Polarization Loss From Magnetic Field Noise

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TARGET AUDIENCE This abstract is targeted toward scientists interested in utilizing the enhanced signal of hyperpolarization for metabolic & molecular imaging and researchers designing parahydrogen induced polarization (PHIP) equipment.

PURPOSE Hyperpolarization by RF irradiation spin transfer utilizing parahydrogen requires low magnetic fields. These fields have been created with solenoids using current to determine the field strength. This abstract is intended to show how noise in the current results in magnet field noise, leading to sporadic loss of polarization in echo sequences. We will demonstrate how coherent and random noise results in variations in the polarization refocusing. The loss in temporal refocusing is a crucial issue in the reliability of RF irradiation spin transfer PHIP hyperpolarization, since the last part of such sequences contains an echo period in the transverse plane.

METHODS To demonstrate how magnetic field fluctuations can result in errors in refocusing; we have collected data with a current source designed in our lab (JCC) and an off the shelf power supply (voltage source) (HB) and have set up an experiment which simulates the end of an RF spin transfer method. For the experiment, each datum point was collected by first polarizing a 0.5g solution of ^{13}C-acetate in D2O in a 9.4T magnetic field to generate a high polarization. The sample was rapidly moved to the low field (1.8mT) and the following RF pulse sequence was applied on the ^{13}C nucleus: 90x RF pulse, ½ tau period, 180x RF pulse, ½ tau period, 90x RF pulse and returned to the 9.4T magnet field for a 90 degree read pulse. Five data points were collected for each tau period (tau periods; 1.66, 4, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62 ms). The highest polarization for each tau period was set to an index value of 1; the other 4 magnetizations were a fractional ratio of that polarization. The index is used to account for the small amount of T_2^* loss and J-coupling variations[1]. For the data acquisition, when the first ½ tau period has different average procession frequency (υ) than the second ½ tau period then the refocused echo temporal resolution is distorted resulting in an observed lower magnitude a the refocus time point. Since the noise is made up of random noise and coherent noise there is variability in the frequencies for the two ½ tau periods and variability in the refocusing point (Figure 1). Current noise from the power sources were indirectly measured with an Agilent 34411A multimeter by measuring the average voltage drop across a 1 ohm current sense resistor (ohms law V=IR; where R=1 Ohm, thus V=I) and collecting 50,000 points at a sampling rate of 1ms.

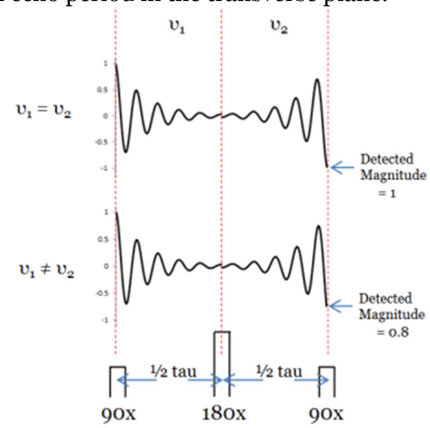

FIGURE 1: Date collection scheme showing how frequency variations result in partial storage of the magnitude

RESULTS Our current supply had a measured current of 0.7990255 ± 0.0000065 (mean ± std. dev.) and the purchase power supply measured current was 0.7990337 ± 0.0000197 when connected to the magnetic field coil (Figure 2). With nearly the same average current required to produce a 1.8 mT magnetic field the HB power supply had 3 times more deviation in the noise. The data for the two power supplies had similar indexed polarizations (JCC;0.974 ± 0.024 (Figure 3), HB; 0.962 ± 0.037 (Figure 4)) while the HB supply had a larger standard deviation resulting generally larger point scattering across tau periods (random noise contribution) and larger deviations around 16 ms from coherent noise contributions (JCC;0.976 ± 0.019, HB; 0.926 ± 0.061, p=0.03).

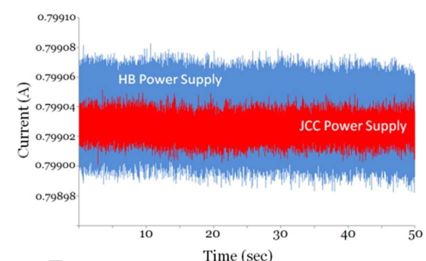

FIGURE 2

DISCUSSION The reliability of polarization by PHIP methods has been a consistent problem which has been demonstrated in a quality control paper for the hyperpolarization of succinate.[2] Until now there has not been an explanation of the potential cause. We have shown that increased noise in the current used to produce the magnetic field results in larger deviations in the polarization. It should be noted that the apparent polarization loss observed is purely due to <u>temporal movement of the refocused echo and not loss in coherence.</u>

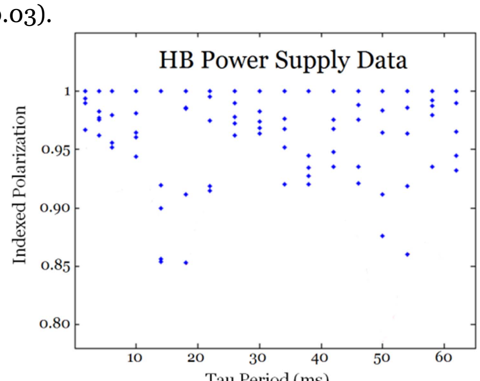

FIGURE 3

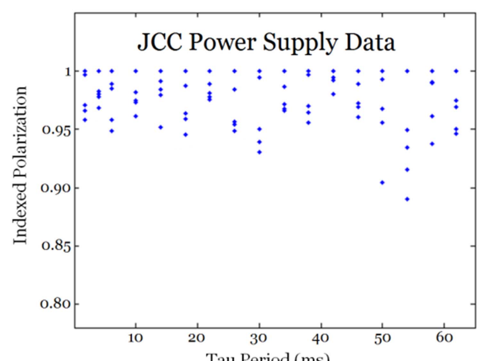

FIGURE 4

CONCLUSION Our current source with less noise is able to produce a stable field of ±8 ppm, this directly results in less frequency variation and an improved reliable for storing polarization which is crucial for increasing the reliability of PHIP instrumentation.

REFERENCES

1 Hahn, E. L. & Maxwell, D. E. Chemical Shift and Field Independent Frequency Modulation of the Spin Echo Envelope. *Physical Review* **84**, 1246-1247 (1951).
2 Hoevener, J. *et al.* in *International Society of Magnetic Resonance in Medicine*.