Considerations for Enhanced SNR Performance of a Spiral Array Coil with Many Elements using a Common End Ring Design

M. Mueller[1], T. Lanz[2], M. Blaimer[1], F. Breuer[1], R. Heidemann[1], A. Webb[1], M. Griswold[1], P. Jakob[1]

[1]Department of Physics, University of Wuerzburg, Wuerzburg, Germany, [2]RAPID Biomedical, Wuerzburg, Germany

Introduction:

In the last years large receiver banks providing up to 64 channels have been developed [1]. To date, standard planar surface coil arrays have primarily been used for these receiver chains. Although they have provided impressive results [2] this type of array coil is primarily limited to surface applications. On the other hand, several recent studies have considered different volumetric array coil designs for high-performance massive parallel 3D imaging. Within these surveys, a double spiral array configuration appeared to be a promising array set-up due to construction difficulties and imaging performance [3]. Based on these results a prototype 8 channel double spiral head array coil was built for pilot studies [4].The goal of this work is to determine how much further the number of channels could be feasibly increased for a routine double spiral head array coil. In addition, difficulties in constructing such a massive element double spiral coil array are discussed and possible solutions are presented.

Materials:

Several array elements corresponding to double spiral array coils with 8 (4 inner and 4 outer), 16 (8 and 8) and 24 (12 and 12) channels were constructed. They were built on a cylindrical G10 former with a diameter of 28 cm and a length of 28 cm using 8 mm wide copper tape. For each element, the unloaded and loaded quality factor (Q-factor) values were determined and the B_1 field strength in the middle of the G10 tube was measured. With these numbers, the signal to noise performance and the B_1 penetration depth of the future double spiral phased array could be estimated. Though the long spiral legs of each element were already capacitively shortened to prevent standing wave losses, alternative designs for these copper conductors were considered as well regarding a further gain in Q.

	B_1	Q_u	Q_l	Q_u / Q_l
8 channel double spiral array	-37 dB	325	92	3.5
16 channel double spiral array	-38 dB	380	167	2.3
24 channel double spiral array	-39 dB	373	215	1.7

Table 1: Q factors and B_1 field strength of different spiral array elements

Results:

The unloaded and loaded Q factor values as well as the measured B_1 field strength in the middle of the cylindrical former are presented in Table 1 for elements of an 8, 16 and 24 double spiral array coil respectively. These numbers indicate that a double spiral array with up to 16 channels could provide a reasonable performance in terms of signal to noise ratio (SNR) and B_1 penetration depth. Spiral array coils with a larger number of elements suffer due to a smaller effective element area for the magnetic flux. This fact leads to a bad loading of the array coil and thus the Q factor ratio is rather low.

Another cause for a severe decrease of the Q ratio and therefore SNR is the application of the active decoupling network. As an example, in a 16 channel array element, the quality factor ratio drops from 380/167 to 210/120 with the addition of the active decoupling circuit. This results in a Q ratio decrease from 2.3 to 1.8. Since the design of this active decoupling network has already been optimized and this circuit is essential to detune the elements of the double spiral array coil during transmission, other ways of gaining in Q factor ratio must be considered.

To this end, the loss properties of different conductor set-ups for the long legs of a spiral array element were determined. For this, various element configurations were tested: 1) legs of copper tubes intermittently spaced by three capacitors, 2) legs of double sided 8mm wide copper strips alternatively cut on the top and bottom layers respectively and 3) legs of double sided 8mm wide copper strips each cut three times alternatively with capacitors between the gaps on top. The Q factors of these different element set-ups were compared to the results of an element with a primary leg design of 8 mm copper tape shortened by 3 equally distant chip capacitors. Regarding the results presented in Table 2, the original leg construction provides the best Q factor ratio and so the least losses.

For this reason, it is clear that the SNR performance of the double spiral array coil has to be improved through some other approach. For this reason, the $+\pi$ and $-\pi$ spiral array, formerly built separately on two tubes, were constructed on one common cylindrical former with one common end ring. On this ring a $+\pi$ spiral array element and the corresponding $-\pi$ element share the same common chip capacitor. By changing its value, the intrinsic geometrical decoupling of the $\pm\pi$ spiral array coils could be further increased. Thereby the mean isolation factor between these two spiral arrays could be enhanced from -18 dBs to -21 dBs. By placing the active decoupling network at this joint capacitor, two elements can be detuned at the same time during transmission. Additionally the noise contribution of the decoupling circuit is equally dispersed on both elements. In summary, this common end ring double spiral array design provides a better SNR performance due to the decreased distance of the outer spiral array to the sample, the decreased number and relative impact of the active decoupling networks.

	Q_u	Q_l	Q_u / Q_l
copper tape, 3 equidistant caps	380	167	2.3
copper tubes, 3 equidistant caps	335	160	2.1
double sided copper strips	70	56	1.3
double sided copper strips with caps	145	96	1.5

Table 2: Q factors for various spiral array element leg designs

Conclusions:

Several array coil elements of different sizes corresponding to spiral arrays with 8, 16 and 24 channels have been constructed. According to Q factor and B_1 field strength measurements, more than 16 channels are not reasonable for a spiral array coil designed in this way. The Q factor ratio and thus the SNR performance of the double spiral array coil is further decreased by the additional losses in the active decoupling networks. A different conductor set-up for the long element legs could not improve the intrinsic signal to noise ratio of a spiral element. However, it was shown that another double spiral array coil design could reduce these SNR problems. Both $+\pi$ and $-\pi$ spirals were constructed on the same cylindrical surface decoupled over a shared capacitor on a common end ring. This reduced the distance between the sample and the former outer array elements resulting in higher SNR. By placing the active decoupling network at a common capacitor, half of these circuits could be spared and their overall noise contribution reduced. Though the number of elements for such a designed double spiral surface coil array is still limited, the total number of array elements could be increased by constructing an end plate on top of the cylinder with 4, 6 or even 8 surface coil elements.

References:

[1] Brown et al, ISMRM 2002 p. 863
[2] Wright et al, Proc., 2002 IEEE/EMBS Ann. Symposium
[3] Mueller et al, ISMRM 2003 p. 2340
[4] Mueller et al, ISMRM 2004

Acknowledgments:

We acknowledge RAPID Biomedical for supporting this project and Randy Duensing and Steve Wright for their helpful discussions. This project was funded by DFG JA 827/4-1.