7T 22ch Wrap-around Coil Array for Cervical Spinal Cord Imaging

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Target Audience: MRI RF coil designer, 7T cervical spinal cord imaging researcher.

Introduction: Most of the coil arrays for 7T cervical spinal cord imaging are designed as an array positioned in the half plane posterior to the subject [1, 2, 3]. Due to significant decay in the RF energy propagating to the region-of-interest (ROI) at 7T, the transmit efficiency of the half plane coil is limited. A wrap-around coil, on the other hand, can generate the highest transmit field (B_1^+) in the center of the ROI by achieving a correct phase relationship between transmit elements. Moreover, by using B_1 shimming, the peak B_1^+ can be shifted off-center as needed. In this work, a 22-channel (22ch) wrap-around coil array was built for 7T cervical spinal cord imaging. The coil employs four transmit-receive (Tx/Rx) elements and eighteen receive-only elements. The four Tx/Rx elements, two of which are anterior and two of which are posterior to the subject, follow the contours of the body. For the eighteen receive-only (Rx) elements, six are anterior and twelve are posterior to the subject. The Rx elements surround the Tx/Rx elements and follow the contours of the body in order to maximize SNR. Simulations and experiments were performed to show high transmit efficiency and SNR with this wrap-around coil array design.

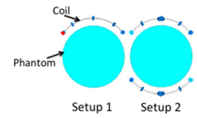

Figure 1

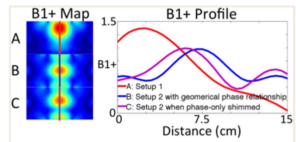

Figure 2

Methods: *Simulations*: Two setups were tested through simulation. Setup 1 used two posterior Tx elements and setup 2 used one anterior and one posterior Tx element. Both setups were loaded with the same cylindrical phantom (diameter=15cm, σ=0.5S/m and ε_r=60), as shown in Figure 1. Simulation of B_1^+ maps and maximum 10g averaged SAR was performed for both setups using the finite difference time domain method in Microwave Studio (CST, Framingham, MA). The size of each coil in setup 1 is half of that in setup 2 in the z direction so that both setups have the same coverage. The input transmit power in both setups was identical.

Coil Design and Experiments: The coil frame was 3D printed (Fortus 360, Stratasys). The coil consisted of anterior and posterior parts, connected to each other using a BNC cable. The inner diameter was 16 cm in the neck area and 24 cm in the lower-part of the head area. The total length of the coil in the z direction was 38 cm with 8 cm covering the neck. Eight coil elements, including 2 Tx/Rx elements, were integrated into the anterior part of the coil and 14 coil elements, including the other two Tx/Rx elements, were integrated into the posterior part of the coil. The average diameter of the Rx elements was 10 cm and that of the Tx/Rx elements was 13 cm. All elements were made with 16 AWG tinned copper wire (Arcor Electronics, IL, US). The coil elements were connected to Siemens 7T preamps by coax cables. Preamp decoupling was achieved by adjusting the coax cable length. An active detuning circuit was built around the matching capacitor. Detuning effect was measured with a double pick-up probe by comparing the response from the coil when terminated with a 50 Ohm load to that when the coil was detuned. The phase relationship between the transmit elements was first set based on the simulation results, and then finely adjusted in the experiment with the BNC cable length. Human subject studies were performed following a protocol approved by our institutional review board, and informed consent was obtained from each subject. *In vivo* proton density weighted (PDw) and T_2* weighted (T_2*w) images were acquired with a 2D multi-echo Flash sequence (resolution=0.3×0.3×0.3mm, 7 axial slices individually positioned perpendicular to the cervical cord (C1-C7), GRAPPA=3, phase-encoding=left-right, FA=20°, TR=300 ms, TE=3.3/14.3/18.7/23ms, BW=260 Hz/pixel, average=6, and TA=5.5 min) on a whole body 7T scanner (Siemens Magnetom). Sum-of-squares averaging was performed for the magnitude images at the four echo times.

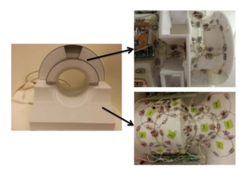
Figure 3

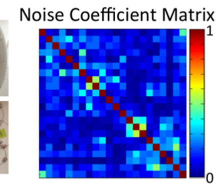

Figure 4

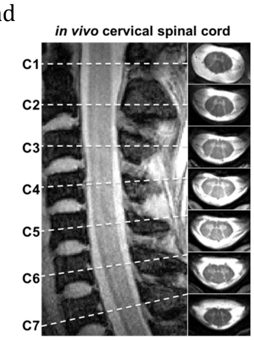

Figure 5

Results: *Simulations*: The $B_1^+$was highest near the surface area for setup 1, and decayed quickly as RF propagated towards the center. For setup 2, with a geometrical phase relationship, the $B_1^+$was highest in the center and the peak B_1^+ could be shifted off-center by 1.5 cm with respective phase shimming, as shown in Figure 2. Using the same input power, setup 2 can gain 38% higher B_1^+ in the center with the geometrical phase relationship. In the 1.5 cm off-center condition, setup 2 can gain 8% higher B_1^+ in the ROI with phase-only shimming. With 1 watt input power, the absorbed powers in setups 1 and 2 were similar. However, the maximum 10g averaged SAR was 0.93W/kg in setup 1, 0.58W/kg in setup 2 with a geometrical phase relationship, and 0.55W/kg in setup 2 with phase-only shimming. These results show that greater B_1^+efficiency as well as reduced SAR may be achieved by employing a wrap-around coil design for spinal imaging. *Experiments*: A picture of the coil geometry is shown in Figure 3. For the Rx elements, the ratio of unloaded-to-loaded quality factor was 11.5, the tuning/detuning difference between the receive coil was larger than 35dB, and the average noise correlation was 17.8%. *In vivo* high in-plane resolution axial PDw/T_2*w combined-echo images of the cervical spinal cord are shown in Figure 5 (right column). A sagittal image (left column with dashed reference lines indicating each axial slice position) was acquired with similar TE/TR. Images show excellent grey and white matter contrast in the cervical spinal cord (C1-C7). **Conclusion**: The wrap-around coil design (i.e., Tx elements on both the anterior and posterior of the subject) demonstrates high B_1^+ efficiency and SAR benefits for cervical spinal cord imaging at 7T. High-resolution cervical spinal cord imaging is feasible with this 7T 22ch wrap-around coil array.

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