Improved Signal Efficiency of Blipped-Planar 2D-Selective RF Excitations Using a "Center-Always" Segmentation Scheme

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Introduction

2D-selective RF (2DRF) excitations [1, 2] can be used to minimize partial volume effects in single-voxel MR spectroscopy (MRS) [3-5]. The different approaches involve radial [3], PROPELLER [4], and blipped-planar [5] 2DRF trajectories. The main advantage of the blipped-planar trajectory is the focal appearance of the side excitations within the desired distance that can easily be eliminated, e.g. by one of the refocusing RF pulses in a PRESS [6] based MRS sequence [5]. Thus, unwated signal contributions from outside of the desired excitation profile can be easily avoided. To shorten the 2DRF pulse duration, segmentation can be applied. However, for the blipped-planar trajectory, segmentation has the adverse effect that only one segment covers the center of k-space. In this work, a modified ("center-always") segmentation scheme for 2DRF excitations based on the blipped-planar trajectory is presented in which every multi-line segment covers the central k-space line (Fig. 1). With an appropriately adapted sampling density correction, the signal amplitude and, thus, the efficiency is increased compared to the conventional segmentation approach.

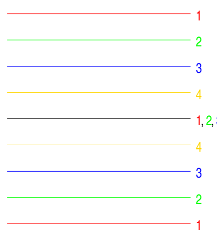

Fig. 1: "Center-always" segmentation of a blipped-planar trajectory with four segments, each covering three k-space lines. The central k-line is covered in every segment which must be accounted for when considering the sampling density.

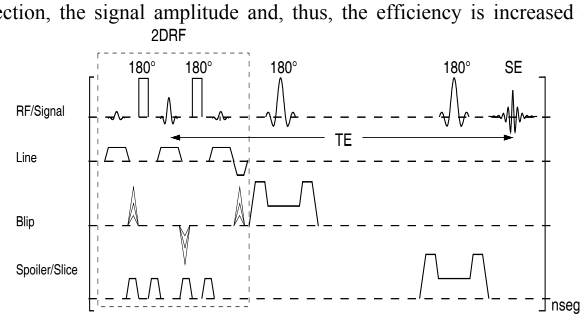

Fig. 2: Basic PRESS-based pulse sequence for MR spectroscopy using a segmented, "center-always" blipped-planar 2DRF excitation with three k-lines per segment. The middle one of the three lines covers the centre of k-space in each segment. Non-selective refocusing RF pulses were inserted between the k-lines to avoid chemical-shift displacement artifacts. One slice-selective refocusing RF pulse is used to eliminate side excitations in the blip direction.

Methods

Figure 2 shows the basic pulse sequence used for the MR spectroscopy acquisitions. As the initial RF excitation a multi-line segment of the blipped-planar trajectory is used. For every segment, the middle one of the lines covers the k-space center (see also Fig. 1). The multiple coverage of the central line must be taken into account when considering the sampling density. Complex averaging of all segments yields the desired excitation profile. Non-selective refocusing pulses between the k-lines ensure the avoidance of chemical-shift displacement artifacts [3, 4]. The 2DRF pulse calculation was based on the small-tip-angle approximation [2].

Measurements were performed on a 3T whole-body MR system (Siemens Magnetom Trio) using a 12-channel head coil. A dedicated spectroscopy phantom (see Fig. 3a) consisting of a smaller bottle filled with aqueous NAA solution (80 mM) inside a larger bottle filled with aqueous creatine (Cr) solution (70mM) was used for the MRS experiments. As target regions, a ring-shaped profile (inner diameter 45 mm, outer diameter 60 mm) was defined that surrounds the inner bottle of the spectroscopy phantom (see Fig. 3a) and an irregularly shaped profile (91×59 mm²) were used. The 2DRF excitations were applied with a flip angle of 30°, a resolution of 2×2 mm², and a field-of-excitation of 70 mm yielding 35 k-lines for the unsegmented trajectory.

Three different segmentation schemes were compared: (i) 35 segments with a single k-space line per segment and two averages yielding a total number-of-excitations (NEX) per spectrum of 70, (ii) 11 segments with three k-lines per segment where every k-line of the trajectory was covered only once, and six averages (NEX 66), and (iii) 18 segments with three k-lines per segment where the central k-line was covered with each segment, and four averages (NEX 72). The spectra were acquired with en echo time of 36 ms and a TR of 6 s yielding a total acquisition time of approximately 7 minutes per spectrum. For the profile acquisitions a fast-spin-echo variant of the pulse sequence of Fig. 2 with phase and frequency-encoding gradients applied was used with an in-plane resolution of 1×1 mm², 7 echoes per shot, a slice thickness of 10 mm, and a TR of 6 s. The signal-to-noise ratio (SNR) was determined using the profile acquisitions by taking the mean signal intensity within the voxel and dividing it by the standard deviation of the noise signal intensity in a background region outside of the phantom.

Results and Discussion

Results for MRS and profile acquisitions in the spectroscopy phantom for the ring shaped ROI are presented in Fig. 3b-d. The images and spectra show a good localization and definition of the ring shaped voxel. In the spectra, no NAA signal contaminations of the inner, sourrounded bottle are detectable. Compared to the MR spectrum acquired with a single line per segment (Fig. 3b), the signal amplitude for acquisitions with three lines per segment is increased by a factor of 2.5 (Fig. 3c) due to the effectively increased number of averages (Fig. 3c). With the "center-always" segmentation where each segment covers the central line the signal amplitude is further increased by a factor of 1.4 (Fig. 3d) which reflects the better coverage of the central k-space line. For the profile acquisitions, relative signal amplitudes of 2.9 and 4.4 are obtained for the conventional multi-line segmentation (Fig. 3c) and the "center-always" multi-line segmentation (Fig. 3d). The ability to excite irregularly shaped ROIs with "center-always" segmented, blipped-planar 2DRF excitations is demonstrated in Fig. 3e which was acquired in an oil phantom.

The increased signal efficiency of the "center-always" segmentation approach may help to improve the applicability of MR spectroscopy of irregularly shaped target regions based on for blipped-planar 2DRF excitations in order to minimize partial volume effects.

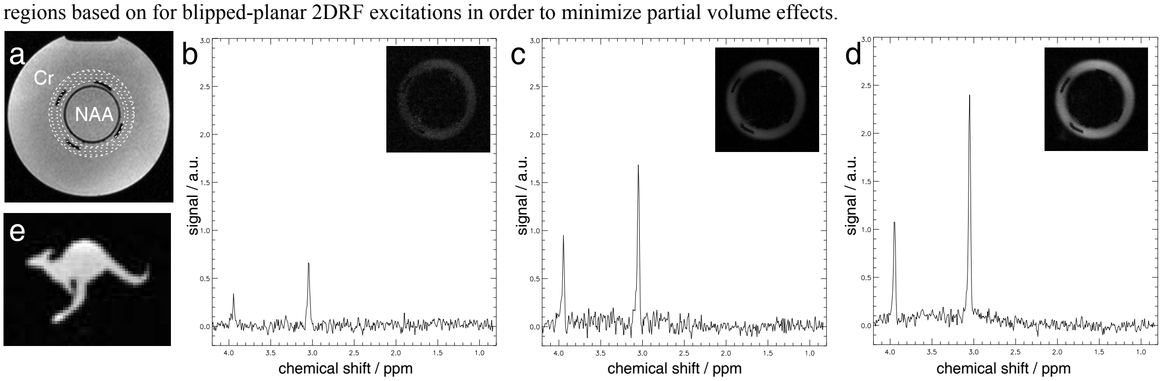

Fig. 3: (a) MR image of the spectroscopy phantom containing NAA in the inner and creatine in the outer bottle. (b-d) MR spectra and profile images acquired for the ring shaped ROI depicted in (a) with (b) single-line segments, (c) conventional multi-line segmentation, and (d) "center-always" multi-line segmentation. (e) Irregularly shaped excitation profile measured in an oil phantom with a "center-always" multi-line segmentation..

References

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