Design of a multi-segmented flexible loop-gap resonator for high sensitivity imaging of the human wrist at 7 tesla

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Introduction. Human musculoskeletal studies at 7 tesla can take advantage of the higher signal-to-noise compared to 3 tesla for either improved spatial resolution or decreased imaging time. The majority of studies have concentrated on trabecular bone and cartilage MRI in the knee (1-5). In this study we investigate the utility of 7 tesla MRI for imaging of the wrist, in light of initial results at 3 tesla having showed significant improvements over those obtained at 1.5 tesla (6). Since no commercial specialized wrist coils exist for 7 tesla, the aim was to design a high-sensitivy coil for optimal signal-to-noise and patient comfort and flexibility. The choice was a loop-gap resonator (7,8), which is a very low inductance design with approximately twice the sensitivity of transverse resonators such as the birdcage. In addition, the electric fields are confined to the capacitive dielectric "gap", and do not penetrate the patient, thus reducing SAR. Finally, the geometry allows comfortable natural positioning of the wrist transversely above the lower abdomen, unlike other designs which require either unnatural stretching above the head in the "superman" position, or sub-optimal positioning by the side very far from the magnet isocenter.

Methods. A close-fitting, flexible wrap-around loop-gap resonator coil was designed and constructed. When placed around the wrist, the coil formed an ellipse with dimensions ~ 8 x 6 cm (Figure 1a): the width of the copper band was 5 cm. Two or four capacitive series segmentations were used, with one formed by the variable overlap of the teflon former and copper conductor which allows the coil to be used for a number of different wrist diameters. Standard balanced impedance matching used variable capacitors. Elasticated fabric wristbands were used between the coil and wrist, and also to keep the coil in place. The coil was connected to the Philips 7 tesla Achieva via the standard interface box. B1 maps on phantoms showed a homogeneous RF distribution (data not shown).

Results. The flexible coil was positioned over the distal radius of the volunteer, as shown in Figure 1(a). Figures 1(b) shows results from a standard 3 tesla spin-echo imaging protocol which was transferred to the 7 tesla system, except that a reduction in signal averages from two to one was possible given the higher coil sensitivity and magnetic field. Figure 1(c) shows an axial slices from a high-resolution three-dimensional gradient echo data set, with tendons, nerves, muscle and trabecular bone clearly delineated.

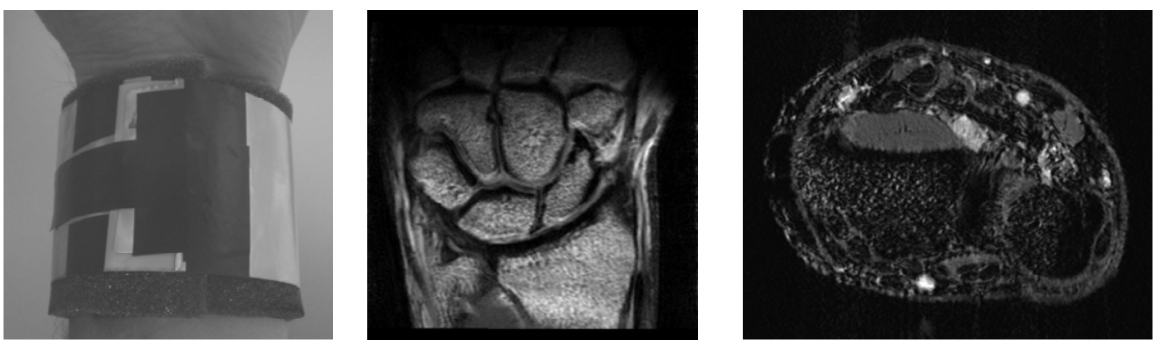

Figure 1. (left) Photograph of the flexible loop-gap resonator wrapped around the left wrist of a volunteer. (centre) Coronal T1-weighted spin-echo sequence acquired (TR/TE 1514/20, 228 x 180 data matrix zero filled to 480x480, fifteen 2 mm slices, flow compensated, 1 signal average). (right) One slice from a high-resolution 3D gradient echo data set (TR/TE 56/5.6 ms, data matrix 400x324x52, spatial resolution 0.18 x 0.18 x 0.4 mm, 1 signal average, 8 minutes data acquisition time).

Discussion. In addition to the intrinsically high sensitivity of the loop gap resonator, the geometry allows a very natural and comfortable positioning of the hand in the centre of the magnet. Imaging protocols at 3 tesla which require two signal averages can be performed at 7 tesla with a single average, as well as improved spatial resolution in the slice select dimension. The loop gap resonator can also be used as a large efficient transmit coil in combination with a phased array to reduce further imaging times using parallel imaging. Currently, we are investigating the use of sequences such as balanced gradient- and spin-echo sequences, as well as ultrashort echo time imaging, in order to optimize data acqusition protocols.

References. 1. Krug R. et al. Magn.Reson.Med. 2007, 58, 1294-1298. 2. Krug R. Et al. J.Magn.Reson.Imag. 2008, 27, 854-859. 3. Regatte RR and Schweizer ME, J.Magn.Reson.Imag. 2007, 25, 262-269. 4. Zuo J et al. Magn.Reson.Imag. 2008, 26, 560-566. 5. Banerjee S et al. Magn.Reson.Med. 2008, 59, 655-660. 6. Ludescher B et al. Acta Radiol. 2005, 46, 306-309. 7. Froncsz W and Hyde JS, 1982, J.Magn.Reson. 47, 515. 8. E.A. Marshall et al. Magn. Reson. Med. 1989, 9,36.