Fast B1 mapping using transient phase signals of α/3 prepared bSSFP

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Introduction: Fast B1 mapping is desired for applications such as parallel transmission system or monitoring dynamic B1 changes. Conventional B1 mapping techniques basically use either magnitude information of two images acquired with different flip angles[1] or phase information by modifying RF pulses[2]. All methods have their pros and cons such as T1, T2 dependencies, long acquisition time, B0 sensitivity or high specific absorption ratio (SAR). Recently, B1 mapping using the transient phase signals in steady-state free precession (SSFP) has been introduced[3], which uses the analysis of oscillatory signals pattern from RF to RF. In this work, we propose an extremely fast B1 mapping method based on the oscillatory signal behaviors in transient phase of balanced SSFP (bSSFP) sequences.

Methods: Conventional bSSFP sequences use α/2 preparation pulse (Fig. 1a) to reduce initial signal fluctuation during the transient phase and acquire data by applying opposite-phase α pulse repeatedly. Here, we introduce α/3 pulse instead for preparation. In this case, signals during transient phase of the bSSFP oscillate along two separate flip angle axis of α/3 and 2α/3 (Fig. 1b). The α/3 and 2α/3 signals are acquired at different data bins and reconstructed separately. Consequently, a B1 map can be calculated from these two data set in a similar manner to the double angle method (DAM)[1]. After the transient data acquisition for B1 mapping is finished, conventional bSSFP images can be acquired if desired. Various flip angles were tested to estimate the dependency on flip angles. B1 inhomogeneities were simulated to estimate the mapping accuracy for various relaxation parameters of T1 (from 1 to 3000ms) and T2 (from 1 to 1500ms). Simulations were also performed on human model phantom with assumed T1 and T2 components. Simulated imaging parameters were TR/TE= 4.0/2.0 ms, matrix size = 128 x 128, Cartesian centric reordering and α =1°~135°. The mapping accuracy is calculated from the difference between input and estimated B1 map.

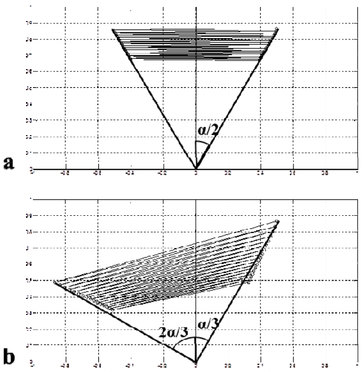

Figure 1.Magnetization diagrams of α/2 prepared bSSFP (a) and proposed α/3 prepared bSSFP.

Result: Figure 2a shows the B1 estimation error as a function of the flip angles (T1=1000ms, T2=100ms). The estimation error decreases as the flip angle increases. In Fig. 2b, the estimation error depending on the T1 and T2 parameters is shown (α =135°). It is seen that longer relaxation parameters are preferred in the proposed method as expected since oscillating condition (i.e. transient condition) can be maintained. Figure 3 show simulated phantom and head B1 map results using our proposed method. The results match well with the presumed B1 inhomogeneity. Results indicate that estimation errors are relatively high at regions where T1 and T2 are relatively short as was previously determined. The total scan time required to acquire the data for B1 mapping is 512 ms.

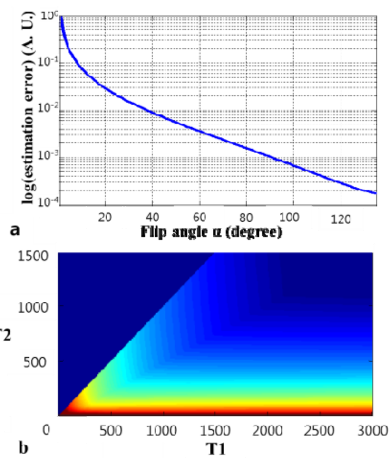

Figure 2. B1 estimation errors are shown in log-scale according to flip angle (a) and T1, T2 relaxations (b).

Discussion and Conclusion: We have shown a very fast B1 mapping which uses the transient state information of the bSSFP with a α/3 preparation pulse. Simulations show that the approach can be applicable for a range of T1 and T2 with an acquisition time less than 1.0 s. Several implementation issues need to be overcome for the approach to be usable. Although higher flip angles are preferred, SAR could limit its utility. Short T1 and T2 spins increase estimation errors since its transient state is shorter. To compensate this, a variable flip angle approach can be considered which prevents fast convergence of signals. In addition, low frequency k-space regions should be acquired during the initial stages with short TR. Data acquisition using centric reordering is desirable but care should be taken because it can increase eddy current related artifact[4]. Finally, the dependence on B0 inhomogeneity should be taken into consideration.

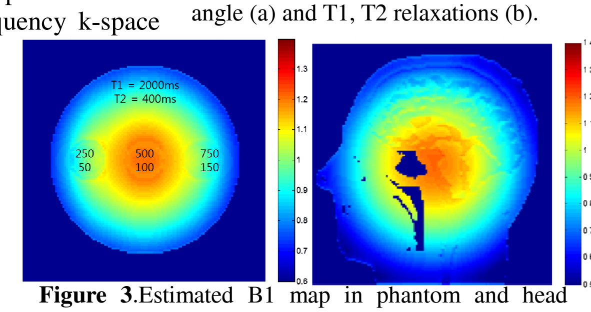

Figure 3.Estimated B1 map in phantom and head model using the proposed method.

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