

B_1^+ inhomogeneity compensation for RF refocusing pulses in spatially selective excitation (SSE) at 7T

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Introduction

Parallel transmission (pTx) is often used to compensate B_1^+ inhomogeneities at ultrahigh magnetic fields ($B_0 \geq 7$ T) [1-3]. The powerful Tx-SENSE technique allows not just B_1^+ homogenization, but also provides spatially selective excitation (SSE) [4]. First results on 3D-SSE are promising but still expensive to calculate and hardware limited especially on whole-body scanners. 2D-Tx-SENSE pulses are well established for planar SSE but have no spatial selectivity along the third direction. They can be combined, however, with a conventional slice-selective refocusing pulse in order to restrict the field of excitation. This approach has the disadvantage of starting with a clean pTx excitation but ending with all the RF inhomogeneity issues of the ultrahigh field now induced by the refocusing pulse. Here we present an adapted parallel excitation (aPEX) scheme to compensate for such detrimental effects.

Methods

All experiments were performed on a clinical whole-body 7 T scanner (Siemens Healthcare, Erlangen) equipped with an eight channel Tx array. An eight channel Tx/Rx head coil (Rapid Biomedical, Rimpax) was used to acquire data from a cylindrical agarose gel phantom (0.66 g/l CuSO₄, 1.33 g/l NaCl, i.d.=19cm, l=20 cm) and a healthy human volunteer. pTx pulses were calculated as described in [1-4]. Excitation k -space was a 32-turn spiral using fourfold acceleration and constant slew rate (pulse length 2.5 ms). In vitro a conventional 2 ms RF-shimmed sinc pulse with nominally 180° flip angle was used for refocusing. Under in vivo conditions a CP-mode (i.e. non RF-shimmed) refocusing sinc pulse was used. The target pattern for SSE was a homogeneous square (in vitro: (80 mm)²; in vivo: (50 mm)²). To avoid excitation artifacts due to relaxation a phase modulation approach [5] was used for all in vivo experiments. In phantoms the common amplitude modulation approach was sufficient to get good results.

Results

In Fig. 1a,b) a spatially selective pTx pulse was used to excite the quadratic region of interest in a phantom. For slice selection an RF-shimmed refocusing pulse was used. RF-shimming removes the most severe distortions but is not sufficient to ensure signal homogeneity over the whole region of interest. An unsatisfactory signal variation is thus observed over the target area. Based on the measured B_1^+ maps for each coil element the RF-shimming efficacy and residual distortions due to the refocusing pulse can be determined prior to the SSE experiment. By pre-distorting the target pattern correspondingly, adapted 2D-SSE pulses were calculated anticipating and compensating the imperfections of the subsequent refocusing. With this approach we achieve excellent definition of the target pattern in vitro (Fig. 1c,d). The corresponding in-vivo experiments are shown in panels e) to h) but now a CP refocusing pulse was used to define the excitation region of interest along the third dimension and to ensure a flip angle of 180°. The much better performance of the adapted pTx pattern (Fig. 1g,h) vs. the non-adapted case (Fig. 1e,f) is clearly visible.

Conclusion

We demonstrated the feasibility of corrective measures if 2D SSE is to be combined with a conventional (RF-shimmed or CP-mode) slice selective refocusing pulse in vitro and in vivo. The pattern adaptation can be easily implemented into any existing SSE pulse calculation algorithm and improves image quality significantly.

Reference

- [1] Katscher et al. (2003) MRM 49:144
- [2] Yip et al. (2005) MRM 54:908
- [3] Grissom et al. (2006) MRM 56:620
- [4] Ullmann et al. (2005) MRM 54:994
- [5] Schneider et al. (2011) Proc. ISMRM 19:20

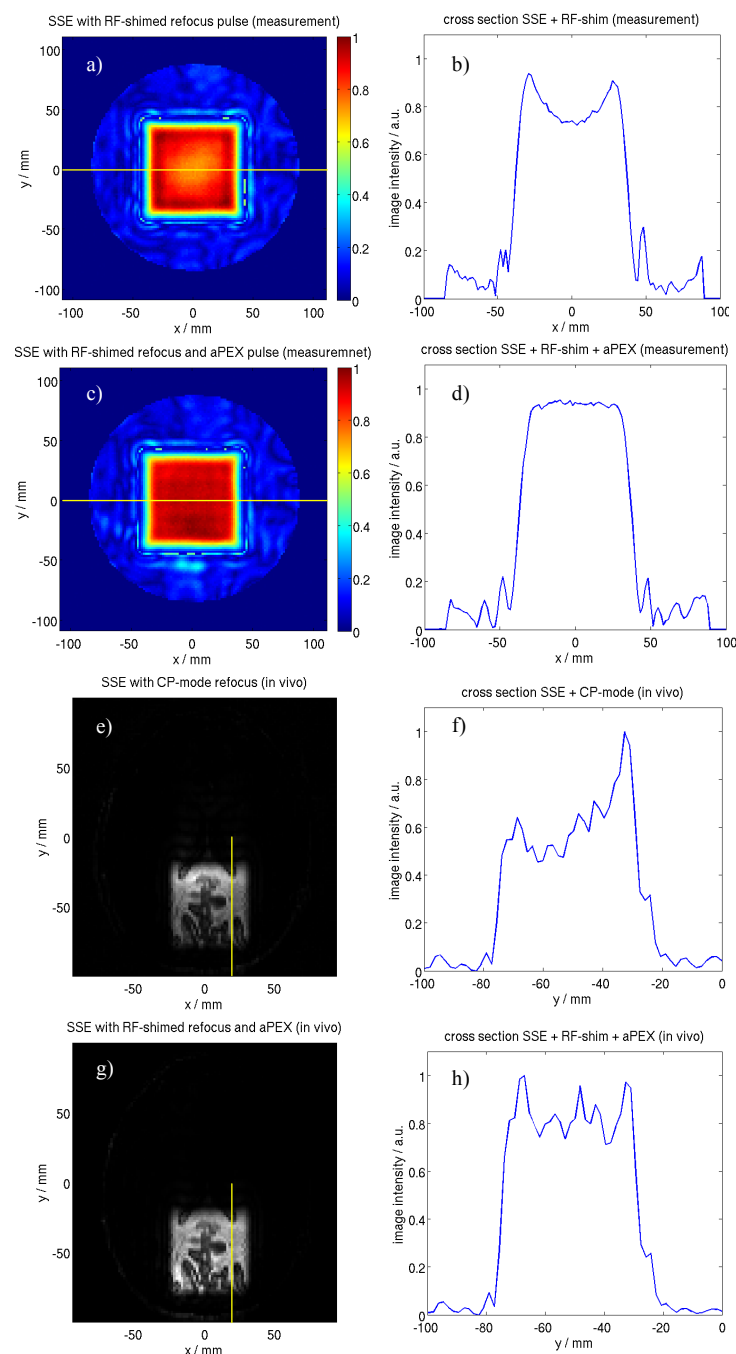


Fig.1: a) flat top SSE pattern, c) adapted SSE pattern with RF-shimmed refocusing pulse. e) flat top SSE pattern, g) adapted SSE pattern with CP-mode refocusing pulse. b) d) f) h): cross sections along the yellow line