Segmented 2D-Selective RF Excitations Based on a Weighted Blipped-Planar Trajectory

J. Finsterbusch[1,2]

[1]Department of Systems Neuroscience, University Medical Center Hamburg-Eppendorf, Hamburg, Germany, [2]Neuroimage Nord, Hamburg-Kiel-Lübeck, Germany

Segmented 2D-selective RF excitations (2DRF) [1,2] recently have been demonstrated to be useful for single-voxel spectroscopy of arbitrarily shaped regions-of-interest [3,4]. One of the proposed techniques used a segmented blipped-planar trajectory [2] with a single line per segment to avoid chemical shift-related displacement artifacts [4]. However, this approach is at the expense of a considerable signal loss because only the segments covering the central k-space lines deliver significant flip angles. In this work, a modification of the k-space sampling scheme is presented that favours a flip angle increase over averaging for the segments with low intensities in *k*-space: This improves the SNR efficiency considerably, in particular for broader profiles that exhibit a narrow intensity distribution in *k*-space.

Methods

Consider a segmented 2DRF excitation with flip angles α_i for the individual segments. After n averages, each segment will yield an accumulated signal proportional to $n\sin(\alpha_i)$. However, for low α_i this is rather time ineffective and the same accumulated signal can be obtained within a shorter acquisition time by using a larger flip angle α_i' and reducing the number of averages to $n_i' = n \sin(\alpha_i)/\sin(\alpha_i')$. This weighted sampling approach effectively increases the flip angles applied and therefore improves the SNR efficiency. This gain is in particular pronounced for broader excitation profiles that yield a narrow weighting function in *k*-space with most of its intensity concentrated in the centre. Ideally, the weighted trajectory would end up with the same flip angle for all segments where only the number of averages for each segment reflects the different *k*-space weightings. This case would deliver the optimal SNR per time but because n_i' needs to be an integer some compromise is required in real experiments. In practice, the flip angle of the central segment would be considered as an upper boundary for the usable flip angle of the other segments.

Measurements were performed on a 3T whole-body MR system (Siemens Magnetom Trio) using a standard twelve-channel head coil and a water phantom. Profiles of the 2D RF excitations were acquired with a spin echo sequence (one echo per shot). 2DRF segments were applied with a maximum flip angle of 30° to avoid severe deviation from the the low-flip-angle approximation.

A square of 20 mm edge length was used as excitation profile. The trajectory was chosen to deliver a resolution of 5 mm in line and blip direction and a field-of-excitation (i.e. a distance of the side excitations) of 45 mm yielding nine *k*-space lines. Side excitations were suppressed by an additional refocusing RF in blip direction [4].

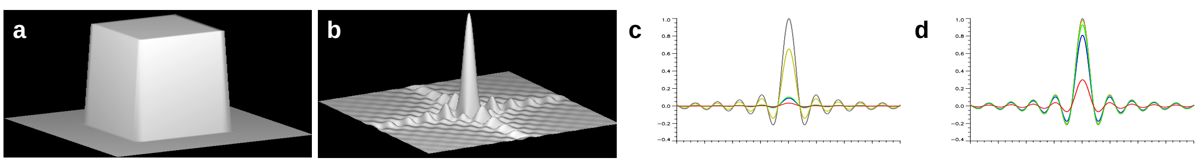

Figure 1: Basic principle of the weighted blipped-planar trajectory for (a) a quadratic excitation profile yielding (b) a two-dimensional *sinc*-function *k*-space. (c) The nine lines of the trajectory have different amplitude that for a total number of 27 acquisitions can be scaled to the amplitudes shown in (d) for an appropriate number of averages for each segment.

Results and Discussion

An example for the weighted trajectory approach is sketched in Figure 1 for a rectangular excitation profile and a trajectory of nine segments with one line per segment. Assuming a flip angle of 30.0° for the central segment, the flip angles of the other segments would be 19.6°, 2.7°, 3.1°, and 1.0°, i.e. six of nine segments would have flip angles around or below 10% of the maximum. For 27 acquisitions, each of the nine segments would be averaged three times with the unweighted approach. Using the weighting trajectory with the same number of acquisitions, the flip angles can be increased to 29.4°, 24.3°, 27.9°, and 9.0° in combination with six, one, one, and one averages, respectively, while using nine averages for the central line (30.0°).

Measured excitation profiles for this example are presented in Figure 2. The gain of the signal-to-noise ratio achieved for the weighted approach is clearly visible in the reduced noise level of Fig. 2b and can be quantified to an improvement by a factor of about 2.9. This is very close to the value of 3.0 that would be expected when considering the threefold number of averages of the central line for the weighted trajectory. The difference between the measured profiles (Fig. 2c) is marginal. Although the profile obtained with the weighted trajectory exhibits less distortions, it should be emphasized that this may be due to the limited dynamic range of the MR image data that may shift the distortions in the high signal acquisition down to below the digitalization level.

In summary, the weighted approach may help to overcome current SNR limitations of the segmented blipped-planar trajectory.

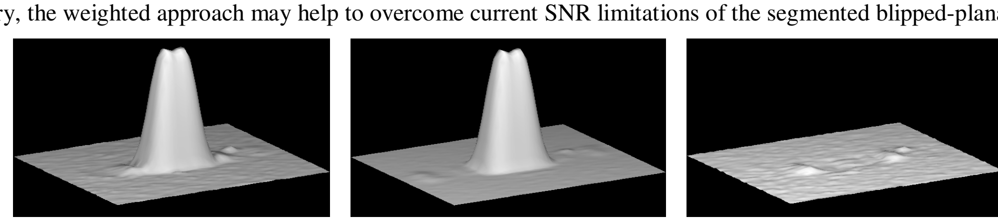

Figure 2: 2DRF excitation profiles obtained with the standard (left) and the weighted trajectory (middle) and difference of both profile (right).

References

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