Fast, indirect assessment of the ^{19}F B_1 profile by ^{1}H Bloch-Siegert B_1 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_1^+ 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_1 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_1 (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_1 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 ($^{1}H \sim 300$ MHz, $^{19}F \sim 282$MHz). 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 = ±16kHz. 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 preformed (TE/TR = 20/2500ms, NE = 36, Spectral points = 512, NA = 32, $T_{exp1H/19F}$ = 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_1 mapping the following MRI parameters were chosen: Echo time/Repetition time ($TE/TR_{1H}/TR_{19F}$) = 10/2500/3500ms; Echo Images (NE) = 36; Matrix Size (MTX) = 32x32; Field-of-View (FOV) = 30x30mm^2; Slice Thickness (ST) = 12mm; Averages (NA) NA_{1H}/NA_{19F}= 1/128, T_{exp1H}/T_{exp19F} = 1min20s/240min.

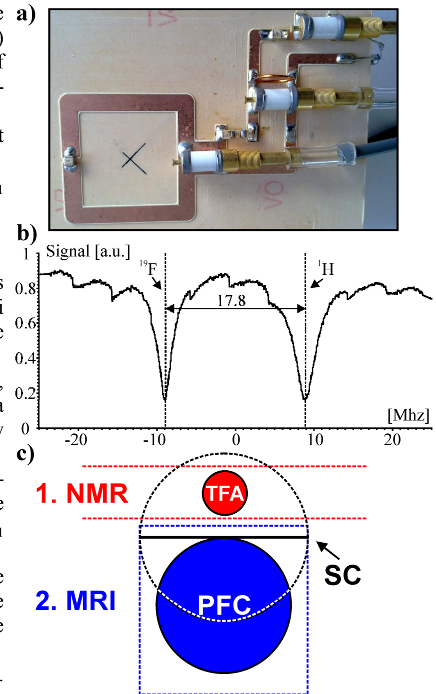

Fig.**1a)** Picture of the double-resonant surface coil. **b)** Exemplary wobble curve of the coil presented in **a**. **c)** The scheme illustrates the positions of surface coil (SC), the TFA reference and the PFC emulsion phantom. Furthermore, the dashed lines show the excited area in the NMR (red) and the MRI (blue) experiments.

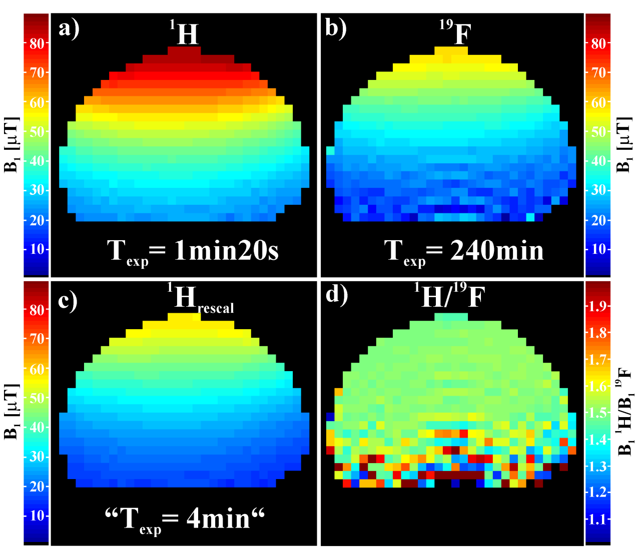

Fig.2 Results from the MRI experiments of the PF15C emulsion phantom. **a)** B_1^+ map calculated from the ^{1}H data. **b)** B_1^+ map calculated from the ^{19}F data. **c)** ^{19}F B_1^+ map calculated from the acquired ^{1}H data rescaled by the spectroscopically obtained $^{1}H/^{19}F$ B_1 ratio. **d)** Image showing the ratio of the ^{1}H and ^{19}F B_1^+ maps.

Results

Fig.1b, shows that the coil could be successfully adjusted to both frequencies. In Fig.2a, the B_1^+ profile of the coil in the PF15C emulsion phantom at the ^{1}H resonance frequency is shown. Different B_1^+ 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_1^+ maps (Fig.2d). Thereby, the spatial derived $^{1}H/^{19}F$ B_1 ratio was ~ 1.51.

This factor is in very good agreement with the ratio obtained from the selective, spectroscopic BS-MSE experiments (~ 1.52). Furthermore, the proposed spectroscopic BS-CPMG-MSE sequence allowed the acquisition of both BS-phase states necessary for quantifying both B_1 values in a single echo train (data not shown). Fig.2c shows the B_1^+ map obtained from the ^{1}H data rescaled by the spectroscopically derived $^{1}H/^{19}F$ B_1 ratio. The rescaled ^{1}H B_1 map aggress 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.

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-B_1^+ 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 sensitivity profile to match the values of the ^{19}F sensitivity profile. Thereby, it is important that the $^{1}H/^{19}F$ distributions in the reference are comparable to minimize deviations in the spectroscopic BS data due to spatial B_1 variations of the coil.

Taken together, this methodology is of great interest for ^{19}F quantification studies using double-resonant coils since the ^{19}F B_1^+ sensitivity profile can be quickly mapped using the ^{1}H signal together with two fast spectroscopic reference scans to evaluated the $^{1}H/^{19}F$ B_1 ratio.

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