Simultaneous Fast Quantitation of B1 and T1 Maps at 7 T Using the TESSA Principle

K. Zhong[1], and O. Speck[1]

[1]Department of Biomedical Magnetic Resonance, Otto-von-Guericke University, Magdeburg, Germany

Introduction: Fast methods based on variable flip angles (VFA) have been applied at 1.5 and 3 T [1, 2] to obtain B_1 and T_1 maps. Such methods exploit the dependence of steady-state magnetization on repetition time (TR) and flip angle to determine B_1 and T_1. In this study, a new fast acquisition method is proposed based on the TESSA (**T**ransition from **E**quilibrium into **S**teady **S**tate **A**cquisition) principle. This method utilizes the transient magnetization from equilibrium to steady state which otherwise is discarded and is self-contained, i.e. only a single acquisition is required to determine both B_1 and T_1. Other methods require at least two consecutive acquisitions and thus longer scan time. The new method has no specific requirement for the acquisition parameters TR and flip angle.

Theory: For a series of RF pulses (flip angle α) separated by TR, the longitudinal magnetization after the (n+1)-th pulse is given as $M_{n+1} = M_0(1-E) + M_n \cdot \cos\alpha \cdot E$, where M_0 is the equilibrium magnetization and $E = \exp(-TR/T_1)$. For the transverse signal $S_n = M_n \cdot \sin\alpha$ the normalized differential Δ_n and transient magnetization F_n are defined: $\Delta_n = (S_{n+1} - S_n)/S_0 = (\cos\alpha \cdot E - E) \cdot \cos^n\alpha \cdot E^n$; $F_n = S_n/S_0$. This leads to the following linear relationship $\Delta_n = (1-E) + F_n \cdot (\cos\alpha \cdot E - 1)$ (Fig. 1) which describes the transition into steady state. T_1 and α can be determined by fitting Δ_n and F_n to experimental data from the slope (k) and the intercept (δ) as $\alpha = \arccos((1+k)/(1-\delta))$ and $T_1 = -TR/\ln(1-\delta)$.

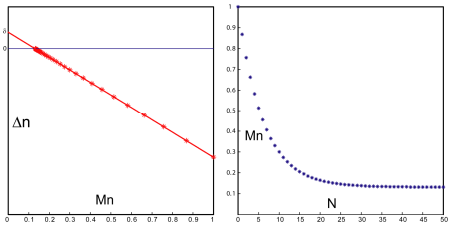

Fig. 1: Diagram depicts the TESSA principle. The transient magnetization (right) follows a linear relationship between Δ_n and M_n defined by the red line (left).

Method: Experiments were performed on a Siemens MAGNETOM 7 T system using an 8 channel TX/Rx coil array. Phantom and human brain data were acquired. An EPI sequence with distortion correction was used for image acquisition [3]. The acquisition parameters for the phantom (p) and volunteer (v) were: FOV: 256x256 mm^2; Matrix: 80x80 (p) / 160x160 (v); TE: 11 ms (p) / 24 ms (v); Flip angle and TR varied from 10° to 60° and 300 to 800 ms.

Result and Discussion: Previous studies [1, 2] suggested that precise determination of B_1 is crucial for accurate T_1 mapping. The B_1 maps for different flip angles using the TESSA method in a gel phantom with different T_1s are shown in Fig. 2A-2D. All B_1 maps are normalized by the nominal flip angle for easy comparison. All maps show very similar features, suggesting that the TESSA method is insensitive to flip angle variation. The B_1 map at 20° is slightly degraded due to low SNR. In comparison, a standard B_1 mapping method using the $\alpha/2\alpha$ method (Fig. 2E) shows quite consistent result compared to the TESSA method.

The result of an *in vivo* measurement is shown in Fig. 3. The T_1 map shows clear contrast between gray and white matter. The CSF space with high T_1 is also detected and separated from gray matter. The T_1 contrast is consistent with studies at low field [2] and shows enhancement due to a wider T_1 distribution at 7 T. In addition, T_1 maps can be obtained in less than 5 s per slice. This is an increase of 300% in acquisition efficiency compared to previous methods [2].

Although T_1 quantification based on TESSA has no specific requirement on TR and flip angle, the current implementation has to be combined with a fast readout such as EPI and thus suffers from the intrinsic problems associated with EPI. Distortion correction methods can partly resolve this problem. Using parallel acquisition with short EPI readout also helps to reduce the errors in B_1 and T_1 quantitation.

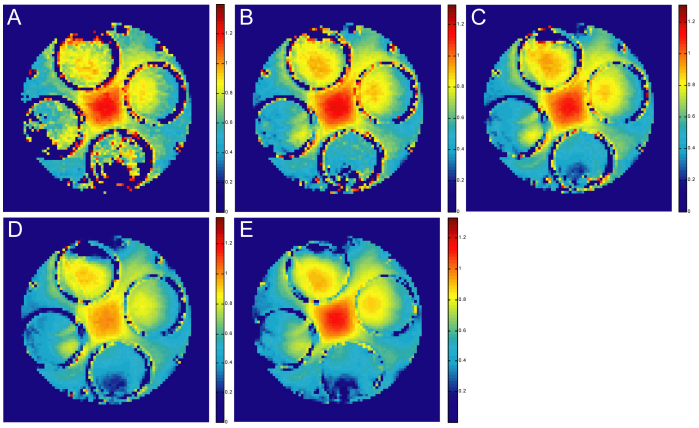

Fig 2: B_1 maps from phantom measurements. All maps are normalized by the nominal flip angle. (A-D) α = 20°, 30°, 40°, 50°; TR = 300ms. (E) The $\alpha/2\alpha$ method determination shows similar result compared to TESSA measurement (B).

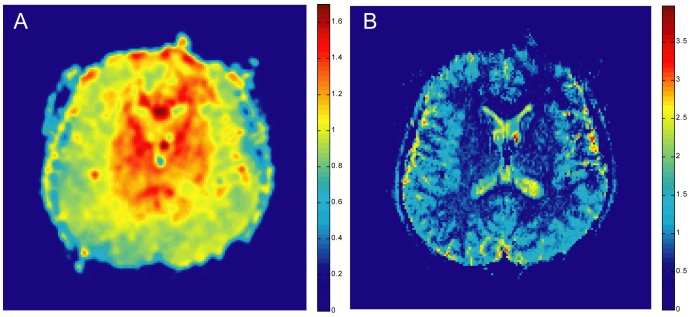

Fig. 3: *In vivo* B_1 (A) and T_1 (B) maps from 7 T. The T_1 map shows clear contrast between gray and white matter. Long T_1 components can also be separated from gray matter.

Conclusion: The TESSA principle describes the general behavior of transient magnetization. The application at 7T allows fast and simultaneous *in vivo* B_1 and T_1 quantitation with a 300% gain in efficiency. This could potentially stimulate further *in vivo* high field applications using the TESSA principle.

Reference:

1. Treier R. *et al. Magn Reson Med* 57:568-76 (2007)
2. Cheng H. *et al. Magn Reson Med* 55:566-74 (2007)
3. Zaitsev M. *et al. Magn Reson Med* 52:1156-66 (2004)