Simple implementation of an inductively coupled synthetic signal injection method on a clinical MR scanner for absolute quantification

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Introduction

We previously described a synthetic signal injection method for MR spectroscopy that addresses some of the challenges with absolute quantification, such as variable coil loading conditions and receiver gain stability [1-3]. Our method uses mutual inductance (or shared magnetic field) that allows the pseudo-FID to be transmitted by a second RF coil and received by the main RF coil so that it is acquired and processed under the same conditions as the real FIDs. This robust approach allows reliable absolute quantification for *in vitro* MRS [1], *in vivo* muscle MRS [3] and *in vitro* MRI [2] on a research MR scanner at 4.7 T.

Here, we report a simple way to implement this signal injection method on a clinical MR scanner. This approach can be implemented with a single RF amplifier and does not require any software modifications. A low cost RF synthesizer, which is not synchronized with the pulse sequence, can be used to generate stable injection signals. To eliminate unwanted radiation coupling between the injector and receive circuits, all injector RF components were placed in a shielded box. The system was used to obtain *in vivo* human muscle ^{31}P MRS with a pseudo signal acquired simultaneously.

Methods

In vivo human muscle ^{31}P MRS data were acquired on a 3 T human MR scanner (Philips Achieva with release 2.6.3 software; Philips Healthcare, Best, the Netherlands) using a custom-built surface coil (diameter of 76 mm) for receiving ^{31}P signals from a human leg muscle and for receiving pseudo-signals. A two-turn injector loop (diameter of 1 mm) was securely placed on one side of the surface coil conductor. A programmable crystal oscillator chip Si570 was used to generate synthetic injection signals in the frequency range of 1 to 181 MHz. Injection signals generated by the RF synthesizer chip were further attenuated by attenuators (a 15 dB fixed attenuator immediately after the chip and a variable attenuator with 1- 70 dB attenuation range) to reduce the amplitude of the synthetic signal to about the same level as the signal arising from in vivo nuclei.

Results and Discussion

Figure 1 shows a simple setup of our injection system containing a Si570 RF synthesizer chip, driving unit and fixed attenuator for both suppressing output and matching 50 ohms. The injection unit was RF shielded with copper tape to eliminate potential RF leaks and connected with nonmagnetic Microflex 165 (United Microwave Products Inc., Torrance, CA) to the injector coil via the external attenuator. We then acquired phantom signals as a function of RF powers for synthetic signals and *in vivo* ^{31}P metabolite MRS simultaneously with a pseudo-signal for absolute quantification as seen in Fig. 2. The pseudo-signal for the *in vivo* spectrum was not in phase with the real signal due to complete separation of the injection device from the main MR scanner, which does not affect spectral line fitting and the quantification outcomes. The injector unit is only connected to an injector coil used for the generation of the synthetic signal during the acquisition of the real signal.

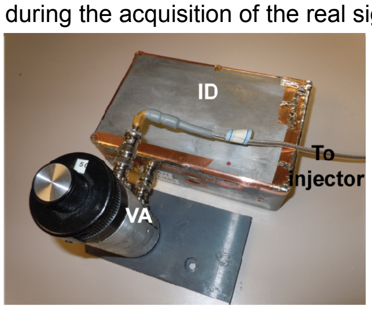

Figure 1. An RF shielded injection device (ID) connected to a variable attenuator (VA) whose output is introduced to an injector. The injection device, containing a Si570 RF synthesizer chip, generates synthetic signals for an inductive signal injection method for absolute quantification.

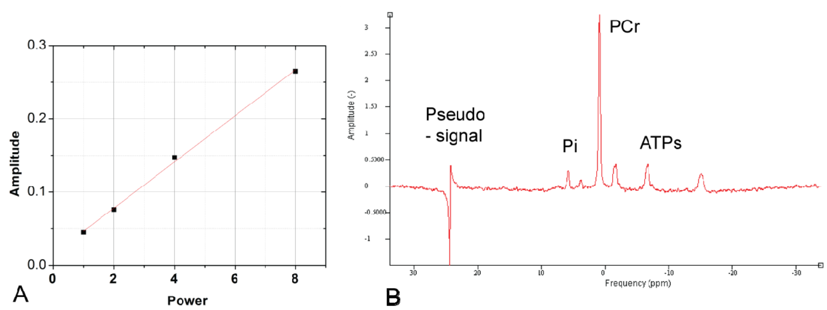

Figure 2. A. 31P phantom calibration: pseudo-signal intensity as a function of RF power for the signal injection. The RF power levels for the pseudo-signals were changed by a 3 dB step to obtain a twofold increase between two consecutive power levels. B. 31P MR spectrum acquired from a healthy human leg muscle in addition to a pseudo-signal for absolute quantification.

Conclusions

We presented a simple way to implement our signal injection method on a clinical MR scanner for *in vivo* absolute quantification. The implementation of the injection device is relatively easy and inexpensive enough to be incorporated in any MR scanners without any hardware/software modifications. This simple but robust method/device would allow reliable *in vivo* absolute quantification on any clinical MR scanners. Also, the portable feature of the device would allow a variety of applications for absolute quantification.

References

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Acknowledgements

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