An experimental comparison of B1-mapping Techniques at two field strengths

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Introduction: During the last years, a high interest in mapping of the B_1-field has led to the development of a large number of techniques. Sequences designed for 2D and 3D acquisitions, based on amplitude or phase information have been presented. For an experimental comparison of these techniques, six different sequences were implemented on animal scanners with field strengths of 7 T and 16.4 T. In a number of phantom experiments, the behavior of the techniques for different B_1-ranges, T_1-values and frequency offsets was evaluated.

Methods: A phantom consisting of five samples with T_1 between 375 ms and 2658 ms (at 7 T) was used in a birdcage coil with relatively homogeneous field distribution (Fig. 1). For all tested sequences, the following experiments were performed: 1. Variation of the flip angle in 27 to 30 steps from 5° to 180°; 2. Repetitive acquisitions with flip angles of 15°, 30°, 60° (ten times each) to evaluate reproducibility and standard deviations; 3. Acquisitions with a flip angle of 30° and frequency offsets between -700 and 700 Hz; 4. B_1-maps with flip angles from 10° to 110° with frequency offsets of 1 ppm and 0.5 ppm. The sequences used are presented with their main parameters in Tab. 1. No phase unwrapping or B_0-corrections were applied.

Name	Ref	Dim	Principle	Duration	Parameters
AFI	[1,2]	3D	Amplitude	3 min	TR = 20ms/100ms
Pre-TFL	[3]	2D	Amplitude	28 s	
SE/STE	[4,5]	2D	Amplitude	15 s	
Bloch-Siegert	[6]	2D	Phase	20 s	5 ms Fermi pulse with offsets of 4000, 7000, 10000 Hz
Phase	[7]	3D	Phase	5 min	
Adiabatic Phase	[8]	3D	Phase	5 min	0.1 ms block pulse, 5 ms adiabatic pulse

Table 1: Parameters of the B_1-mapping experiments. Acquired images had a matrix size of 128×48 (×32). Only single gradient echoes were acquired.

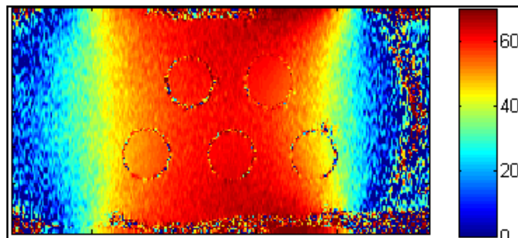

Fig 1: Flip angle map of the used phantom with five samples with different T_1, acquired with AFI (nominal flip angle: 60°).

Results: Fig. 2 shows flip angles obtained with all eight measurements with standard deviations over 10 repetitions. All sequences give good values with low variations for flip angles of 40° and more, while lower angles lead to higher standard deviations and often biased values. This is also visible in Fig. 3, which displays the measured flip angles for nominal angles between 5° and 100°. While some of the techniques fail at low excitation angle due to low SNR (SE/STE), low flip angle sensitivity in this region (Phase) or failed adiabaticity (adPhase), especially AFI and Bloch-Siegert techniques yield stable values even for angles as low as 5°. All sequences show negligible dependence on T_1. Only slight variations with offset frequency are observed for some of the sequences, like BSS with low offset frequency, the phase technique and even AFI. No significant differences in the properties of the techniques were observed between 7 T and 16.4 T.

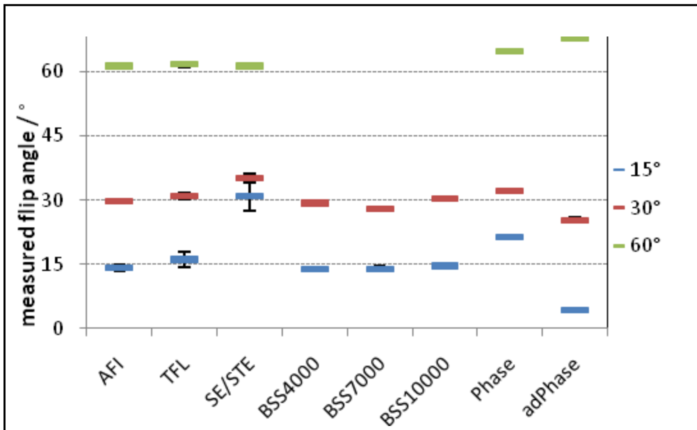

Fig 2: measured flip angles and standard deviations for nominal angles of 15°, 30° and 60°. To allow comparisons, BSS values are the B_1 (in µT) multiplied by 3.

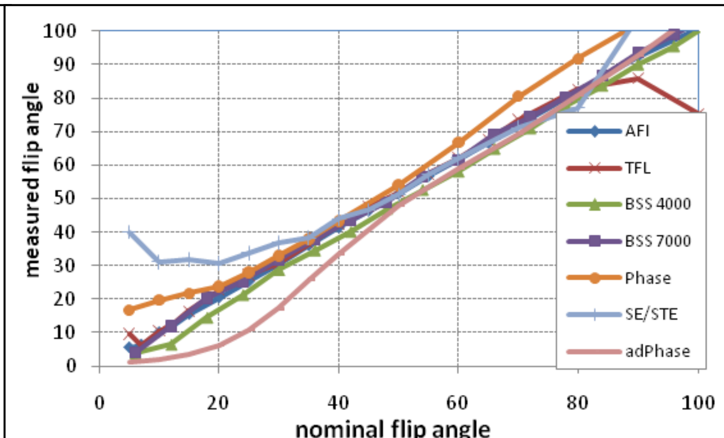

Fig 3: measured vs. nominal flip angles for 7 techniques and angles between 5° and 100°. Systematic errors appear for some sequences mainly for very low B_1.

Conclusions: All used sequences are able to accurately measure flip angles within a certain range. The main difference between the techniques, apart from the number of dimensions and the measuring time, are their dynamic ranges: Most sequences suffer from loss of sensitivity at low and ambiguity at high flip angles. In most cases, further reduction of the measuring time is possible with multiple echo techniques.

References:

[1] V. Yarnykh, MRM 57 (2007); [2] V. Yarnykh, MRM 63 (1010); [3] S. Chung, MRM 64 (2010); [4] Akoka, MRI 11 (1993); [5] Jiru, MRM 56 (2006); [6] Sacolick, MRM 63 (2010); [7] Morrell, MRM 60 (2008); [8] Hennel, ISMRM 2010, 237