B1 Transmit Field Correction at 7T using Coupled Inner Elements

H. Merkle[1], S. Wang[1], P. van Gelderen[1], T. Q. Li[1], J. Murphy-Boesch[1], A. P. Koretsky[1], and J. H. Duyn[1]
[1]LFMI, NINDS, National Institutes of Health, Bethesda, MD, United States

Introduction: RF dielectric effects at 7T cause brightness of intensity in the images at the center and dark regions in the periphery of the human head. While image intensity variation from receive phased arrays can be corrected in post processing, the transmit (Tx) B1 field profile in the human head needs to be corrected in hardware in order for many sequences to work efficiently and provide uniform contrast. To date, isolated loop elements tuned off-resonance have been considered for this application [1-3], and their effects have been evaluated using image intensity, which combines the effects and Tx field and receiver array. Here we consider the implementation of a radially distributed, multi-loop array and evaluate its performance using direct B1-field measurement [4] in a phantom.

Methods: An 8-element array of circular loops was assembled and mounted on a 17.8 cm (7") Lucite™ cylinder. Within this cylinder was positioned a 15.2 cm dia. loading phantom described below. The element diameters were chosen to be 9.5 cm so that their overlap would inductively decouple neighboring elements. The elements used 6 capacitive breaks and were activated during Tx using PIN diodes, which were controlled by circuitry external to the magnet room. The loading phantom had inner diameter and length of 14 cm each, was filled with 9.5 mm diameter 14 cm long acrylic tubes, and then filled with a 2/3 normal saline solution for loading and doped with 0.5 mM Gd DTPA (Magnevist™, Berlex Labs, N.J.) to reduce T1. The tubes serve to reduce the dielectric constant to a value similar to that found in human brain. With this construction, the phantom exhibits a dielectric effect similar in amplitude to that of the human head. The field-focusing elements were centered and individually tuned to 310 MHz within the volume of a commercial 7T 4-Port, Tx coil, model NM008B-7T-GE (NOVA Medical, Wilmington, MA). The sequence for measuring the B1 field in the phantom uses a stepped saturating pulse before normal excitation by an EPI sequence [4]. Image data from this sequence is processed off-line.

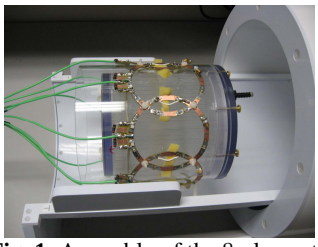

Fig. 1: Assembly of the 8-element array on the loading phantom.

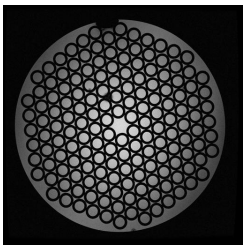

Fig. 2. Axial image of the dielectric adjusted phantom.

Results: Gradient-echo images were acquired using a 7T GE Signa whole-body MRI scanner, and B0 shimming was performed using an imaging based sequence to correct 3 first order and 5 second order shims. A typical axial image of the phantom acquired using a gradient echo sequence is shown in Fig. 2. The B1-field mapping sequence was then used to acquire image data. In Fig. 3(0), the field was mapped with all elements off. The field shows an axially symmetric distribution. Figs. 3(1-8) show field measurements with elements turned on one at a time. Observed with a network analyzer and a small pick-up loop, individual elements did not significantly modify the tuning of the volume coil modes. For the case when all elements were activated, coupling of the resonant elements and other issues resulted in disabling of the loop array and evidence of the production of a new birdcage mode.

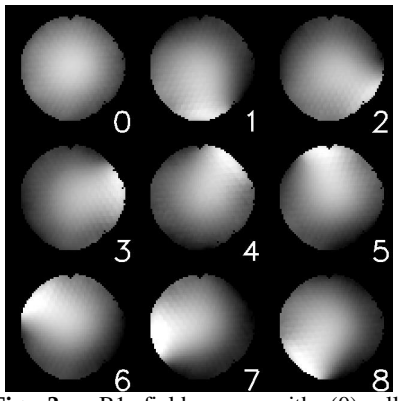

Fig. 3. B1 field maps with (0) all elements off, and (1-8) one element at a time on.

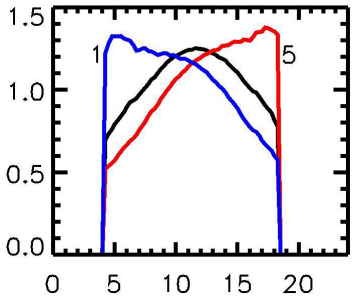

Fig. 4. Vertical profiles from field maps of (0), and top (5) and bottom (1) elements.

Discussion: The method proposed here [3] for improving the Tx B_1 field homogeneity uses an outer-layer volume coil coupled to an inner-layer array of field-focusing elements. The advantage of using an array of focusing elements separate from a receiver array [2] is that the arrays can be individually optimized and separately controlled. Our results demonstrate that individual elements provide more than adequate field correction for the dielectric mode of the phantom. The problem with the current phantom is that the circular symmetry results in a birdcage-like resonant mode, thwarting B1 compensation. Since the symmetry of the head is different from that of a circular phantom, application to the head (or a similarly shaped phantom) should suffer this problem to a less degree. The combination of B1 field mapping sequence with the adaptable focusing coils allows for B1 shimming in a form quite similar to higher order B0 shimming.

References: 1) M. Schmitt, et al., ISMRM 13th Meeting, p. 331 (2005), 2) G. Wiggins et al., ISMRM 15th Meeting, p. 1054 (2007), 3) S. Wang et al., ISMRM 15th Meeting, p. 3275 (2007), 4) V. Ikonomidou et al., ISMRM 13th Meeting, p. 899.