**Gradient coil array for the super-parallel MRI: theory and design**

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## Introduction

The super-parallel MRI is a concept in which a number of gradient coil sets and RF coils are operated in a large bore (superconducting) magnet to simultaneously acquire MR images of a number of samples (1,2). This system has a great advantage to acquire MR images of a large number of samples, and 3D MR microscopic images of 1,200 chemically fixed human embryos (Kyoto Collection of Human Embryos) were acquired using this system (3,4). In this study, we have developed a method to design gradient coil arrays using the target field method (5) to extend the possibility of the super-parallel MRI.

## Theory

Figure 1 shows schematic view of a one-dimensional gradient coil array. The vertical lines and elliptic areas show electric current planes and sample areas where linear magnetic field gradients are produced. Homogeneous and equal-intensity magnetic field gradients are required to be generated by the planar electric currents.

The z component of the magnetic field between the current planes is calculated by summing up the contribution from all the planar currents as

$$B_z(x,y,z) = -\frac{\mu_0}{4\pi^2}\sum_{m=-N}^{m=n-1}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} k_z \frac{j_x^m(k_x,k_y)\exp(-k_z(z-md))}{2ik_y}\exp(ik_x+ik_y)dk_x dk_y - \frac{\mu_0}{4\pi^2}\sum_{m=n}^{m=N}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} k_z \frac{j_x^m(k_x,k_y)\exp(k_z(z-md))}{2ik_y}\exp(ik_x+ik_y)dk_x dk_y$$

## Numerical calculation

For N=2 (five current planes), Fourier components of the current densities for the transverse coils are described as

$$j_x^{-1}(k_x,k_y) = j_x^0(k_x,k_y) = j_x^1(k_x,k_y) = \frac{2}{i\mu_0}\cdot\frac{k_y}{k_z}\{\exp(k_z d)-1\}\{\exp(k_z c)+\exp(k_z(d-c))\}^{-1} b_z^t(k_x,k_y,c)$$

$$j_x^{-2}(k_x,k_y) = j_x^2(k_x,k_y) = \frac{2}{i\mu_0}\cdot\frac{k_y}{k_z}\exp(k_z d)\{\exp(k_z c)+\exp(k_z(d-c))\}^{-1} b_z^t(k_x,k_y,c)$$

Similar equations were solved for the axial coils. Figures 2 and 3 show current wire patterns of the transverse and axial coils for the interior and exterior plates when the ratio of the gap to the diameter of the current is 1:4. Figures 4 and 5 show regions with homogeneous magnetic field gradients (deviation from the central intensity is within 10%).

## Discussion and conclusion

The homogeneous regions for the magnetic field gradients have been drastically extended using our formulation comparing with those calculated with the conventional approach. This design will be applied to various configurations including MR microscopy of fixed specimens.

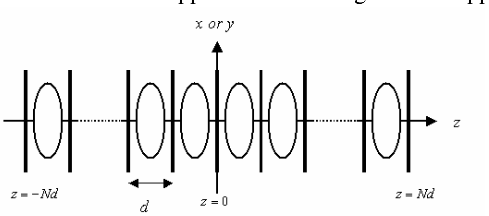


Fig.1 Schematic view of the gradient coil array

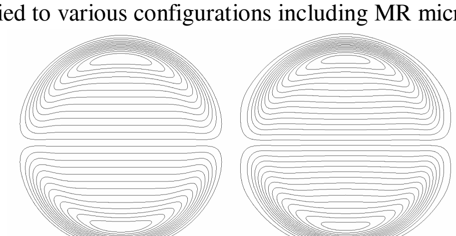

Fig.2 Wire pattern for the transverse coils; interior (left) and exterior (right)

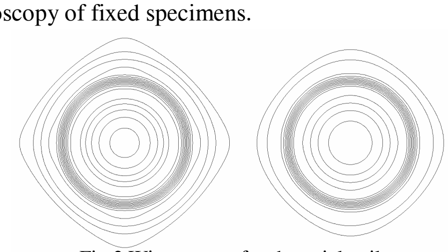

Fig.3 Wire pattern for the axial coils; interior (left) and exterior (right)

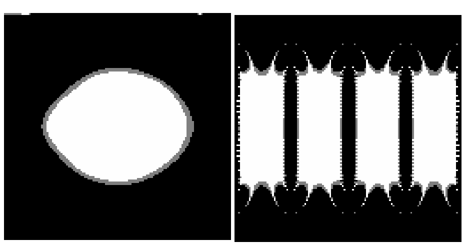

Fig.4 Homogeneous region for the transverse coils; in the xy (left) and zx (right) planes

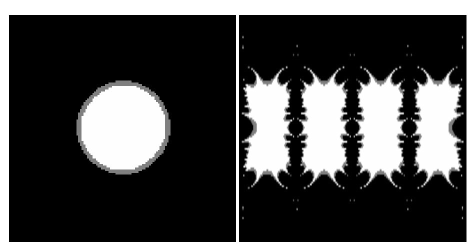

Fig.5 Homogeneous region for the axial coils; in the xy (left) and zx (right) planes

## References

[1] Kose K, Haishi T, Matsuda Y, Anno I, Proc of the 9th ISMRM, Glasgow, 2001, p609.

[2] Matsuda Y, et al. Magn Reson Med 2003; 50:183-189.

[3] Matsuda Y, Ono S, Handa S, Haishi T, Kose K, Proc of the 12th ISMRM, Kyoto, 2004, p

[4] Matsuda Y, Ono S, Handa S, Otake Y, Haishi T, Kose K, Uwabe C, Shiota K, Proc of the 13th ISMRM, Miami Beach, 2005, p

[5] Turner R, J Phys. D: Appl Phys 1986; 19:147-151.