Prototype 8-Channel Parallel Transmit Body Array in a Clinical 3T System

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Introduction: In our previous studies[1-3], the performance of a whole body transmit array with 8- and 16-channel was investigated numerically for body imaging at 3T, particularly in terms of excitation homogeneity and specific absorption rate (SAR). The 8-channel transmit array was further investigated and implemented such that it can be inserted into a commercial 3T system above the patient bed with minimal coupling to the existing body birdcage coil. This setup also allows for the use of commercial receive-only arrays in combination with transmission through the whole body array[3]. Such a design benefits from the signal-to-noise ratio (SNR) offered by the commercial receive-only array. Meanwhile, a trade off for this design is limitations in the geometry and placement of the transmit array coil elements. Here, we report progress on a prototype where 7 stripline transmit elements are placed in the space above the patient bed and the 8th stripline element sits on the patient bed.

Method: Array Description: The elements of the 8-channel transmit array were constructed with copper plates, wood, and Derlin, as shown in Figure 1*a*. Wood planks with dimensions of 4×6×56 cm^3 were used as the supporting member of each coil element, where two sets of copper plates (42 cm and 50 cm in length) could be mounted on and made up the inner conductor and ground plate of the element. Two in-house-made male joints, created from Derlin boards, were mounted on both ends of the wooden supporting member and were later used to attach the coil element onto the array skeleton (described below). Each element was tuned to the resonant frequency of ^1H at 3T by three static (100C; ATC Ceramics, NY, USA) and two variable capacitors (NMAF20; Voltronics Corp., Denville, NJ, USA), located evenly on the inner conductor and both ends of the coil element, respectively. A simple matching circuit and a cable trip were soldiered on a PCB board which was placed at one end of the coil element. A passive detuning method with two PIN diodes was utilized in this array design to detune the transmit array during reception. The array skeleton was constructed with two end arcs (222-degrees and O.D.: 59 cm) and four supporting rungs (67-cm in length) in a gapped toroid shape. The end arcs and the supporting rungs were also made by Derlin boards. On each of the end arcs, seventeen in-house-made female sockets were installed with equal spacing to allow the coil elements to attach to the array skeleton at a desired azimuthal angle that minimize the interference between the 8-chnnel transmit array and the existing system body birdcage coil. In the current design, seven coil elements were attached to the array skeleton at the 2th, 4th,6th,9th, 12th, 14th, and 16th sockets. The 8th element was situated on the center of the patient bed. Additionally, coil elements 3, 4, and 5, located on the 6th,9th, and 12th joints were moved 1 inch toward the magnet center compared to the other elements on the array skeleton. After construction, the array, shown as Figure 1*b*, was inserted into a 3T whole body system (Magnetom 3T, Siemens Healthcare, Erlangen, Germany) equipped with a 8×8 kW peak RF power amplifier (Analogic, Peabody, MA) for imaging. Experimental Measurement: For testing purposes, a plastic cylindrical container (2.5 gallon; Eagle Manufacturing Co, Wellsburg, W.VA) filled with deionized water and doped with 50 mM NaCl was imaged using our 8-channel transmit array for excitation and two phased-array coils (4-Channel Flex Coil, small; Siemens) for reception. Relative B_1^+ magnitude and phase were mapped with 9 small tip angle GRE images: 1 image obtained pulsing through all coils with a quadrature-type excitation and 1 image from each individual coil (8 total). An AFI acquisition was performed to convert relative B_1^+ magnitude to absolute magnitude[4]. RF shimming was performed with an in-house routine written in IDL[5]. An in-vivo experiment was performed on the upper thighs of a healthy volunteer. The aforementioned B_1^+ mapping and RF shimming techniques were utilized. GRE images with a resolution of 1.37 x 1.37 mm, TR = 200 ms, and a 6 degree flip angle were acquired with both quadrature drive and RF shimming settings.

Results and Discussion: All elements were tuned to better than -25 dB on the phantom and the next neighbor coupling for all elements was better than -8 dB. This indicates that the array elements were properly placed between the rungs of the system body birdcage coil and a decent isolation between any two transmit coils was achieved. The magnitude and phase of the B1+ maps for each individual coil element across the center slice of the phantom are shown in Figure 2. The variation of the average B1+ magnitudes between the channels are closely related to the distance between the coil element and the phantom. The shorter the distance, the stronger the field intensity, as shown in the maps for channels 3, 4, 5 and 8. Channel 4 and 8 are close enough to the phantom that a center brightening is exhibited. A clear excitation pattern for a single element was shown in the magnitude maps on channel 1 to 3 and channel 5 to 7, which reflects the good isolation between channels. To demonstrate the RF shimming capability of this 8-channel transmit array, the flip angle maps on the same phantom under a pseudo quadrature and an RF shimming excitations are shown in Figure 3. The coefficient of variation was reduced from 0.305 with quadrature to 0.103 with RF shimming. Lastly, an axial GRE image of the human thigh with these two excitations is presented in Figure 4. The power level for each individual channel was limited under 200 W to ensure the volunteer safety.

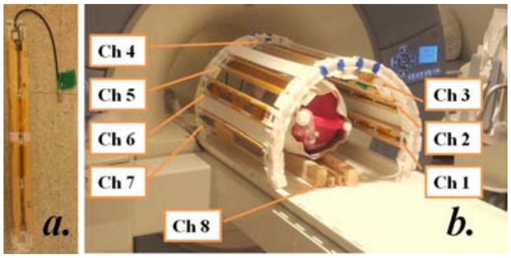

Figure 1: ***a*) a coil element of the transmit array. *b*) the implemented transmit array placed above the patient bed before it is inserted into the magnet.**

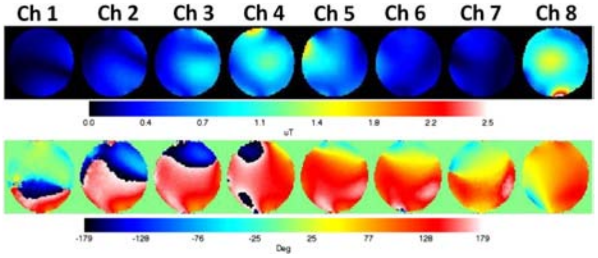

Figure 2: Magnitude (top row, in μT) and phase (bottom row, in degrees) of the B_1^+ maps for each individual channel across the center slice of the phantom.

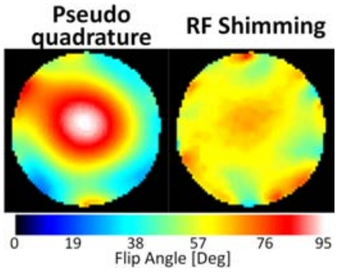

Figure 3: The flip angle maps across the center slice of the phantom using a pseudo quadrature (left) and an RF shimming (right) excitation with a nominal flip angle of 60°.

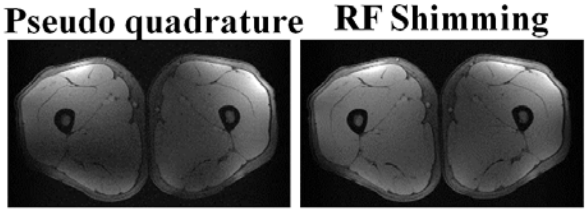

Figure 4: Human thigh images using a pseudo quadrature (left) and an RF shimming (right) excitation.

References: [1] Ryu *et al.*, ISMRM 2009; 3046. [2] Ryu *et al.*, ISMRM 2011; 3827. [3] Ryu *et al.*, ISMRM 2012; 2613. [4] Van de Moortele *et al.*, ISMRM 2007; 1676. [5] Sica *et al.*, ISMRM 2012; 3481.