Improved B1+ field using a 16-channel Transmit Head Array and an 8-channel pTx System at 7T

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INTRODUCTION

At 7T, transmit coil arrays using parallel transmit (pTx) [1] systems enable techniques to substantially improve B_1^+ transmit fields. Receive coil arrays offer enhanced sensitivity and parallel imaging performance. However, significant challenges in ultra high field systems are still remaining for the design and implementation of RF-coils for dedicated transmit channels and their integration into existing pTx systems. It has been suggest to increase the number of array elements for both parallel transmission and receive. Most transmit head-arrays at 7T were designed as 8 separate channels for transmission and reception, using variable cylindrical geometries. Frequently, strip-line, hybrid coil elements, or TEM resonators were used as coil structures. However, a large benefit of loop elements is the ability to minimize interactions between elements. This work was therefore focused on the construction of a 16-channel head-array for available combined 8-channel and individual 16-channel transmission systems, resulting in a RF-coil with a total of 8-channel pTx system. The flip angle (FA) maps of an oil and water sphere phantom were acquired using this prototype. The 16 individual FA maps for all channels and 8 combined FA maps of the 16-channel head-array were compared to a commercially available 7T 8-ch. Tx/Rx head-array (RAPID Biomedical, Würzburg, Germany).

MATERIALS AND METHODS

All measurements were performed on a whole body 7T scanner (Siemens Medical Solutions, Erlangen, Germany) equipped with an 8-ch. transmit array feeding eight 1 kW peak RF power amplifiers. For 16 RF excitation of the head-array, 8 Wilkinson power splitters were used with 22.5° out of phase shift through an extra cable length as shown in Fig. 1. The head-array was placed on formers with a diameter of 27 cm as shown in Fig. 2. For a uniform birdcage mode, the phase difference of each element was distributed every 22.5° out of phase by 8-ch. pTx system using 45° difference. The 16-ch. array was designed without overlap. The distance was 1.4 cm between elements (horizontal / vertical = 3.9 cm / 15 cm and conductor width of 0.5 cm). For reducing crosstalk between neighboring elements, capacitive bridge technique was adapted with decoupling capacitance of 15 pF. An approach to B_1^+ characterization of 16-ch. array involves individual 16 FA maps as well as combined 8-ch. excitation using two elements in order to compare FA maps. The B_1^+ maps of the oil and water sphere phantom were obtained with the AFI (Actual Flip Angle) sequence [2] including its spoiling improvements [3]. The sequence parameters were: 2.56 ms sinc pulse, TR_1 / TR_2 = 50 / 150 ms, 6 mm isotropic resolution with a 64 x 64 x 32 matrix. Thus, the whole set of AFI acquisitions took 6 minutes for each channel.

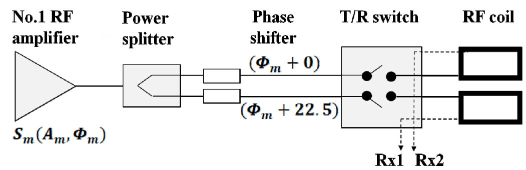

Fig 1: Schematics of a 2-elements RF excitation with 1 transmit RF excitation.

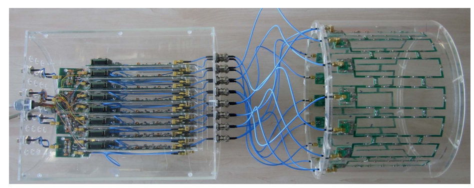

Fig 2: 16-channel transmit coil to drive eight 1 kW RF amplifiers

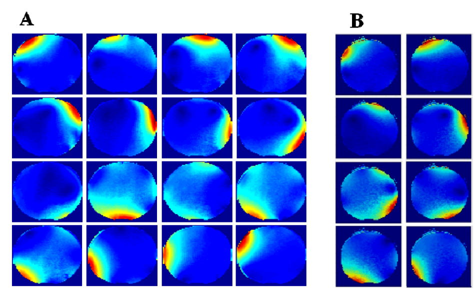

Fig 3: Flip angle measurement of the designed 16-channel head-array. A) 16 individual FA maps for the odd and even channels B) 8 individual FA maps of combined excitation using 2 elements

RESULTS

Tuning, matching and decoupling for all elements was optimized at 297.2 MHz (7T) being loaded with the oil phantom (17 cm dia.). S_{12} coupling between neighboring elements ranged between -18 dB to -24 dB. S_{11} match was also better than -25 dB for each element. Fig. 3A shows FA maps of the 16 individual elements on a central axial slice of the oil phantom. The 16 normalized FA maps were acquired for the odd and even channels of 16 elements head-array using dedicated 8-channel driven pTx system. In Fig. 3B, 8 individual FA-maps from combined excitation of two elements were measured. The differences of the FA for RF-array was evaluated as effective FA for the chosen FA (α = 100°). In Fig. 4, the FA map of 16-ch. (Fig. 4A), 8-ch. (Fig. 4B) using combined excitation, and RAPID 8Ch. Tx/Rx transmit coil (Fig. 4C) showed good B_1^+ field homogeneity. Both measurements were acquired with an identical FA and on the same oil phantom. The distribution of FA maps in the 16-ch. transmit (Fig. 4A) is more homogeneous than the two 8-ch. transmit configurations. The 16-ch. transmit array standard deviation is 3.2 of effective FA for α = 100°. On the other hand, the RAPID 8Ch. Tx/Rx transmit coil has a standard deviation of 4.3. Therefore, the FA difference of the 16 excitation channel configuration was measured to be decrease by 68% compared to 8 excitation channels. For better comparison of B_1^+ field, FA-maps were modeled by mesh plots and compared with a water phantom as shown in Fig. 5 The FA distribution of 16-ch. transmit (Fig. 5A) exhibits a more homogeneous transmit field than the RAPID 8Ch. Tx/Rx transmit coil. The FA difference of 16-ch. transmit array has 15% higher than standard 8-ch. transmit case (16-ch. / 8-ch. = 14.32 / 16.56).

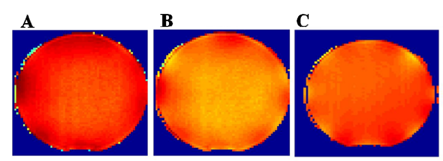

Fig 4: FA distributions of A) 16-channel transmit, B) 8-channel combined excitation, and C) RAPID 8Ch. Tx/Rx transmit array using oil phantom. The standard deviation value was measured for each array (A / B / C = 3.2 / 5.4 / 4.3).

CONCLUSION

The designed 16-channel transmit array and RF-Interface (Fig. 2) shows different FA-maps in comparison to the 8-ch. combined excitation and RAPID Biomedical 8Ch. Tx/Rx head-array at 7T. The B1+ homogeneity generated by the 16-channel transmit array was more uniform compared to the 8-ch. combined excitation and RAPID Biomedical 8Ch. Tx/Rx head-array.

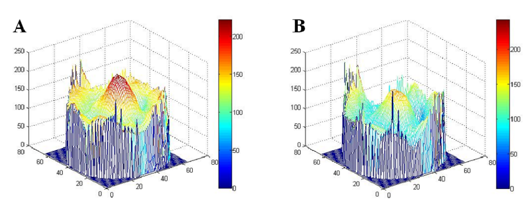

Fig 5: FA distributions of A) 16-channel transmit, B) 8-channel excitation using water phantom. The standard deviation value was measured for each array (A / B = 14.32 / 16.56).

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