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 shows the electrical schematic of the array. The end of the strip is connected to the ground plane with a capacitor \( C_n = 6.8 \text{ pF} \), the matching network consists of a tunable series capacitor \( C_0 = 0.7-2 \text{ pF} \) and a tunable parallel capacitor \( C_p = 2.5-12 \text{ pF} \). 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 \( C_{n1} = 0.7 \text{ pF} \), the connection to the next neighbors is accomplished with a capacitor \( C_{n2} = 1 \text{ pF} \) 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 \( C_p = 1000 \text{ pF} \) 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 (\( \rho = 463.3, \sigma = 0.8 \Omega^{-1} \text{m}^{-1} \)). 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 auto calibration 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 results show that the g-values are strongly dependent on the position 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 position 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).

Result and Discussion
Although the coupling to neighboring and next-neighbor elements is independent of 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 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 B0 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.

References