En route to clinical ultrahigh field musculoskeletal MR using multi-purpose transceiver RF modules for spine und shoulder imaging at 7.0 T.

Andreas Graessl[1], Soenke Langner[2], Marko Hoehne[3], Matthias A Dieringer[1], and Thoralf Niendorf[1,4]

[1]Berlin Ultrahigh Field Facility (B.U.F.F.), Max Delbrück Center for Molecular Medicine (MDC), Berlin, Berlin, Germany, [2]University of Greifswald, Institute for Diagnostic Radiology and Neuroradiology, Greifswald, Germany, [3]Helios Kliniken, Berlin-Buch, Germany, [4]Experimental and Clinical Research Center (ECRC), Charité Campus Buch, Humboldt-University, Berlin, Berlin, Germany

Target audience: This work is of interest for clinical scientists, engineers and highfield experts interested in musculoskeletal MR at 7.0 T.

Purpose: A growing number of reports eloquently refer to explorations into (pre)clinical musculoskeletal (MSK) imaging at 7.0 T [1-4]. Notwithstanding the eye-opening quality of the anatomical images electro-dynamic phenomena caused by wave length shortening at 7.0 T can undermine the benefits inherent to UHF-MR. Destructive and constructive RF interferences make it a challenge to match clinically acceptable image quality when moving to imaging of the spine, the shoulder and other musculoskeletal anatomy with dimensions similar or larger than the effective RF wavelength ($\lambda \approx 13$ cm). Here the use of local transceiver arrays is prudent to tackle the transmission field (B_1+) inhomogeneities. Given the limited availability of RF coils for MSK-MR and recognizing the versatile range of musculoskeletal MR applications it is conceptually appealing to pursue multi-purpose TX/RX arrays which suite the geometry needs of a broad spectrum of musculoskeletal anatomy including spine and shoulder. For this purpose this work proposes a RF coil building block to form multi-purpose TX/RX arrays for MSK imaging at 7.0 T. The applicability of the modular configurations tailored for spine and shoulder imaging is examined in healthy volunteers.

Methods: The proposed multi-purpose RF arrays for musculoskeletal UHF-MR are comprised of planar and modestly curved modules. Each module is equipped with a four-channel loop transceiver building block [5]. This multi-purpose approach affords combinations of modules that conform to the body geometry/anatomy of interest. RF characteristics of both configurations were examined for four subjects (2 male, 2 female; BMI 18-23) without subject- or application specific tuning and matching. Electromagnetic (EM) field and SAR simulations were performed using Studio Suite 2012 (CST, Darmstadt, Germany) together with the voxel model Duke from the Virtual Family (ITIS Foundation, Zurich, Switzerland). MR imaging was conducted using a whole body 7.0 T scanner (Magnetom, Siemens Healthcare. Erlangen, Germany). For shoulder imaging a circular polarized mode with phases according to the angular position of the modules was employed. For spine imaging the left row of elements had a 180° phase shift against the right row [2]. All elements were connected to multipurpose transmit/receive switch boxes with integrated low-noise preamplifiers. MRI was performed in healthy subjects without subject or application specific tuning and matching.

Results: The modules are lightweight ($m < 400$ g). For shoulder imaging a planar and two curved modules were combined for a 12 channel TX/RX configuration that closely fits to an average shoulder (Fig. 1a). For spine imaging four planar modules were used for a 16 channel TX/RX configuration that provides whole spine coverage (Fig. 2a). The assessment of the RF characteristics provided adequate S-parameter performance for the spine and shoulder configurations (Fig 1c, 2b). SAR values derived from EM simulations using the phase settings of the *in vivo* studies were well below the limits of the IEC guidelines [6] for 6.4 W_{RMS} input power for the shoulder application and 6.8 W_{RMS} input power for the spine application. The multi-purpose configurations afforded the acquisition of sub-millimeter spatial resolution images of the spine and shoulder (Fig 1e, Fig. 2d) within clinical acceptable scan times. The modular shoulder configuration supported four-fold accelerated parallel imaging without impairing image quality significantly (Fig. 1e). The sensitivity of the modular spine TX/RX configuration facilitated a spatial resolution as low as (0.13x0.13x1) mm³ for 3D GRE. This resolution helped to depict small structures such as the transverse processes, the capsule of the facet joint and the medial ramus of the posterior division of the spinal nerve (Fig 2d).

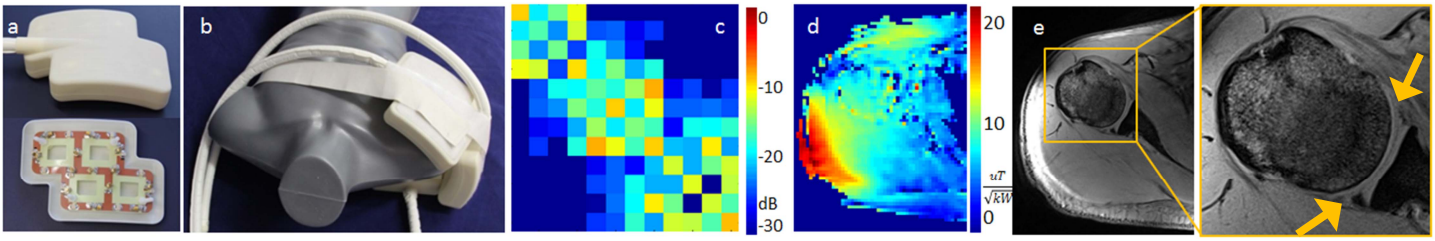

Fig. 1: Shoulder imaging at 7.0 T: a) A 4 channel transceiver building block. **b)** 12 channel RF coil setup consisting of three modules. **c)** Maximum projection of S-parameter measurements of 4 subjects. **d)** Absolute B_1^+ map in µT/√kW, depicting the homogeneity and penetration depth of the excitation field. **e)** Transversal high resolution image of the shoulder derived from gradient echo acquisition depicting the labrum structure (yellow arrows) (voxel size (0.3x0.3x1.5) mm³, TE/TR=4.04/11.5 ms, TA 1:47 min, R=4)

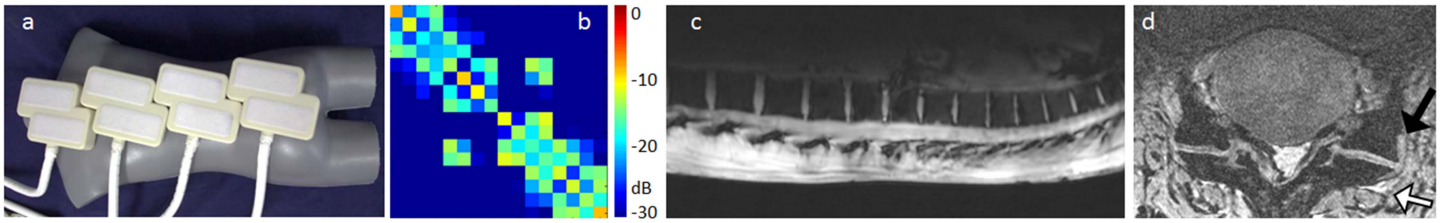

Fig 2: Spine imaging at 7.0 T: a) Coil setup comprising four planar modules to cover the cervical, thoraric and lumbar spine. **b)** Maximum projection of S-parameter measurements of 4 subjects. **c)** Low resolution GRE localizer demonstrating the coverage of the proposed array (TE/TR 3.36/7.5 ms). **d)** 3D GRE image depicting the transverse processes, the capsule of the facet joint (black arrow) and the medial ramus of the posterior division of the spinal nerve (white arrow) (voxel size (0.13x0.13x1) mm³, NA=2, TE/TR 4/3312 ms, TA 2:44min).

Discussion: Bringing musculoskeletal UHF-MR into the clinic remains challenging. Notwithstanding this challenge our results demonstrate that a modular arrangement of the proposed RF building block provides versatile TX/RX array configurations for MSK-MR which cover a broad spectrum of body geometry/anatomy including whole spine coverage and shoulder imaging. The multi-purpose approach fosters translational research and may be expected to continue to drive clinical UHF-MR research with the ultimate goal to advance the capabilities of musculoskeletal MR.

References: [1] Trattnig S et.al. Eur Radiol 2012;22(11):2338-46.[2] Kraff et al. Invest Radiol 2009;44(11):734–40. [3] Zhao et al. Magn. Reson. Med. 2013.[4]Brown et.al. Invest Radiol 2013. [5]Graessl et.al. Mag. Reson. Med. 2013. [6] IEC 60601-2-33, Geneva, 2006.