Open Design 8-Channel Tx/Rx Ankle Coil for High-Resolution and Real-Time Imaging at 7 Tesla

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Introduction

Since the introduction of parallel transmission techniques like transmit SENSE or RF shimming, arbitrarily shaped arrays can potentially be used for excitation. Here we present a U-shaped 8-channel transmit/receive strip line coil for 7 Tesla MRI capable of high-resolution, real-time joint imaging of the human ankle (1).

Materials and Methods

The array consists of 8 strip lines modularly arranged in a U-shape as seen in Figure 1A. The strips have a width of 7.5 mm and a length of 15 cm. The distance between the strip and the ground plane is 9 mm and filled with air. The ground plane of each module is 5 cm wide and 20 cm long (1 cm longer in the head direction and 4 cm longer in the feet direction than the strip conductor).

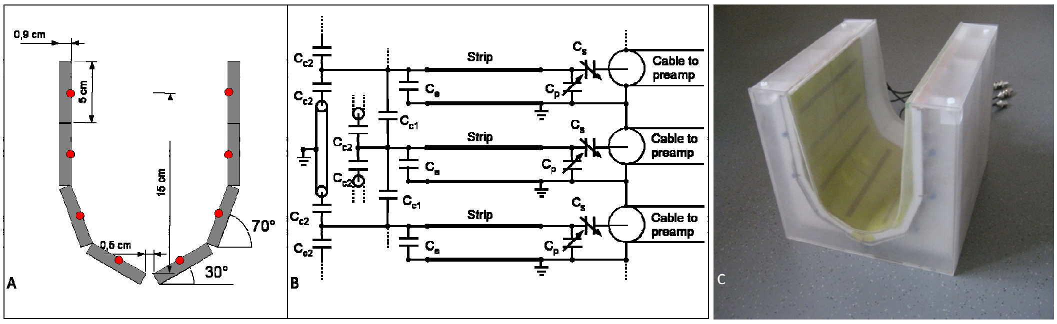

Figure 1: (A) Geometry of the U-shaped array, **(B)** electrical schematic, **(C)** image of the array with housing.

Figure 1B shows the electrical schematic of the array. The end of the strip is connected to the ground plane with a capacitor C_e = 6.8 pF, the matching network consists of a tunable series capacitor C_s = 0.7-2 pF and a tunable parallel capacitor C_p = 2.5-12 pF. To optimize decoupling, the end of each strip is connected to the neighbor and the next neighbor. The connection to the neighbor is realized with a capacitor C_{c1} = 0.7 pF, the connection to the next neighbors is accomplished with a capacitor C_{c2} = 1 pF on each element interconnected with a length of semi rigid cable necessary to cover the distance. There is no connection over the open side of the U-shaped array. The ground planes of all modules are interconnected with capacitors C_g = 1000 pF to reduce eddy currents. Cable traps are included in the cables to the preamps to prevent shield currents, and the preamps are located in a multipurpose preamplifier box about 30 cm away from the coil. The housing for the coil is made from semi transparent PMMA. Its height, width and length are 20 cm, 21.5 cm and 24 cm, respectively. The U-shaped opening is 12 cm wide at the top.

All images were acquired on a Siemens 7T whole-body system (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) using gradients with maximum amplitude of 40 mT/m and maximum slew rate of 200 mT/m/ms. This system is equipped with a custom-built 8-channel RF shimming system (2). For phantom measurements a cylindrical phantom with a diameter of 7.8 cm and a length of 15 cm was used, filled with tissue-simulating liquid (ε_r = 46.3, σ = 0.8 Ω^{-1} m^{-1}). To estimate the g-factor of the array, two fully sampled gradient echo images with an image matrix of 384 by 384 were acquired and reconstructed with openGRAPPA (3) (reconstruction parameters: 48 autocalibration lines for R = 2, 3 and 4). SNR for each reduction factor was determined from both images with a dual acquisition and subtraction method (4).

The left/right ankle of 3 healthy subjects were imaged. Using a vendor provided relative B_1 mapping sequence and an in house developed shimming tool with a shimming algorithm that homogenizes the magnitude of the transmit B_1 but ignores the phase, the phases and amplitudes for all elements were calculated individually for each subject. For in vivo real-time imaging, a TurboFLASH sequence was used with an in-plane resolution of 1.16 x 1.16 mm² and a slice thickness of 4 mm. With an image matrix of 256 by 256, a TR of 339 ms (e.g. 3 images per second) was achieved when using GRAPPA reconstruction with R = 4 and 48 reference lines. Additional parameters: TE = 1.5 ms and bandwidth = 465 Hz/pixel.

Results and Discussion

Although the coupling to neighboring and next-neighbor elements is dependent on the posture of the human volunteer's ankle used as coil load, the coupling was always below -14 dB or -20 dB, respectively. Additionally, the reflection factor stayed well below -13 dB when changing the posture of the ankle inside the coil.

Figure 2 shows g-factor maps for GRAPPA reconstruction with nominal acceleration factors of R = 2, 3 and 4. The maps clearly show that even for a nominal acceleration factor of 4 in the A>P-direction the g-factor stays well below 2 (mean values: 1.05, 1.09, 1.28).

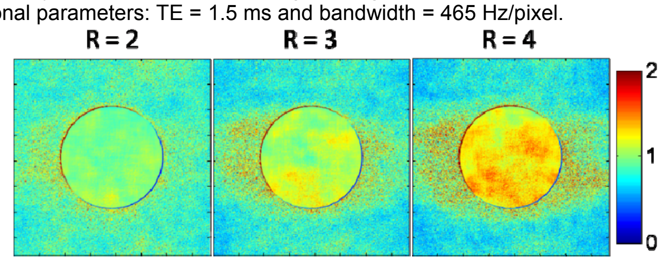

Figure 2: GRAPPA g-factor in a homogeneous phantom. Axial slice, phase-encoding direction A>P. Effective reduction factors: 1.78, 2.4, 2.91.

Figure 3 shows a set of 6 TurboFLASH real-time images acquired during free movement of the ankle. No acceleration artifacts are perceptible in these images. The in-plane resolution was limited to 1.16 x 1.16 mm² as the smallest selectable resolution in the vendor sequence. Real-time sequences like SFFP, which are normally used at lower field strength, appear to be problematic, since severe banding artifacts appear as soon as the foot leaves the position in which the B_0 shimming was applied.

The presented open U-shaped coil has proven its feasibility for real-time imaging with high spatial resolution in conjunction with a high parallel imaging acceleration factor.

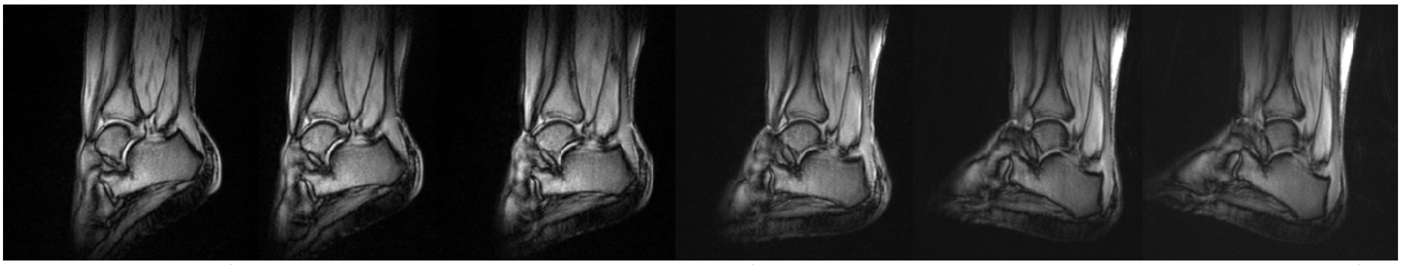

Figure 3: TurboFLASH images (3 per second) acquired during movement of ankle. The in-plane resolution is interpolated to 0.58 x 0.58 mm².

References [1] Quick et al, JMRI (2001); [2] Bitz et al, Proc. Intl. Soc. MRM (2009); [3] Griswold et al, MRM (2002)
[4] Firbank et al, Phys. in Med. and Biol. (1999);