A numerically optimised receive-only coil array at 3 T

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Introduction

In this contribution, we present the optimisation of a 2D coil array in order to decouple all adjacent and next neighbouring coils simultaneously. To obtain high image SNR, the coils sensitivities have to be independent from each other. For adjacent coils, this can be achieved by geometrical overlapping. Non-adjacent coils are most often isolated by means of low-Z LNAs. Here we have extended the geometric overlapping approach to non-adjacent elements by shape-optimisation of the coil elements.

Theory

The isolation of adjacent coils by geometric overlapping is a well-known technique since the beginning of array development. Decoupling of non-adjacent is however performed by either separate transformers or by low-Z LNAs. We extended the shape of a hexagonal surface coil by small loops that overlap the next neighbouring coils. See fig. 1 for illustration. In order to obtain the optimal size and shape of a single element, we built a parametric model of the single element's geometry. A combination of Matlab[2] and FastHenry[3] was used to optimise an array of seven elements at 3 T:

Matlab's optimisation function (fminsearch.m) calculates a set of parameters for the single element geometry. In the next step, an input file for FastHenry of the whole array is synthesised by arranging the single coil elements. FastHenry then calculates the impedance matrix of the array in order to obtain the coupling between all elements and passes the result back to Matlab. The optimisation loop is terminated when the mutual impedance between all elements is < j*0.1 Ω at 123 MHz. After termination of the optimisation loop, Matlab writes a dxf-file of the coil geometry for PCB production. FastHenry however only calculates the inductive coupling of the conducting elements and neglects the capacitive parts. To verify the results, we imported the optimised design in ADS momentum[4] to run a full-wave simulation. At 3 T the capacitive effects do not notably degrade the isolation between the elements. At higher fields, however, the capacitive effects cannot be neglected anymore during optimisation.

Experimental

From the optimised design, we produced a set of PCBs of the single hexagonal elements (30 mm edge length) on a flexible polyimide substrate. A support made of PMMA was used to fix the elements by means of nylon screws. A separate PCB on top of the element in the centre contains the symmetric tuning and matching circuitry for all seven elements. In order to use the array for reception only, PIN diodes (BAR 64) are used to detune the elements during transmission. Fig. 2 shows a picture the demonstrator.

Results & discussion

In order to verify the achievement of the optimisation, we first measured the coupling between all elements of the unloaded array by means of a network analyser at 123 MHz. All adjacent elements show an isolation of > 25 dB, the next neighbouring elements even > 30 dB. The circuit Q of a single element was calculated by the bandwidth of the input reflection measurement and is, on average, 50 [5]. First MR-measurements were performed with a Siemens Tim Trio 3 T System. Fig. 3 shows the reconstructed sum-of-square image of a self-made iso-H_2O phantom, acquired with the seven elements of the array.

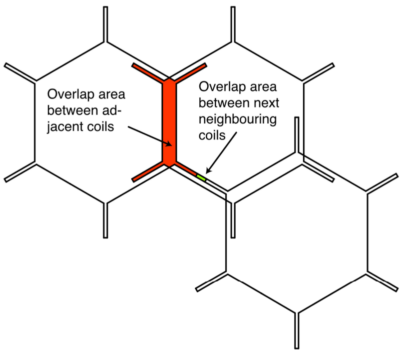

Fig 1. Illustration of the overlapping coils. The hexagons have a diameter of 60 mm.

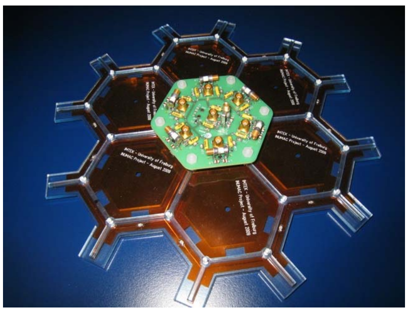

Fig 2. Picture of a coil array demonstrator with seven elements.

Fig 3. Image of a self-made iso-H_2O phantom (sum of square reconstruction of seven coils without LNAs).

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References: [1] Roemer et al., Magnetic Resonance in Medicine 16, 192-225 (1990); [2] The Mathworks, Inc; [3] RLE Computational Prototyping Group, MIT, Cambridge, MA; [4] Agilent GmbH, Böblingen; [5] Mispelter et al., NMR Probeheads (2006).