Optimization of 24-Channel Receive-Only Coil Array for Brain Imaging at 7.0 Tesla by the Genetic Algorithm

S. Wang[1], P. J. Ledden[2], J. H. Duyn[1]

[1]LFMI, NINDS, National Institutes of Health, Bethesda, MD, United States, [2]Nova Medical, Inc., Wilmington, MA, United States

Introduction: With the advances of high-field MRI and parallel imaging techniques 1), there is growing interest in the design of RF receive coil arrays for high-field SENSE imaging. Since the array performances depend on the geometric features, an optimized design in terms of geometry is of great importance in practice. However, optimization is very challenging due to the number of variables involved (especially for multi-channel arrays) and the inefficiency of available electromagnetic solvers to evaluate coil profiles. In this work, we developed an optimization strategy by using the Genetic Algorithm and the rigorous solution of Maxwell's equations. It is applied to 24-channel array for brain imaging at 7.0 Tesla.

Methods: The Genetic Algorithm 2) is based on the evaluation of cost functions and searches for the optimized design in an evolution manner. In this study, the cost function is determined by the SNR, which is evaluated via the rigorous solution of Maxwell's equations by using an in-house developed integral-equation-based computer program. The coil profiles as the results of the electromagnetic field distributions are combined into phase-sensitivity SNR maps. Since coil profiles decay rapidly inside phantom, the combined SNR is extracted on a series of sampling lines. The cost on each sampling line is defined as the weighted summation of the average SNR and the signal variation on that line. The cost of a slice is the weighted combination of the cost on each sampling line. Because the SNR of different arrays defers less in deeper region, we assign the highest weight to the shallowest line and the lowest weight to the deepest one. The weight varies linearly in between. If multiple slices are considered, the overall cost is the weighted combination of the cost on each slice.

Results and Discussion: The array consists of 24 small oblong loops that are divided into 8 rows (Fig. 1). The number of coils in each row is fixed and the coil overlap in each vertical row and the inter-row gap size are variables in the optimization. With 2.5 mm increment of the vertical overlap and 5 mm increment of the inter-row gap size, the optimization weights on 14,600,960 designs. Fig. 2 shows the combined SNR map of an oblique slice cutting through the middle of a row of 4 coils. The SNR evaluated on the second shallowest sampling line are also shown. It is observed that large signal variation occurs with the minimum coil overlap (zero overlap) in z-direction. By increasing the coil overlap, the signal variation can be significantly reduced. The optimized coil overlaps for each row of coils with equally weighted average SNR and signal variation are shown in Fig. 1. After optimizing each row of coils, the final optimization is selected from different inter-row gap sizes based on the SNR on 8 axial slices. Fig.3 shows a combined axial SNR map and the sampling lines defined in the anterior and the posterior sections. The final results are shown in Figs. 4 and 5. It is observed that the optimized design depends on the SENSE acceleration rate and whether signal variation is taken into account. In all cases, no inter-row overlap is suggested. Moreover, the higher the SENSE rate is, the wider the inter-row gap size should be.

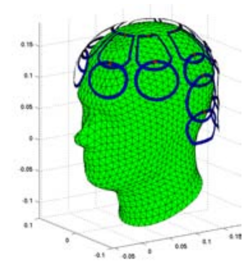

Figure 1: The computer model of a 24-channel coil array.

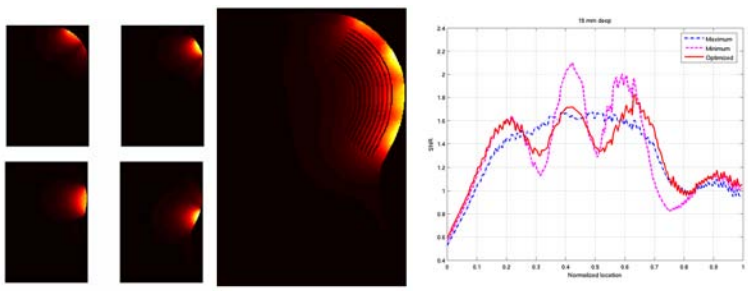

Figure 2: Left: SNR profile of each element in one row. Middle: the phase-sensitive combined SNR map and the sampling lines. Right: the combined SNR on one line.

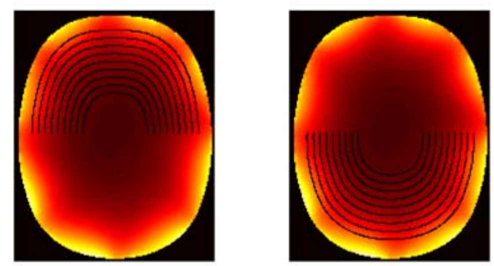

Figure 3: Left: sampling lines in the anterior section. Right: sampling lines in the posterior section.

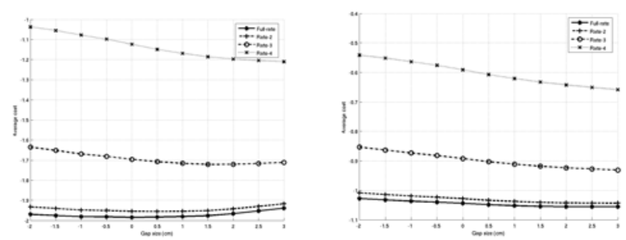

Figure 4: Left: costs of different inter-row gaps evaluated by an equal weight of the average SNR and signal dropout. Right: costs of different inter-row gaps evaluated only by the average SNR. Lower cost means better performance.

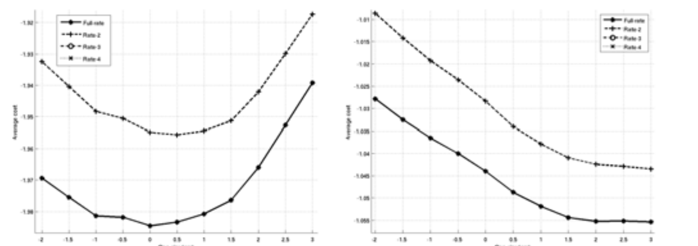

Figure 5: Left: zoomed view of the left of Fig. 4. Right: zoomed view of the right of Fig. 4. Lower cost means better performance.

Conclusion: The results show that the optimized SENSE coil array design depends on the SENSE acceleration rate and how much signal variation is weighted. Coil overlap in z-direction and inter-row gaps are preferred for both better SNR coverage and SENSE performances.

References: 1) Pruessman, K.P., et al, MRM 42:952-962, 1999. 2) R. Hault, et al, Practical Genetic Algorithms.