EXPERIMENTAL INVESTIGATION OF ONE-DIMENSIONAL "DESIRE" FOR NMR MICROSCOPY

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Introduction NMR microscopy has the great potential of providing the plurality of NMR contrast mechanisms also to very small biological samples, such as e.g. single cells [1]. However, at a spatial resolution of a few micrometers it is increasingly difficult to obtain sufficiently high signal-to-noise-ratio (SNR) within a reasonable measurement time. Furthermore, conventional Fourier encoding techniques suffer from loss of true resolution due to a *k*-space filter arising from diffusion [2]. This effect can be reduced by the use of very strong gradients. However, during frequency-encoding this leads to a decrease of the SNR, favouring purely phase-encoded methods [3]. The DESIRE technique [4] follows a completely different approach with the spatial definition being accomplished only by the selectivity of an RF pulse with an associated gradient. A series of such pulses separated by delays takes advantage of the spins being replaced by diffusion. Hence, an enhanced signal is obtained from the selected volume. Preferably, saturation pulses and a difference technique are used rather than excitation pulses. The predicted enhancement effect was observed experimentally for a saturation thickness of 7.8 µm in a 1D implementation of DESIRE [5]. In the present work, 1D DESIRE is investigated for a wide range of resolution values down to 1.6 µm, also demonstrating the crucial importance of the saturation profile.

Methods The saturation volume after a single pulse V_{SP} or after a series of pulses V_{SER} can be defined as $V = \int (1 - M_Z(z)) dz$, assuming normalized equilibrium magnetisation. The DESIRE signal enhancement [4] can then be calculated as $E = V_{SER} / V_{SP} - 1$. The aim of this study was to enable the calculation of E with experimentally determined values of V_{SP} and V_{SER}. To this end the saturation period was followed by gradient echo imaging of the saturation profile. The profiles were subtracted from data obtained without saturation and integrated. Experiments were carried out with pure water in a sample tube of 5 mm diameter on a Bruker AVII spectrometer at 7 T using a Micro 5 probehead and 60A gradient amplifiers.

Results and Discussion Fig. 1a) shows the saturation profiles for a block pulse with D = 766 µm, with the nominal saturation thickness D being defined at M_Z = 0.5. At this resolution diffusion is negligible and the increased saturation volume is simply due to repeated saturation of the effectively static spin pool. Hence, signal originates from a much larger than the intended volume. This demonstrates that pulses creating shapes with considerable side lobes are not suitable for DESIRE. Fig. 1b) is the equivalent result of a sinc pulse with a single RF lobe. Here, the saturated volume is much more confined to the region of interest due to the smaller side lobes. However, the saturation thickness of the pulse series is increased, and generally one has to be aware that the effective resolution of the DESIRE experiment depends on the local diffusion. The experiment was executed for D = 766 - 1.6 µm with sinc pulses of length 3 - 10 µs, the series of 30 pulses separated by 30 ms, gradient strengths 1.3 - 189 G/cm, and imaging with resolution 50 - 3 µm. For D = 38 µm Fig. 1c) shows the saturation volume increased by diffusion. For small D the measured values of V_{SP} are difficult to determine, hence they were substituted by the theoretical values for the calculation of E. Fig. 2 shows $E(D)$ with values up to 35 and in reasonable agreement with those predicted in [4]. Note that the asymptotic value $E \approx 1$ for large D results from repeated saturation.

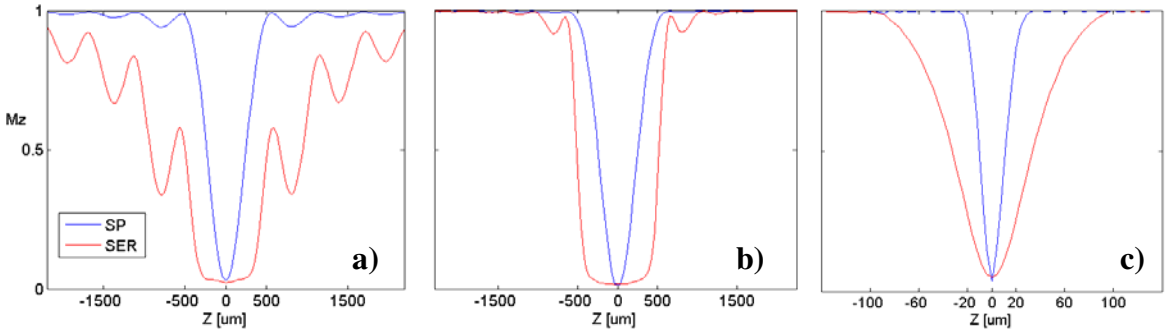
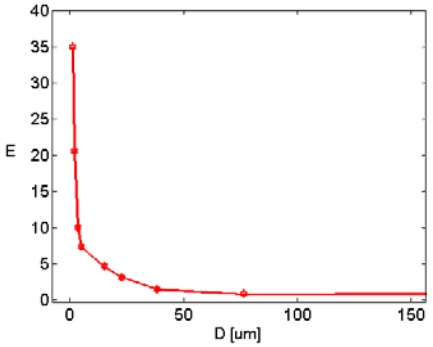


Figure 1 (left) Saturation profiles for a single pulse (SP) and a series of pulses (SER) as used for DESIRE. a) block D = 766 µm, b) sinc D = 766 µm c) sinc D = 38 µm.

Figure 2 (bottom) DESIRE enhancement as a function of the nominal saturation thickness D.



References

1. L. Ciobanu, A.G. Webb, C.H. Pennington, Magnetic resonance imaging of biological cells, Prog. Nucl. Magn. Res. Spectrosc. 42 (2003) 69-93
2. P.T. Callaghan, C.D. Eccles, Diffusion-limited resolution in nuclear magnetic resonance microscopy, J. Magn. Reson. 78 (1988) 1-8
3. S. Gravina, D.G. Cory, Sensitivity and resolution of constant-time imaging, J. Magn. Reson. B 104 (1994) 53-61
4. C.H. Pennington, Prospects for diffusion enhancement of signal and resolution in magnetic resonance microscopy, Concept. Magn. Reson. 19A (2003) 71-79
5. L. Ciobanu, A.G. Webb, C.H. Pennington, Signal enhancement by diffusion: experimental observation of the "DESIRE" effect, J. Magn. Reson. 170 (2004) 252-256