Simultaneous measurement of B0- and B1-maps with modified Actual Flip Angle Imaging sequence

A. Amadon[1], and N. Boulant[2]

[1]DSV, I2BM, Neurospin, LRMN, CEA-Saclay, Gif-sur-Yvette, France, [2]Siemens Medical Solutions, Saint-Denis, France

Introduction: At high static fields, the dielectric resonance and RF destructive interferences cause images of objects larger than the RF wavelength to be largely inhomogeneous and to lose contrast in some areas (human head images at 3T and above give a good example of such RF inhomogeneities). The Actual Flip Angle Imaging sequence (AFI) can be used to measure a 3D map of the transmit B1 RF field in an object [1]. Here the sequence was modified to measure a 3D map of the static B0 field in addition to the B1-map. This simultaneous dual mapping allows to do a fast calibration of Strongly Modulating Pulses used to homogenize the flip angle in non-selective 3D gradient echo images [2].

Methods: The AFI sequence [1] makes use of two distinct consecutive TR-values TR_1 and TR_2 in a gradient echo scheme to measure the flip angle (FA) in every voxel, which is proportional to B1 if a square pulse at resonance is used. On the other hand, B0-maps are commonly obtained with a multi-echo gradient echo sequence [3], whereby the phase evolution between echoes after a single RF pulse is governed by the resonance offset $\Delta B0$. In every voxel, a fit of the slope of this unwrapped phase evolution therefore yields a $\Delta B0$ map. Two echoes can be sufficient to give an estimate of $\Delta B0$, but three or more echoes make the fit more robust. In this work, this multi-echo technique was combined with the AFI sequence to offer a simultaneous measurement of B0 and B1 maps. Although dead time is a priori available in TR_2 to accommodate extra echoes ($TR_2 = n\ TR_1$, with $n>1$), three gradient echoes were concatenated in the TR_1 period because of larger SNR, the first one of which remains the exact equivalent of the single echo present in TR_2. Figure 1 shows the modified AFI sequence with those extra echoes in TR_1, separated by ΔTE_1 and ΔTE_2. For brain images where fat can be ignored, ΔTE_1 is chosen as short as possible (~1.5 ms at 3T) to prevent phase excursions beyond $+/-\pi$ during that time, which then eases the temporal phase unwrapping in the following inter-echo period $\Delta TE_2 > \Delta TE_1$. In this way, more difficult spatial phase unwrapping can be avoided. In addition to RF spoiling, the presence of spoiler gradients (dark blue on the figure) should be noticed on different axes in TR_1 and TR_2. Indeed if a constant spoiler is set on the same axis in TR_1 and TR_2, artefacts show up on images probably due to residual magnetization refocused by the spoiler.

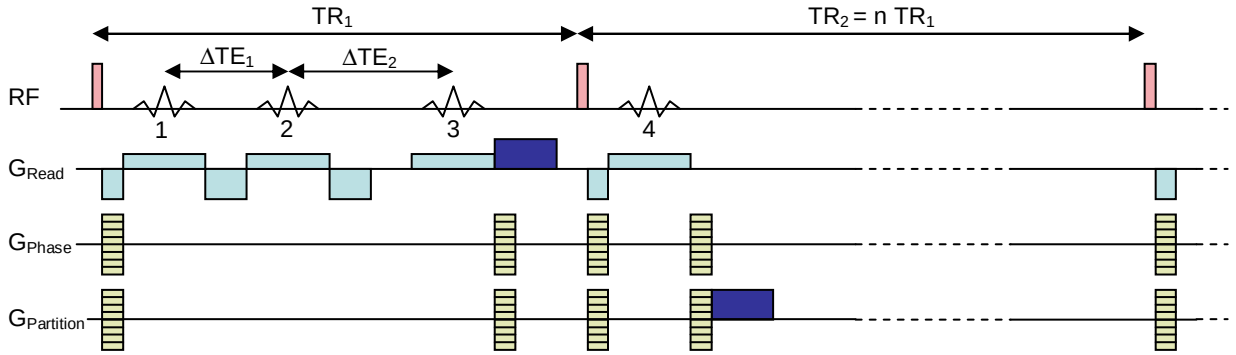

Figure 1: Modified AFI sequence to allow for simultaneous B0- and B1-mapping. Phase images from echoes 1, 2, and 3 are used to derive the B0-map whereas the ratio of amplitude images from echoes 1 and 4 yields the B1-map assuming the RF pulse is not phase-modulated, or a mere flip-angle map if the pulse is arbitrary.

Using this modified AFI sequence, 3D B1- and B0-field maps were acquired simultaneously on a couple of human brains in a 3T Trio scanner (Siemens, Erlangen, Germany) equipped with a quadrature RF head coil. This was performed to calibrate some Strongly Modulating Pulses used to homogenize the flip angle in non-selective 3D gradient echo images [2]. Acquisition parameters were : TR_1 = 20 ms, n = 5, nominal FA = 60°, matrix size = 64 x 64 x 64, FOV = 210 x 210 x 192 mm, where the latter z-dimension corresponds to the read-axis to avoid neck aliasing. Total acquisition time = 8 minutes.

Results: Example images of B1 and B0 obtained from the sequence described above are shown in Figure 2, after raw data were filtered to prevent Gibbs artefacts. Three orthogonal cross-sections were arbitrarily chosen from the 3D B1 and B0-maps. These images are in agreement with what is expected from separate B0 and B1 measurements, making this modified AFI sequence an ideal tool to quickly quantify B0 and B1 inhomogeneities at high field.

References: [1] V.L. Yarnykh, MRM 57:192-200 (2007). [2] N. Boulant et al., abstract ISMRM 2008. [3] E.A. Schneider et al., MRM 18, 335-347 (1991).

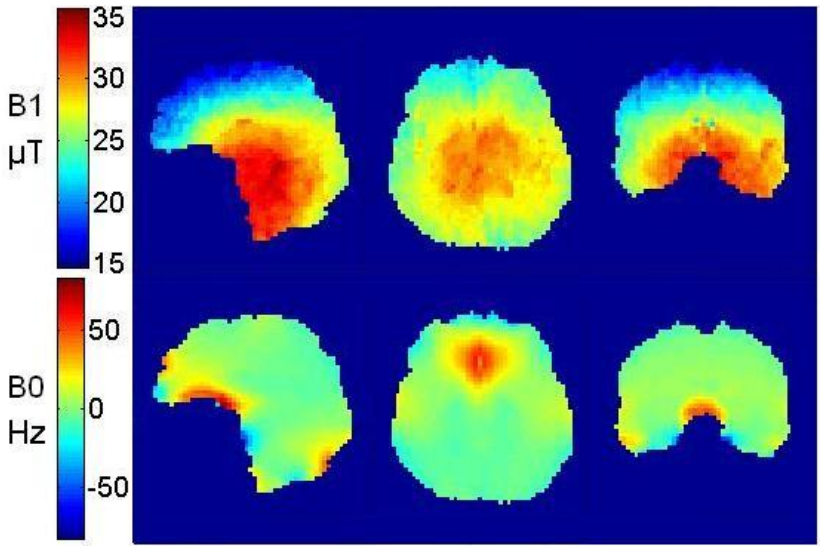

Figure 2: Orthogonal cross-sections of a human brain's B1- and B0-field maps measured simultaneously with the modified AFI sequence proposed here, using a quadrature head coil at 3T.