An Eight-Channel Tx/Rx Multi-Purpose Coil for MSK MR Imaging at 7 Tesla

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Introduction:

MRI plays a leading diagnostic role in assessing the musculoskeletal (MSK) system and is well established for most questions at clinically-used field strengths (up to 3T). However, there are still limitations in imaging early stages of cartilage degeneration, very fine tendons and ligaments, or to locate nerve lesions, for example. High field systems (7T) may address this issue by providing increased SNR and hence higher spatial resolution. 7T MRI of the knee has already received increasing attention in the current published literature, but there is a strong need to develop new RF coils to cover more regions of the MSK system [1].

In this work, an eight-channel transmit/receive RF array was built as a multi-purpose coil for imaging some of the thus far neglected regions. The array was made of four overlapping loop coils per side to enable flexible positioning. We show first in vivo results of the human wrist, shoulder, elbow, and ankle.

Methods:

Eight 0.8-mm-thick surface loop coils with a dimension of 6 x 7 cm^2 were machined from FR4 circuit board material. Each coil element has 5-mm-wide circuits with a copper-clad layer of 35 μm thickness. Three 2 mm gaps were bridged by 8.2 pF capacitors on each element. To facilitate easy positioning, two coil clusters, each with four loop elements, were combined to one RF array (Fig. 1A). An overlapped and shifted arrangement of the coil elements was chosen to reduce the mutual inductance between neighboring coils. Common mode cable current suppression was provided by a cable trap located directly at each coil element. The preamplifiers and transmit/receive switches (Stark Contrast, Erlangen, Germany) were placed next to the array. The elements were matched to 50 Ohms at 297 MHz.

A phantom made of body-simulating liquid ($\varepsilon_r = 43$, $\sigma = 0.8\ S \cdot m^{-1}$) was used for tuning and matching on the bench with a network analyzer (Agilent E5061A). Afterwards, the S-parameters were verified on a human wrist, elbow, and shoulder. For safety validation, numerical computations [2] of the RF field distribution and the corresponding SAR were performed based on a member of the Virtual Family (70 kg male) [3] for the regions elbow, shoulder, and ankle.

In vivo images of four volunteers were assessed with gradient echo and spin echo sequences modified to obtain optimal image contrast, full coverage, and the highest resolution within a reasonable acquisition time.

Results:

Measured reflection and coupling between neighboring elements of the coil loaded with the phantom were S_{11} = -16 dB and S_{12} = -17 dB, respectively. Similar values were found for the verification on the human wrist and slightly better values of around -20 dB were found with the elbow and shoulder load.

In vivo images revealed good excitation over a 180 mm field-of-view and rendered very fine anatomic details such as fascicles of the median and ulnar nerves shown in the MEDIC-2D images (resolution 0.35x0.35x1.5 mm^3, TA=4:40 min) in Fig. 1B and 1D, respectively. In Fig. 1C, a ganglion appears hyperintense in the T2-weighted STIR image of a wrist (resolution 0.6x0.6x3 mm^3, TA=1:25 min). Also, the shoulder joint could be imaged with full coverage with a 3D-DESS sequence with 0.35x0.35x1.5 mm^3 resolution within 5:40 min (Fig.1E). Additionally, TSE sequences performed very well as shown in the PD-weighted axial slice of an ankle in Fig. 1 F (resolution 0.35x0.35x2 mm^3, TA=3:51 min).

Discussion:

This study demonstrates that the concept of two four-channel transmit/receive RF arrays can be used as a multi-purpose coil for high-resolution in vivo MR imaging of the musculoskeletal system at 7 Tesla. Not only gradient echo but also typical clinical and SAR intensive sequences like STIR and TSE performed quite well. Imaging of small structures (labrum) and peripheral nerves could in particular benefit from this technique. Work is underway for a detailed investigation in patients.

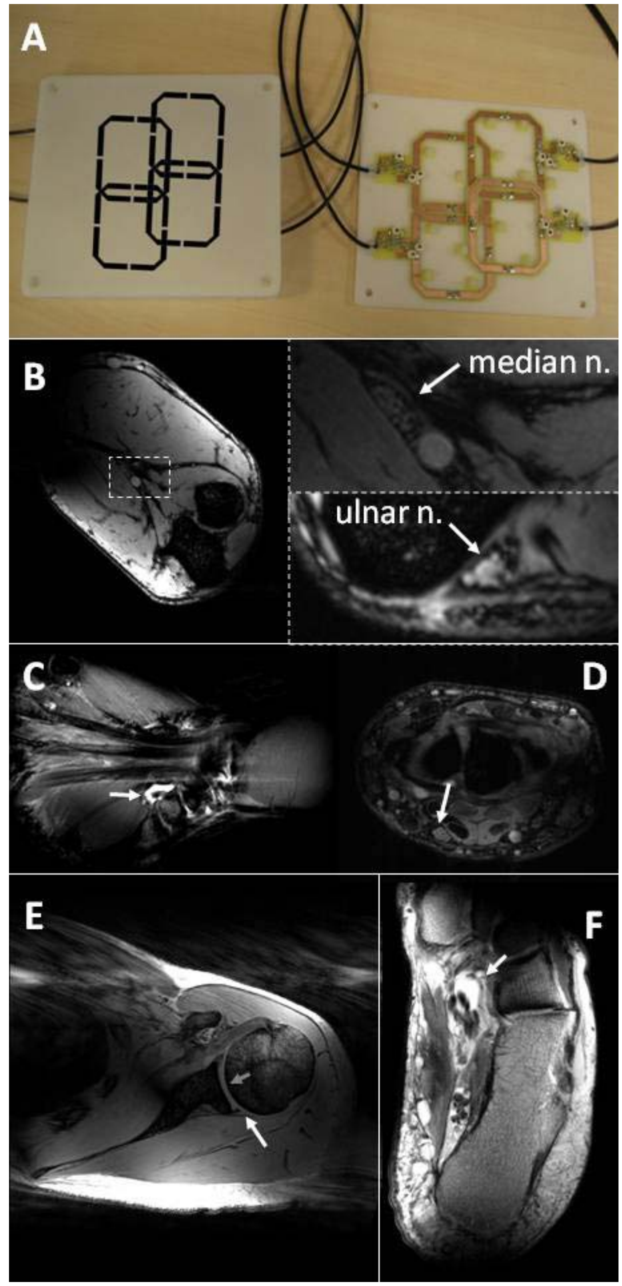

Fig. 1: (A) Assembled coil clusters with (left) and without cover (right) showing the array geometry. **(B)** MEDIC images of an elbow with additional magnifications of the median (same slice) and ulnar (different slice) nerves and their fascicles. **(C/D)** A wrist imaged with a coronal STIR sequence showing a known ganglion hyperintense (**C**, arrow) and with an axial MEDIC image with the arrow pointing to the median nerve. **(E)** Shoulder image obtained with a 3D-DESS sequence rendering the humerus, the scapula, as well as the rotator cuff. Excellent visualization of the labrum (white arrow) and cartilage (gray arrow). **(F)** Axial PD-w TSE image of an ankle rendering excellent contrast between peritendineal hyperintense fluid (arrow) and tendon.

References:

1. Krug, R., et al., *Imaging of the musculoskeletal system in vivo using ultra-high field magnetic resonance at 7 Tesla.* Invest Radiol, 2009. 44(9): p. 613–618.
2. *CST MICROWAVE STUDIO®, CST GmbH*: Darmstadt, Germany.
3. *Virtual Family Models, http://www.itis.ethz.ch/index/index_humanmodels.html.*