SIMULTANEOUS B_1 AND B_0 MAPPING USING DUAL ECHO ACTUAL FLIP ANGLE IMAGING (DE-AFI)

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Introduction. Only recently, actual flip angle imaging (AFI) has been introduced as a fast and robust 3D method for mapping the B_1 transmit field by measuring the spatial variations of the effective flip angle (1). The AFI pulse sequence consists of a dual TR (repetition time) conventional spoiled gradient echo pulse sequence, where $TR_2 > TR_1$. In this work, a second echo has been added to the standard AFI timing diagram, which enables additional B_0 mapping by reconstructing phase difference maps based on the phase images of the two acquired echoes. In vivo results of fast simultaneous B_1 and B_0 mapping using dual echo AFI (DE-AFI) are presented.

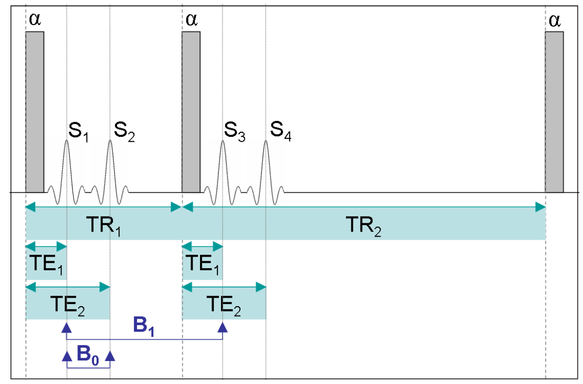

Fig.1: Schematic timing diagram of the applied pulse sequence.

Methods. The timing diagram of the modified AFI sequence enabling both B_1 and B_0 mapping is illustrated in Figure 1. Assuming complete spoiling of the transverse magnetization and TR shorter than the longitudinal relaxation time, the flip angle α (and thereby the final B_1 maps) can be calculated according to the signals S_1 and S_3 with (1):

$$\alpha \approx \arccos\left(\frac{rn-1}{n-r}\right), \quad with \quad r=\frac{S_3}{S_1} \quad and \quad n=\frac{TR_2}{TR_1}. \qquad [1]$$

In order to achieve complete spoiling of the transverse magnetization, the modified spoiling scheme proposed in (2) was implemented in the applied pulse sequence. B_0 maps were reconstructed according to the phases and magnitudes of the signals S_1 and S_2 by using the four-quadrant arctangent function (3):

$$\Delta\Phi = \arctan 2\left[\mathrm{Im}\left(Z_1 Z_2^*\right), \mathrm{Re}\left(Z_1 Z_2^*\right)\right], \quad with \quad Z_1 = r_1 \exp\left(i\cdot\varphi_1\right) \quad and \quad Z_2 = r_2 \exp\left(i\cdot\varphi_2\right), \qquad [2]$$

where $\varphi_{1,2}$ depict the phases and $r_{1,2}$ the magnitudes of $S_{1,2}$. Experiments were performed on a 1.5T system on the brain of one healthy volunteer based on a 3D matrix of 64 x 64 x 40, 4 x 4 x 5 mm^3 resolution and non-selective excitation. Moreover, the following parameters were chosen: TR_1 = 20 ms, TR_2 = 100 ms, TE_1 = 2.48 ms, TE_2 = 7.24 ms, α = 45°, partial Fourier 6/8 and radio-frequency spoiling phase increment = 129.3°. The total scan time for the combined B_1 and B_0 mapping pulse sequence was 131 seconds. In order to validate the proposed technique, two separate standard pulse sequences were acquired. For comparison of the B_1 field maps, a triple α scheme, as described in (4), was acquired with similar parameters than the ones indicated above. For comparison of the B_0 field maps on the other hand, a built-in scanner solution was used that as well acquires two gradient echo datasets. The ΔTE of the built-in protocol was similar to the one given above (ΔTE = 4.76 ms).

Results & Discussion. Figure 2 presents the 3D B_1 and B_0 mapping in vivo results from one healthy subject. The resulting B_1 maps look smooth and yield values close to the reference flip angle (6 % deviation in maximum). The calculated deviations remain small in both brain tissue and the ventricular system (see profile). Furthermore, the B_1 maps correspond well with AFI results from literature (1,2) and show no significant discrepancy when comparing to the results acquired using the triple α scheme. Reconstruction of the B_0 maps based on averaging between S_1, S_2 and S_3, S_4 did not lead to an improvement of the maps. Hence, S_4 was no taken into account for neither the calculation of B_0 nor B_1 variations. Besides that, for the calculation of the B_0 maps from our data sets, no phase unwrapping was necessary due to the application of the four-quadrant arctangent function. Additionally, good correspondence between the resulting B_0 maps and the B_0 maps acquired using the built-in scanner protocol can be observed.

Conclusion. We present a new solution to simultaneous B_1 and B_0 mapping using a DE-AFI pulse sequence. The proposed technique has the advantages of offering whole brain coverage and a fast acquisition time (131 seconds), which is twice as fast as using separate conventional B_1 and B_0 mapping procedures. Moreover, the simultaneous B_1 and B_0 mapping method yields reliable and robust maps, that offer similar quality compared to the standard approaches. The presented DE-AFI procedure might therefore provide a real alternative to conventional separate B_1 and B_0 mapping.

References. 1. Yarnykh, *MRM* **57** (2007) 2. Nehrke, *MRM* **61** (2009) 3. Bernstein et al., *Handbook of MRI Pulse Sequences*, *Elsevier* (2004) 4. Akoka et al., *MRI* **11** (1993)

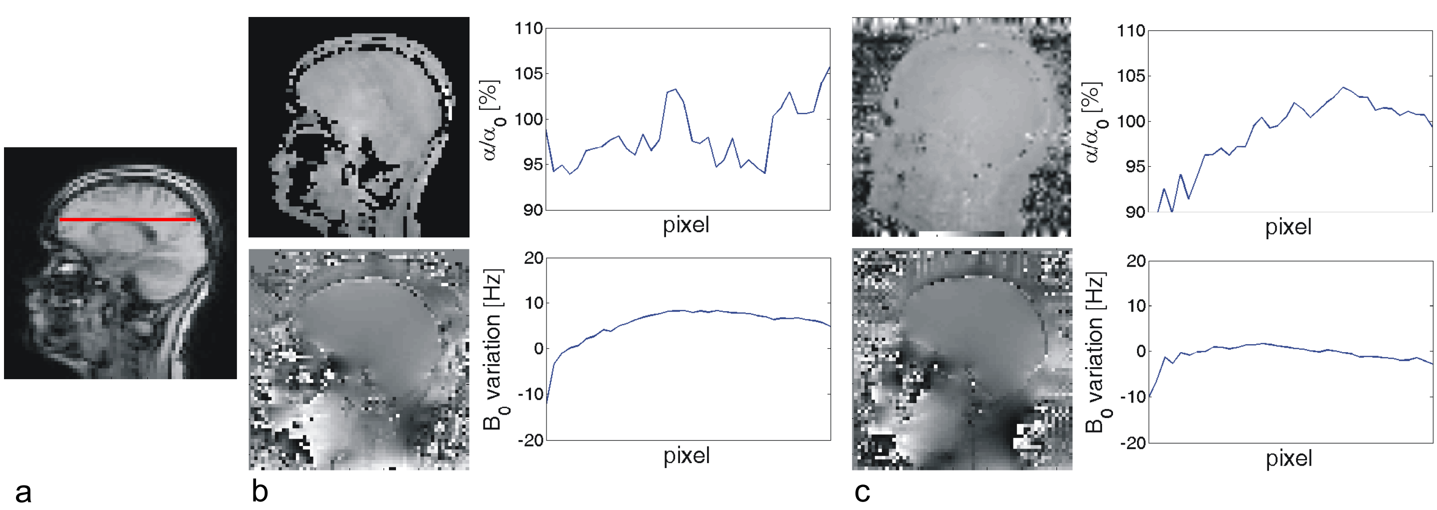

Fig.2: In vivo results showing both B_1 and B_0 maps. ***a.:*** *Anatomical image indicating the location of the selected profile (red line).* ***b.:*** *Representative B_1 (top) and B_0 (bottom) maps acquired with the proposed simultaneous B_1 and B_0 mapping sequence and corresponding profiles.* ***c.:*** *B_1 (top) and B_0 (bottom) maps acquired with the two separate standard pulse sequences and corresponding profiles.*