Promising Double Spiral Design for Volume Array Head Coils

M. Mueller, F. Breuer, M. Blaimer, R. Heidemann, A. Webb, M. Griswold P. Jakob
Universität Würzburg, Würzburg, Germany

Introduction:

In the last years parallel imaging techniques have been presented with reduced phase encoding steps in more than one direction such as 2D-SENSE [1], 2D-CAIPIRINHA [2], etc. With these methods the limitation of reduction factor for standard 1D partially parallel acquisition [3] can be overcome. However to use the whole potential of these methods in clinical routine, coil arrays with special capabilities are needed. These must provide sensitivity variations in such a way that the encoding direction can be chosen freely within the whole sample volume.

For cylindrical array geometries on one surface, like general head coils, this can be achieved by extending the normal one ring of array elements, to two adjacent rings of surface coils. For a large number of receiver channels even designs with three rings are imaginable. Though impressive results have been provided by such array designs [4] constructing these is not an easy task. For an array set-up with 2 rings an element has to be decoupled from five adjacent surface coils compared to only two in a 1 ring coil array. In a 3 ring design, up to 9 adjacent array elements have to be isolated (Figure1). Thus building a multi ring volume coil array on one surface with many elements could potentially reach the limits of constructional feasibility.

For this reason we have considered leaving the single surface set-ups and arranging the array elements on different surfaces which are geometrically decoupled [5]. An example of such an array design is a double spiral head array coil. In these arrays half of the elements form a 1 ring volume array which is twisted by an angle of $+\pi$ (Figure2). The other half of the elements are placed in the same way on a slightly bigger cylindrical surface but with a twist of $-\pi$. Due to these opposed twists both individual spiral arrays are geometrically isolated and can be driven as a double spiral array with twice the channels of the single spirals. This fact allows the separate construction of both single spiral coil arrays similar to a simple 1 ring birdcage like array but provides the encoding performance of a comparable 2 ring volume array.

The goal of this work is to discuss the theoretical capabilities of multi surface volume coil array design and present some practical examples.

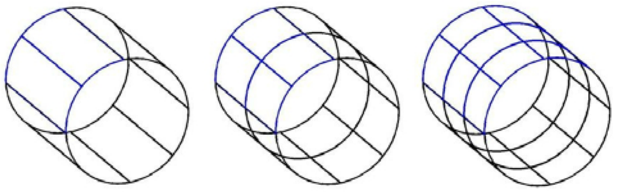

Figure 1: Birdcage-like arrays using a one, two and three ring set-up

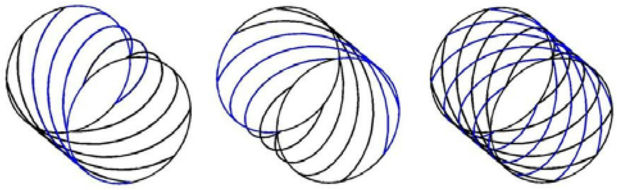

Figure 2: Spiral arrays with $+\pi$ twist, a $-\pi$ twist and a double spiral array set-up

Methods:

As a first approach, different array types were simulated using a Biot-Savart integration determining B1 field distribution and a SENSE reconstruction for calculating g factor maps for different encoding directions. In the following, single elements of various array designs were constructed on a cylindrical G10 former using copper tape. By measuring the B1 field strength in the middle of the cylinder and the unloaded and loaded Q factors of these elements, the intrinsic performance of the different array designs could be estimated. Based on this, a prototype 8 channel double spiral head array coil was built to investigate the feasibility of construction and the possible in vivo performance of such a spiral array design (Figure3). In particular, the decoupling of the single spiral arrays on the two different cylindrical surfaces, the noise correlation between the array elements and the encoding ability of the array were investigated.

Results:

The simulations of B1 field distributions and g factor maps for 2 ring birdcage-like arrays and comparable double spiral arrays with the same number of elements did not show any significant advantage for either design in the center. Furthermore, the comparison of the elements of different array designs built of copper tape on a G10 former also showed no large benefit in using a birdcage-like array instead of a double spiral array set-up or vice versa.

For the prototype 8 channel double spiral head array coil, the two 4 channel single spiral arrays with a twist of $+\pi$ and $-\pi$ were built completely separately. Within each array an intrinsic isolation of less than -20 dB could be attained for each element. When stacked into each other, both spirals could be geometrically decoupled by a mean isolation of -17dB. Taking into account the further -20 dB isolation provided by the low noise preamplifiers, all elements of the double spiral array coil are well decoupled from each other.

This is also confirmed by the uncombined in vivo images from each channel of the double spiral array coil. Furthermore, in an in vivo 3D parallel imaging dataset with reduced phase encoding in transverse and in axial direction, no loss in image quality due to reconstruction problems was noticeable (Figure4). In addition, a noise correlation of no more than 15% was measured between the array elements. Thus a double spiral array design could possibly provide more intrinsic SNR than a comparable birdcage-like ring array [5].

Figure 3: Prototype 8 channel double spiral array headcoil

Conclusion:

In terms of parallel imaging performance a double spiral array coil provides results similar to the comparable birdcage like volume array. According to the constructional feasibility of these arrays a double spiral design is much easier to build due to the two intrinsically decoupled surfaces. Further the uncorrelated noise distribution between the two single spiral arrays and consequently higher possible intrinsic SNR points a double spiral array set-up out as a promising design for multi channel volume arrays.

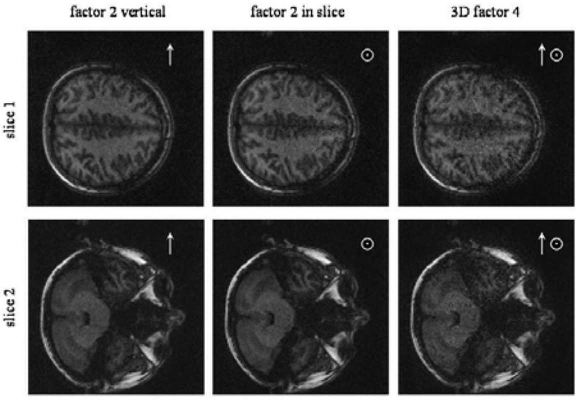

Figure 4: In vivo 3D data set; reconstruction with GRAPPA

References:

[1] Weiger et al, MAGMA 14:10-19 (2002)
[2] Breuer et al, ESMRMB 2003, p. 40
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