Impact of number of Tx channels for RF shimming – an in vivo study

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Introduction: At high static field strength (≥3T), the inhomogeneity of the transmit (B_1^+) field results in spatially varying contrast artefacts that can significantly reduce the diagnostic quality of images. Utilising multi-channel transmission, RF shimming can be performed on each subject individually to mitigate B_1^+ inhomogeneity and improve image fidelity but the impact of the number of channels has not yet been investigated thoroughly in vivo. A systematic study is presented where 8-channel transmission hardware is used to study coil configurations with 1, 2, 4 or 8 independent channels.

Methods: In vivo scanning (7 volunteers, 2 male and 5 female, age; 23-56, BMI: 18-27) was performed on a 3T Multi-Channel Transmit MRI system (Philips Healthcare, Best, Netherlands) equipped with an 8-channel TX/RX body coil [1, 2]. A 6-channel torso array was used for signal reception. Actual Flip angle Imaging (AFI) [3] with slice-profile correction [4] was used to acquire axial 2D B_1^+ maps of the pelvis and thighs (440x220 FOV, 64x63 matrix, angle = 80^o, TR_1=30ms, TR_2 = 150ms, TE = 4.6ms). Predefined linear combinations of the channels were used to create a 4-channel, 2-channel and a single channel (nominal quadrature) mode. Magnitude Least Squares optimization with Tikhonov regularization was used to perform RF shimming for each coil configuration via the local variable exchange method [5], implemented in MATLAB. The relative drive parameter combinations used for each number of channels were chosen using test data from 10 subjects to be the most efficient in terms of the shim error/power trade-off encountered due to power regularization. Once RF shims were calculated, B_1^+ maps were reacquired for each configuration as well as T_1w-TSE images (440x220 FOV, 400x318 matrix, TR = 605ms, TE = 10ms, TSE turbo factor = 3), in order to quantify B_1^+ homogeneity and image performance. Specific Absorption Rate (SAR) was limited to 10% of the maximum allowed SAR for all acquisitions for safety reasons. B_1inhomogeneity was quantified using coefficient of variation $C_v = \sigma (B_1)/|\mu (B_1)|$, which provides a pure measure of homogeneity that is robust to scaling. Successive differences with number of channels were tested for significance using a paired t-test. Image improvements were verified visually and graded by an expert blinded to the shim settings on a 5-point scale [6].

Results: For the quadrature case, all B_1^+ maps had regions of low flip angle and these were apparent in the resulting T_1w images, as severe shading artefacts. Calculating RF shims for each configuration took approx 10s in total on a standard desktop PC. The average homogeneity improvement, $1\text{-}C_v/C_{v\ quad}$, in the pelvis was 11±3%, 26±3%, 30±1% and in the thigh region was 6±1%, 31±4%, and 44±4% for the 2, 4 and 8 channel configurations respectively. Minimizing total RF drive power (as a proxy for SAR), quadrature homogeneity can be achieved with an average of 18±8%, 24±7% and 30±4% less power for the 2, 4 and 8-channnel configurations. All differences were significant ($p< 0.01$). Fig.1 shows pelvis and thigh results for a typical subject. Major B_1^+ signal dropouts in both anatomical locations are progressively mitigated as the number of channels is increased. Corresponding improvement is seen in the T1w images (No correction applied for receiver effects). The images grading results were 4.0±0.63, 4.33±0.52, 4.50±0.55, 4.67±0.52 and 2.5±0.55, 3.67±1.03, 4.33±0.52, 4.67±0.52 for pelvis and thighs respectively for quadrature, 2, 4 and 8 channels.

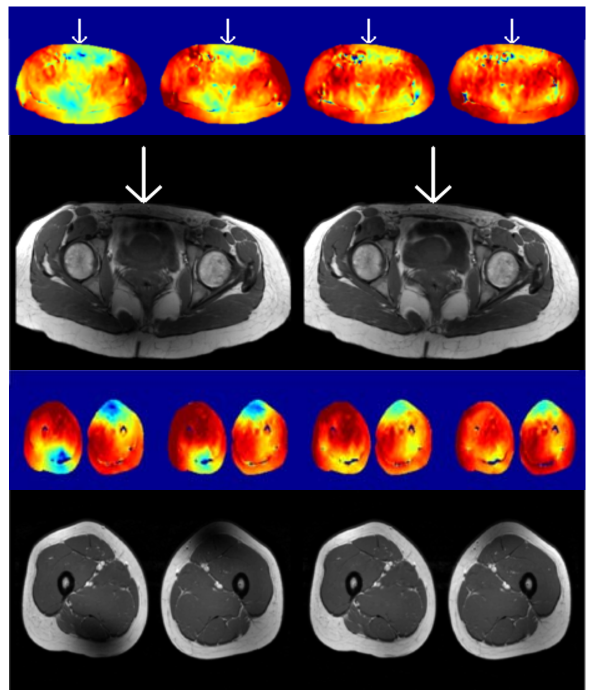

Figure 1 - B_1^+ maps (1st, 3rd row) of the pelvis and thighs are shown for quadrature, 2-, 4- and 8-channel (left to right).T_1w-TSE images (2nd, 4th row) acquired in quadrature mode (left) and with 8 channels (right), loss (and recovery) of signal in the pelvis is shown by arrows.

Discussion: For each anatomical region, a significant progressive improvement in B1+ homogeneity with increase in number of channels has been found. Conversely, the drive power (and hence global SAR) required to achieve quadrature homogeneity significantly decrease with increasing numbers of channels. The levels of improvement are obviously specific to the coil geometry used for the study, but are likely to provide a reasonable guide for enveloping arrays. The consequences for imaging performance depend on the specific choice of sequence, however, more robust control over the homogeneity yields greater contrast uniformity and lower drive power is likely to allow time savings.

References: [1] Vernickel P et al. MRM 2007;58:381-9. 15 [2] Grässlin I et al., ISMRM 2006, p.129. [3] Yarnykh VL. MRM 2007;57:192-200. [4] Malik SJ et al. MRM 2011;65:1393-1399. [5] Setsompop K et al. MRM 2008;59:908-915 [6] Willinek WA et al, Radiology 2010;256:966–975.

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