A New Decoupling Method for Coil Elements on a Cylinder Surface

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Introduction: Decoupling of multi-element coil is becoming increasingly important due to the parallel transmitting application. The conventional method to decouple coil elements distributed in the azimuthal direction is to use the Butler matrix to form the Eigen modes of the multi-element set-up [1]. Because the Eigen modes of the birdcage coil are orthogonal to each other, the elements after Butler matrix are decoupled. Although this method is theoretically applicable to any symmetrically arranged coil elements with arbitrary number of coil elements on the cylinder surface, the implementation of the Butler matrix is very expensive and requires a lot of efforts. Another state-of-the-art method is to use inductive coupled transformer to remove the coupling between arbitrary coil elements. This method has but the drawback of high power loss due to the lossy transformer. Capacitive decoupling [2] is easy to implement and capacitors with high Q-value are easy available. But because conventional capacitive decoupling requires galvanic connect coil elements together, the capacitive decoupling can be only used to a limited number of elements. In this paper we present a novel method to achieve decoupling between any coil elements up to a total element number of 6 or 8 without using inductance.

Methods: Fig. 1 shows schematically decoupling of a 6 element coil arrays. Due to the symmetrical arrangement of the coil elements, we only need to achieve decoupling of adjacent, next adjacent and coil element on the opposite side. In the decoupling method shown in Fig.1, the adjacent element is decoupled by mean of geometrical decoupling, the next adjacent coil element is principally decoupled by the common capacitor C2 and the opposite coil elements are decoupled by the end-ring capacitors C1. All these decoupling measurements can influence to each other so that iterative adjustment of the decoupling capacitors and geometrical decoupling distance is required. This method can be used up to an element number of 7.

Fig.2 shows a modification of the method presented in the Fig.1. By adding one additional capacitor C3, a decoupling of an 8 element coil can be also achieved. This decoupling method can be easily extended to 9 elements.

Results: Fig.3 shows a picture of the experiment setup build with 8-coil elements. The decoupling is realized according to the decoupling schematic shown in Fig.2. The pre-amplifiers are connected directly to the coil without coaxial cables. The matching circuits are adjusted according to the reflection of the pre-amplifiers to achieve maximum pre-amplifier decoupling. This improves also the signal decoupling between coil elements. Because all coil elements are connected to each other, the ground must be floating to each other. This is achieved by using RF-Trap (or Balun) to isolate the 8 different ground points of every coil elements to each other. The RF-Traps are inserted behind pre-amplifiers to achieve best possible SNR. Fig 4 shows the single element images acquired in the MRI System. Each coil element achieves very good single loop element field pattern, which indicates good decoupling to other coil elements. The S-parameters between the elements are as follows: the adjacent element: $S_{12} = -15dB$; the next adjacent element : $S_{13} = -12dB$; the 3rd adjacent element: $S_{14} = -14dB$; the opposite element : $S_{15} = -17.3dB$. The poorest decoupling between all of the 8 elements is $S_{13} = -12dB$.

The decoupling network presented here doesn't change the signal profile of each individual element which could be an advantage for the parallel transmitting applications. On the other hand, because the signal profile will be not changed, this method can be only used to remove the inductive coupling. The resistive coupling, which is the main reason for the noise correlation cannot be removed by using this decoupling method. According to our experience a decoupling value below -12dB is sufficient for coil adjustment.

Conclusion: we demonstrated a novel method to decouple up to 9 coil element symmetrically distributed on a cylinder surface. The method can be used for TX array for parallel transmitting application.

References:
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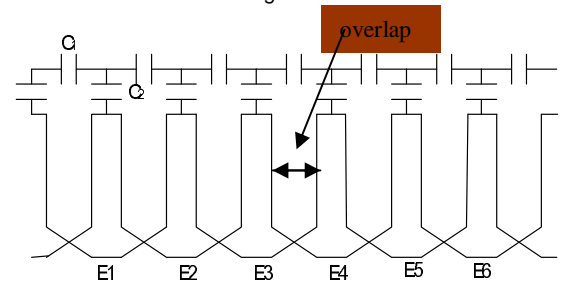[2] Wang, J. Proc. 4th ISMRM p.1434 (1996)
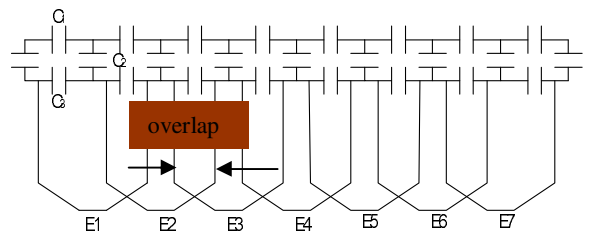
Fig.1 schematic of decoupling method for 6-channel coils

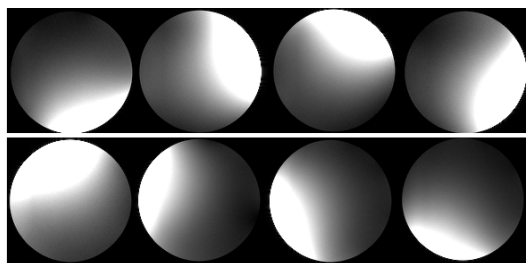Fig.2 schematic of decoupling method for 8-channel coils

Fig.3 8-channel coil with a phantom

Fig.4 Eight single-channel element of the phantom in transversal planes