In-Vivo Assessment of a STEAM Sequence for B1-mapping

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Introduction: RF field inhomogeneities are a main source for image inhomogeneities, spatial dependent SNR and CNR and systematic errors in particular in quantification of MRI data. The assessment of RF-inhomogeneities or the actual flip angle distribution becomes mainly important for field strength above 1.5T. As the RF-inhomogeneities depend on the individual interaction of the RF system and the investigated body, the individual measurement of the actual flip angle distribution is necessary. Such an additional scan in whole procedure should be as fast as possible. Methods which have shown in-vivo applicability (1-3) have typical scan durations in the order of several minutes. We explored the in-vivo capability of a three pulse sequence originally proposed for optimizing flip angles during scanner preparation (4). With this method it is expected that the actual flip angle distribution can be determined in approximately one minute.

Methods: The explored flip angle mapping sequence is based on a stimulated echo sequence with three identical excitation pulses α (Fig. 1). The actual flip angle distribution (∝ B_{1+}) is calculated from the ratio of the stimulated (STE) and the primary spin echo (SE) (Eq.1). Residual errors can occur for short T_1-times from longitudinal relaxation during the mixing time τ_m. This small possible error can be further reduced in the present implementation by prior knowledge of T_1 of the investigated tissue. Multiple scans with different nominal flip angles can be performed to extend the dynamic range of the measurement. Specific attention was given to optimized slice selective pulses and to the suppression of unwanted coherences. The whole analysis was performed on a 3T System (Siemens Magnetom Tim-Trio). The possible T_1-influenece on the measurement was studied by using a phantom with different relaxation times. The basic properties of the sequences were studied using a pick-up coil in advance of the in-vivo evaluation. In-vivo, the flip angle distribution was measured in the head (FOV/THK=256/6), the abdomen and the pelvis of seven healthy volunteers (FOV/THK=400/8). The influence of a dielectric pad on the abdominal and pelvic B_{1+} distribution was investigated too.

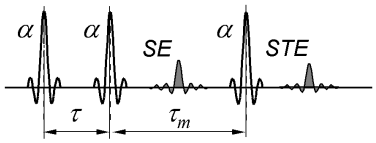

Fig. 1. Schematic RF pulse diagram

$$\alpha_{(x)} = 2\arccos\left(\sqrt{\frac{I_{STE}}{2I_{SE}}e^{\tau_m/T1(x)}}\right) \quad [1]$$

τ_m	mixing time (see Fig. 1)
$\alpha(x)$	local flip angle
$T_1(x)$	longitudinal relaxation time
I_{STE}	intensity of stimulated echo
I_{SE}	intensity spin echo

Results: The acquisition time for a scanning matrix of 128*64 (or 64*64) and a single flip angle was 47s for TR=800ms and 78s for TR=1300. Even with a short TR the coverage of typical investigated regions is possible (TR=800/1300, max. # of slices=21/34). The phantom study (Fig. 2) demonstrates the little influence of T_1 due to the short mixing period τ_m. A ROI analysis was performed to compare different approaches with vials (R1..R5) containing doped water with different T1 values (Tab. 1.).The in-vivo analysis showed that the method worked fine in the head and the pelvis (Fig. 3, 4), however in regions with pronounced physiological motion and flow (e.g. Liver, Heart) artefacts occurred. The B_1 distribution is very homogeneous in the brain, only minor artefacts occur at the scull (Fig. 3.).

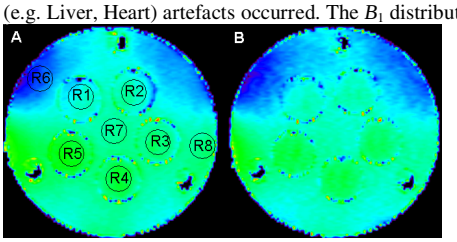

Fig. 2. (A) Scan with TR=800ms and an estimated mean T_1 of 500ms. (B) Scan with TR=1300ms and addition fast T_1-mapping for compensation relaxation effects.

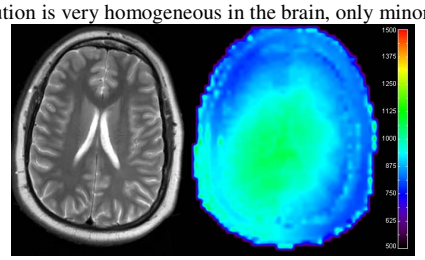

Fig. 3. Morphological reference scan (left) and B_1 mapping within the same slice (right). A value of 900 represent the nominal flip angle, a deviation of 1° equals a value of 10.

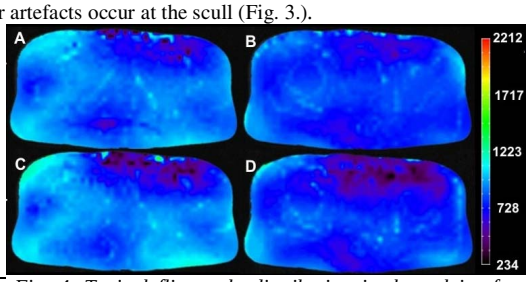

Fig. 4. Typical flip angle distribution in the pelvis of a male volunteer. Measurements (A+B) with the dielectric pad show improved homogeneity of the RF-field in comparison to the measurements (C+D) without the dielectric pad. One flip angle was used for image (A+C), five flip angles for (B+D).

	R1	R2	R3	R4	R5	R6	R7	R8
T1 [ms]	828	1003	788	563	324	360	360	360
reference [°]	78,4	79	81,9	83	82,7	74	83	80,3
TR=800[%]	-0,38	-0,25	-0,49	0,24	1,33	1,62	1,08	1,49
TR=1300[%]	0,00	0,00	-0,49	0,60	1,81	2,30	1,57	1,49

Table 1.: Relative errors of two scans with constant T_1-compensation and two different repletion times (TR=800 (A, Fig.2), TR=1300). The reference scan was performed with included fast T1-estimation and TR=1300 (B, Fig. 2)

Table 2.: Flip angle distribution of 7 subjects in a representative slice in the in head and the pelvis (flip angle mean value, SD, 0.05-quantile, 0.95-quantile)

	head 1	head 2	head 3	head 4	head 5	head 6	head 7	pelv. 1	pelv. 2	pelv. 3	pelv. 4	pelv. 5	pelv. 6	pelv. 7
mean [°]	91,2	93,5	91,4	91,3	91,6	90,5	95,9	81,2	89,9	69,5	83,5	80,6	86,2	90,2
SD [°]	10,1	10,4	15,3	11,5	9,7	10,1	9	14,8	11,5	17,5	12,3	15	23,6	11,5
0.05-quantile [°]	79,1	80,6	67,5	76,5	77	78,3	82,3	55,6	69,6	38,9	59,3	60,8	44,6	67,6
0.95-quantile [°]	105,9	107,1	109,4	106,6	103,8	103,7	109,4	96,9	104,7	90,9	96,9	105,4	122	104,2

Discussion: The evaluated technique is in principle based on a single scan which eliminates possible registration problems. To minimize the T1 influence on the B_1 map the mixing time τ_m should be as short as possible. For a τ_m of 12,4ms and a T_1 1000ms an error of only 0.64% occurs if no compensation is applied. If the B_1-mapping is performed for quantification purposes in a single tissue the compensation with a priory T_1-estimate seems to be adequate. The explorations of scans with multiple flip angles show a slight increased homogeneity of the B_1-map but could not remove all artefacts. The dynamic range of a single flip angle measurement was sufficient for 3T applications. As slice selective pulses are used for excitation the method is not sensitive for B_0-inhomogeneities.The body mass of the subjects varies in a wide range from 45 (pelv. 6) to 150 kg (pelv. 5). The B1 field tend to be more homogenous in adipose people. In the meantime the method has been also successfully applied in a clinical DCE-MRI study with 41 patients.

References: 1) Stollberger R, Wach P, MRM 35:246- (1996), 2) Yarnykh VL, Yuan C, Proc. Intl. Soc. Mag. Reson. Med. 11; p194 (2004), 3) Dowell NG, Tofts PS, Proc. Intl. Soc. Mag. Reson. Med. 14; p3003 (2006), 4) W.H. Perman, Magn. Reson. Med. 9, 16-24 (1989)