Fast, indirect assessment of the $^{19}$F $B_1$ profile by $^1$H Bloch-Siegert $B_2$ mapping using double-resonant $^1$H/$^{19}$F coils

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Introduction

Due to $^{19}$F properties such as high sensitivity, unambiguous localization of labeled cells and direct quantification, the MR community has regained great interest in $^{19}$F MRI (1,2). For these applications surface coils are often used (1,2) due to the low SNR in $^{19}$F images. Since an inhomogeneous $B_1$ profile is inherent with surface coils quantification of the $^{19}$F signal is hampered and thus strategies to map the $^{19}$F $B_1$ profile are of great interest. Importantly, double-resonant coils provide comparable $B_1$ profiles for both nuclei and allow simultaneous detection (3). Bloch-Siegert based $B_2^*$ mapping was recently introduced by Sacolick et al. (4). Furthermore, it was shown that fast spectroscopic BS-based methods can be used for flip-angle calibration (5) even with $x$-nuclei (6). The present study shows that $^{19}$F $B_1$ profiles of a double-resonant surface coils can be assessed using fast $^1$H BS $B_2$ mapping.

Materials and Methods

Experiment Setup: Since different coil sensitivities might occur for both nuclei when double-resonant surface coils are used the $B_1$ ratio of both nuclei must be known. Thus, fast spectroscopic BS-CPMG $B_2$ (7) scans of both nuclei were obtained from a small external reference with comparable $^1$H/$^{19}$F distributions. With the help of the spectroscopically obtained $^1$H/$^{19}$F $B_1$ ratio, fast $^1$H BS-CPMG $B_2$ mapping could be used to derive the $^{19}$F $B_1$ map.

Hardware: A square surface coil with a side length of 30mm was constructed (Fig.1a). To obtain double-resonance, the strategy using a birdcage coil proposed in Reference 1 was adapted. Thus, the surface coil was coupled with a secondary resonator located in the tuning and matching network. The resonance frequencies were adjusted to allow operation at $7T$ ($^1$H ~ 300 MHz, $^{19}$F ~ 282MHz). MR experiments were performed on a $7T$ small animal scanner.

BS Parameters: BS-CPMG-MSE NMR/MRI experiments for both nuclei were performed. Gaussian-shaped off-resonant pulses were used for encoding the BS phase. The BS pulse duration was set to 1ms and the same BS pulse amplitude was chosen for both nuclei. Moreover, the off-resonance of the BS pulses was set to $\pm 16$kHz. The $B_1$ information was calculated as described in References 4,7.

NMR: A tube containing trifluoroacetic acid (TFA) diluted in $H_2O$ was used as spectroscopic $^1$H/$^{19}$F reference (Fig.1c). Spectroscopic BS experiments based on the BS-CPMG-MSE method presented in Reference 7 were performed (TE/TR = 20/2500ms, NE = 36, Spectral points = 512, NA = 32, $T_{exp}$/$T_{ref}$ = 1min20s). Using slice selective pulses, only the $^1$H/$^{19}$F signal from the TFA reference was acquired (Fig.1c).

MRI: A $^1$H/$^{19}$F phantom was used for imaging that contained a perfluoro-15-crown-ether (PF15C) emulsion (Fig.1c). For $B_2$ mapping the following MRI parameters were chosen: Echo time/Repetition time (TE/TR) = 10/2500/3500ms; Echo Images (NE) = 36; Matrix Size (MTX) = 32x32; Field-of-View (FOV) = 30x30mm; Slice Thickness (ST) = 12mm; Averages (NA) $NA_{H}/NA_{F}$ = 1/128, $T_{exp}$/$T_{ref}$ = 1min20s/240min.

Results

Fig.1b, shows that the coil could be successfully adjusted to both frequencies. In Fig.2a, the $B_2^*$ profile of the coil in the PF15C emulsion phantom at the $^1$H resonance frequency is shown. Different $B_2^*$ values were obtained for the $^{19}$F resonance frequency (Fig.2b); however, the relative sensitivity pattern was comparable as seen from the ratio of the two $B_2^*$ maps (Fig.2b). Thereby, the spatial derived $^1$H/$^{19}$F $B_2$ ratio was ~ 1.51.

Discussion and Conclusion

Due to the often low SNR in $^{19}$F images direct assessment of the $^{19}$F $B_1$ profile is normally impossible. The present study solves this issue by using fast $^1$H BS-CPMG mapping to assess the inhomogeneous $^{19}$F $B_1$ profile of a double-resonant $^1$H/$^{19}$F surface coil. Thus, it was shown that acquiring additional spectroscopic $^1$H/$^{19}$F BS-CPMG data from a reference tube allows rescaling of the $^1$H data resolved by the spectroscopically obtained $^1$H/$^{19}$F $B_1$ ratio. The rescaled $^1$H $B_1$ map is very well to the $^{19}$F $B_1$ map (Fig.2b). Furthermore, the noise influence in the rescaled $^1$H $B_1$ map is weaker compared to the $^{19}$F $B_1$ map.

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References