

Remote Calibration of Accurate Hyperpolarized Gas Polarimetry to Thermally Polarized Water

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Problem

Measuring the polarization of hyperpolarized gas samples is of great importance and yet poses several problems to MR researchers:

- Hyperpolarized gas is by definition in a state of high non-equilibrium, so measurements must be fast and nondestructive as well as repeatable.
- Measurements must be calibrated using a polarization standard like thermally polarized water; however, at fields <1kG the magnetization of water is orders of magnitude smaller than that typically achieved in hyperpolarized gases, making comparison nontrivial.
- Sample geometry is critical, particularly when comparing samples in two different nonstandard volumes.

Methods

Our polarization measurement device is based on a low frequency (24.5 kHz), tuned, precision-wound NMR surface coil. Circuit design and component selection were done with both stability and standardization in mind. The Q of the circuit is determined almost entirely by a precision resistor, minimizing the effects of relatively large coil and capacitor tolerances.

A software-controlled FET switch based on the hardwired switch of ref. [1] quickly damps ringing in the tuned coil. This has two benefits: 1) the recovery time of the NMR circuit is less than a tenth of the recovery time when not actively damped, and 2) the pulse delivered has a reproducible square envelope, assuring measurement repeatability and reducing circuit-to-circuit variations.

As compared to other applications of NMR, several factors make hyperpolarized gas polarimetry somewhat unusual. We have only one line in the FID frequency domain, and apart from roughly matching the FID frequency to that of our tuned circuit, we are uninterested in the exact response frequency. Likewise, we are uninterested in the lineshape and phase; we only need to know the initial amplitude of the time domain envelope. For these reasons and because we are able to operate at low frequency, we have found it more convenient to sample FIDs directly (rather than mixing them down) and analyze FIDs in the time domain. A numerical algorithm extracts the envelope function and compensates for uncorrelated circuit and pickup noise. We are then able to apply a curve fitting routine to the envelope function itself and extrapolate backwards, mitigating the effects of varying T_2^* on the measurements. In this way, our measurements are robust with respect to ambient local field gradients. We will compare this procedure to more standard NMR analysis methods.



Fig. 1 Polarization measurement device

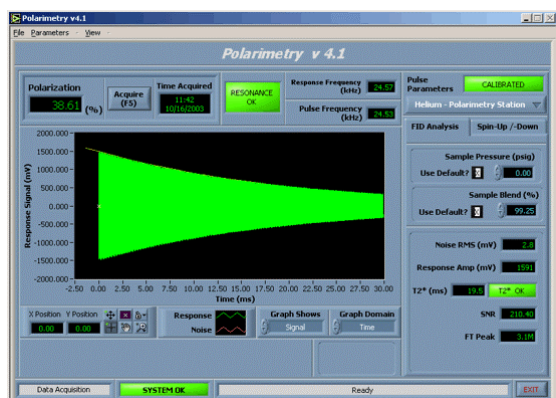


Fig. 2 Screenshot of FID analysis software, showing typical hyperpolarized gas signal

Calibration of the device may be performed one of two ways: 1) via comparison with thermally polarized water with a very well defined geometry in a higher field NMR system "in house", or 2) remotely via a polarization transfer standard. The transfer standard is an active device designed to mimic the low flip-angle behavior of a hyperpolarized gas sample with fixed polarization. This allows us to quickly perform accurate *remote water-traceable calibrations*.

Results

These methods have allowed us to produce reliable polarization measurement systems stable to better than 1% over time and with minimal variation between units. Our calibration procedure is accurate to better than 3%, even when transferred to remote locations.

Conclusions

We have developed an accurate, repeatable means by which to measure the polarization of hyperpolarized gas samples. A novel remote calibration method allows us to transfer calibration to a remote device while retaining the traceability to thermally polarized water.

References

1. Conradi, M.S., *FET Q switch for pulsed NMR*. Rev. Sci. Instrum., 1977. **48**(3): p. 359-361.