Decoupled RF-Pulse Phase Sensitive B_1 Mapping

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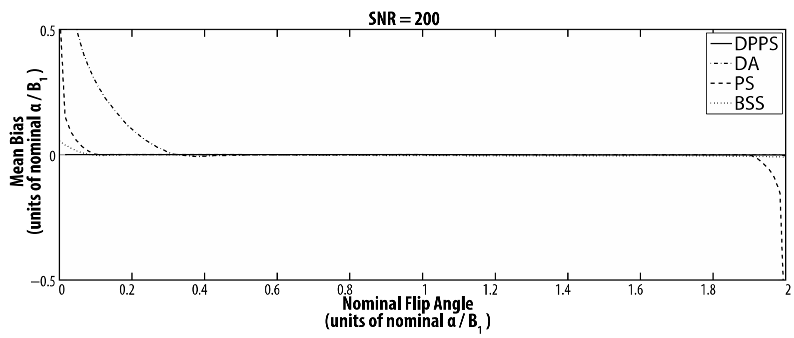
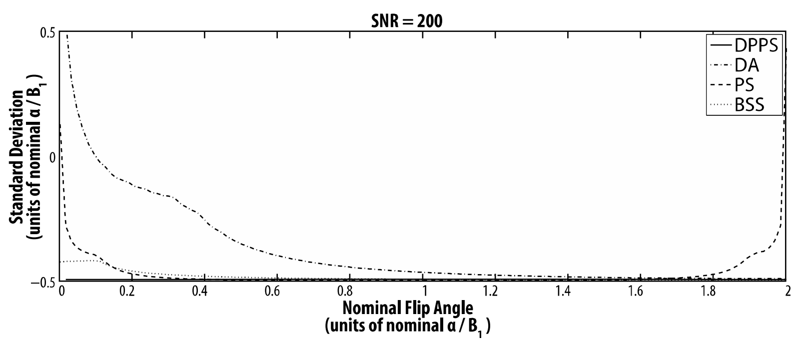
Introduction: B_1 mapping is an important component of quantitative MRI and parallel transmission [1-2]. Analyses by Morrell et al. [3], Allen et al. [4], Pohmann et al. [5], and Park et al. [6] have begun to shed light on the strengths and weaknesses of many of the B_1 mapping methods. However, there is still no clear method that is superior. Phase-based B_1 mapping methods have shown great potential with consistency while measuring large ranges of flip angles, especially in lower SNR environments. One of the phase-based methods, the Bloch-Siegert Shift (BSS) method, has demonstrated potential for characterizing parallel transmission systems because of the ability to separate excitation from the B_1 encoding pulse. This allows for a more homogenous excitation pulse to maximize the MR signal followed by the B_1 encoding pulse (e.g., parallel transmit array or body coil excitation and individual coil B1 mapping).

In this abstract, we introduce a modification of Morrell's Phase Sensitive (PS) B_1 mapping method which allows separation of the B_1 encoding from the excitation pulse for greater flexibility while still achieving accurate B_1 mapping. We refer to the new technique as the Decoupled RF-Pulse Phase Sensitive (DPPS) method. The DPPS method also allows the flip angle mapping to be tailored to the desired range of flip angles. Following our description of the new technique, we provide a brief statistical analysis of the DPPS method's performance (mean bias and standard deviation of flip angle estimate) relative to other B1 mapping techniques using Monte Carlo simulations. The statistical analysis suggests that the DPPS modification achieves excellent performance

Theory: The Phase Sensitive method typically uses a compound excitation pulse of $2\alpha_x$–α_y from the same RF source. We propose that this compound excitation pulse be decoupled which allows more freedom to tailor B_1 mapping for specific needs. This decoupled pulse is β_x-α_y, where β_x is effectively the B_1 encoding pulse and α_y can be considered the excitation pulse. The first RF pulse, β_x, rotates the initial magnetization in the yz-plane. The second RF pulse, α_y, rotates the magnetization in the yz-plane into the xy-plane for readout. The two RF pulses do not need to come from the same coil.

Methods: Monte Carlo simulations were run using 1000 realizations on the DPPS method and three other methods: Dual Angle (DA), Phase Sensitive, and Bloch-Siegert Shift. The assumed system SNR, as defined in [6], is 200. TR is assumed infinitely long, TE=0 ms, and differences in imaging time are not accounted for. Axes are scaled relative to the nominal flip angle for each method. The nominal flip angles are 60° (DA) and 90° (DPPS and PS) with the nominal B_1 for the BSS method is 0.1G. All methods use gradient echoes. BSS parameters: K_{BSS}=74.01 rad/G^2, α=90°. For the proposed method α_y is a constant 90° while β_x varies. A second RF source with uniform field is assumed available for the proposed method and the BSS method.





Results and Discussion: The mean bias and standard deviation for the DPPS method are nearly zero in the case where a uniform excitation field is available apart from the field to be mapped. The uniform mean bias and standard deviation are a result of a uniform signal magnitude in the resulting image from tipping the yz-plane completely into the xy-plane. The DPPS method of flip angle mapping achieves great accuracy in situations where the sensitivity of one element of an array is being mapped. We note that the current results were obtained for flip angles ranging from zero to 2π. In practice, any range of flip angles including angles greater than 2π can be measured by this method if phase images are correctly unwrapped.

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References:

[1] L.I. Sacolick et al., *Mag Res Med*, 63:1315-22 (2010)
[2] G.R. Morrell, *Mag Res Med*, 60:889-894 (2008)
[3] G.R. Morrell et al., *Phys Med Biol*, 55:6157-74 (2010)
[4] S.P. Allen et al., *Mag Res Med*, 65:1125-30 (2011)
[5] R. Pohmann et al., NMR Biomed, 26:265-275 (2013)
[6] D.J. Park et al., *Phys Med Biol*, 58:5673-91-74 (2013)