Inductive Decoupling of RF Coil Arrays: A Study at 7T

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INTRODUCTION

The elimination of inductive coupling is a very important step for the use of RF coils arrays in parallel imaging [1]. If in the coil array geometry there is remaining mutual inductance among coils, the NMR signal pick up from one coil can disturb the flux in the other coils, making it difficult to tune and match each individual circuit to the input impedance of its preamplifier. Some resultant effects of this undesired situation have been previously described [2].

The most common method employed to isolate coil arrays involves the use of preamplifiers with very low input impedance (typically < 2Ω) and decoupling networks with lumped elements [1,3]. The construction of preamplifiers with extremely low input impedance is a hard task to accomplish and it imposes a technical limitation on the flexibility of coil design, especially when considering geometries that require overlapping loops that can produce a significant amount of mutual inductance. The purpose of this work is to develop a novel way of uncoupling RF coil arrays that overcomes the above-mentioned limitations.

METHODS

The coil array decoupling circuit as described by Roemer [1] can be modified to employ a transformer to match to the input impedance Rp of the preamplifier, as shown in figure 1. The transformer parameters are: coupling coefficient “K2” and primary:secondary turn ratio “n”. The signal that reaches the preamplifier is coupled in an inductive fashion to the RF coil decoupling network through the transformer’s primary coil. Because primary and secondary coils in the transformer are isolated, the preamplifier circuit (and the MRI scanner electronics) are electrically isolated from the NMR pickup coil. This arrangement provides a perfect electrical balance and isolation between the array channels, thus making it unnecessary to use traps and balluns in the circuit. Some of the advantages related to the use of inductive balanced circuits can be found in [4].

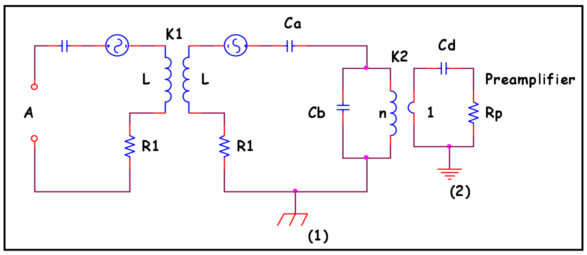

Figure 1. Inductively matched approach for decoupling MRI coil arrays.

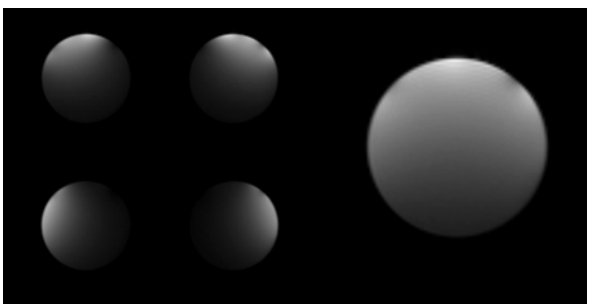

Figure 2: Left: Individual FLASH images of the individual coils. Right: Sum of squares reconstruction

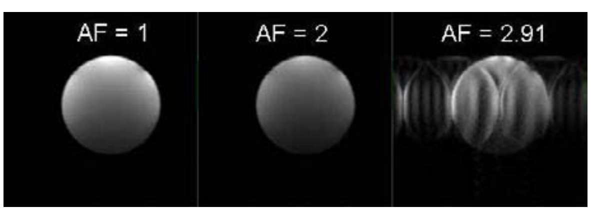

Figure 3: FLASH images acquired with GRAPPA reconstruction at different acceleration factors

For the analysis of this configuration, it can be shown that the impedance of the circuit as seen from the neighbor network circuit point “A”, can be given as:

$$Z_A = R_1 + \frac{w^2 \cdot k_1^2 \cdot L^2}{R_1 + \frac{n^2 \cdot R_p}{k_2^2}} \quad . \qquad (1)$$

In order to achieve high isolation between the coils, Z_A should be just R1. Thus, the second term in Eq. (1) must be made as negligible as possible. This can be accomplished if both “n” and “R_p” are chosen to be high.

RESULTS

The methodology described was tested in a 7T/30 cm Bruker Avance MRI. A four-coil array for imaging the rat brain was built using the concept described in Fig. 1. A PIN diode circuitry was incorporated to allow decoupling of the coil array from the transmit coil. The coil array was connected to regular 50 Ω input impedance preamplifiers. The transformers were made very small with a 7:1 turn ratio between the primary and the secondary. No trap or balluns were employed in the circuit array. This configuration in theory could give the same isolation level as described by (1), if one consider in that situation the use of 1 Ohms input impedance preamplifier.

The measured isolation between the channels in our design was better than 45dB. Figure 1 shows individual FLASH axial images obtained with each coils (left), and the sum of squares combined image on the right. No significant coupling is observed between the RF coils. Figure 3 shows FLASH images acquired with the GRAPPA acquisition scheme at 3 different acceleration factors. Reconstruction artifacts are only noticeable for AF = 2.91, in the form of aliasing banding along the phase encoding directions.

CONCLUSIONS

A 4-channel small animal coil array for 7T was designed and built using inductive decoupling between the different channels. It shows good performance with excellent isolation of all channels and immunity to standing waves or other parasitic signals. The isolation limits for coils arrays can be further enhanced by the use of higher input impedance preamplifier, and this can represent a technical solution for the use of highly mutual inductively coupled coil MRI array system.

REFERENCES

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