A Compact 10-channel RF Array Coil for MR Imaging of Mice

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Introduction

Parallel imaging techniques have recently begun to be applied to MRI of the laboratory mouse [1]. Two-channel cardiovascular MR imaging of multiple mice has been reported [2]; eight-channel small animal coil arrays have been implemented on a clinical 3T scanner [3] and at 9.4T [4]; sixteen-channel rat body coil arrays have been introduced at 7T [5]. Most recently, a 20-channel volume array for use in a clinical 3T system was reported [6]. In general, researchers note the challenges associated with the miniaturization of the coils, including but not limited to maintaining sample noise dominance, sensitivity in the element-to-element decoupling process, and the lack of space for traditional hardware such as baluns and cable traps, active decoupling networks, and low input impedance preamplifiers. This abstract presents a 10-channel array, transmit coil, and a modular multi-channel low impedance preamplifier board that together constitute a compact parallel imaging system for mice. The integrated anesthesia chamber provides streamlined imaging capability. The dual plane pair (DPP) element design [7] described 1) ensures that no coil-to-coil decoupling mechanism is needed other than the preamplifiers and 2) inherently decouples from a homogenous transmit field, eliminating the need for active decoupling of the elements and 3) reduces, and in this case, eliminates, the need for baluns and/or cable traps. The transmit coil design described ensures an extremely uniform sensitivity pattern, and the multi-channel preamplifier board described is compact and modularized for straightforward use with any array coil up to 16 channels.

Methods

Array coil: A 10-channel array of dual plane pair (DPP) elements was designed and constructed in house as a top-bottom half rack design. The receive-only arrays are seperated into two 5-channel sub arrays similar to human cardiac imaging arrays (Fig 1). The unbalanced feed of DPP elements (center element splitting to two ground elements on either side) reduces, and in this case of such small elements eliminated, the need for a balun before RF input to the low input impedance amplifiers. ***Transmit Coil:*** The transmit volume coil was a linearly excited 60mm i.d. high-pass birdcages coil resonated at 200 MHz for use with our 4.7 Tesla Varian scanner and actively decoupled during receive. The symmetric design (unbalanced feed) of the DPP elements allows them to inherently decouple from a homogenous transmit field. The homogeneity of the volume coil was ensured by using a “trombone” design, tuning the coil by changing the length of the rungs rather than perturbation of a single rung [8]. ***Low-input impedance preamplifier board:*** The goal of this 16 channel preamplifier system was to be “interchangeable” between array coils in order to facilitate testing of various coil designs. The final board design with preamplifiers is shown in Fig. 3. Test imaging was performed using a standard spin echo sequence with TE 30 ms, TR 1000 ms, slice thickness 2 mm, Navg=1.

Results & Discussion

Individual profiles were obtained to indicate isolation between the array elements and between the volume coil and the array. T/R birdcage imaging with the array in place verified the homogeneity of the birdcage as well as the “transparency” of the array to the volume coil due to its inherent decoupling from the homogenous field. This decoupling of the top-bottom positioned elements was verified with S21 measurements between the volume coil and a single DPP element rotated to 16 different locations around a cylinder inside the volume coil. Fig. 4 shows the S21 measurements around the cylinder, with decoupling occurring between the transmit coil and the element when it was in the top and bottom positions on the cylinder, all relative to the volume coil feed on the side. Initial SNR comparisons were made only to the linear 60mm transmit birdcage, but immediate future work will be to compare to a standard 3.5cm quadrature mouse coil. In this comparison, the sum of squares reconstructed images presented a 3.45 times higher SNR than the volume coil (Fig. 5). Altogether, the system should allow for compact and straightforward investigation of parallel imaging of mice for certain applications.

Figure 1. 10 channel DPP element arrays with tune/match network and semi-rigid coaxial cable.

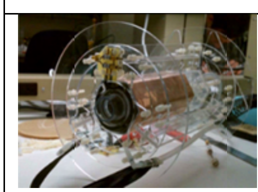

Figure 2. Linear mode trombone birdcage with arrays and animal holder with anesthesia configuration concentrically.

Figure 3 16 channel preamplifier board designed using Altium Desginer 6.0, and outsourced for fabrication The circuit board layout includes the mother-daughter board design to switch out the preamp modules quickly and the SMB coaxial connections for the RF coil array elements.

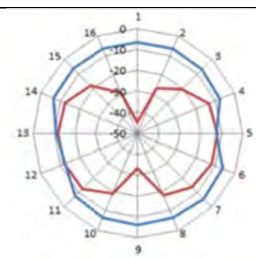

Figure 4. Coupling measurement between transmitting and receiving elements. Number 1 to 6 denotes the position of 16 rungs of transmitting birdcage coil. Radius distance represents the S21 coupling in dB. Blue represents loop coil and red is DPP element. DPP and Loop coil are placed inside the birdcage.

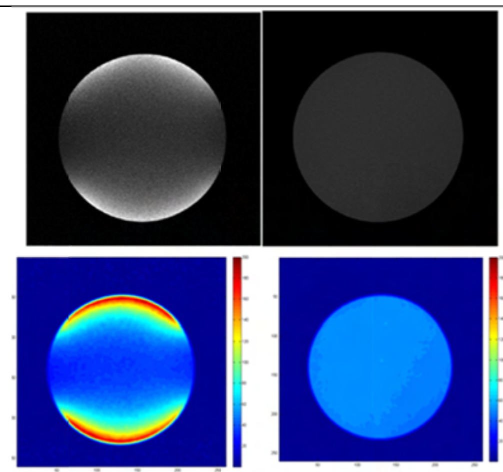

Figure 5. Reconstructed imaging on the left side indicated high SNR on the top-bottom configuration for cardiac imaging. The bottom SNR maps display 10 channel arrays combines higher SNR than volume coil reference imaging on the edge of phantom.

References 1. [1] Schneider JE,et al. MRM 2008; 59(3): 636-641 [2] Ramirez MS, et al. MRM 2010: 63 803-810. [3] Dietrich O, et al. ISMRM Procedings of 15th Annual Meeting 2007, p1759 [4] Lanz T, et al. MRM 64 2010 80-87 [5] Tabbert M, et al. ISMRM Procedings of 18th Annual Meeting 2010, p4735 [6] Keil B, et al. MRM 2011:66 582-593 [7] Chang CW, et al. MRE 2011 159-165. [8] Xu Y, et al. MRM 1997:38 168-172. Acknowledge: Research Supported by AHA Grant #0930231N