Sodium B_1 mapping at 9.4 T

Christian C. Mirkes[1,2], G. Shajan[1], Jens Hoffmann[1], Daniel Brenner[3], Rolf Pohmann[1], and Klaus Scheffler[1,2]

[1]High-Field MR Center, Max Planck Institute for Biological Cybernetics, Tübingen, BW, Germany, [2]Department for Biomedical Magnetic Resonance, University of Tübingen, Tübingen, BW, Germany, [3]MR Physics, German Center for Neurodegenerative Diseases (DZNE), Bonn, NRW, Germany

TARGET AUDIENCE

Researchers interested in sodium MRI and sodium quantification at ultra-high field (UHF).

PURPOSE

Quantitative sodium imaging relies on accurate knowledge of the actual B_1 field distribution in order to correct for intensity variations. This becomes particularly important at UHF strengths (≥7 T), where effects such as central brightening start to become apparent. At lower fields phase sensitive (PS) sodium B_1 mapping[1] has proven to perform well even in the low signal-to-noise (SNR) regime. At UHF specific absorption rate (SAR) limits may reduce the choice of available B_1 mapping techniques. In this study the performance of the PS, the double angle (DA)[2], and the Bloch-Siegert shift (BS)[3] based methods was evaluated for sodium B_1 mapping at 9.4 T.

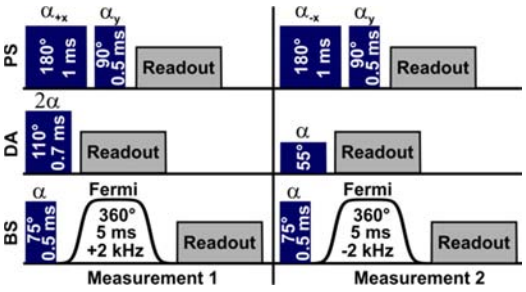

FIG. 1. Basic sequence diagrams stating pulse durations, nominal flip angles, RF phases, and frequencies for the PS, DA and BS methods. (Pulse lengths not drawn to scale.)

METHODS

All measurements were performed on a Siemens (Erlangen, Germany) 9.4 T human whole-body MR scanner. A two-channel proton patch antenna[4] was used for shimming and B_0 field mapping. The sodium signal was acquired with a 16-rung high-pass birdcage coil. The readout scheme was identical for all three B_1 mapping sequences and consisted of an acquisition-weighted stack of spirals[5] (48 partitions, 12 spiral arms per partition). The field-of-view was 240 mm^2 and the nominal spatial resolution was 3x3x5 mm^3. The shortest possible echo time was chosen for each sequence: TE(PS) = 1.0 ms, TE(DA) = 0.4 ms, and TE(BS) = 5.4 ms. Given a repetition time of 250 ms and the additional sequence parameters specified in Figure 1, the BS and PS sequences made full use of the maximal allowed SAR, while the DA method stayed well below the prescribed SAR limit. The RF field produced by the birdcage in a cylindrical phantom containing an aqueous of solution of sodium chloride (75 mM, $T_1 \approx T_2^* \approx 55$ ms) was mapped 15 times with each sequence in order to assess the standard deviation (StD) of the measured B_1 values. A Hanning filter was applied to the raw images before calculating the B_1 maps. The acquisition time for a single B_1 map with any of the three sequences was 5 min. Additionally, a B_0 map (FIG. 2) was acquired with the patch antenna to correct the maps produced with the PS method for inhomogeneities of the local static magnetic field.

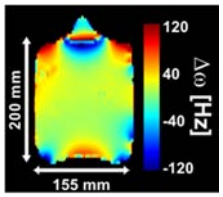

FIG. 2. B_0 map.

RESULTS

Figure 3a shows the B_1 maps generated by the three mapping sequences based on one acquisition. The PS method performs best and allows mapping even weak B_1 fields, except for regions at the very top of the phantom for which the B_0 field was not correctly mapped. If all acquisitions are averaged the three sequences show similar field distributions (FIG. 3b). Nevertheless, the calculated StD is much lower for the PS method than for the other two mapping techniques (FIG. 3c). As expected, the reliability of the DA method decreases significantly with decreasing flip angle. A similar effect can be observed for the BS method.

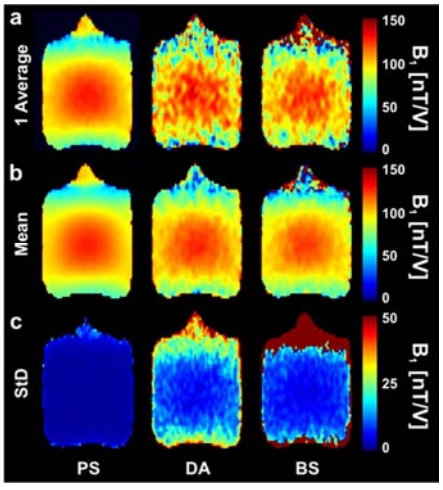

FIG. 3. a. B_1 maps generated based on one acquisition for all three mapping sequences. **b.** Mean B_1. **c.** Calculated StD across all acquisitions.

DISCUSSION & CONCLUSION

Even though the phantom used in this study had a long longitudinal relaxation time, saturation effects, which might decrease the performance of the mapping methods, could be neglected due to the long TR chosen. However, the impact of relaxation during the RF pulses needs further investigation, since the transverse and longitudinal relaxation times found in vivo are in general much shorter than those of the used phantom. Nevertheless, the PS method combined with an optimized sampling scheme for sodium appears to be a promising technique also at UHF despite its SAR intensive nature.

REFERENCES

1. Allen et al. Phase-sensitive sodium *B*$_1$ mapping. Magn Reson Med 2011;65:1125–1130.
2. Stollberger et al. Rf-field mapping in vivo. In: Proc Soc Magn Reson Med 7, San Francisco, CA, USA; 1988. p. 106.
3. Sacolick et al. *B*$_1$ mapping by Bloch-Siegert shift. Magn Reson Med 2010; 63:1315–1322.
4. Hoffmann et al. Human brain imaging at 9.4 T using a tunable patch antenna for transmission. Magn Reson Med 2013;69:1494–1500.
5. Qian et al. High-resolution sodium imaging of human brain at 7 T. Magn Reson Med 2012;68:227-233.