Comparison of cylindrical and elliptical geometry gradient coils

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

[1]UCAIR (Utah Center for Advanced Imaging Research), Radiology, University of Utah, Salt Lake City, UT, United States

I. INTRODUCTION: Serious demands for high performance gradient coils for magnetic resonance imaging have led to the introduction and evaluation of planar and elliptical gradient coils. Cylindrical gradient coils are the current industry standard and give a wide homogeneous imaging region and the most room for patient access. Elliptical gradient coils can attain higher efficiency and lower inductance, leading to higher spatial and temporal resolution in some applications. In spite of the potential increased performance, there have been few if any studies comparing cylindrical and elliptical gradient systems. In this study, we have compared cylindrical and elliptical gradient coil design to assess the relative advantages of each.

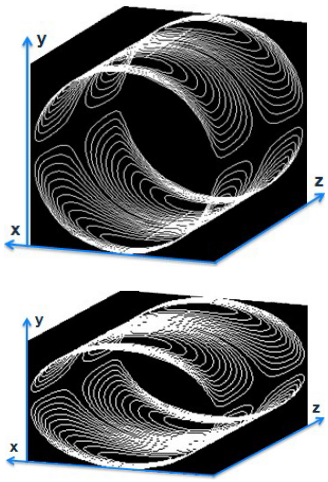

Figure 1. Cylindrical (top) and elliptical (bottom) y-gradient coil geometry.

II. METHODS: In our method a stream function is used to specify a current density on the cylindrical surface from which the magnetic field of the gradient, inductance, efficiency, and homogeneity are calculated analytically. Simulated annealing (*SA*)[1] is used to adjust the stream function to find a current density that optimizes a figure-of-merit (*FOM*), which is defined as[2] $FOM = \left(\sigma_{wire}\sqrt{L}\sqrt{\max Bo_{x/z}}\right)/\eta^2$. For each SA iteration, the magnetic field in the cylindrical geometry is scaled along the y-axis to create an elliptical field and the *FOM* for elliptical coil is calculated accordingly based on this transformed field. For the transformation, the x-axis width (left/right) remains the same and y-axis (anterior/posterior) is scaled down by 60%. The results from both cylindrical and elliptical geometries are plotted in a feature space to compare *FOM* parameters. We chose an imaging volume of 25cm(x) / 25cm(y) / 40cm(z) for the simulation. The dimension for each coil is described in the table.

III. RESULTS & DISCUSSION: Figure 2 shows comparisons of cylindrical and elliptical y and x gradients over the central axial slice for the y-gradient and x-gradient. The results in table 1 show that the elliptical y-gradient has a higher efficiency than that of the cylindrical y-gradient. However, both x-gradients have similar efficiencies. As we expected, the cylindrical coil shows better homogeneity compared to the elliptical coil for both the x- and y-gradients.

Figure 3 shows simulated annealing results in a feature space. Each dot represents a solution visited during the simulated annealing. The blue points clustered near the bottom left corner are solutions from the cylindrical coil, and the white points are solutions from the elliptical coil. Figure 3 clearly shows that cylindrical coil is more homogeneous than elliptical coil. Also the elliptical coil has higher efficiency than the cylindrical coil. The diamond symbols indicate the operating point that was chosen to obtain the wire patters for the fields calculated for Figure 2.

IV. CONCLUSIONS: These results confirm the expectation that transformation to an elliptical coil can increase efficiency with a small loss in homogeneity. The method used in this transformation is very simple, but the calculations for the fields in Figure 2 were performed using the Biot-Savart Law. Overall performance of each geometry can be vary depends on designing method and/or optimization processes that one use.

	Cylindrical	Elliptical
Target Imaging volume	25cm(x),25cm(y),40cm(z)	25cm(x),25cm(y),40cm(z)
Efficiency	0.245 mT/m/A	0.28mT/m
Inductance	189 μH	201 μH
Dimension	60cm(x),60cm(y),80cm(z)	60cm(x),36cm(y),80cm(z)
Imaging volume / total volume(%)	45.8 %	76.4%

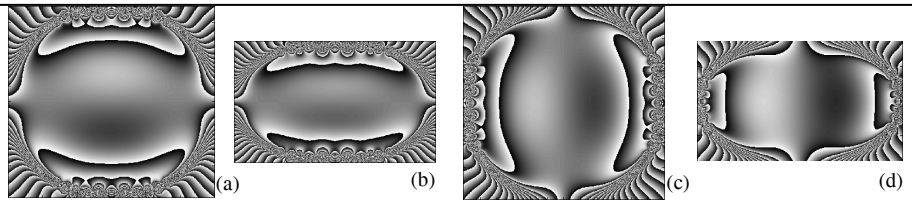

Figure 2. Gradient maps. (a) for the cylindrical y-gradient, (b) for the elliptical y-gradient, (c) for the cylindrical x-gradient, and (d) for the elliptical x-gradient

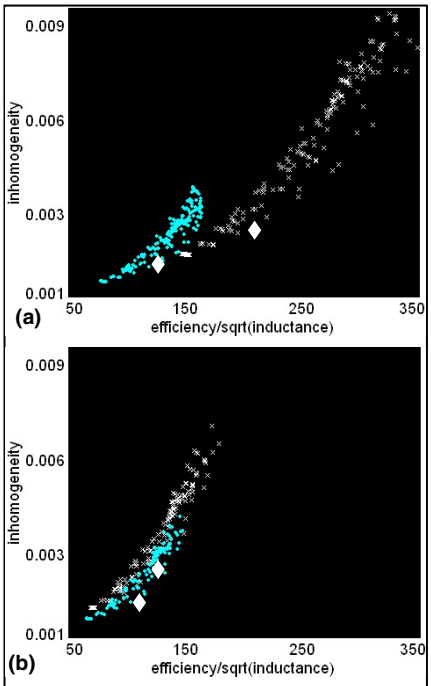

Figure 3. FOM plot in the feature space. (a) for the y-gradient, (b)for the x-gradient

IV. REFERNCE

1) Tomasi D. *Stream function optimization for gradient coil design*. MRM;45:505-512,1999.
2) Moon SM, Goodrich KC, Hadley JR, Parker DL. *Local uni-planar gradient array design using conformal mapping and simulated annealing*. 16th ISMRM Proceedings:1168, 2008.