Rapid Slice-Selective B1 Mapping for Transmit SENSE

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Introduction: Parallel RF excitation is a novel technology that can significantly accelerate multidimensional selective excitation and reduce SAR [1-3]. One caveat however is that the transmit array B_1 sensitivity profiles must be known. Previous experimental demonstrations [4-5] have relied on having a uniform transmit reference but this cannot generally be assumed. We have previously described a general approach that provides robust estimation of volumetric B_1 maps in ~40s/coil [6]. Here we describe an extension of our method to a slice-selective approach, as well as an extension of the magnetization preparation technique of [7]. Both techniques include careful compensation for B_0 off-resonance and acquire B_1 maps in less than 3s/coil.

Method: Figure 1a shows a multi-tip extension of the slice-selective B_1 mapping sequence of [8]. The sequence includes two 8-ms BIR4 non-selective adiabatic pulses transmitted in parallel from multiple coils and followed by gradient spoilers in order to effectively "reset" the longitudinal magnetization to a fixed state. The relative transmit phases to achieve a quasi-uniform excitation for the RESET pulse is estimated from small-tip single-coil images. The spectral-spatial RF pulse is stepped on the coil under test by factors of γ from α to $\gamma^{N-1}\alpha$ between TRs, with the whole process being repeated enough times to acquire N images.

Figure 1b shows a similar RESET preparation, but in this case a magnetization-preparation pulse (a hard pulse) [7] is stepped through multiple tip angles on the coil under test. A common zero-amplitude hard pulse result can be shared for all coils. A gradient spoiler follows the preparation, and then a spectral-spatial excitation is transmitted in parallel similar to the RESET pulse, and finally a gradient-echo readout. As Fig. 1 illustrates, the multi-tip excitation of (a) is appropriate for multislice acquisition, however T_1 recovery during the first acquisition in the hard-pulse preparation approach (b) will introduce errors in the B_1 estimation if, as we assume, T_1 is unknown.

The imaging sequence uses a 3-interleaf spiral acquisition with 8-ms readouts providing 64x64 resolution over a 40-cm FOV (GE Signa HD 3T system, 23 mT/m, 77 T/m/s). An additional single image acquisition with a 2-ms delayed echo is used to calculate a B_0 off-resonance map.

The multi-tip excitation data for each pixel is fitted using a least-squares nonlinear optimization to the complex signal model (Fig. 2) of the spectral-spatial excitation for the given B_0. This determines the absolute transmit B_1 amplitude and relative phase maps. In the case of the multi-tip preparation model, the signal is fitted to a model that includes the effect of B_0 variations on the prepared longitudinal magnetization M_z. This determines the absolute transmit B_1 amplitude maps. The relative B_1 phases are obtained from separate small-tip images acquired from single coil excitations.

Results: An eight-channel frequency and phase-locked multi-transmit platform [4] based on an integrated set of four GE HD system electronics was used for our experiments. A 16-element TEM body array was configured with opposite elements being driven in tandem but 180° out of phase by each channel. Figure 3 presents the B_1 magnitude profiles measured using the multi-tip excitation and preparation schemes. Each approach used 4 tip-angles with a scale factor γ of 2. With a TR of 180 ms (T_1~600ms), the total acquisition time for measuring all 8 channels was less than 24s for each approach. Figure 3 shows good agreement between the two methods where the B_1 transmit amplitude is over 2µT. At lower values, the multi-tip excitation is very sensitive to SNR as the excitation is in the small-tip linear regime. The preparation approach is much more robust in contrast.

Figure 4 presents further validation of the multi-tip preparation scheme when mapping B_1 in a large *ex vivo* meat sample. In this case, the RESET approach could not be used, as insufficient B_1 was available for the BIR4 pulse. This is due to the current experimental setup running in a reduced power mode and is not deemed to be a serious shortcoming. As a result, a TR of 2s was used (total acquisition time ~3.3 min for 8 channels). Validation of the acquired B_1 maps was obtained by using them to design a parallel-transmit 3D slice-selective excitation similar to that in [9-10].

Discussion: Two slice-selective approaches for rapid estimation of B_1 maps over a large dynamic range, including careful compensation of slice-profile and off-resonant effects were presented. The multi-tip excitation method is potentially more appropriate for a multislice acquisition but is more sensitive to regions of low B_1 compared to the multi-tip preparation approach. A validation of the B_1 maps was obtained by performing a successful demonstration of a parallel excitation design.

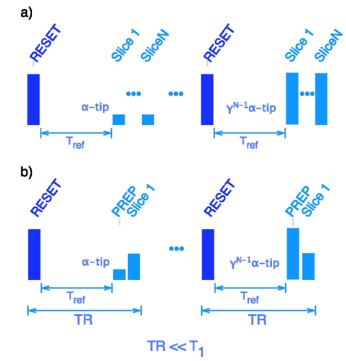

Figure 1: Schematic of B_1 mapping pulse sequences.

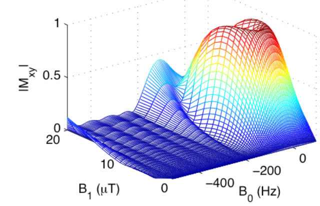

Figure 2: Simulated signal magnitude expected from spectral-spatial excitation as a function of B_0 and B_1. Up to 4x the nominal slice thickness was included to account for any out-of-slice ripple.

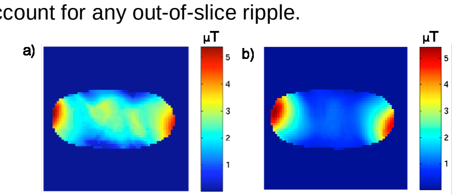

Figure 3: B_1 magnitude maps of dielectric phantom determined using (a) the multi-tip excitation approach and (b) the multi-tip preparation approach.

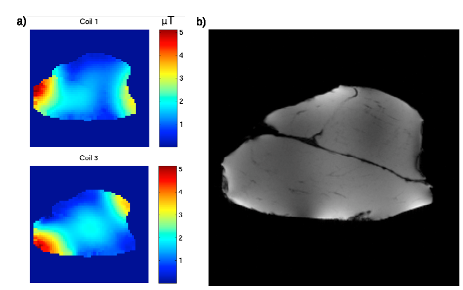

Figure 3: a) B_1 magnitude maps for two channels of an 8-channel body array on an *ex vivo* meat sample. b) Demonstration of parallel transmit RF shimming using a 3D spokes excitation based on the acquired B_1 maps. Receive-sensitivity shading is still present.

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[Acknowledgement: This work partly supported by NIH R01 EB008108, NIH R01 EB007715, NIH R01 EB005307.]