Local Uni-Planar Gradient Array Design using Conformal Mapping and Simulated Annealing

S. M. Moon[1], D. G. Roy[1], K. C. Goodrich[1], J. R. Hadley[1], and D. L. Parker[1]

[1]UCAIR, Dept. of Radiology, University of Utah, Salt Lake City, UT, United States

I. INTRODUCTION

Many imaging problems, such as breast lesion characterization, can require high spatial and temporal resolution. The improved gradient performance required to achieve high spatial and temporal resolution may be achieved by specially designed local gradient coils such as planar gradient inserts. We present simple and rapid method for design of flat gradient inserts to produce a high strength gradient field and a reasonably uniform imaging region. The planar gradient set is to be placed inside of the imaging bore of the magnet (within the body gradients). For cylindrical gradients, a one dimensional stream function (SF) is used to specify currents on the cylinder surface. For planar gradients, however, this becomes a more complicated two dimensional problem. In this abstract, we present the geometrical design and field map simulation for X (Left/Right) and Y (Anterior/Posterior) gradients.

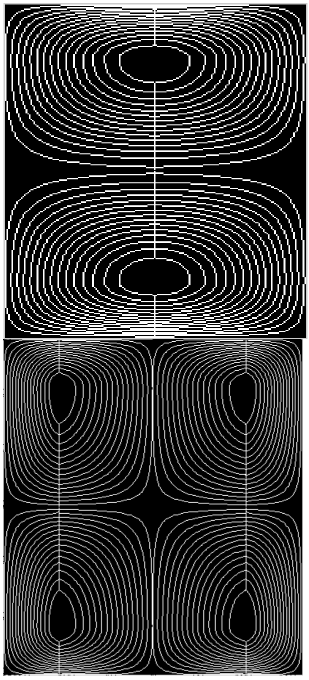

Figure 1. Wire patterns. (Top) Y gradient, (Bottom) X gradient

II. METHODS

In this technique, a one dimensional stream function is used to create a current density and resulting wire pattern on a cylinder surface. Conformal mapping transforms this pattern to a planar surface where the Biot Savart Law is used to create field maps. Comparison field maps are obtained by conformal mapping from the fields within the cylinder. Using a figure-of-merit calculated from the planar B-fields, simulated annealing[1)] is used to optimize the initial stream function and resulting final field map.

Although bi-planar gradients would achieve better homogeneity, a uni-planar gradient system will have better patient accessibility. Our target *field-of-view* (FOV), 57cm (L/R), 24cm (S/I), and 19.2cm (A/P), is typical for breast scanning. The planar insert will be placed slightly below the center of the magnet bore in order to position the imaged object (breast) in the center.

In each iteration, the simulation starts with randomly chosen control parameters, which determine a stream function. Next, a wire pattern on the cylindrical surface is created from this stream function. In this process, more random variables such as the number of wires per finger print and wire diameter can also be added if necessary.

After selecting the wire pattern, closely spaced points along this wire pattern in cylindrical coordinates are mapped to a plane by conformal mapping. In this process, we add a control parameter to adjust the current density in the transverse direction to optimize the homogeneity within the desired imaging volume. Finally, this wire pattern is used to calculate cost function parameters such as efficiency, homogeneity, max B_0, and inductance.

There are several distinguished advantages in our technique. First, we are able to control the two-dimensional planar wire pattern with a one-dimensional SF by using conformal mapping. Second, the simulated annealing algorithm process has been simplified to a small number of parameters to save computation time dramatically. Third, using a wire pattern to calculate the fields and cost function rather than using an analytical formula allows easy parameter calculation for arbitrary geometries. Simulated Annealing also finds families of near-optimum solutions, allowing exploration of the feature space.

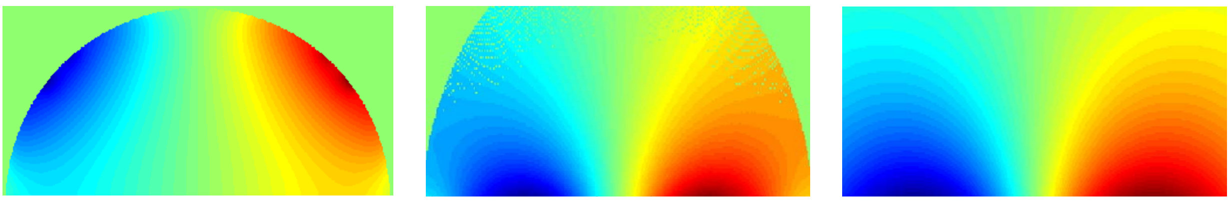

Figure 2. Simulated B-field map. (a) Field map from conventional cylindrical wire pattern, (b) Conformal mapped B-filed map from (a), (c) B-field map from planar wire pattern, which is conformal mapped from same cylindrical wire pattern. Note that current distribution on the bottom for (b) and (c).

III. RESULTS & DISCUSSION

Simulation results show efficiency up to 0.91mT/m/A for the X gradient and 0.54mT/m/A for the Y gradient, which in turn, translates into gradient strength of 273mT/m and 162mT/m with 300A. Figure 2 shows simulated B-field maps of cylindrical wire pattern, conformal mapped B-field from cylindrical to planar gradient, and B-field from the planar gradient. The similarity between the conformal mapped B-field (b) and planar B-field (c), indicates that the application of the Biot Savart law in the planar geometry could be replaced by the faster analytic calculation of B-field from current densities in the cylindrical geometry.

IV. REFERNCE

1) Bulent Aksel, et al. Local Planar Gradients with Order-of-Magnitude Strength and Speed Advantage, MRM, 58:134-143, 2007.
2) M. A. Martens, et al. Insertable biplanar gradient coils for magnetic resonance imaging, Rev. Sci. Instrum., 62(11), 1991.