

MR Spectroscopy of Arbitrarily Shaped Single Voxel Using Half-Fourier 2D-Selective RF Excitations Based on a PROPELLER Trajectory

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The measured signal in conventional single-voxel proton MR spectroscopy (MRS) is generated by three orthogonal slice-selective excitation pulses. This localization method limits the region of interest to cuboidal shapes. 2D-selective RF (2DRF) excitations [1] can be used to excite arbitrarily shaped regions of interest matching the shape of the target region in order to maximize SNR and minimize partial volume effects [2, 3]. In this work, MRS with segmented 2DRF excitations based on a PROPELLER-Trajectory [4] is presented. The trajectory consists of segments of parallel lines which are rotated to one another called blades. Spatially selective refocusing pulses after each segment are used to eliminate signal contributions from side excitations. The combination of the half-Fourier method, known from slice selective excitations [5], with every blade allows short echo times comparable to those obtained with conventional localization.

Methods

The side excitations are caused by the discrete sampling of k-space and occur for each PROPELLER segment. They can be partially suppressed by the complex averaging of the measured data of all blades, when using a sampling density correction based on a Voronoi diagram [6]. Better suppression can be achieved by eliminating the side excitations after each segment by a spatially selective refocusing pulse. With eliminated side excitations the sampling density correction for the RF amplitude weighting can be approximated based on the number of blades covering a point of the trajectory in k-space (blade-wise density correction). Non-selective refocusing pulses between each k-line are inserted to reduce the 2DRF's sensitivity to frequency offsets. With the half-Fourier method only half of a single k-line contributes to the echo time instead of half of the duration of one blade with the full-Fourier method. Covering only half of the k-space during a PROPELLER segment distorts the desired profile because it is convoluted with the Fourier transformation of the Heaviside function. These distortions can be compensated with a second acquisition of the other half of k-space for each blade. The complex sum of all segments then yields the desired profile. The central k-line is sampled twice by two half-Fourier segments which had to be considered for the density correction.

Measurements were performed on a 3T whole-body MR system (Siemens Magnetom Trio) using a standard twelve-channel head coil. The excitation profiles, a circle with 30 mm diameter and a ring with 40/60 mm diameter, were acquired with a fast spin echo sequence with 7 echoes per shot, an echo spacing of 9 ms and a spatial resolution of 1x1 mm² in a spherical oil phantom. The spectrum of a cylinder-shaped volume with a diameter of 30 mm was acquired using a short echo time of 30 ms with 64 averages. The utilized PROPELLER trajectory had 16 half-Fourier segments and was designed to obtain a profile sharpness of 1 mm. The phantom consists of a cylindrical bottle of 100mM N-acetylaspartate (NAA) with a diameter of 32 mm which was inserted into a larger bottle containing 80 mM creatine (Cr). Water suppression was achieved by three preceding CHESS pulses.

Results and Discussion

Magnitude and phase images of a circular-shaped excitation profile of one of six PROPELLER segments with Voronoi weighting are shown in Fig. 1a and 1b. The complex sum of all segments (Fig. 1c) still shows some uncompensated side excitations which are up to 20 % of the intensity of the desired excitation. A magnitude image of a PROPELLER segment with the blade-wise weighting is shown in Fig. 1d. The side excitations are eliminated by one of the refocusing RF pulses (Fig. 1e). Complex averaging yields the desired excitation profile without significant contributions from side excitations (Fig. 1f). MR images of a ring-shaped excitation profile with side excitations of two half-Fourier segments are shown in Fig. 2a and 2b. Complex averaging of all 16 segments of this excitation yield the desired excitation profile (Fig. 2c). No major deviations are observed compared to the excitation profile with the full-Fourier trajectory. The trajectories contribution to the echo time could be reduced from 37.2 ms to 8.5 ms in this case. The spectrum of a cylinder-shaped volume with 30 mm diameter in the inner part of the phantom containing mainly NAA is shown in Fig. 3a.

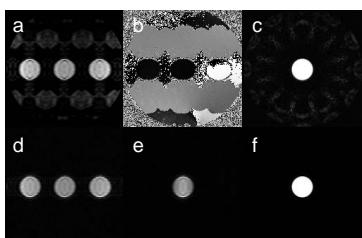


Figure 1: MR images of a circular-shaped excitation profile with PROPELLER-2DRF:
(a) Magnitude and (b) phase image for one of six segments and (c) magnitude of the complex sum of all six segments with Voronoi weighting. (d) Magnitude of one of six segments with blade-wise RF weighting. Side excitations are eliminated by spatially selective refocusing pulses (e) and do not appear in the complex sum of all segments (f).

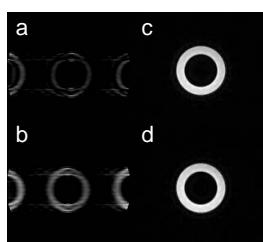


Figure 2: MR images of a ring-shaped excitation profile:
(a) and (b) magnitude images of two half-Fourier segments, (c) the complex sum of all 16 half-Fourier segments and (d) the complex sum of a full-Fourier excitation with PROPELLER-2DRF.

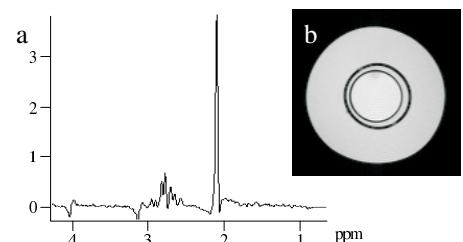


Figure 3: (a) Spectrum of a cylinder-shaped excitation in a phantom and (b) the MR image of the phantom. The inner part of the phantom contains NAA, the outer part Cr.

References

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