

## B1 Correction using Double Angle Look-Locker (DALL)

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**Introduction:** B1 inhomogeneity has become an increasingly obvious problem in high field human MRI. As stronger main field magnets are used, wavelength effects distort the RF field, leading to image intensity gradients and incorrect values in quantitative maps, in particular in fast T1 and T2 mapping methods such as DESPOT1 and DESPOT2 [1], which require accurate knowledge of the flip angle. Here we introduce a combined B1 and T1 mapping method, which we call DALL (Double Angle Look-Locker). This method, unlike other double angle B1 mapping methods [2,3], is highly efficient at measuring low flip angles, and additionally yields a corrected T1 map for free.

**Methods:** The Look-Locker sequence utilizes an inversion pulse followed by a low flip angle, spoiled gradient echo read out train [4], which can be further accelerated and integrated into a fast 3D imaging acquisition [5]. The sampled recovery curve is similar to a standard inversion recovery curve, but it approaches steady state following a modified time constant, T1\*, that depends on the repetition time, flip angle and T1 value (equation 1). By performing the same experiment and extracting T1\* a second time with double the original flip angle (2α instead of α), simple analytical solutions for both true flip angle α (and hence B1), and by subsequent substitution into equation 1, true T1, can be derived (equations 2 and 3).

$$\frac{1}{T_1^*} = \frac{1}{T_1} - \frac{\ln(\cos \alpha)}{\tau} \quad (1) \quad E_1^* = \exp\left(\frac{\tau}{T_{1,\alpha}^*} - \frac{\tau}{T_{1,2\alpha}^*}\right) \quad (2) \quad \alpha = \arccos\left\{\frac{1}{4}\left(E_1^* + \sqrt{E_1^{*2} + 8}\right)\right\} \quad (3)$$

Experiments were performed on a spherical 0.5%-NaCl, 21.8mM-NiCl<sub>2</sub> doped agarose-filled phantom (17.5 cm diameter). The DALL

sequence consisted of an inversion pulse followed by a 384 long α pulse train with inter-pulse interval, τ = 2.7 ms. The train was segmented into 24 slices (kz encodes) times 16 Look-Locker recovery points, to acquire a 64x64x24 matrix in 64 TR intervals, with 1 NEX and two flip angles (6 and 12 deg, total imaging time 2.5 min). Non-linear least squares fitting was used to obtain the two T1\* values, and the results were combined as above to obtain corrected T1 and B1 (shown in units of true flip angle α in degrees) maps.

**Results:** If no T1 correction is used, the Look-Locker method results in inaccurate T1 maps (Figure 1a) with apparent T1 variation of over 30% over the 17.5cm diameter phantom, based on the incorrect assumption that B1 is uniform. Using the DALL method as described here, a true flip angle map (Figure 1b) can be obtained, which then can be used to correct the T1 map (Figure 1c). A 1D profile through the centre of each slice is shown below. Notice that the true flip angle variation is from approximately 5 degrees to 7 degrees (for a nominally prescribed 6 degree flip angle) across the phantom, and that this true flip angle variation explains the apparent T1 variation in the uncorrected LL T1 map. The DALL-corrected T1 map has had the systematic variation completely removed.

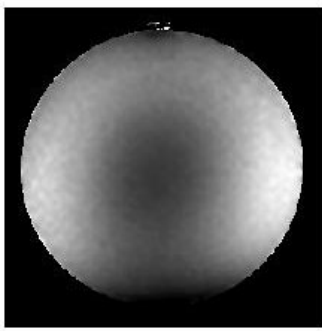


Figure 1a. Uncorrected T1 (ms) (LL)

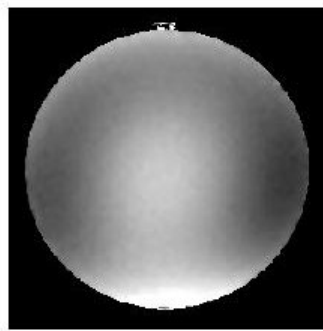


Figure 1b. Flip angle map Map (deg) (DALL)

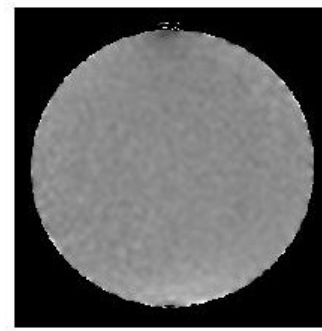


Figure 1c. Corrected T1 (ms) (DALL)

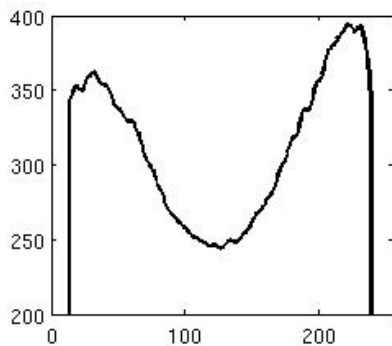


Figure 1d. T1 profile (LL)

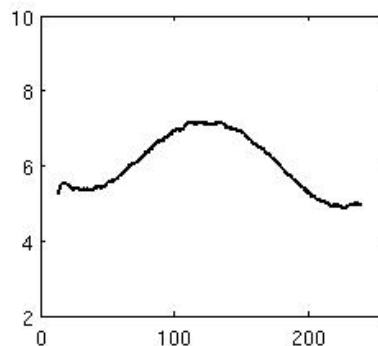


Figure 1e. Flip angle profile (DALL)

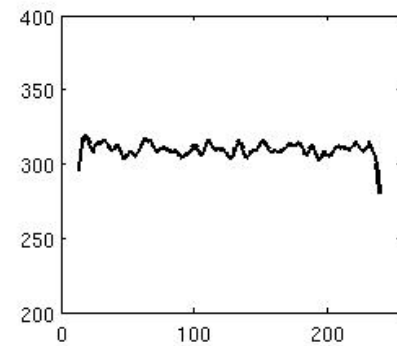


Figure 1f. T1 profile (DALL)

**Discussion and Conclusion:** The DALL method performs best at the low flip angles where most fast 3D steady state imaging protocols are performed. This means that the same RF pulse can be used in B1 calibration as in the actual fast imaging sequence. In addition, the sequence can be tailored as necessary for the desired flip angle or tissue T1 by altering a few imaging parameters, or the sampling of the recovery curve.

**References:** [1] Deoni, S.C.L., Peters, T.M., Rutt, B.R., *Magn Reson Med*, **53**:237-241, 2005; [2] Stollberger R, Wach P, McKinnon, G, Justich, E., Ebner, F., Rf-field mapping in vivo. In: *Proceedings of the 7th Annual Meeting of SMRM, San Francisco, CA, USA, 1988*. p. 106; [3] Cunningham, C.H., Pauly, J.M., Nayak, K.S., *Magn Reson Med*, **55**:1326-1333, 2006; [4] Look, D.C.; Locker, D.R. *Rev. Sci. Instrum.* **41**:250-251; 1970. [5] Henderson, E., McKinnon, G., Lee, T-Y., Rutt, B.K., *Magn Reson Imag*, **17**:1163-1171.