RF Coil Array Optimized for 2D SENSE Imaging

G. Chen[1], L. T. Muftuler[1], O. Nalcioglu[1]
[1]Tu & Yuen Center for Functional Onco-Imaging, University of California, Irvine, Irvine, CA, United States

Introduction: RF coil configuration plays a very important role in determining the final SNR in SENSE imaging. Finding the optimized RF coil configurations for various SENSE imaging applications is important but challenging. In this work a recently proposed "target field" SENSE coil optimization method [1,2] is modified such that the SENSE coil array is now modeled by the locations of the metal strip vertices that make up the RF coil, instead of the finite element mesh method. By this new optimization method, a 4-channel RF coil array was designed and built for 2D SENSE imaging [3] in 3D Fourier MRI. Significant improvement in SNR was obtained when compared to standard coil array reported in [3].

Methods: SNR is one of the main criteria in the design of the RF coil arrays for SENSE imaging. Theoretically, when only the sample noise is considered, the final SNR of a given pixel ρ in SENSE imaging $SNR_{SENSE,\rho}$ can be formulated in terms of the $\boldsymbol{B}$ field generated by the RF coil. RF coils usually consist of finite numbers of metal strip segments attached on the coil former. In this scenario, the RF coil can be modeled only using the locations ($\boldsymbol{r}_i$) of the vertices of the segments. Then we can formulate the RF coil's $\boldsymbol{B}$ field in terms of $\boldsymbol{r}_i$. Finally, $SNR_{SENSE,\rho}$ as a function of $\boldsymbol{r}_i$ can be derived. Once this relationship is established, we can optimize $\boldsymbol{r}_i$ to yield the best $SNR_{SENSE,\rho}$ in any defined region of interest (ROI).

In order to find the optimized RF coil array for 2D SENSE imaging, we first defined the coil former as a cylinder with a diameter of 28 cm and a height of 28 cm. $\boldsymbol{B}$ field was calculated using quasi-static approximation. The object was considered to have a diameter and a height of 80% of the coil former and average SNR_{SENSE} is maximized inside this ROI. In the numerical optimization, symmetry in the two phase encoding directions was taken into account, so only one coil element was calculated. The $\boldsymbol{r}_i$ of this coil element were allowed to vary for optimizing the SNR, but they were confined in one of the quadrants on the coil former.

After the coil geometry was found by numerical optimization, the RF array was built according to the results. The coil was tuned to 64MHz to operate on a 1.5T Philips Eclipse system and matched to the 50 ohm line impedance; isolation between the coils was achieved with a capacitive network. The sensitivity maps were acquired from a uniform cylindrical phantom using a 3D RF-FAST sequence; the 2x2 accelerated 2D SENSE images as well as the 1x4 accelerated 1D SENSE images were acquired for comparison. The SENSE images were then reconstructed according to [4].


Fig. 1: SENSE optimized coil.

Results: Fig. 1 shows the home built RF array according to the numerical optimization result. Figure 2.a-c shows the simulated and measured RF sensitivity and the SENSE image from one of the coil elements with 2 times acceleration rate along both the primary and secondary phase directions. Fig.2.d-e shows the SENSE reconstructed images from 2D SENSE and 1D SENSE acquisitions, respectively.

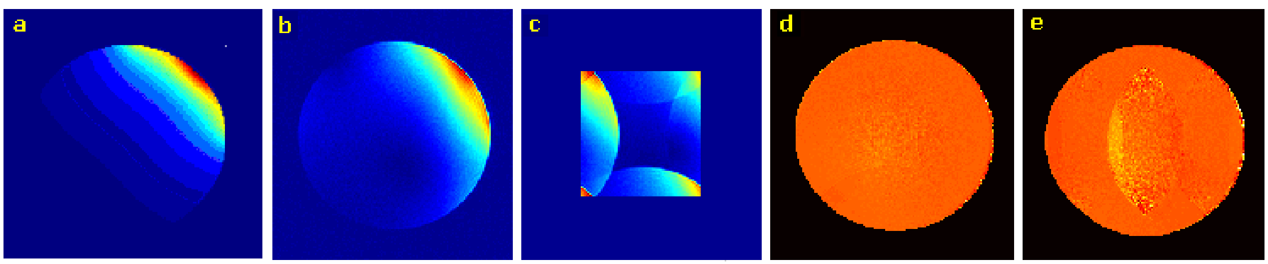

Fig. 2: The calculated (a) and measured (b) sensitivity maps and the 2x2 accelerated SENSE image (c) from one channel and the reconstructed 2D SENSE (d) and 1D SENSE images

Discussion: As seen in Fig.2.d, the optimized coil for 2D SENSE imaging provided images with minimal g-factor related artifacts even at full acceleration rate (4 fold); there are no significant artifacts as those found in the 1D SENSE case. One should also note the highly uniform SNR in Fig.2.d that is provided by the reduced mean and variance of the g-factor, when compared to that of a standard coil array described in [3]; The coil array presented here is designed to maximize average SNR in a large volume and significant SNR improvement over standard coil designs was observed on the outer regions of the object. The SNR increased by 25% over the standard design when the outer 3cm cylindrical shell was considered. Thus, this design is best suited for applications such as imaging the neocortex. A different design was also considered that maximized the SNR in the central 60% of the object volume using the same approach, and the conductor layout of such a coil array design is shown in figure 3. This design has not been implemented yet, but simulations show that the average SNR was improved by 6% inside this smaller ROI but the biggest gain was in uniformity. The standard deviation of SNR was 1.5 and 2.7 in the optimized and standard coils, respectively. This gain in uniformity suggests minimal artifacts even at highest acceleration rates. In this study, we have demonstrated that one can design coils with improved SNR and uniformity for 2D SENSE imaging using the target field approach.

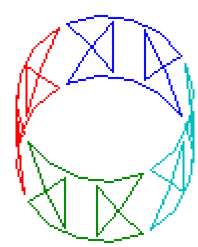
Fig. 3: Diagram of the RF coil optimized for improving the SNR uniformity and SNR in the center

References: 1. Muftuler LT, et al., Proc. ISMRM p.886, 2005. 2. Muftuler LT, et al., submitted to IEEE TMI.
3. Weiger M, et al., MAGMA 14: 10-19, 2002. 4. Pruessmann KP, et al., MRM 42:952-62, 1999.