PRE-POLARIZATION USINGU IN ADIABATIC PULSES FOR DETECTION OF SURFACE NUCLEAR MAGNETIC RESONANCE

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Abstract

The technique of surface magnetic resonance (SNMR) has been widely used for hydrological investigations by the advantage of locating the bulk of aquifer directly. However, the low signal-to-noise ratio (SNR) is one of the most difficult problems. For the purpose of improving SNR, a new approach using pre-polarization (PP) applying by a direct current (DC) in adiabatic pulses has been introduced to improve the excitation volume and thus the signal amplitude both in shallow and deep depth, instead of using alternating current (AC) field in the traditional way. To substantiate the effectiveness of this method, we conduct the numerical simulations of PP adiabatic pulses using in SNMR. We expect this development to open up new applications for SNMR technology, especially in high-noise level places.

Introduction

Surface nuclear magnetic resonance (SNMR) is, thanks to its direct sensitivity to groundwater, a more and more frequently applied geophysical technique used for near-surface hydrological characterisation. In recent years, fundamental progress has occurred, extending the method to allow for 2D [Hertrich 2008; Hertrich *et al.* 2009; Dlugosch *et al.* 2014] and 3D [Legchenko *et al.* 2011; Jiang *et al.* 2015a] subsurface imaging. Further, new measurement configurations [Davis *et al.* 2014; Jiang *et al.* 2015b], new measurement sequences [Grunewald & Walsh 2013], improved inversion techniques [Müller-Petke & Yaramanci 2010], and data processing schemes to enhance signal-to-noise ratios (SNR) were develop. Two specific strategies are followed to improve the SNR by (i) suppressing noise and (ii) increasing the signal amplitude. In terms of noise suppression, previous research has focused on using reference loops to cancel correlated noise [Walsh 2008; Dalgaard *et al.* 2012; Müller-Petke & Costabel 2014] and to process harmonic [Legchenko & Valla 2003; Larsen *et al.* 2014] and impulse noise [Jiang *et al.* 2011; Costabel & Müller-Petke 2014; Larsen 2016]. To increase the signal amplitude, sophisticated transmitting pulses or pulse sequences are necessary. Grunewald *et al.* [2016] and Grombacher & Knight [2015] proposed the methods of adiabatic pulses and composite off-resonant pulses, respectively, and de Pasquale & Mohnke [2014] introduced the pre-polarization to SNMR. The three methods all effectively increase the excitation volume and thus, the signal amplitude, as the amplitude of the measured signal depends on the number of protons that are excited.

On this basis, here, a method is proposed that increases the detected signal amplitude by utilising the pre-polarization (PP) technique to adiabatic pulses. Thus taking advantage of a significantly enhanced SNR. To verify the effectiveness of our approach, we present a simulation study of PP using in adiabatic pulses and compare it to traditional alternating current pulses.

Method

The combined sequence and waveform for transmitting of PP using in adiabatic pulses are shown in Figure 1. And the kernel functions are shown in Figure 2. As we expected, PP using in adiabatic pulses could improve the kernel function obviously comparing to traditional AC pulses. The simulated pulse current and initial amplitude curves of the water content modeling can also prove the improvement of the signal amplitude both in shallow and deep area (Figure 3).

Conclusions

Compared to traditional SNMR pulses, which is used to apply a weak signal easily submerging in noise, the PP adiabatic pulses can enhance the sensitivity and signal amplitude obviously. We provide the forward modeling of PP adiabatic signals and show the increase of sensitivity for both shallow and deep regions by comparing 1-D kernel function. In the future, we expect considerable interests in the instrument system using PP adiabatic pulses in actual measurement for water detection.

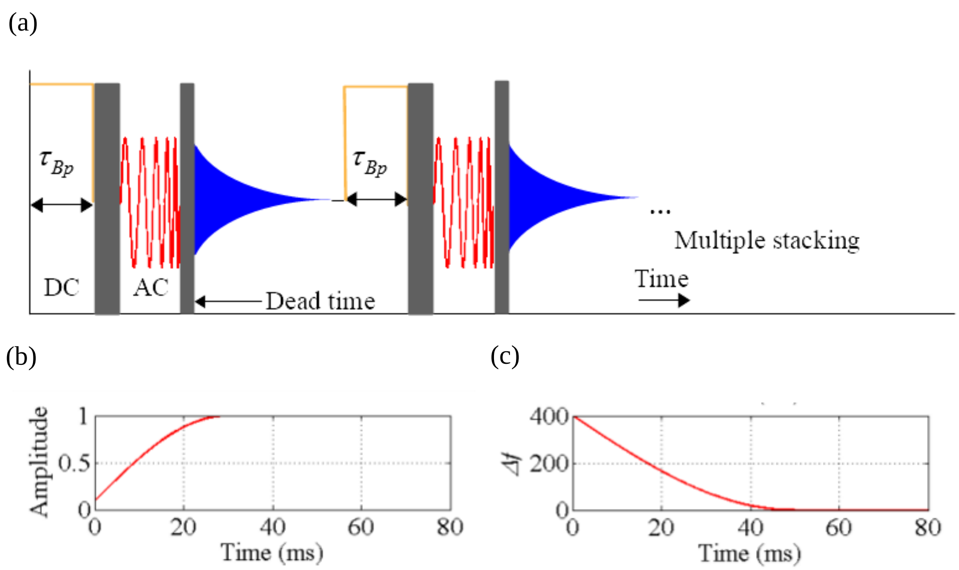

Figure 1: Schematic of pre-polarization using in adiabatic pulses. (a) The PP pulses, adiabatic pulses, dead time and measured signals show in timing diagram is in dark red, read, gray and blue. (b) The amplitude modulation function of adiabatic pulses. (c) The frequency modulation function of adiabatic pulses.

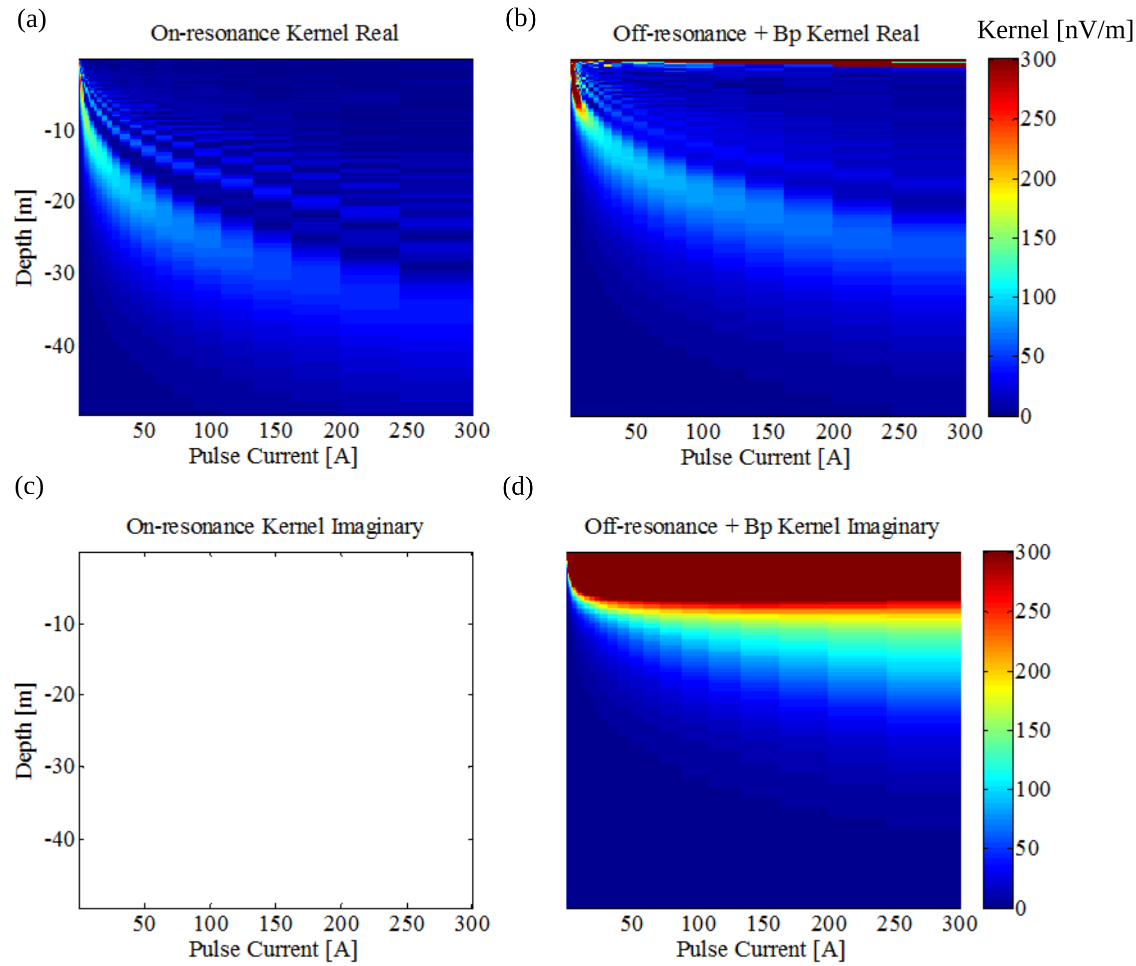

Figure 2: Comparison of kernel function for the pulses. The magnitude of the real and imaginary part of the on-resonance kernel in (a) and (c), respectively, the off-resonance with PP in (b) and (d), respectively.

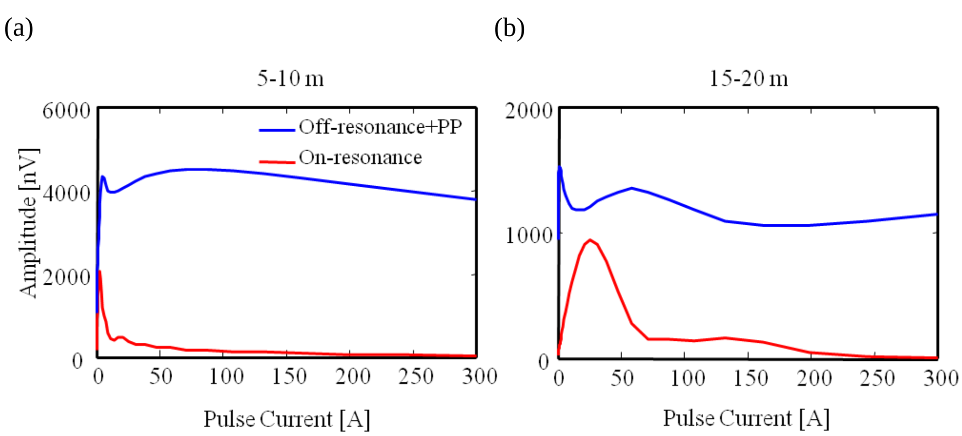

Figure 3: Simulated sounding curves of the pulse current and initial amplitude for the aquifer with (a) 100% water content in 5-10 m depth, (b) 100% water content in 15-20 m depth.

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