

7 Tesla MRI of the shoulder and upper extremities using an 8-channel Tx/Rx Coil

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Introduction: MRI plays a leading diagnostic role in assessing the musculoskeletal (MSK) system, and recent publications have shown improved diagnostic capabilities of 7T MRI compared to MRI performed at standard clinical field strengths (up to 3T) [1]. However, so far, research at 7T has focused mainly on knee, ankle and wrist imaging, as dedicated RF coils for imaging more proximal joints of the upper extremities, esp. the shoulder, have not been available. A recent publication [2] introduced a multi-purpose coil for MSK imaging at 7T based on transmit/receive (Tx/Rx) loop arrays, which rendered first images of the shoulder joint but also showed limitations in terms of low mean B_1 values and degraded B_1 uniformity in the shoulder compared to smaller joints. In this work, a Tx/Rx coil optimized for imaging the upper extremities is introduced.

Methods: Eight previously described meander stripline elements [3] with a width/length of 8/25 cm were mounted on a c-shaped holder which can be split into two parts for easy patient positioning (Fig. 1). While the anterior part consists of 3 elements covering the shoulder joint, the posterior part consists of 5 elements covering the medial to lateral region from the spine to the arm for additional applications in assessing nerves of the brachial plexus. The opening of the coil array allows comfortable positioning of the volunteer with additional space for local receive elements, which will be introduced in a further development. So far, the coil has been operated as a combined Tx/Rx coil only. Preamplifiers and Tx/Rx switches (Stark Contrast, Erlangen, Germany) were placed at the head of the patient table.

All measurements were performed on a 7T whole-body system (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) equipped with a custom-made RF shimming system [4] and 8 x 1 kW peak RF power amplifier. The transmit RF phase of each channel was optimized for homogeneous excitation in the region of interest (shoulder, elbow joint) after evaluation of individually obtained relative B_1 maps (Fig. 2A) in a single transverse slice [5].

In vivo images of two volunteers were assessed with a T1-weighted 2D spoiled gradient echo (GRE; resolution $0.4 \times 0.4 \times 3.0 \text{ mm}^3$, TA 2:46 min) sequence with fat saturation, a double echo steady state (DESS; resolution $0.4 \times 0.4 \times 1.5 \text{ mm}^3$, TA 4:41 min), and T1-weighted turbo spin echo (TSE; resolution $0.5 \times 0.5 \times 3.0 \text{ mm}^3$, TA 1:34 min) sequence. Absolute B_1 maps were acquired with the actual flip angle imaging [6] sequence with 250 μs pulse length and 200 V pulse amplitude.

Results: Measured reflection and coupling between neighboring elements of the coil loaded with a phantom were $S_{11} < -25 \text{ dB}$ and $S_{12} < -13 \text{ dB}$. Noise correlation was found to be better than -20 dB on average between neighboring elements.

Fig. 2B shows a much more homogeneous excitation over the entire shoulder joint compared to the coil in [2], which is also demonstrated in the transverse GRE image (3C). In vivo images revealed uniform excitation over the whole field-of-view in both gradient and spin echo images. As shown in Fig. 3, the coil can be used for imaging the right (3A, 3B) or left shoulder (3C). Also, the elbow joint (Fig. 4) could be imaged with very good quality, rendering fine anatomic details of bone, cartilage and tendons.

Conclusion: The proposed RF coil allows MRI of the upper extremities with very good B_1 homogeneity and overall image quality in high-resolution images. The achievable spatial resolution is expected to be improved further with additional receive elements.

References: [1] Welsch, et al., *Europ Radiol*, 2011, 21(6): 1136-43; [2] Kraff, et al., *Med Phys*, 2010, 37(12): 6368-76; [3] Orzada, et al., *ISMRM 2010*, #50; [4] Bitz, et al., *ISMRM 2009*, #4767; [5] van de Moortele, et al., *ISMRM 2009*, #367; [6] Yarnykh, et al., *MRM*, 2007, 57(1): 192-200.

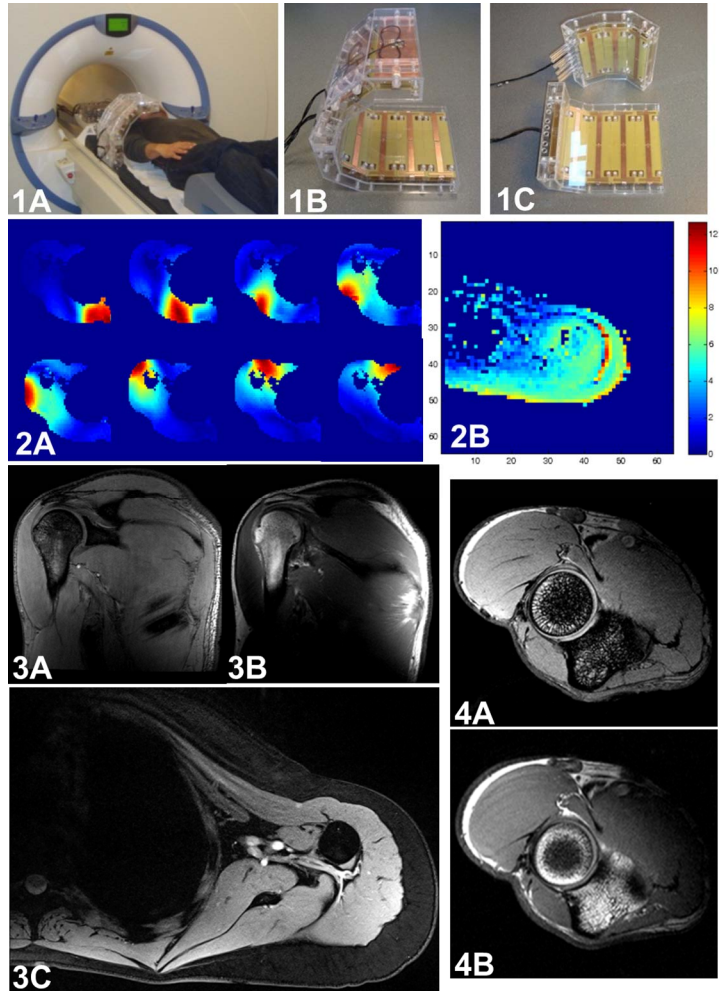


Fig. 1: Images of the RF coil with a volunteer positioned for MRI of the right shoulder (1A). The anterior part of the coil can be removed for positioning of the volunteer (1B, 1C). The opening of the coil is 28 cm in height, which offers adequate space for volunteers of various body physique and the future inclusion of additional receive elements.

Fig. 2: Relative B_1 maps from all eight individual channels (2A) show good separation of transmit sensitivities. In (2B) an absolute B_1 map (in μT) is given documenting a homogeneous excitation over the whole joint.

Fig. 3: Oblique coronal images of the right shoulder acquired with the DESS (3A) and T1 TSE (3B) sequence. The axial T1 GRE of the left shoulder (3C) rendered a very homogeneous image of the whole FOV with hyperintense vena and arteria circumflexa humeri posterior. Also note the uniform fat saturation.

Fig. 4: Axial DESS (4A) and T1 TSE (4B) images of the right elbow rendering fine anatomical details of cartilage, bone, fascicles of the ulnar nerve, and tendons.