Voxel Based Transmit Gain Calibration using Bloch-Siegert Shift Method for MR Spectroscopy

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Introduction

The SNR and excitation profile achievable by a localized MR spectroscopy experiment depends on the correct setting of the transmit gain (TG) to assure that the excitation pulses have correct flip angles across the prescribed ROI. Patient dependent spatial B_1^+ inhomogeneities that can be observed at $B_0 \geq 3T$ in the brain or the breasts require a voxel based TG calibration method to achieve this. Automated calibration techniques using the average signal from a fully excited slice can yield to miscalibrated TG that degrades excitation profile especially when B_1-sensitive pulses are used.

The recently introduced phase-based B_1^+ mapping method using the Bloch-Siegert shift method encodes the B_1 information into a signal phase resulting from off-resonant RF pulses within the sequence. Volume based implementation in gradient and spin-echo sequences [1,2] as well as in fast spin-echo sequences [3] were demonstrated.

This study will present a voxel based TG calibration based on the Bloch-Siegert shift method embedded into a standard clinical spectroscopy sequence and determining TG for the same volume that is excited for the spectroscopy experiment.

Methods

Bloch-Siegert shift method was implemented by modifying a standard PRESS sequence (BS-PRESS). Two off-resonant Fermi pulses (6 ms, ±4 kHz relative to water, ω_{RF}) applied symmetrically around the last refocusing pulse were included (figure 1). Center frequency of PRESS excitation pulses was set to water resonance frequency.

Phantom experiments were done using a MRS phantom (MRS HD Sphere, GE Healthcare, diameter = 18 cm) on a whole body 3T scanner (GE Healthcare, Milwaukee, WI, USA) with standard quadrature head coil and 12-element head configuration of HNS coil.

Data processing including coil combination for the multi-element receive coil, averaging, phase subtraction and unwrapping was implemented in MATLAB (MathWorks, Natick, MA, USA). Bloch-Siegert mean phase shift (φ_{BS}) and phase error ($\Delta\varphi_{BS}$) derived from the first 1024 of the totally acquired 4096 points (figure 2) were used to calculate the predicted optimal transmit gain ($TG_{predicted}$).

$TG_{starting}$ was first set by the standard slice-based multi-echo sequence in the automated prescan (APS) process [4]. Parameters of BS-PRESS were: TE = 47 ms or 144 ms, TR ranging from 750 ms to 2 s, NEX = 2 or 8, voxel size from 2 × 2 × 2 cm^3 to 100 × 100 × 2 cm^3 with total acquisition time between 6 and 48 seconds. In addition, excitation slice profile of the PRESS refocusing pulse was determined by acquiring an image of voxel for various refocusing pulses and settings of TG.

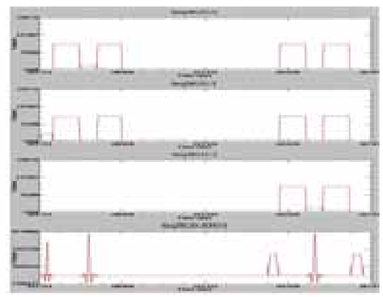

Figure 1: BS-PRESS sequence. Two 6 ms Fermi pulses symmetrically placed around the last refocusing pulse. The first pulse is at off-resonance frequency ω_{RF} and the second at $-\omega_{RF}$.

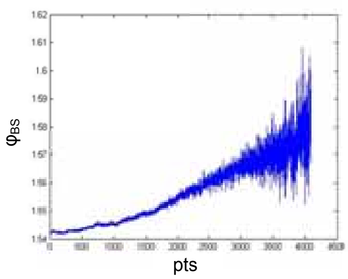

Figure 2: Bloch-Siegert phase shift φ_{BS}. To calculate predicted optimal gain $TG_{predicted}$ the mean value of first 1024 points is used.

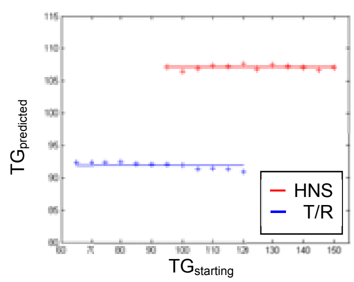

Figure 3: $TG_{predicted}$ vs. $TG_{starting}$ acquired with standard transmit/receive quadrature head coil (blue line) or with receive only 12-element head coil, body coil for transmission. The Bloch-Siegert shift method gives consistent results over a large range of starting TG setting.

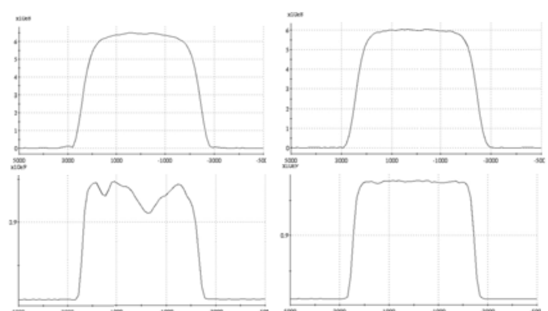

Figure 4: Pulse profile of standard reduced flip angle refocusing pulse (top) and broadband refocusing pulse (bottom: n • BW = 175, [5]). $TG_{starting}$ = 100 (left) and $TG_{predicted}$ = 92 (right) demonstrates the effect of a wrong TG setting. For the standard pulse the correct TG result in a flatter excitation profile. The excitation profile of the used broadband pulse depends strongly on B_1 amplitude (TG) and deviates significantly from the expected profile with the (wrong) TG determined by the automated prescan.

Results

Different parameters of BS-PRESS sequence (TE, TR, NEX) reproducibly result in $TG_{predicted}$ = 92.0 ± 0.2 for fixed $TG_{starting}$ = 100. Measurements with a range of values for $TG_{starting}$ results in $TG_{predicted}$ = 91.9 ± 0.5 using the quadrature head coil and 107.2 ± 0.3 using the HNS coil (figure 3). With $TG_{starting}$ set by the default automated prescan, the slice profile deviates from the expected profile for a voxel located in the center of the sphere both for the standard refocusing pulse as well as for a broadband refocusing pulse [5]. Changing the transmit gain to the predicted value $TG_{predicted}$ gives a much better profile especially in the case of the B_1-sensitive broadband pulse (figure 4).

Discussion

It has been demonstrated that the proposed voxel based transmit gain calibration technique using the Bloch-Siegert shift method for MR spectroscopy increases the accuracy of TG setting. The proposed implementation assures that the volume used for TG calibration and the finally desired excitation volume are identical. The method supports small SV up to large CSI volume sizes. The acquisition time of 6 seconds is comparable to other TG calibration techniques. Broadband RF refocusing pulses used to reduce chemical shift induced errors in MRS, usually very prone to B_1-miscalibration, benefit largely from correct TG setting.

References

1. Sacolick et al, Magn Reson Med 63: 1315 - 1322 (2010) **2.** Sacolick et al, Magn Reson Med 66: 1333 - 1338 (2011) **3.** Sacolick et al, Proceedings of ISMRM: 2927 (2011) **4.** King et al, Proceedings of ISMRM: 699 (1995) **5.** Schulte et al, J Magn Reson 190: 271 - 279 (2008)