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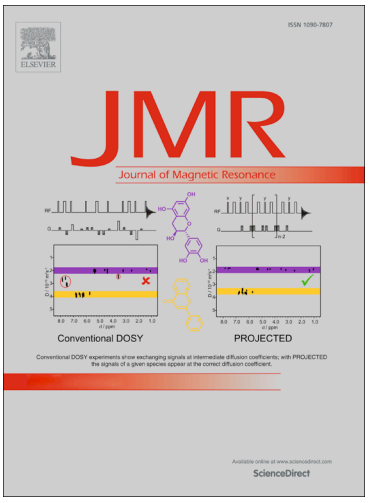

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Direct Enhancement of Nitrogen-15 Targets at High-field by Fast ADAPT-SABRE

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Abstract

Signal Amplification by Reversible Exchange (SABRE) is an attractive nuclear spin hyperpolarization technique capable of huge sensitivity enhancement in nuclear magnetic resonance (NMR) detection. The resonance condition of SABRE hyperpolarization depends on coherent spin mixing, which can be achieved naturally at a low magnetic field. The optimum transfer field to spin-1/2 heteronuclei is technically demanding, as it requires field strengths weaker than the earth's magnetic field for efficient spin mixing. In this paper, we illustrate an approach to achieve strong ^{15}N SABRE hyperpolarization at high magnetic field by a radio frequency (RF) driven coherent transfer mechanism based on alternate pulsing and delay to achieve polarization transfer. The presented scheme is found to be highly robust and much faster than existing related methods, producing $\sim$ 3 orders of ^{15}N signal enhancement within 2 seconds of RF pulsing.

Keywords: Hyperpolarization, PHIP, SABRE, ADAPT

1. Introduction

Despite the huge success of NMR in a wide assortment of research fields ranging from structural material characterization to the imaging of internal human organs, it is still regarded to be underexploited based on its theoretical potential [1, 2]. Most of the successes of NMR and MRI applications have been achieved utilizing the thermal level of nuclear spin polarization which is only of the order of 10^{-5} at room temperature in a standard high field spectrometer [2]: only one spin over 30,000 contributes to the NMR signal for protons in a 9.4 T magnet. Improving this poor sensitivity would make NMR and MRI more widespread and cost-efficient. The solution to this quest is offered by hyperpolarization methods that enhance the nuclear spin polarization by up to 5 orders of magnitude compared to standard thermal polarization [3]. This large sensitivity enhancement enables the completion of high-end MRI applications e.g. *in vivo* study of human cancer, which could otherwise not be performed due to sensitivity issues [4, 5, 6].

Within the class of hyperpolarization techniques, the Para-hydrogen Induced Polarization (PHIP) method employs a highly ordered nuclear singlet, para-hydrogen (p-H_2) gas, to enhance poorly polarized substrate spins by several orders of magnitude [7, 8]. An important variant of the PHIP technique, SABRE was introduced in 2009, that no longer requires active hydrogenation to hyperpolarize targeted molecules [9]. It relies on the temporary association of the substrate at a metal center where the associated J-coupling network ultimately enables the generation of hyperpolarized substrates(see Fig. 1a). SABRE provides a simple, fast and cost-efficient approach to hyperpolarize substrates in its original form and they can be re-polarized several times in quick succession, providing the opportunity to achieve continuous hyperpolarization [10]. The method has been successful in polarizing a large class of biologically relevant substrates where their ^{1}H , ^{13}C and ^{15}N nuclei [11, 12, 13, 14] are senitised, and also in prepar-

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