Consistent High Acceleration Factor In-vivo Tx SENSE with Generic (Measured or Simulated) Set of B1+ Maps on Load Independent Whole-Head Tx Arrays

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Introduction

PTX approaches [1-3] have emerged as promising techniques for reducing RF inhomogeneity and/or exciting a particular pattern in an ROI as well as the minimizing potentially unsafe RF power deposition associated with 7T human MRI. Several major obstacles have prevented the widespread implementation of main-stream parallel transmission methods, specifically Tx-SENSE [4], for 7T head imaging. These include a) the need for accurate B_1^+ field maps (both phase and amplitude), b) coil and subject dependent increases in local SARs as a result of RF excitation (B_1^+ field) losses, and 3) concerns regarding the unclear RF safety assurance of the PTX experiment due to inappropriate electromagnetic models for the estimation of the SAR at ultra-high fields (mapping the B_1^+ field does not provide the complete picture of the electric field and thus power deposition.) This work demonstrates consistent (12 subjects were imaged) high acceleration factor in-vivo Tx-SENSE with a generic measured or simulated set of B_1^+ Maps on load independent whole-head 7T Tx Arrays. The Load Independent 16-channel Tx array covers the whole head volume.

Methods

Tx Array: The current configuration of the 16-channel transmit array contains 5 decoupled sets of coupled arrays. The coupled arrays are devised as follows: 2 elements on the top of the head, 3 elements on each side of the head and 4 elements in-front and back of the head. The elements on each side are arranged in a cross-pole configuration. This design was realized from extensive simulations and practicality (photograph of the Tx/Rx array set-up in the scanner is shown in Fig. 1.) The strong coupling in this design exists only between elements on an array side, minimal coupling (maximum of -15.4dB and an average well below -25dB) is observed between elements on different sides. As we currently posses an 8-channel transmit array, the 5-sided coil was tested using 8-ports (front and back Tx ports or top and sides Tx ports.)

Pulse-Design: RF pulses for parallel transmit experiments were designed using Grissom and et al. method [4] with the small angle approximation. The interleaved spiral gradient waveform was designed with the maximum gradient amplitude and slew rate equal to 24 mT/m and 80 mT/m/ms, respectively and designed excitation FOV is 220 mm. To achieve accelerated excitation factors of 2 and 4-folds, the spiral with 2 and 4 interleaves were used. The durations of the spiral waveforms for the 2 and 4-folds accelerated excitation were 3.31 ms and.

RF Simulations: We used a finite-difference time-domain method that includes an accurate transmission-line feed model mechanism to calculate the B_1^+ and E-field profiles. The resolution of the model is 0.16cm to guarantee all the fine structure of the coil is captured for accurate modeling. All array channels of the coil are connected to 50Ω transmission line. The S-parameters of the loaded coil is calculated and successfully verified (including all the high-coupling values between the designated coupled elements) with measurements obtained using a network analyzer.

Experiments and B_1^+ Mapping: We have imaged 12 subjects with 6 of them multiple times. The B_1^+ maps were obtained for every subject.

Results and Discussion:

Fig. 2 displays B_1^+ maps obtained from two different subjects. The maps display almost identical patterns for both subjects. Fig. 3 displays in-vivo Tx SENSE obtained using B_1^+ maps that were obtained from the numerical simulations on visible human project. Figs 3-5 shows wide variety of Tx-SENSE results on sample 4 different subjects. The B_1^+ maps were interchanged between subjects and the Tx Pulse design was directly implemented from one subject to another in the same session. The results show excellent insensitivity to different subjects as the B_1^+ maps were seamlessly exchanged between different subjects with minimal (if any) observable effects on the design of the Tx-SENSE patterns. Clearly the B_1^+ field distribution is dominated by positioning in the coil geometry rather than in the subject as the designed excitation patterns are observed in the same coil positioning. The proposed approaches can pave the way for more robust and repeatable PTX applications on 7T.

Acknowledgements: NIH 1R01EB, ADRC

References:

1. Adriany, G., et al., MRM, 2005. p. 434-45. 2. Alagappan, V., et al. in *ISMRM*. 2006.
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Fig. 3: In-Vivo Tx SENSE using simulated B1+ maps with Acceleration factor of 2 and using 4-channel (coupled) Tx.

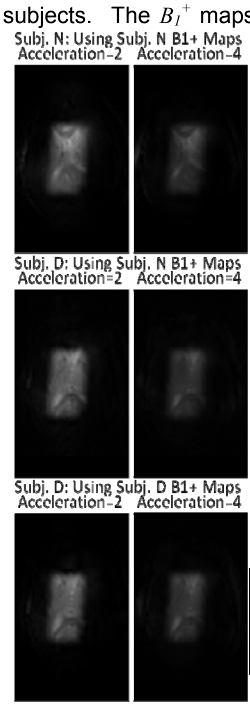

Fig. 4 Tx SENSE using 8-ch Tx/Rx array tuned to Subj. N and the B1+ maps from Subj. N (Fig. 2) is used for designing the Tx-SESNSE pulses for both Subjs. N & D.

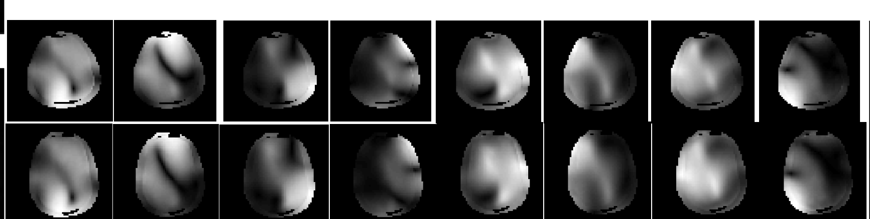

Fig. 2 (Top): B1+ / (SOS B1+) Maps from 8-chs: Subj. N (Top) and Subj. D (Bottom). Same (Subj. N) tuning/matching is used for both subjects.

Fig. 1 (Right): 8 or 16-Ch. Tx /Rx Array inside the 7T scanner.

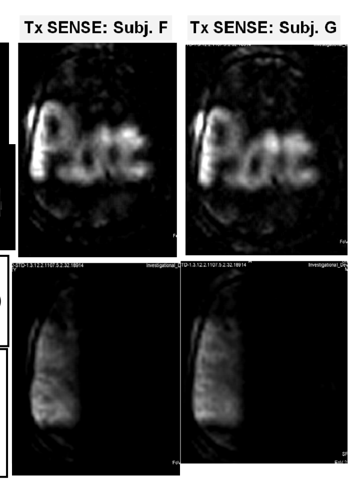

Fig. 5 (Right): Acceleration Factor = 4 Tx SENSE. The 8-ch Tx/Rx array is tuned using Subj. C and the B1+ maps from Subj. G is used for designing the Tx-SESNSE pulses for both Subj. F & Subj. G.