Rapid RF-mapping using TurboSTEAM

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Introduction:

Magnetic resonance imaging at static field strengths higher than 1.5 Tesla involves deformation of the radio-frequency (RF) field as the wavelength approaches the typical dimensions of the human body. Deviation of the local flip angle (FA) from its nominal value, the so called "transmit bias", may affect local contrast and signal strength. Using multi-slice TurboSTEAM MRI (1), we implemented a method for 3D- mapping of the transmit bias in the human brain in less than one minute. It comprises a calibration strategy to account for non-linear slice effects of the slice and a 2-point-approximation.

Theory:

Local deviation of the local flip angle $\alpha(\underline{x})$ from its nominal value, α_{nom}, can be described by a multiplicative transmit bias field $f_T(\underline{x})$:

$$\gamma \int B_1(\underline{x})\, dt = \alpha(\underline{x}) = f_T(\underline{x})\, \alpha_{nom}. \qquad [1]$$

In non-selective excitation on-resonance, $f_T(\underline{x})$ simply described the shift of the signal maximum of the sinusoidal FA-dependence. In slice-selective excitation, non-linearities of the integrated slice profile may occur. Typically, positive residues are found when the FA approaches 180°, and the maximum is shifted to a flip angle $\alpha_{max} > 90°$ (2,3). This "profile bias" depends on the shape of the RF-pulse, but can be determined by comparing non-selective and slice-selective behaviour. Because the FA is typically varied around he signal maximum, the FA-dependence (in *radians*) may be approximated by a parabolic curve:

$$S_{slice} = S_{max}\,[1 - q^2 (f_T(\underline{x})\, \alpha_{nom} - \alpha_{max})^2\,]. \qquad [2]$$

α_{max} and q are fitted to the calibration experiment, after the non-selective case yielded $f_T(\underline{x})$. From two signals (S_1, S_2) acquired with nominal FA (α_1, α_2), $f_T(\underline{x})$ is calculated by solving equation [2]. The solution is unique and robust if at least one point is off the maximum.

Methods:

The procedure was implemented on a 3 T Siemens Trio (Erlangen, Germany) using a single-shot TurboSTEAM sequence (2.8+0.7 mm interleaved axial slices, FOV 223 mm, 64x54 matrix, readout α = 12°, TR = 8 ms, BW/px = 191 Hz). An optimized pulse shape was used for excitation and flip-back, either one of these FA can be varied (β in Fig. 1). Nominal FA values of α_1 = 60° and α_2 = 100° were chosen, taking into account the calibration and typical B1 distribution across the brain. After conversion to ANALYZE format, images were processed using the routines of FSL 3.2 (University of Oxford). Signals were low-pass filtered (Gaussian, 5mm FWHM) prior to calculating f_T (x). The quality of the T2-w TurboSTEAM images was sufficient for brain extraction and co-registration to anatomical volumes.

Results:

Figure 2 shows the phantom calibration at f_T = 1.257, as fitted to the FA-dependence for non-selective excitation (black). The maximum of slice-selective excitation (red) was shifted by 6%; that of a filtered sinc-mainlobe by more than 20% for (blue). Note the good congruence of quadratic approximation and sinc (solid red) between nominal 25° and 115°. The corrected range between 35° and 145° was covered by the choice of α_1 and α_2. A typical in vivo map of f_T (x) is shown in Fig 3, ranging approximately from 0.75 (red) to 1.2 (yellow).

Discussion:

A rapid B1-calibration method is presented that does not suffer from spatial distortions seen in EPI-based mapping. For this application, the intrinsically lower SNR of TurboSTEAM may be compensated by increasing the voxel size. Saturation effects in Mz may be neglected due to multislice implementation. The errors of 2-point approach less cannot be assessed as with non-linear fitting (4). However, the suggested dorrection for slice-profile effects is of general nature (3) and can easily be implemented into fitting approaches. By virtue of calibration, the f_T(x) may be applied to correct qMRI schemes involving non-selective RF-pulses.

Fig. 1: TurboSTEAM sequence diagram

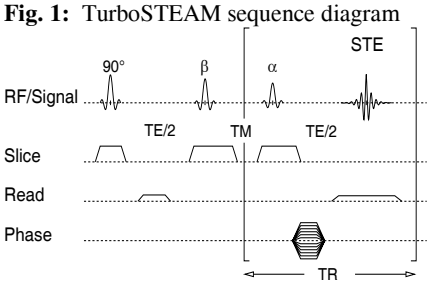


Fig. 2: Calibration measurement

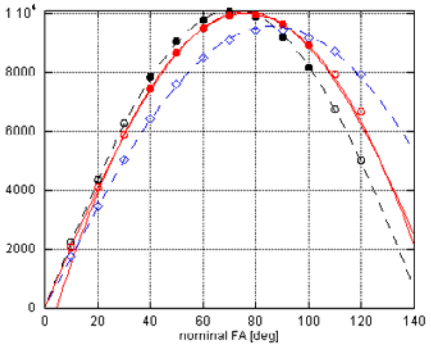
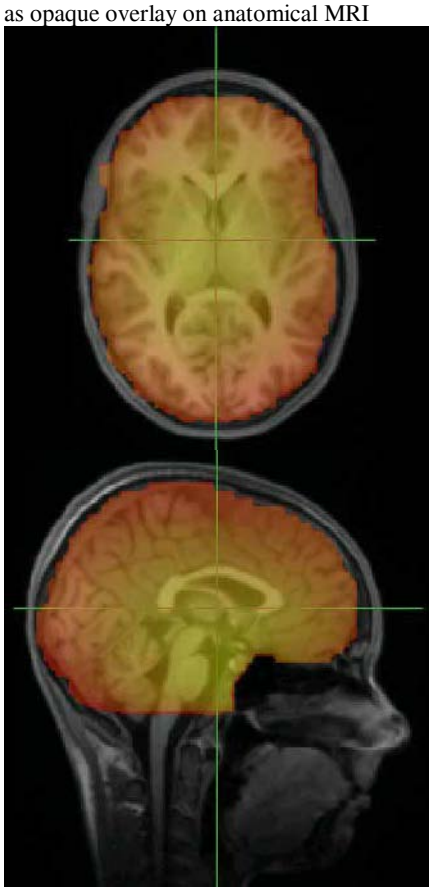


Fig. 3: Map of transmit bias, displayed as opaque overlay on anatomical MRI



References:

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(2)Helms G: PhD thesis, Göttingen 1994. (4)Helms: *NMR Biomed* 2000; 13:398-406.

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