Supplementary information

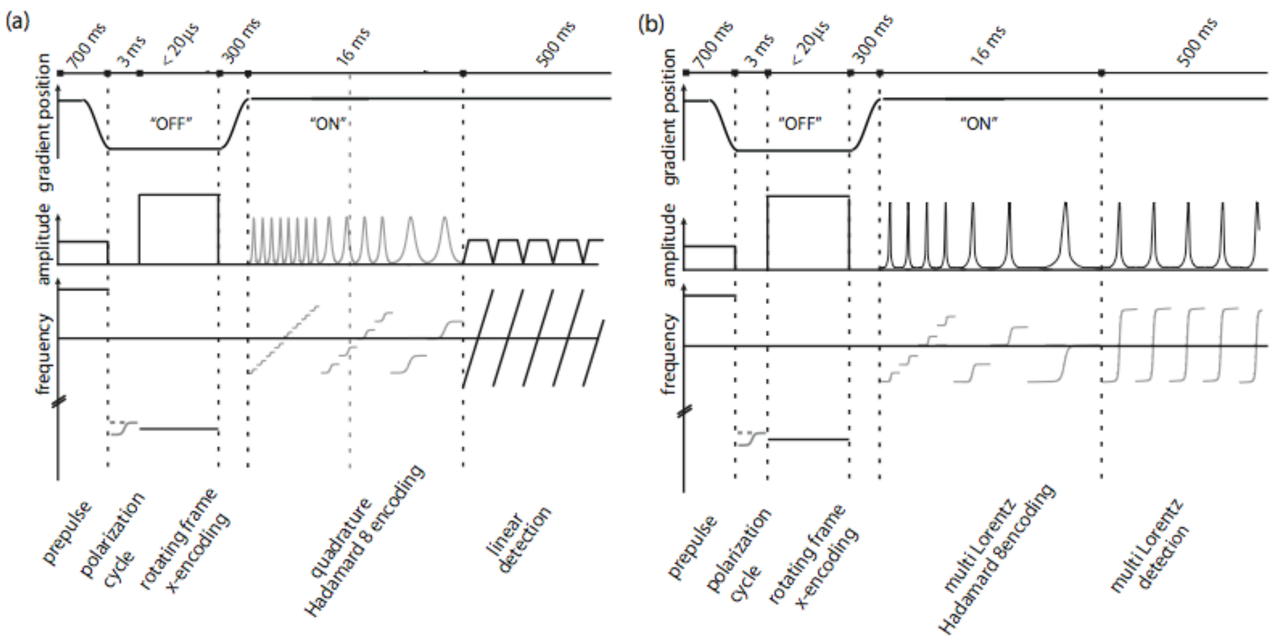

Figure S1) Detailed pulse sequences used for the 2D full-volume images. a) represents the experiment with linear inversion sweeps during detection and HS inversion sweeps for the Hadamard encoding (truncation β=6), which was used for 2D full-volume imaging in ref S1. b) shows the pulse sequence with lorentzian inversion sweeps used for Hadamard encoding and detection.

The basic scheme of the MRFM pulse sequence was described in detail in ref S1. Here we focus on the differences in implementing the 2D full-volume pulse sequence with linear inversion sweeps or Lorentzian sweeps.

Figure S1 shows the detailed pulse sequences used for the 2D full-volume images. Figure S1a represents the experiment with linear inversion sweeps during detection and HS inversion sweeps for the Hadamard quadrature encoding[S2] (truncation β=6). Figure S1b shows the pulse sequence with Lorentzian inversion sweeps used for Hadamard encoding and detection are presented. The truncation factor (β=40) was optimized experimentally, schematically indicated in the AM line of figure S1b with higher maximal amplitude and sharper shaped inversion sweeps. For both experiments the average B_1 amplitude over the time period of one inversion cycle was kept at 11mT, the maximal average amplitude supported by our micro rf coil. Although conventional Hadamard quadrature detection[S2] is not possible anymore with the Lorentzian inversion sweeps the SNR gain per unit time is ca. a factor six.

The MRFM probe, spectrometer and software have been described before.[S3] The probe works at room temperature under vacuum conditions (10^{-3} mbar) in a 6.0 T wide-bore NMR magnet. The cantilever is oriented orthogonal to the main field and static gradient. Boltzmann polarization is detected in the amplitude mode.[S4] To allow the B_1 gradient to encode the sample independently of the static B_0 gradient we used a piezo bender actor to move the static B_0 gradient 2 mm away from the sample during encoding pulses. The technical piezo bender details are described in [S1]

The polymer blend sample was cut out manually with a scalpel from a 30 µm thick polymer film. And then glued to the tip of a custom-made cantilever [19] (k=420 µN/m, f_c=900 Hz and Q~8k).

As a gradient source for the B_0 field we used an iron cobalt (saturation magnetization of 2.3 T) cylinder of ~380 µm diameter and 10 mm length. The B_1 field was generated with a ~220 µm inner diameter solenoid coil. The mathematical description of the two fields can be found in [S1].

The 2D image taken with the Lorentz Hadamard 8 was resolved by recording 32 and 96 image points in x and z direction for both nuclei. The quadrature Hadamard 8 [S2] image was recorded with 32 and 98 points in x and z direction for both nuclei. The 32 points in the x direction were encoded by incrementing the hard nutation pulse in 32 steps of 600 µs. The nutation frequency is $\omega_1/2\pi \approx 400$ kHz at the sample centre, with a B_1 gradient ranging from 200-600 kHz over the x-position in the sample. The acquisition period was set to 0.5 s. The mean value of rf amplitude over the sample during signal detection was ~75 kHz. Finally the x dimension was zero filled up to 512 points and Fourier transformed. Full details of the image reconstruction are given in ref. S1.

The scans were repeated four times for the PEEK phase with the Lorentz Hadamard 8 and six times with the quadrature Hadamard 8,[S2] resulting in 200 h and 180 h measurement time respectively. This long acquisition time is mainly caused by the long proton T_1 relaxation of PEEK in vacuum (ca. 25 s). For the PTFE phase twice as many averages than in the PEEK case were taken for both detection methods. Resulting in a measurement time of ca. 60 h and 56 h for the Lorentz Hadamard and quadrature Hadamard technique [S2], respectively. The larger number of averages is needed due to the fast T_1 relaxation of the PTFE (1.3 s), resulting in half of the signal amplitude being relaxed during the waiting time for the piezo bender movement.

References

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