Combinations of Weighted First and Second-order Clockwise CP Modes To Improve Image Homogeneity with a 16-Channel Head Array at 7 Tesla

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INTRODUCTION

Standing wave effects inside the object at ultra-high field create inhomogeneous B_1^+ field distributions that cause strong signal fluctuations in the resulting image. Recently, several methods using parallel transmit (pTx) systems [1] and variable transmit array coil configurations [2] were proposed to mitigate B_1^+ inhomogeneity acting as an RF-shimming method [3]. More recently, in order to access different circularly polarized (CP) modes sequentially, Butler matrix [4] networks were used for the excitation of the available phase modes of the RF coil arrays. However, not all modes are of the same importance since the CP^+_1 mode (first-order clockwise CP) as the dominant mode is always necessary to get a homogeneous image. Remaining anti-CP modes are less important for acquiring homogeneous images. In this work, selected combinations of weighted CP^+_1 and CP^+_2 mode are proposed to reduce B_1^+ field inhomogeneity. A designed 16-ch. transmit head-array coil was connected to a 16x16 Butler Matrix network using an 8-channel pTx system for excitation of a coil array in a 7T system.

MATERIALS AND METHODS

The experiments were performed on a Siemens 7T whole-body system (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) equipped with 8 transmit (8 × 1 kW peak RF power) and 32 receive channels. A 16-channel transmit array (dia. 27cm, length 15cm) was constructed with lumped element components. Adjacent elements were capacitively decoupled. The 16 ch. head-array was driven by the 16x16 Butler Matrix network [4], which was connected to the outputs of the 8x8 Butler Matrix used as a variable power combiner with an 8 ch. pTx system for acquiring several clockwise CP modes [5]. For the comparison of the B_1^+ homogeneity distribution, B_1^+ mapping sequences were applied to acquire gradient recalled echo images (GRE, TR=100, TE=10, α=25°) for several clockwise CP modes. A spherical sugar/water mix phantom (dia. 17 cm, ε_r =45.20, σ = 0.87: Water 38.05%, Sugar 56.05%, Salt 5.9%) was chosen as the permittivity (ε_r) and conductivity (σ) a comparable to the human brain tissue.

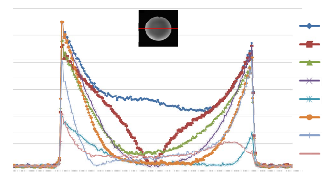

Fig 1: 1D Profiles along the L-R direction of the phantom's central GRE axial slice for several clockwise CP modes

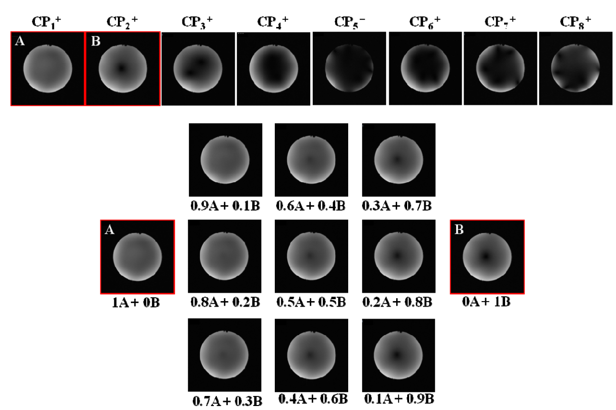

Fig 2: GRE sugar/water phantom. **Top row**: images generated by CP^+_1 mode and clockwise higher CP modes. **Remaining rows**: to estimate the optimal image combination, selected combinations of weighted CP^+_1 mode (A) and CP^+_2 mode (B) were generated.

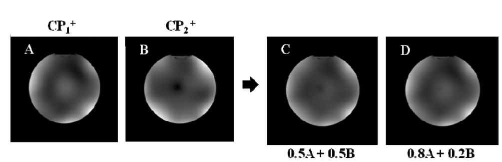

Fig 3: The optimal combination based on weighted images (C / D = 0.5A + 0.5B / 0.8A+ 0.2B) of GRE water sphere phantom images generated by CP^+_1 mode (A) and CP^+_2 mode (B).

RESULTS

Spatial-dependent flip angle (FA) maps using sugar phantom were measured from the CP^+_1 to the CP^+_8. To compare the B_1^+ field homogeneity on the central axial GRE slice along the left-right (L-R) direction, the one dimensional signal intensity (SI) profiles for several modes of the top row of Fig. 2 are shown in Fig. 1. The CP_1^+ mode has a higher homogeneity in the entire image compared to the other modes despite of some variance across the center of the image with lower SI. Especially the CP^+_2 mode has a lower B_1^+ SI in the central region as compare to the peripheral region. In Fig. 2, the GRE images according to different modes are shown in top row ranging from the CP_1^+ to the CP_8^+. A good agreement was achieved between FA maps and GRE image for all modes. To estimate the optimized image combination CP^+_1 and CP^+_2 modes were added using different weighting factors. Some weighting combinations (CP^+_1 : CP^+_2 = 0.9 : 0.1, 0.8 : 0.2, 0.7 : 0.3) were found to exhibit the most homogenous B_1^+ fields for the designed 16-ch. transmit head-array. Within the combined images more than 40% of the B_1^+ field inhomogeneity was significantly decreased in the center region. In Fig. 3, GRE images of a water sphere phantom was compared using weighting factors of CP^+_1 : CP^+_2 = 0.5 : 0.5, 0.8 : 0.2. The image combination using 0.8 CP^+_1 and 0.2 CP^+_2 showed the best B_1^+ field homogeneity compared to the other combinations.

CONCLUSION

Different combinations of weighted CP^+_1 and CP^+_2 modes were analyzed. Compared to other combination as well as to the uniform birdcage mode the best B_1^+ field homogeneity was found by a combination using 0.8 CP^+_1 and 0.2 CP^+_2. With this RF-shimming method combined with data post processing more homogeneous images can be achieved than using solely the pure CP^+_1 mode in 7T.

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