A CLOSER LOOK INTO "DESIRE" FOR NMR MICROSCOPY

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Introduction The major challenge of NMR microscopy at a spatial resolution of a few micrometers is the limitation of the signal-to-noise-ratio (SNR) due to the small voxel size and the effects of molecular self-diffusion. Despite great advances in the development of dedicated hardware [1], at very high resolution the required measurement times are still too long for biological applications. In contrast to conventional Fourier techniques the real-space DESIRE approach utilises diffusion to increase the SNR [2] by means of a spatially localised but temporally extended saturation of the magnetisation. The potential of this approach has been emphasised by the intriguing prospects of a signal enhancement of up to three orders of magnitude [3], an initial experimental observation of the effect [4], and an experimental investigation of the saturation procedure [5]. In this work, an extensive analysis of one-dimensional DESIRE is presented [6]. Simulations, quantitative DESIRE experiments, and DESIRE imaging serve to investigate the aspects of true spatial resolution, signal enhancement, and contrast in structured objects.

Methods For DESIRE saturation a train of equally spaced saturation pulses was used. Simulations of this implementation were carried out for free and restricted diffusion employing the Bloch-Torrey equations. From the simulated saturation profiles the expected DESIRE enhancement was calculated. The true spatial resolution was determined by means of an effective excited profile, thus including the effects of repeated saturation [5]. Experiments were conducted on a Bruker AVII spectrometer at 7 T equipped with a standard microimaging setup and using pure water in a cylindrical sample tube of 5 mm diameter. Selective saturation was applied perpendicular to the cylinder axis with profile widths down to 3 µm.

Results The dependencies of signal enhancement E and true spatial resolution d_{true} on the parameters saturation profile width d, pulse duration t_p, delay between pulses t_d, and duration of the saturation period T were examined in simulations as well as experimentally. For unrestricted diffusion Fig. 1 shows selected results with E as a function of T for different d, indicating a good agreement of simulated and experimental data. E can be increased for T up to about $3T_1$, and E is generally larger for smaller d. Here, a maximum value of 25 is obtained. Further results yield that for given T, t_d must be optimised for sufficient saturation efficiency without considerably degrading d_{true}. Somewhat surprisingly, t_p is not a critical parameter for d_{true}. For restricted diffusion Fig. 2 shows the simulated contrast in DESIRE images obtained for a single barrier or closed compartments of different size, assuming that the saturation acts on only one side of the barrier. The behaviour of decreasing signal close to a barrier is supported by experimental data. Fig. 3 shows E simulated for saturation acting on both sides of a very thin barrier, exhibiting a signal peak at the location of the barrier.

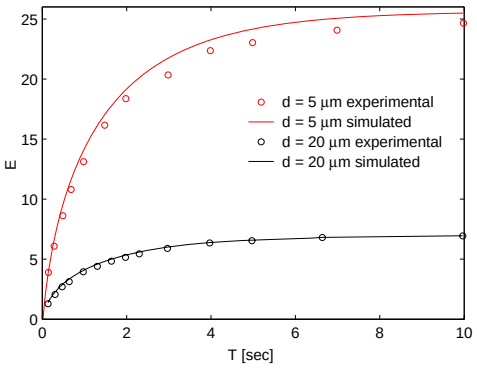

Fig. 1 DESIRE enhancement as a function of the total saturation duration.

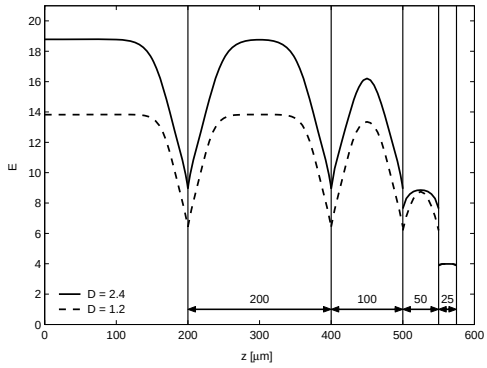

Fig. 2 Simulated DESIRE enhancement for restricted diffusion with constant D [µm²/msec].

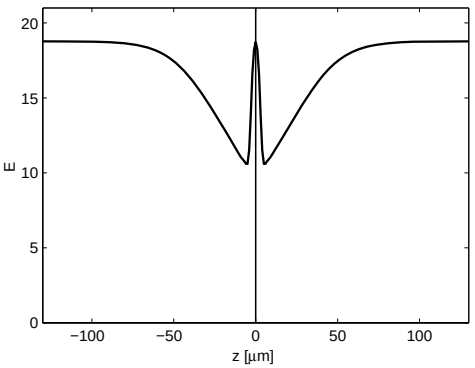

Fig. 3 Simulated DESIRE enhancement at an infinitesimally thin barrier.

Discussion Simulations enable a suitable choice of the saturation parameters and consistent DESIRE enhancement could be demonstrated experimentally. In structured objects the signal obtained for a location depends also strongly on the situation in the neighbourhood. This may be considered as a loss of true spatial resolution but on the other hand appropriate interpretation provides information about compartment sizes and thickness of the barriers. In particular, even barriers with a thickness far below the spatial resolution may be visualised. Experimental investigation of this effect and expanding DESIRE imaging to two and three dimensions are now required to demonstrate the full potential of the DESIRE technique.

References

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