Improving the Accuracy of T1 Measurements In Vivo: The Use of the Hyperbolic Secant Pulse in the Saturation Recovery/Inversion Recovery Sequence

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Introduction

Proton NMR relaxation times reflect some of the physical properties of tissues and provide a basis for objectively measuring change in NMR images. In vivo NMR relaxation times are being measured to quantitate tumour response to therapy. This requires measurement methods that give reproducible and accurate values of relaxation times in a manner that is fast and convenient to use. The saturation recovery/inversion recovery (SR/IR) sequence (Fig. 1) is an efficient method of measuring T1. Only one sequence needs to be loaded and run, and this produces two images from which a T1 map may be readily calculated. This method has been shown to be more efficient than either the multipoint inversion recovery sequence (Kurland 1985) or the SE/SE two-point method (Gowland et al. 1988).

In this paper we consider the change in performance of the interleaved SR/IR sequence when the conventional sinc inversion pulse is replaced by a selective hyperbolic secant inversion pulse (Silver et al. 1985). This pulse

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generates an exact inversion for B1 fields above a threshold value and gives a good slice profile. Experimental measurements are presented, together with a simulation of the pulse profile behaviour.

The SR/IR Sequence with a Sinc Inversion Pulse

Measurements were carried out using a 1.5-T Siemens Magnetom with calibration phantoms obtained from The Hammersmith Hospital, London (Walker et al. 1989), which were contained in a tank of copper sulphate-doped saline solution. The phantoms consisted of gadolinium-doped agarose gel samples, for which T1 and T2 varied independently with values covering a T1 range of 226–1621 ms and a T2 range of 54–387 ms. The ratio of the signals from the IR and SR parts of the sequence (Kurland 1985) was given by

\[ R = \frac{1 - 2 \exp\left(-\frac{T_1}{T_1}\right) \exp\left(-\frac{(T_1 + T_2)}{T_1}\right)}{1 - \exp\left(-\frac{(T_2 - T_1)}{T_1}\right)} \]

where \( g = 2 \exp\left(\frac{T_2}{2T_1}\right) - 1, \)

![Graph showing T1 measurements of agarose gel phantoms using the SR/IR sequence, with Tr1 = Tr2 = 4.0 s, Ti = 1.3 s, plotted against the calibrated Hammersmith T1 values for each sample. This graph shows the results for both the conventional sinc inversion pulse, and the HSC pulse. The diagonal line indicates the line of identity, and the error bars show the standard deviation on five measurements.](image-url)