3D RF Coil Modeling Method and Its Application in Optimized SENSE Coil Design

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Introduction:

In order to improve the SENSE imaging technique, dedicated RF coil arrays for SENSE imaging have been designed by simulating a number of coil array configurations, comparing the SNR and g-factor of the simulated coil arrays, and then selecting the best configurations [1-2]. Recently, several automatic numerical optimization methods have been proposed [3-4]. In these methods, the RF coil arrays were first modeled analytically, and then the parameters used to model the RF coil arrays were optimized to find the optimum average SENSE SNR and/or it's uniformity, thus yield the optimized coil array configurations. The new methods are more efficient and most likely to yield better results than the "simulate-compare -select" approaches. However in these automatic optimization methods, the RF coil arrays were always confined in the predefined cylinder surfaces and it is very likely that the same optimization procedure could yield better RF coil arrays without such a constraint. In order to test this hypothesis, two RF coil array systems were designed for 4xfold 1D SENSE imaging with the automatic optimization approach [4]: one is confined to a predefined surface; the other one was allowed grow into a 3 dimensional volume (fig. 1).

Methods:

Two RF coil arrays were optimized for 4xfold 1D SENSE imaging using the "target field" based optimization method. The RF coil arrays were modeled by the vertex locations ($\boldsymbol{r}_i$) of the metal strip segments that make up the RF coil. For the first coil array (cylindrical surface coil array), $\boldsymbol{r}_i$ were confined to a cylindrical surface with a diameter of 28 cm and a height of 28 cm; for the second coil array (3D coil array) $\boldsymbol{r}_i$ were allowed to move with a cylindrical shell with an inner and outer diameter of 28 cm and 33.6 cm and a height of 28 cm (fig. 1). The same optimization procedures were used for both coil designs: the object was considered to be a cylinder with a diameter and a height of 22.4 cm, and the ROI was defined as a cylinder with a diameter of 22.4cm and a height of 16.8 cm in the center of the object. Both the average SNR and SNR uniformity inside the ROI were considered in the numerical optimization, with a weighting of 30% for the average SNR and 70% for the SNR uniformity. Symmetry of the problem was taken into account in order to reduce the computation time. The resultant RF coil array systems were then simulated and compared with each other and a standard rectangular SENSE coil array as well.

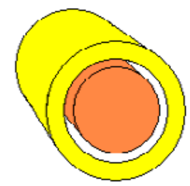

Fig. 1. The object (orange) and the region where the 3D coil array was optimized (yellow).

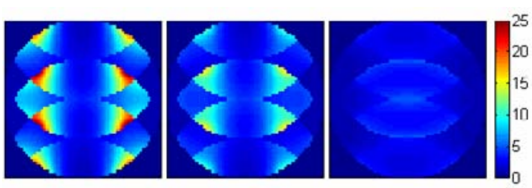

Fig. 2. Simulated g-factor map of (a) the standard array, (b) the optimized cylindrical surface coil array and (c) the optimized 3D coil array.

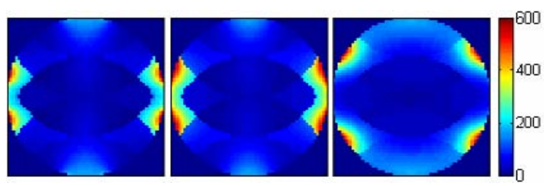

Fig. 3. Simulated SNR map of (a) the standard array, (b) the optimized cylindrical surface coil array and (c) the optimized 3D coil array.

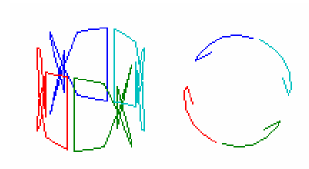

Fig. 4. Side view (left) and top view (right) of the optimized 3D coil array.

Results and Discussion:

The simulated g-factor map and SNR map from the center slice for the standard rectangular array, the SENSE optimized cylindrical surface coil array and the optimized 3D coil array were shown in Fig. 2 and 3. The mean SENSE SNR, the normalized standard deviation of the SENSE SNR, the mean g-factor and the maximum g-factor of the three coil array systems inside the ROI were also calculated and listed in table 1. Improvements of these parameters were found for both of the optimized coil arrays compared with the standard coil array. Moreover, the optimized 3D coil array has significant improvement over the optimized cylindrical surface coil array; the SENSE SNR standard deviation improved by 31%, the average g-factor improved by 48% and the maximum g-factor is only one-fifth of that of the optimized cylindrical surface coil array.

	Mean SNR_{SENSE}	STD SNR_{SENSE}	Mean g	Max g
Standard coil array	67.7	1.27	5.8	34.6
Optimized cylindrical surface coil array	78.4	1.22	4.64	25.3
Optimized 3D coil array	90.6	0.84	2.42	5.1

Table 1 Comparison of SNR and g-factor of the coil arrays.

Fig. 4 shows both the side view and top view of the conductor layout of the optimized 3D coil array. The design is reasonably simple to build, and from the top view, it is easily seen that the optimized 3D coil array **did** fill the 3D shell. As a conclusion the proposed 3D RF coil array modeling method provided the more flexible and reasonable constrain to the SENSE coil array optimization problem, and significant improvements have been found in the resultant coil array system compared with the optimized coil array system modeled on a conventional cylindrical surface.

References:

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4. Dodd SJ, et al., Proc. ISMRM p.913, 2005.