Shielded quadrature coil elements for NMR phased-arrays

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Introduction:

Recently MR systems with up to 128 independent receiver channels have been developed [1]. With these, phased-array coils with up to 128 coil elements have been introduced [2, 3]. While these arrays have provided impressive results, the minimal size of elements is limited if maintaining sample noise dominance is required. Thus only a fraction of receive channels can be used to full potential for imaging of more localized region-of-interests (ROI), such as the human heart. Here alternative array coil designs would be beneficial to allow a higher density of independent receive channels. For this purpose, the concept of shielded quadrature array coil elements is introduced which utilizes additional, perpendicular coil elements to improve signal-to-noise ratio (SNR) and encoding capability for parallel imaging.

Materials:

A quadrature array coil element is made of a shielded circular loop [4, 5] as planar coil and an additional rectangular, non-shielded surface coil perpendicular to the shielded loop (Fig. 1). Their magnetic fields and electric fields are orthogonal, leading to adequate isolations as well as a circular polarized B_1 field in the sample volume. The shielded coil was built with an inner diameter of 10cm, a conductor width of 7mm and a spacing of 7mm to a 1mm wide shield ring which guarantees isolation to adjacent coil elements. The upright coil has the same conductor width (7mm) and outer dimensions of 10cm by 5cm and no shielding. Though simulations show a SNR gain up to a factor of 1.4 for large element heights, the perpendicular element was limited to 5cm resulting in an appropriate coil thickness. All elements were etched on 1.5mm FR4 PC boards with 35µm copper layer.

Four of these quadrature array elements were combined to form a 2x4-channel spine receive array for a 1.5T Siemens Avanto MR system (Siemens Medical Solutions, Erlangen). Adjacent planar coils were intrinsically decoupled due to the shielded design, while perpendicular coils were isolated by a larger distance and the utilization of low-noise preamplifiers (Siemens Components, Erlangen).

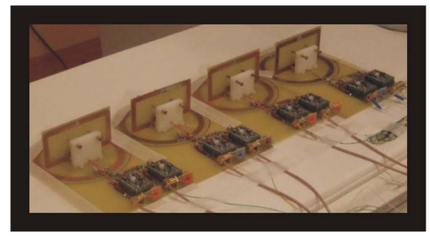

Figure 1: Exemplary 8-channel spine array coil of 4 quadrature array elements

Results:

The four planar elements of the 8-channel spine array show a mean quality factor (Q-factor) ratio of 180/65 (unloaded/loaded), while the mean drop in Q-factor for the perpendicular loop is 175/100. An isolation between the orthogonal coils of a quadrature array element is -33dB (mean) and was geometrically adjusted. The decoupling of all other adjacent elements was determined to be approximately -20dB or better, including preamplifier decoupling.

The efficiency of decoupling of elements is shown by the noise correlation which is at an average of 7.5% (FLASH phantom experiment, Fig. 2). The SNR for the spine array was calculated from a similar data set and was compared to simulation results acquired by a Biot-Savart integration implemented in MATLAB programming environment (MathWorks, Natick, MA). Though the measured SNR gain on a phantom was 15% compared to 25% in simulation, an improvement in sensitivity was seen. Simulated and measured geometry factor maps (g-factor, Fig. 3) with an acceleration factor of R=4 are consistent and show the gain by using the four additional perpendicular coil elements. An enhanced encoding performance can be observed especially close to the array structure. This is also affirmed by in vivo spine images of a healthy volunteer acquired with a 3D T2-weighted spin echo image with PAT factors of 3 and 4. (Fig. 4).

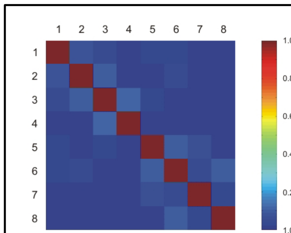

Figure 2: Noise correlation matrix of the spine array coil

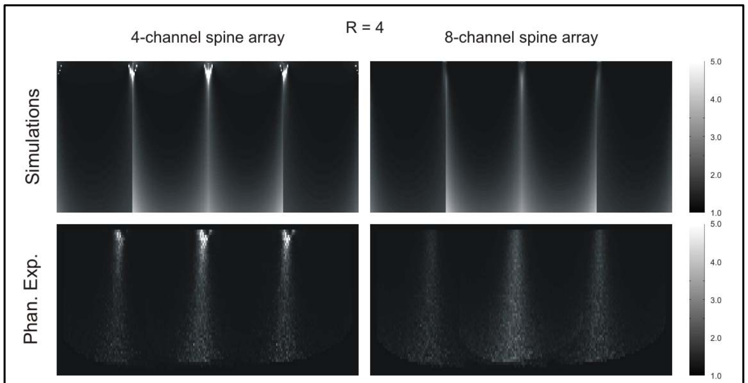

Figure 3: g-Factor maps for a planar 4-channel spine array and a quadrature 8-channel spine array by simulations (FoV 350x150mm^2) and phantom experiments.

Conclussion:

Shielded quadrature coil elements provide a way to increase the minimum number of receiver channels when preserving sample noise dominance of the single coil elements in localized ROIs. An SNR gain of up to a factor of 1.4 can be achieved by the additional perpendicular coil elements. However, space restrictions limit the size of these additional elements. The additional coil elements improve g factors and parallel imaging properties.

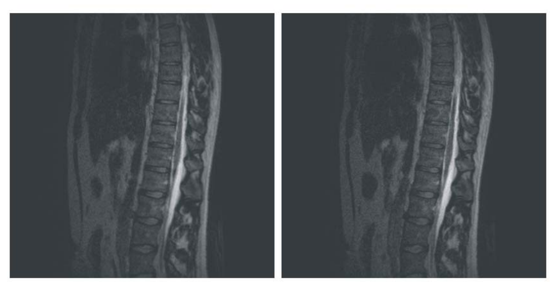

Figure 4: In vivo spine images acquired with a 3D T_2-weighted SE (TE=143, TR=1500, FoV 379^2) with PAT=3 (left) and PAT=4 (right).

Acknowledgments:

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References:

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