MULTI-PURPOSE, FLEXIBLE TRANSCEIVER COIL FOR MUSCULOSKELETAL MR IMAGING AT 7.0 TESLA

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Introduction: Recent reports eloquently demonstrated that musculoskeletal (MSK) MRI benefits from the signal and sensitivity gains intrinsic to ultrahigh field MRI (UHF-MRI) [1]. To date, predominantly rigid or semi flexible transmit/receive (Tx/Rx) coil designs have been used for 7.0 T MSK MRI. A fully flexible coil configuration adds to the patient comfort and broadens the range of applications. Flexible Tx/Rx RF coil designs are challenging due to changes in tuning and matching which might occur during bending of the coil. Recognizing these challenges this work proposes a single channel flexible coil for multi-purpose MSK imaging at 7.0 T. The performance of the flexible coil is evaluated in electro-magnetic field (EMF) simulations and in phantom studies and benchmarked against a rigid geometry. The applicability of the RF coil is examined for high spatial resolution wrist and ankle imaging at 7.0 T.

Methods: The flexible coil has a form of a rectangular loop with the size of (14 x 9) cm². The layout with the conductor width of 1 cm was etched on FR4 substrates with thickness of 0.5 and 1 mm. Tuning capacitors (ATC, NY, USA) were equally distributed around the loop to mitigate dielectric losses (Figure 1A). The tuning and matching circuit together with ceramic trimmers (Voltronics, NJ, USA) was placed on one shorter side as well as the cable trap. The coaxial cable (Leoni, Friesoythe, Germany) has been terminated by a BNC connector. The flexible coil was covered by 1 cm of polyurethane foam from both sides. For comparison, the rigid coil was incorporated in an acrylonitrile butadiene styrene casing produced by rapid prototyping (Figure 1B). EM simulations (CST MWS, CST AG, Darmstadt, Germany) were performed to assure RF safety. Voxel model Duke from Virtual Family [2] with 2 mm voxel resolution was included into the simulation. The coil geometry was matched to reality including planar and bended configurations that resemble coil positioning used for MSK imaging including wrist (Figure 1A), ankle and knee. The specific absorption rate (SAR) was averaged over 10 g as suggested in EN 60601-2-33 Ed. 3. Phantom studies were performed using a phantom with ε_r = 57.8 and σ = 0.78 S/m to mimic human tissue properties [3]. In-vivo imaging was conducted using a T_1-weighted 2D gradient echo technique (TE = 6 ms, TR = 300 ms,).

Fig. 1: A) Conductor layout of the 1 channel flexible Tx/Rx RF coil, **B)** Coil configurations left) flexible geometry right) rigid geometry **C)** SAR distribution over the voxel model's hand.

Results: Based on the simulations the coils power was limited to 4 W to stay below the 20 W/kg local SAR limit as illustrated in Figure 1C. For the flexible and rigid version of the coil reflection characteristics loaded on a wrist were below -30 dB. Placing the coil over ankle and knee changed the loading but the reflection characteristics were below -15 dB. If placed on different volunteers, the reflection characteristics didn't vary significantly. Mean unloaded Q was 135, mean loaded Q was found to be 52 resulting in a mean unloaded/loaded Q ratio of 2.5. Phantom studies indicate an average SNR gain of approximately 14% for the flexible coil over the rigid geometry. Figure 2 shows the SNR profiles through axial slices obtained from phantom studies and averaged over 5 slices. The highest SNR gain was around 22 % at the middle section of the phantom. Figure 3 shows different views of the wrist, knee and ankle derived from T_1-weighted gradient echo imaging and demonstrates the applicability of the coil for human imaging.

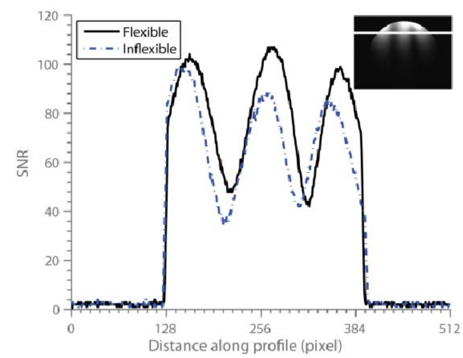

Fig. 2: SNR comparison between the flexible (solid line) and the rigid (dotted line) design using a profile across a spherical phantom. Data were averaged over 5 slices.

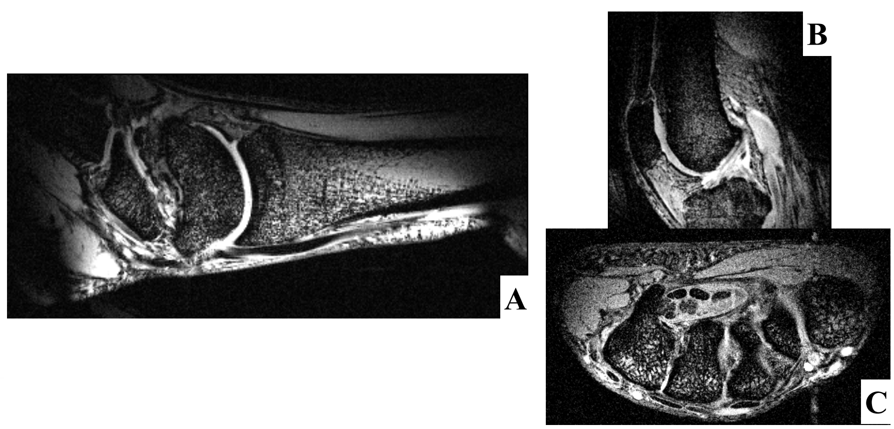

Figure 3: A) Sagittal view of the ankle derived from 2D T_1-weighted acquisitions using a spatial resolution (0.5 x 0.5 x 1.5 mm^3) **B)** Sagittal view of the knee from 2D T_1-weighted acquisitions using a spatial resolution (0.5 x 0.5 x 1.5 mm^3) **C)** Axial view of the wrist derived from 2D T_1-weighted acquisitions using a spatial resolution of (0.23 x. 0.23 x 1.5) mm^3.

Discussion and Conclusions: The proposed flexible multi-purpose RF coil provides patient comfort, ease of use and versatility that is superior to a rigid design of the same dimensions. The coil's flexibility and depth penetration renders it suitable for imaging of joints at 7.0 T but also holds the promise to be beneficial for MSK MRI plus applications such as eye, carotid imaging or MRI of the mandibular glands. The SNR improvement observed with the flexible design might be invested in enhanced image quality and improved spatial resolution. Recognizing the opportunities of the flexible design it is conceptually appealing to extend this architecture to flexible multi-channel Tx/Rx array configurations tailored for musculoskeletal MRI applications.

References: [1] Juras V, et al. (2011) Eur J Radiol. [2] A. Christ, et al. (2010) Phys Med Biol. [3] S. Gabriel, et. al. (1996) Phys Med Biol.