

A Two-part 16-Channel Receive Phased Array for Imaging of Rabbit Heart and Aorta on a 3T Clinical MRI System

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1. Introduction

Phased arrays with high numbers of receive channels are commonly used in clinical imaging but are also developed for small animal research imaging [1]. Especially for accelerated cardiac imaging they are required for sufficient image quality under circumstances of high heart rate and rapid breathing of animals. For MRI of rabbits on a clinical MRI system a knee coil is an obvious choice [2] but not optimal with regard to the filling factor. For the development of a dedicated rabbit heart/aorta array two main goals have to be accomplished. First high signal-to-noise-ratio (SNR) in the heart region and second parallel imaging capabilities has to be achieved by many small receive elements. Moreover sufficient SNR has to be maintained in the center of the animal near by the aorta.

2. Material and Methods

To achieve high SNR and low geometry-factor (g) [3] values a stripe arrangement is chosen for four elements. A second row of four elements is placed parallel to the first to extend the sensitive coverage of the object (Fig.1). To cover the opposite side of the object a second identical part with eight elements was built. This split design gives a certain range of freedom for minimizing the array-to-object distance. The element size of 50mm is chosen to maximize the SNR in the center of the biggest assumed phantom or animal. In addition the elements were bent around an acrylic glass half cylinder to shift the sensitivity to the center of the region of interest [4]. The elements are made of 0.8mm thick copper wire. The next nearest elements are critically overlapped to minimize mutual inductance and all elements are additionally decoupled by low impedance preamplifiers (preamps) [5]. The preamps are placed close to the elements to optimize performance and geometry of the array. RF interferences caused by preamp oscillations were prevented by precisely adjusted cable traps at the outputs of the preamps and careful cable routing. The quality factor Q, mutual coupling between the elements and preamp decoupling were determined by S_{21} measurements of the fully assembled array with all cables attached.

MR imaging was performed on a 3T clinical system (Magnetom Trio TIM, Siemens Medical Solutions, Erlangen, Germany). The coils for comparison were a TxRx 8-channel knee coil (Invivo Corp, Gainesville FL, USA), a TxRx 15-ch knee coil (QED, Cleveland OH, USA) and a 32-ch head coil (Siemens Medical Solutions). The phantoms were one 2 liter and two 1 liter PE plastic bottles (Aqua dist. and 1.25g NiSO₄ x 6H₂O, 5g NaCl per 1000g H₂O). The bottles were positioned directly on the bottom case of each phased array for nearest placement to the adjacent receive elements. T1-weighted images (Spoiled gradient echo, TR/TE/ α =100ms/10ms/24°, FOV=120mm², Matrix(M)=256², 0.5mm², slice(SL)=5mm) were acquired during the 2 liter phantom measurements. For MRI of smaller animals or cardiac only imaging the array can be divided and allows simultaneously imaging of two objects. Two 1 liter phantoms were used to verify this. Using the wide bore of the clinical system both array parts together with the phantoms were positioned outside the twofold object diameter wide FOV resulting in aliasing of the objects in the MR image [6]. The image parameters therefore were adjusted (FOV=190mm², M=384²) maintaining the same voxel resolution. All transversal slices were positioned in the areas of maximum signal intensity identified from coronary and sagittal slices. Additional transversal slices were acquired to verify the one with the highest SNR. SNR units [7] and 1/g maps were calculated for coil validation.

First *in vivo* imaging was performed on a two-year-old 7kg rabbit. A series of turbo spin echo images (GRAPPA R=3, FOV=144mm², M=704x490, 0.2mm², SL=2mm, TR/TE/ α =500ms/19ms/150°, #Averages=4) were acquired.

3. Results and Discussion

The Q_{UL}/Q_L ratio of the fully assembled array is 256/56 = 4.6 +/- 0.3 for the 2 liter phantom. S_{21} decoupling measurements between nearest neighbored elements show values of -31 +/- 11dB and preamp decoupling of all elements is -32 +/- 1dB. The center SNR of the rabbit array is 30% and 50% higher compared to the 8-ch and 15-ch knee coils. In comparison to the head coil SNR values are equal however during *in vivo* measurements the rabbit heart is not in the most sensitive area of the head coil. In the peripheral areas of the phantom the rabbit array has a 1.6-fold and 2.3-fold higher SNR compared to the 32-ch head and 15-ch knee coil. For the two 1 liter phantoms the 1/g-map shows that there is no significant SNR loss to expect due to two-fold accelerated parallel imaging (Fig.3). In comparison to a single phantom experiment with only one 8-ch part and a smaller FOV but the same resolution (FOV=95mm², M=192², 0.5mm², t_{Acq} =21s) two objects with 2x 8-ch (FOV=190mm², M=384², 0.5mm², t_{Acq} =22s, GRAPPA R=2, 24 reference lines) can be imaged with only 1s delay. Figure 4 shows an accelerated (R=3) *in vivo* image. In the future we plan to extend the imaging setup with a second 16-ch array using the full 32 receive channels of the MR-System.

4. Acknowledgement

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5. References

- [1] Keil, B., et al. (2011) MRM 66(2): 582-593. [2] Zhu, D. C. et al. (2011) Proc. ISMRM 19: 3691. [3] Pruessmann, K. P., et al. (1999) MRM 42(5): 952-962. [4] Bottomley, P. A., et al. (1997) MRM 37: 591-599. [5] Roemer et al. (1990) MRM 16(2): 192-225. [6] Ramirez, M. S., et al. (2010) MRM 63(3): 803-810. [7] Kellman, P. (2007) MRM 58(1): 211-212.

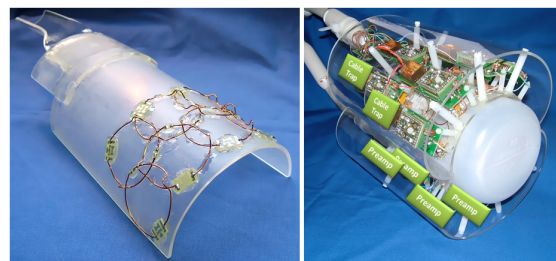


Fig. 1: (Left) Copper wire loops with FR4 circuit boards mounted on an acrylic glass half cylinder. (Right) Both 8-ch arrays with a 2 liter phantom bottle.

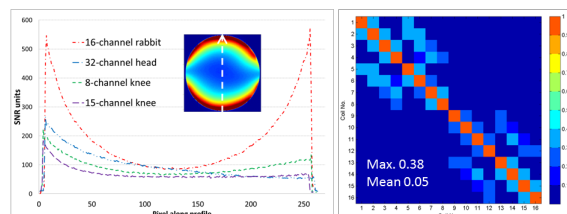


Fig. 2: (Left) SNR Profiles of the 2 liter phantom. (Right) Noise correlation matrix of the 16-ch rabbit array.

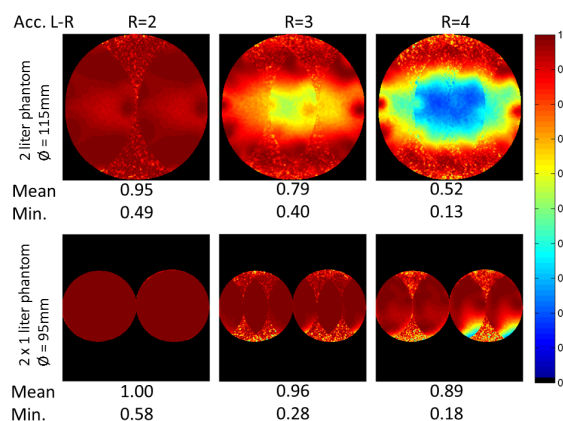


Fig. 3: (Upper row) Masked 1/g maps of a 2 liter phantom imaged with the 16-Channel array. (Lower row) 1/g maps of the divided array with 2x 8-channels and two 1 liter phantoms.

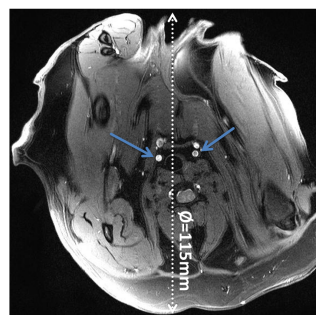


Fig. 4: Cropped *in vivo* image of a 7kg rabbit showing a transversal slice. The marked vessels are carotid arteries, as example for central vessel imaging.