8-Channel Transmit Body Array for Homogeneous Excitation of the Thorax at 3T

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Introduction

To achieve homogeneous nuclear excitation and high sensitivity in signal detection, most clinical systems utilize a large volume coil for excitation and an array of surface coils placed against the subject for reception. In research with transmit arrays for body imaging, a common approach is to utilize transmit/receive arrays placed very near the subject (1). Unfortunately this approach precludes the use of existing receive-only arrays and limits the number of receive channels to the number of transmit channels available, typically a much smaller number. While recently some approaches for whole-body transmit arrays allowing room for receive arrays against the subject have been demonstrated (2), in systems with conventional body coils for routine use it can be desirable to perform some research with arrays placed within the limits of the space available without significant modification to the body coil or patient table, i.e., the space available as when the system is used for clinical purposes. This results in severe limitations regarding options for placement of elements. Here, we report progress toward a case where 8 elements are placed in the space above the patient bed.

Methods

Two different 8-element whole-body transmit arrays for 3T (123MHz) were modeled for use with the finite difference time domain (FDTD) method. The whole mesh matrix size is 180x180x438 in x, y, and z directions and each model contains a model of an adult male (3) at 5x5x5 mm^3 resolution and RF shield with a 68cm diameter. The length of the inner conductor and ground plate for each element are 42cm and 50cm, respectively. Each element is driven with 2 current sources at opposite ends of the element and in opposite directions connecting the element to its ground plate. Distance between the ground plates of opposing elements is 59cm. Figure 1, left shows the two 8-element transmit arrays modeled for this work, one having strip line elements spaced equally about the bore, and the other having elements placed only above the patient bed. The fields produced by each element were calculated using commercially-available software (xFDTD; Remcom, Inc.) and then RF shimming was performed using the principle of superposition using home-built software in Matlab (The Mathworks).

The simulated 8-channel above-bed array coil was constructed with copper plates, woods, and Derlin. The coil array was designed for Siemens 3 T whole body system (Magnetom 3T, Siemens Healthcare, Erlangen, Germany) equipped with 8 x 8 kW peak RF power amplifier (Analogic, Peabody, MA), and a custom-built T/R switch and pre-amplifier box (Stark Contrast, Erlangen, Germany. The relative phase differences of transmit chains were measured and compensated and images and B1 maps (4) were acquired for a 25 cm sphere of water using different combinations of elements.

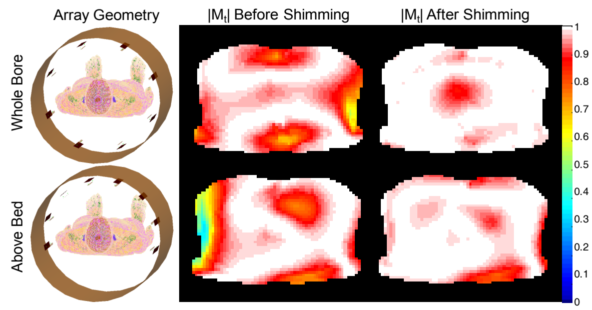

Figure 1 Geometry of two different 8-element whole-body transmit arrays (left) and corresponding distribution of transverse magnetization (M_t, equal to sine of flip angle) before (middle) and after (right) RF shimming within the thorax on an axial plane passing through the heart. After shimming, the array constrained to having all elements above the patient bed (bottom right) can achieve appreciably better homogeneity than an array with elements distributed evenly about the entire bore when driven like a birdcage coil in quadrature (top, middle) and approaching that after shimming of such an array (top right).

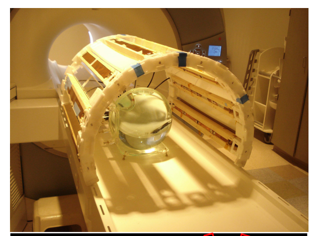

Figure 2 The 8-channel coil on the patient table. TR switching and pre-amplifying box is located outside the array at the head end. A 25-cm inner diameter homogeneous spherical phantom was used for imaging.

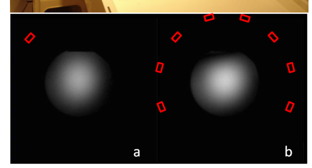

Figure 3 Gradient echo images with a single channel transmit (a) and with whole channel transmit (b) in a 25 cm flask at a true dielectric resonance. While RX, whole 8 channels were used for receiving signal.

Results and Discussion

The middle column of Figure 1 shows the transverse magnetization (M_t, equal to sine of flip angle) for a 90° pulse before shimming, when each element is driven with a phase proportional to its angular position about the bore, and all elements are driven with equal current amplitude. Figure 1, right shows M_t for a 90° pulse after shimming. After shimming, the array having all elements above the patient bed (bottom right) can achieve appreciably better homogeneity than an array with elements distributed evenly about the entire bore when driven like a birdcage coil in quadrature (top, middle), and close to that after shimming of such an array (top right). This comes, however, at a cost of greater SAR. The average and maximum one-cell SAR in the case with all elements above the bed are higher than the case with elements distributed throughout the bore by 28% and 151%, respectively, after shimming. Still, the fact that the array with elements above the bed can achieve better homogeneity than a birdcage coil may make this design suitable for experiments that are not SAR limited in order to facilitate use of receive arrays (including an array in the patient bed) and without significant disruption of the standard system in cases where SAR is not a severely limiting factor. Figure 2 shows the constructed 8-channel array on the patient table. The images with single channel transmit and multichannel transmit (LP) are shown in Figure 3. We acquired B1 maps of each channel from the array using a flip angle maps and relative phase maps. Because a 25 cm sphere has a true dielectric resonance near 128 MHz (5), the field pattern is independent of excitation field, but demonstrations of RF shimming will be available soon.

Acknowledgement

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References

1. Metzger *et al.*, MRM 2008;59:396-409
2. Vaughan *et al.*, MRM 2009;61:244-8
3. Christ *et al.*, ICEBEA 2007; S-4-2
4. Yarnykh V. MRM 2007;57:192-200
5. Collins *et al.*, JMRI 2005;21:192-6