Design of a four-channel array coil for dual high-resolution rat knee MR Imaging

Anne-Laure Perrier[1], Jean-Christophe Goebel[1], Astrid Pinzano[2], Emilie Roeder[2], Pierre Gillet[2], Denis Grenier[1], and Olivier Beuf[1]
[1]*Creatis, Villeurbanne, France,* [2]*PPIA, Vandoeuvre-les-Nancy, France*

Introduction

In Magnetic Resonance Imaging (MRI), multi-channel coils are extensively used to improve Signal-to-Noise Ratio (SNR) in order to increase spatial and/or temporal image resolution. Recent decoupling techniques based on common conductor that do not require additional preamplifier for the decoupling between elements was achieved for the conception of two-channel surface transceiver coils (1-2). In this paper, based on this common conductor decoupling technique (3), a topology of a four-channel coil was described. Based on this concept, a four-channel surface receiver coil was designed to achieve simultaneous acquisition of both rat knee joints at 7T.

Material and Methods

The four-channel coil topology is described in Fig.1. The L_c-C_c and L_d-C_d sections, tuned to have null impedances at the operating frequency are deporting the ground plane to black point 3. These perfect theoretical reports of ground plane in point 3 guarantee a prefect electrical decoupling between channels. A four-channel surface coil was designed for simultaneous imaging of both rat knee joints on a Bruker 7T Biospec MR scanner (Bruker, Ettlingen, Germany). Each element of the coil consists in a rectangular loop with 14x15 mm^2 internal and 22x23 mm^2 external dimensions. To decouple the receiver coil from the transmitter coil, each loop integrates an active decoupling circuit made with one Temex DH80055 PIN diode. Matching of each loop to 50 Ω at f_0=300 MHz was realized using varicap diodes BB149 (Philips Semiconductors) for Ca and Ce capacitors.

|S| parameter measurements of the four-channel surface coil (Fig 2 a)) were carried out with an Agilent E5071C four-port VNA (Agilent Technologies Inc., Santa Clara, CA, USA). The coil is matched in loading conditions using two cylindrical phantoms filled with saline water solution (NiSO4 1.25 g/L and NaCl 5 g/L) to mimic rat legs. HR-MR images of the rat knees were obtained using a 3D FLASH sequence with the following parameters: 30° flip angle, 50 ms TR, 3.6 ms TE, 27.8 kHz receiver bandwidth. A total of 256 partitions (98 µm thick) were acquired using a double slab volume selection, one for each knee, with a FOV of 1.25 x 1.88 cm^2 and an acquisition matrix size of 256 x 384. Because these large data set is not handle by the 32-bits Bruker paravision 5.1, a home-made script (Matlab 7.13a, Mathworks, Milwaukee, USA) was employed to finally obtain the reconstructed slices (in-plane pixel: 49 x 49 μm^2, thickness: 98 µm).

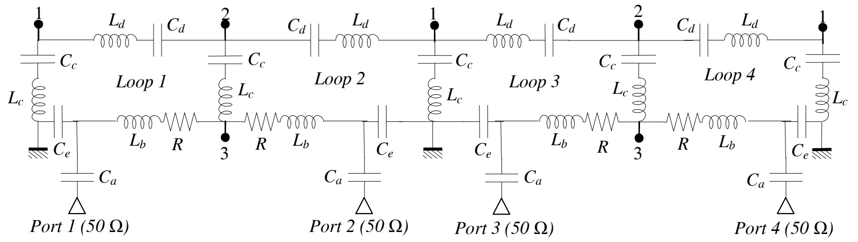

Fig. 1: Equivalent electrical circuit of a four-channel coil based on common conductor decoupling.

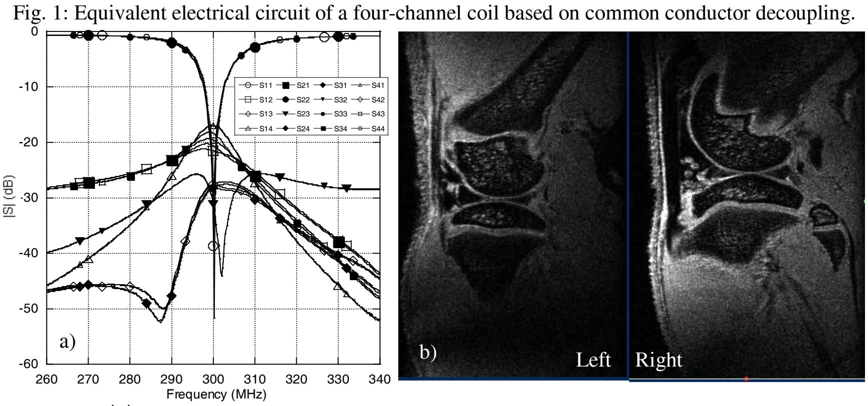

Fig. 2: a) |S| parameters measurements. b) Rat knee imaging.

Results

Measured $|S_{ii}|$ parameters show a coil matching for each loop better than -30 dB at 300 MHz; $|S_{ij}|$ parameters better than -17 dB characterizing a good enough decoupling between loop pairs. Measured quality factors of each loop were 42, 40, 41 and 43 respectively. Fig. 2 b) shows a representative image of the left and right rat knee, respectively. To our knowledge, the voxel size reported here represents the highest spatial resolution achieved in vivo on two rat knee joints in for an acquisition time of 1h22min.

Conclusion

An equivalent electrical circuit of a four-channel NMR surface coil based on common conductor decoupling technique was proposed. The topology allowed good matching and good decoupling between elements without the use of additional low input impedance preamplifier and without additional capacitive network. The design of a four-channel surface coil with a particular wave-like topology for the simultaneous two rat knees imaging was realized at 300 MHz. The capacitor adjustments permit to obtain decoupling better than -17 dB between all element pairs. To our knowledge, this coil represents the first four-channel NMR surface coil based on common conductor not using the preamplifier decoupling technique. Performance of the coil was proved through the simultaneous HR-MRI of both knees joint of a rat. Voxel size of 49x49x98 µm3 was obtained for a 1h22min acquisition time. In future works, similar four-channel coils build with mechanical variable capacitors could be used as transceiver coil. In this case each channel phase and magnitude could be driven to achieve multi-transmit.

References

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