Supporting information

Simulated B_1^+ fields

The simulated coupling between adjacent transmit elements (when converted to a fraction of coupled power) matched experimental measurements to within 2 percentage points: this close agreement ensured consistency between the spatial patterns of the corresponding B_1^+ distributions (**Figure 11**). The mean and 95th percentile simulated and experimental B_1^+ maps of the phantom, when combined in CP mode, differed by -11.5% and 1.4%, respectively. For 10,000 random shim settings (magnitude and phase), the vast majority of solutions resulted in deviations between any combined simulated and experimental B1+ map that ranged within +/-40% (mean and 95th percentile). However, these results included some uncertainty because the masking of the simulated and experimental maps were different.

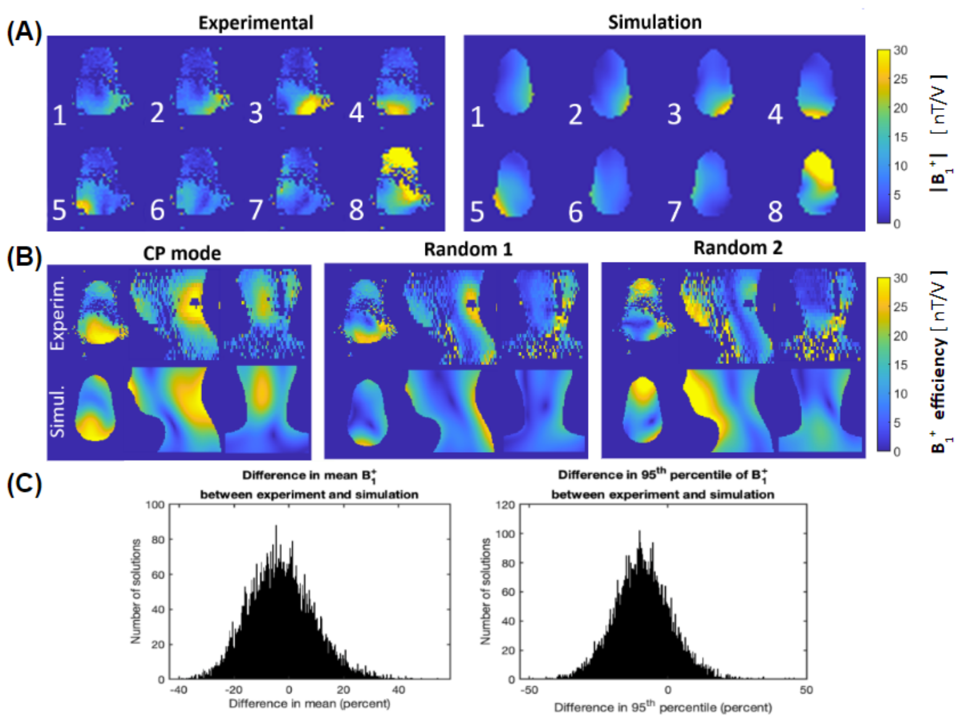

Figure 11. **(A)** A representative axial slice of B_1^+ maps (of the spine phantom) from individual transmitters derived from experiment (left) and simulation (right). **(B)** Complex scaling factors were applied to simulated B_1^+ fields to increase agreement with experimentally derived maps—resulting in a commensurate agreement when comparing B_1^+ maps combined in CP mode (left) and two random shim modes (center, right). **(C)** When combining the eight transmit channels with 10,000 different random shim settings, histograms of the deviation between the mean and 95th percentiles of the simulated and experimental B_1^+ distributions showed that most of the solutions are within +/-40%.

Simulated B_1^+ shimming

B_1^+ shimming provides the flexibility to tailor the B_1^+ field according to the requirements of the pulse sequence, whether that necessitates an improvement in transmit uniformity, efficiency, or local SAR. Individual B_1^+ maps, when combined in the nominal CP mode (phase-only shim solution), produce a mean B_1^+ over the spinal cord of 17.9 nT/V with a CoV of 39.8% (see **Figure 12 (A)**). When a shimming algorithm that maximizes transmit uniformity is employed, this metric is improved to 15.4% with a reduction in mean B_1^+ of 69%. If the transmit efficiency is maximized, a phase and magnitude shim solution can improve the efficiency of the CP mode by 12%, with a 2.8% decrease in uniformity. Shimming solutions can be computed within the bounds of these solutions by altering the regularization of the cost function, which allows a trade-off between B_1^+ efficiency, uniformity, and local SAR.

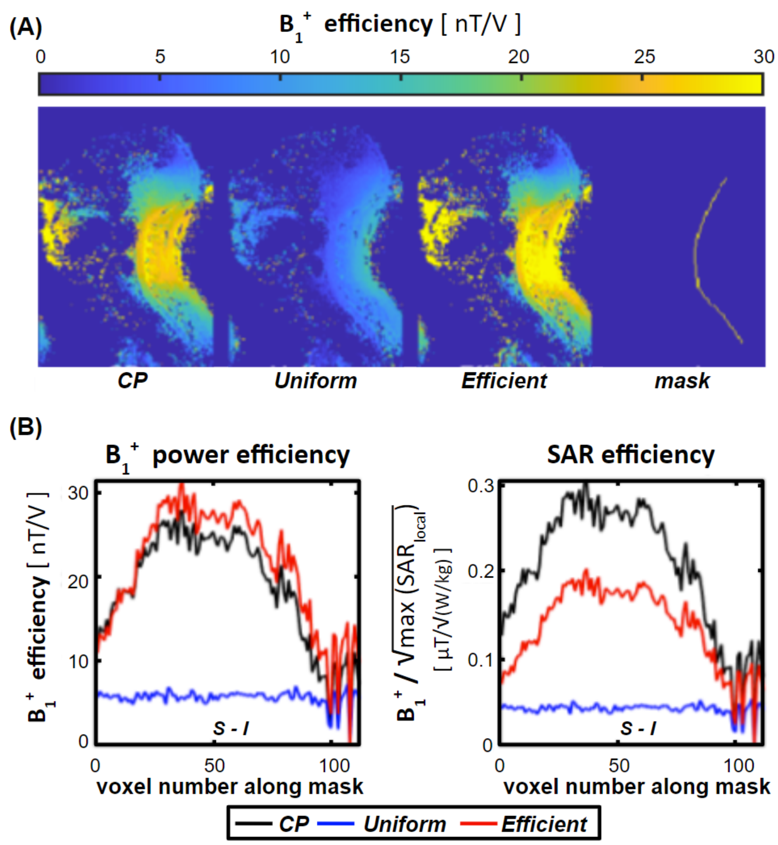

Figure 12. (A) B_1^+ maps with transmitter shim weights set to produce: (left) the nominal CP mode (i.e., a phase-only shim that produces the highest B_1^+ efficiency in the C3 vertebrae); (center) the highest B_1^+ uniformity over the spinal-cord region defined by the mask; and (right) the highest B_1^+ efficiency over the same region. **(B)** Plots of the B_1^+ power efficiency and SAR efficiency for these shim solutions demonstrate the breadth of the solution space—the shimming algorithm can then be tailored to the requirements of the desired pulse.

Whereas high transmit efficiency may be required for short, high flip-angle RF pulse, the SAR efficiency of the shim solution, ${B_1}^+/\sqrt{max(SAR_{local})}$, is often the limitation when determining the allowable number of slices and repetition time. Power efficiency and SAR efficiency are not necessarily synonymous, as evidenced by the ${B_1}^+/\sqrt{max(SAR_{local})}$ of the shim solutions presented in **Figure 12 (B)**, where the CP mode attained the highest ${B_1}^+/\sqrt{max(SAR_{local})}$, but not the highest power efficiency.