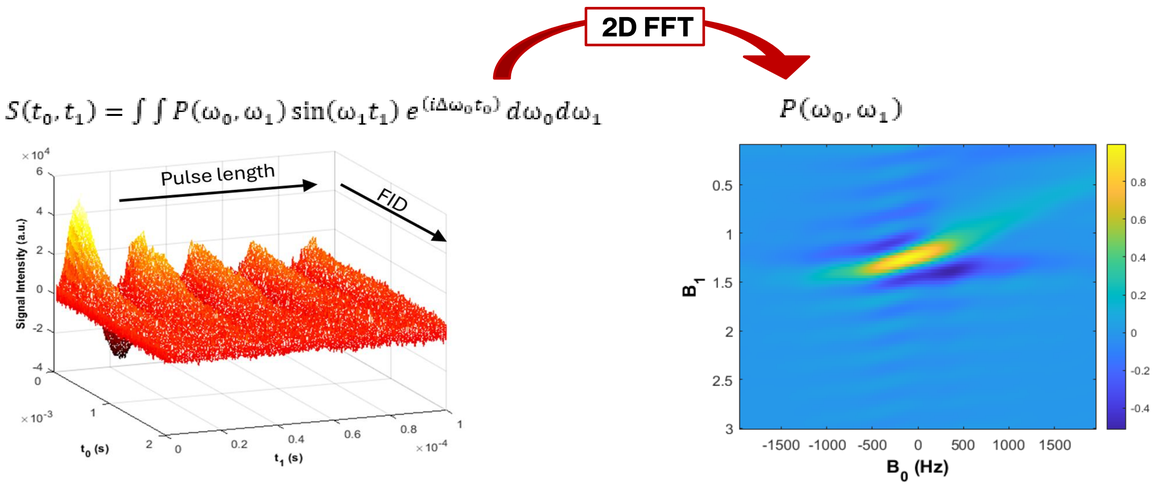


Figure 2: *an example of signal of the 2D-ANGLE-FID sequence for B_0-B_1 characterization and the B_0-B_1 map obtained by the 2D FFT.*

This new Stelar configuration enabled the use of over three times more RF pulses compared to previous implementations [3], enhancing the richness of the acquired signal.

Simulations

MRF signals were simulated using an in-house MATLAB toolbox (MARSS1) using the B_0-B_1 map to create a fingerprint of the signals for the dictionary matching. The dataset for the dictionary consists of 20.000 (T_1, T_2) pairs of entries and a B_0-B_1 correlation function (84x320 map resolution) plus white Gaussian additive noise.

Results

The experimental results demonstrate that it is possible to use fingerprint sequences to reliably distinguish between different samples.
This has been achieved thanks to both the fingerprinting approach and the hardware, which enables experiments to be performed with higher performance and resolution than previously possible.

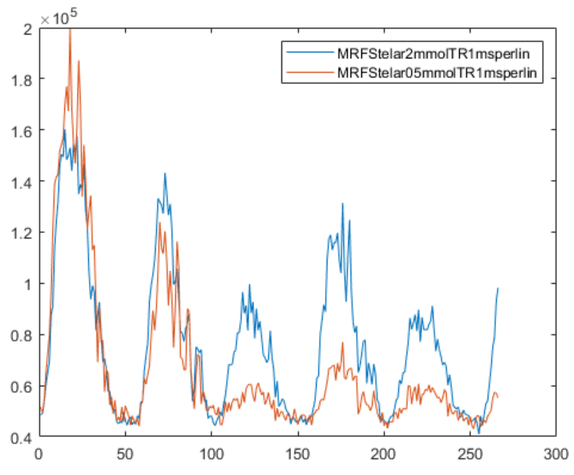
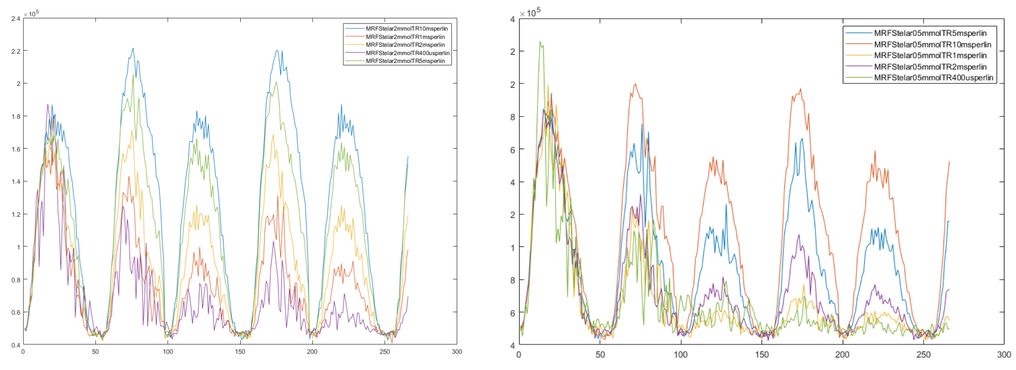


Figure 3: *Experimental results.*

In the near future, the goal is to apply this process to the differentiation of new samples and to extend the experiments to more advanced hardware platforms, such as fast field cycling systems, rather than being limited to fixed-field conditions.

Discussion and conclusions

The preliminary results obtained thus far suggest that low-field nuclear magnetic resonance (NMR) relaxometry is an evolving field of research. The findings indicate the potential for the development of analysis techniques for materials that are versatile and can be employed for a wide range of purposes.



References

[1] Ma D et al, Nature 2013.
[2] Barbieri et al, ISMRM Workshop on MRF, 2017.
[3] Brizi et al, Proc. 16th Bologna Conf. Magn. Reson. Porous Media, 2024.
[4] Barbieri et al, Physica Medica, 2021