Signal Scaling Improves the Performance of Single-Voxel MR Spectroscopy Based on Segmented 2D-Selective RF Excitations

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2D-selective RF (2DRF) excitations [1,2] can be used to acquire irregularly shaped single voxel in MR spectroscopy in order to reduce partial volume effects (e.g. [3-5]). To avoid excessive pulse length, segmentation is usually applied, i.e. in each shot only a part of the 2DRF trajectory is covered and the desired excitation profile is obtained after complex averaging of all signals acquired with the different segments. However, for instance for the blipped-planar trajectory, some of the segments cover only outer k-space lines, i.e. lines with low B1 weightings, yielding small flip angles and correspondingly low signal amplitudes which reduces the signal efficiency [4]. If averaging is performed, the efficiency can be improved by increasing the flip angles of such segments rather than their averages which allows to increase the number of averages for central segments with large flip angles and significant signal contribution [5]. In this study, it is shown that the performance can be further increased by applying all segments always with the full flip angle and scaling down the acquired signals accordingly. This does not alter the signal amplitude but reduces the noise level and, thus, increases the signal-to-noise ratio as is demonstrated experimentally.

Principles

The basic pulse sequences used in the present study are shown in Fig. 1. The initial RF excitation of a PRESS sequence is replace by a 2DRF excitation based on a blipped-planar trajectory with single-line segments to avoid chemical shift displacement artifacts and minimize the achievable echo time. Segments that cover outer k-space lines with only low B1 weightings yield small flip angles and correspondingly low signal amplitudes (Fig. 1a) [4] but are needed to define the high spatial frequencies, i.e. to ensure the desired profile sharpness. In case of averaging, a weighted averaging approach with flip angle scaling can be used to increase the signal efficiency [5]. Thereby, the number of averages for low-flip-angle segments is decreased and their flip angle increased accordingly (“flip angle scaling”) to provide the same accumulated signal in a reduced number of shots which allows to increase the number of averages for central segments with a large signal contribution [5]. However, if many segments are needed, e.g. for high-resolution excitation profiles, the achieved improvement may be small. But the performance can be increased by applying all segments always with the full flip angle (Fig. 1b) and scaling down the acquired signals accordingly (“signal scaling”). While this modification does not alter the signal amplitude, the noise level of acquisitions of outer segments can be reduced. This can increase the signal-to-noise ratio significantly, in particular if many (outer) segments are needed, e.g. for a high resolution excitation profile.

Figure 2 shows the signal scaling factors and their average vs. the total number of averages N for a simple example (rectangular excitation profile, seven segments). For a low N, the scaling factors are quite small which reflects a maximum reduction of the noise level (overall to about 33%). With the total number of averages, the factors increase and approach 1 for large N which means that signal scaling converges with flip angle scaling approach and no noise reduction can be realized (full flip angles are mandatory for all segments).

Some steps appear in the curves of Fig. 2 because the number of averages for each segment must be an integer. Note that the curves depend on the size and shape of the excitation profile and the number of segments involved.

Methods

Measurements were performed on a 3T whole-body MR system (Siemens TIM Trio) using a 12-channel receive-only head coil and a spectroscopy phantom. 2DRF excitations (flip angle 90°) were designed under the low-flip-angle approximation [2] with a resolution of 1×1 mm². A standard rectangular excitation profile (35×35 mm², field-of-excitation 45 mm, 41 non-zero segments) was used to demonstrate the basic principles, an irregularly shaped gray matter profile (28×57 mm², FOE 39 mm, 39 segments) determined from a high-resolution T1-weighted acquisition of a healthy volunteer was used as an anatomically defined target region. MR spectra were acquired with a TE of 30 ms and a TR of 12 s to ensure fully relaxed conditions. Imaging variants of the sequences shown in Fig. 1 with phase and frequency encoding gradients added were used to acquire images of the excitation profiles.

Results

In Fig. 3, excitation profiles and MR spectra of the rectangular profile realized with 45 segments are presented. They experimentally demonstrate the increased signal-to-noise ratio achieved for signal scaling, in particular for a relative low number of averages N. The gain, e.g. about a factor of six for N=41, is much larger than that estimated above (see Fig. 2) because much more segments are involved. This can also be seen in the MR spectra (Fig. 4) and for the irregular excitation profile (Fig. 5). For larger N, the gain compared to the flip angle scaling decreases (see Fig. 3) as both approaches converge.

Fig. 3: Results for the rectangular excitation profile with flip angle (upper) and signal scaling (lower) for different total numbers of averages N. The profile (left panels) and the noise level in a background region (right) are shown. All images as well as all noise levels share the same gray scaling, respectively. Intensity differences directly reflect different signal-to-noise ratios.

References:

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