An Inverse Method for the Design of RF Array Coils with a Sparse Structure and Its Application for Breast Imaging

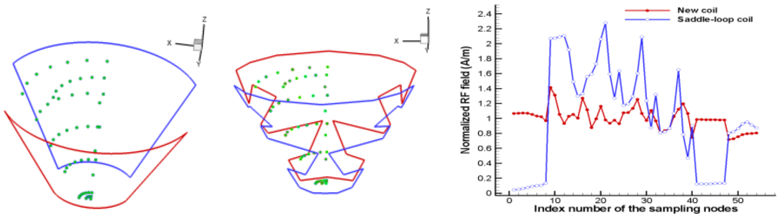
Y. LI[1], F. Liu[1], E. Weber[1], B. Li[1], and S. Crozier[1]
[1]The University of Queensland, Brisbane, Queensland, Australia

Introduction In MRI, significant efforts have lead to the development of new design techniques for RF phased array coils. One of them, the inverse method, has been theoretically and experimentally investigated as a viable approach for RF coil design. The most common methodology starts with the specification of the desired RF field within a predefined region, by utilizing the so-called target field technique, followed by a streamline function method to find the coil winding by discretizing the calculated continuous current density distribution [1-2]. However, this technique tends to produce multi-loops for a targeted RF field profile in the imaging region. In this work, we attempt to implement the inverse design for RF array coils with a sparse structure (less loops) using an iterative optimization technique. A deformation approach has been proposed and a two-loop array breast coil has been designed using this method. The simulated and experimental results presented herein demonstrate the potential of the proposed design technique to produce low-inductance coil structures with improved RF field.

Methods Following the design procedure, the first step is to set the target B1 field in the imaging region, considering a conventional two-loop saddle coil as the initial coil structure. The coil shape is then deformed with a target of uniform B1 field in the imaging area, and the deformation is controlled by a few nodes. Each node has a two-dimensional degree of freedom, which means that the points can freely move on the surface of the coil former. In this case, a cone-shape former has been considered; in a spherical coordinate system, the ρ- and φ- components can be modified during the optimization. Due to symmetry of the problem, only coils located in one quadrant of the structure need to be considered for optimisation. The iterative optimization technique used in this work is the nonlinear least square method [3] and the B1 field evaluation is based on the Biot-Savart law. A hybrid framework is used for the numerical calculation, i.*e*., the optimization is managed using Matlab while the field calculation is implemented using C-language.

Results and Discussion The iterative optimization is efficiently implemented in a Matlab environment, taking approximately 20 secs to find a satisfactory solution. The winding patterns of the constructed prototype RF coils are shown in Fig.1. The left panel shows the conventional saddle loop pattern and the right panel the implemented winding of the newly designed coils. Fig.2 depicts the simulated B1 field homogeneity (Fig.2 (b)) over the sampling space (Fig.2 (a)). From this figure, it is apparent that the new coils have a much larger usable field of view (FOV). In our defined FOV, the B1 inhomogeneity (peak to peak) of the new design and the saddle coil are 69.6% and 223.6%, respectively. Both coils were tested with a cone phantom containing a saline solution (80% of the size of the coil) in a 2T MRI system (Bruker S200). In the experiment, the coil was operated in transceive mode and a standard MSME (multi-slice multi-echo) pulse sequence was used. Fig. 3 shows the acquired MR images of the phantom. It can be seen that the new design (bottom panel) is better than the saddle coil (top panel) and we also note that the phantom images corresponded well with the simulated results. In the coronal section, there are several dark and bright spots located near the edges of the image obtained by the saddle coil. As compared to the saddle coil, the new design offers a more uniform sensitivity profile. In the axial and sagittal planes, the new design presented a much larger homogenous region in the axial plane. Table 1 is the quantitative study of the difference between the saddle coil and the new designed coil. Furthermore it demonstrates the better overall performance of the new design.

Fig.1.The coils structure. (a) Conventional saddle loops coil; (b) new design.



(a) (b)

Fig.2 Normalized B1 field of the saddle-loops and optimized array Coil. (a) Sampling nodes for the B1 field evaluation; (b) normalized B1 field.

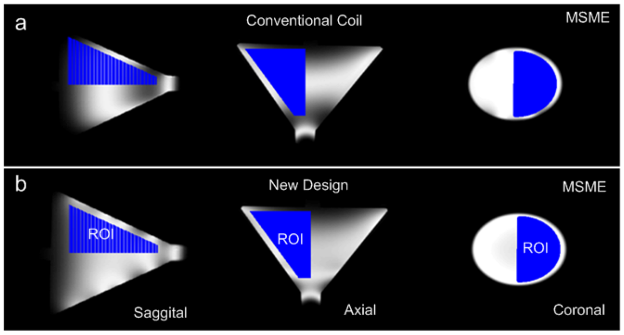


Fig. 3 MSME images of the cone phantom. (a) saddle loops coil; (b) the new designed phased array coil. The field sampling area is colour-coded (for the field quality comparison, see table 1).

Table1. Image inhomogeneity comparison of the two coils

Cross-section	Image inhomogeneity (Peak to Peak)		Image inhomogeneity (rms)	
	Saddle-loops	New coil	Saddle-loops	New coil
Saggital	2.02	1.41	0.64	0.32
Axial	1.60	1.66	0.50	0.42
Coronal	0.27	0.13	0.04	0.04

Conclusions In this work, a novel RF phased array coil for breast imaging was designed, constructed and tested. In the inverse design, an iterative optimization approach was used to determine the coil geometry. Both the simulated and experimental results demostrate the performance of the proposed method in terms of sparsity of the designed coil structure and the resultant B1 field.

References

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