Capacitive decoupled two element phased array coil for mouse cardiac MRI at 7 T

M. ARMENEAN[1], B. HIBA[1], H. SAINT-JALMES[2], M. JANIER[1], O. BEUF[2]
[1]Plate-forme ANIMAGE, Université Claude Bernard Lyon 1, Lyon, NA, France, [2]Laboratoire de RMN, CNRS UMR 5012, CPE, Université Claude Bernard Lyon 1, Villeurbanne, NA, France

Introduction

Despite that on clinical systems phased array technology is now widely used, the high field MRI experimental systems with multiple receiver channels just became available two years ago. For this reason and due to the large range of magnetic field (frequencies between 200 and 500MHz), commercial phased arrays implemented in narrow bore high field applications are rare and relatively expensive. Array coil imaging is an advanced method for acquiring high resolution images with enhanced Signal-to-Noise Ratio (SNR) or enlarged Field Of View (FOV). In this last case, the volume of interest is covered by several coil elements and signals are combined afterwards. In this work, we designed and built a two elements array coil operating at 300 MHz based on capacitive decoupling for high-resolution cardiac MRI in the mouse.

Methods

A phased array coil with two channels was built for 7 T horizontal Biospec 4-channel system (Bruker, Ettlingen, Germany) equipped with 400 mT/m gradient. The coil was fixed on a Plexiglas™ half-cylinder with 30 mm outer diameter and 28 mm inner diameter. The geometry of the coil consists in two identical rectangular single loop elements with 8 x 12 mm^2 internal and 16 x 20 mm^2 external dimensions (Figure 1). The elements are separated by 1 mm. The tuning/matching and actively decoupling circuit was designed to allow the connection with the “Bruker Decoupling Box”. For tuning and matching, hyperabrupt varactor diodes driven with variable voltages delivered by the “Bruker Decoupling Box” were used. The major challenge with coils arrays is the decoupling of the different single element. A good decupling between elements is mandatory to have the ability to operate them independently from each other. The decoupling of coils was done by a fixed decoupling-capacitor determined by simulation and experimentally adjusted to minimize the S_{21} parameter between the two channels. Placed in the distal position, the decoupling capacitors are common for the two surface coils. The S-parameters (S_{11}, S_{22}, S_{21}) and the quality factor (Q) were measured with an Agilent ENA300 Network Analyzer. A whole body coil with an inner diameter of 72 mm was used as transmitter and the phased array coil as receiver. An ECG-triggered fast gradient echo (FLASH) cine sequence was used to achieve cardiac cine short axis images with the following parameters: 25mm FOV; 256×256 acquisition matrix; 1 mm slice thickness; 20° flip angle; 3.2 ms echo time; and 8.5 ms repetition time. With a heart rate of 350 bpm, a total of 12 frames per heart cycle were obtained. The measurements were averaged four times to increase SNR, leading to a total scan time of about 3 min.

Results

Simultaneously acquired images with two elements (Figure 2a and b) show no visible coupling between the two channels. The decoupling S21 between the two channels was 28 dB. Unloaded quality factor Q was about 130 for each channel. If the coil is loaded with a 16 mm diameter cylinder filed with 0.45 % NaCl solution, the Q decreases to 100. The SNR, measured in a region of left ventricular (LV) cavity of end-diastolic image obtained with the two elements, increases by a factor between 1.2 and 1.8 relatively to each single element.

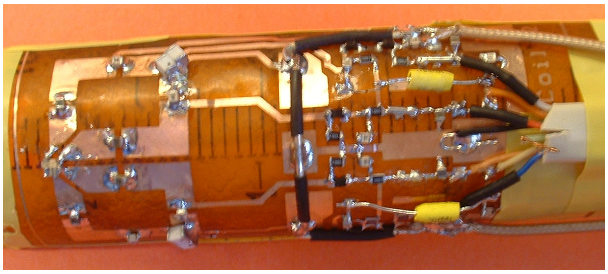

Figure 1: Photograph of the two elements array receiver coil prototype. Each coil element is 8 x 12 mm^2. Curvature of the coil follows a 30 mm diameter cylinder.

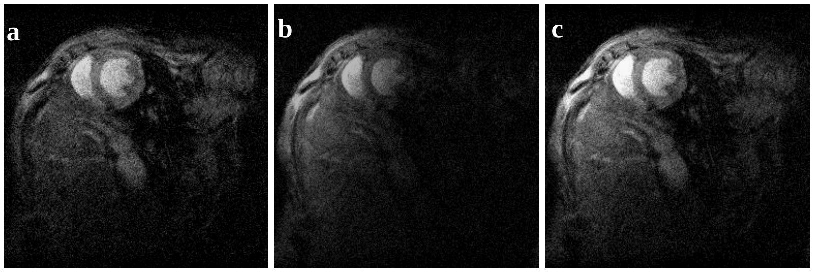

Figure 2: End-diastolic cardiac MR images in the short-axis orientation acquired in adult mouse with: (a, b) Individual coil elements; (c) Reconstructed image using a sum-of-squares combination.

Conclusion

A dedicated small animal array coils with two elements operating at 300 MHz was built and interfaced with regular “Bruker decoupling box”. This coil prototype was applied for cardiac imaging on mouse. The addition of the two independent images leads to a significant SNR increase in the area of interest. The capacitive decupling technique adds supplementary difficulties with the frequency increase, but is also more accurate than the overlapping technique. Finally, it is much less expensive than using special preamplifiers.

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