Construction and experimental evaluation of a planar gradient coil set for a compact permanent magnet

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INTRODUCTION

We have designed and numerically evaluated a magnetic field gradient coil set for a narrow-gap (13cm) and higher magnetic field (0.3T) permanent magnet optimized for whole hand imaging (1). In this study, we constructed a gradient coil set, measured magnetic field distributions produced by the gradient coils with and without pole pieces of the magnet, and quantitatively explained the enhancement factors of the gradient coils.

METHODS FOR CONSTRUCTION AND EVALUATION OF GRADIENT COILS

Figure 1 shows side and front views of the narrow-gap (13cm) and high magnetic field (0.3 T) permanent magnet. Estimated weight of the magnet is about 500 Kg. The transverse gradient coils (Gx, Gy) were designed using the target-field approach (2) and the axial (Gz) gradient coil was designed using a genetic algorithm (3). The design parameters of the gradient set for this magnet were as follows: homogeneous region, 22 cm × 22 cm × 8 cm diameter ellipsoidal volume; magnet gap, 13 cm; diameter of the current flowing region, 40 cm; and number of turns of wires, 25 turns for the transverse coil and 32 turns for the axial coil.

To made planar bases for the gradient coils, grooves for the gradient coil winding pattern were milled on the 2.8 mm thick polyester plates by a numerically controlled milling machine according to the numerical data calculated for the gradient coil set. Polyethylene-coated copper wire (1 mm diameter) was used for the coil winding. After the copper wire was wound in the grooves, the wire was fixed with epoxy resin. The three-axis gradient coil assembly was made by piling up the Gy (Fig.2) and Gz (Fig.3) coils on the Gx coils. At first, the gradient coil set was set up in a free space and the magnetic field distribution was measured using a Hall magnetometer (model 7010 with HTG92-0618, F.W.BELL). Then the gradient assembly was fixed on the pole-pieces (diameter: 40cm, thickness: 3.8cm, material: SS400) of the magnet placed in the same geometry as that of the magnet. The magnetic field distribution was measured using the Hall magnetometer.

RESULTS AND DISCUSSION

Table 1 shows the efficiencies of the gradient coils obtained from a numerical calculation (1) and the measurements described above. Agreement between them is less than several percent. It should be noted that the enhancement factor for axial (Gz) coil was definitely samller than that of the transverse (Gx,Gy) coil. The difference between the enhancement factors was already observed for a magnetic circuit (0.2 T, 16 cm gap) (4). The values of the enhancement factors obtained in this study are nearly the same as those observed for the magnet. This result suggests that the enhancement phenomenon can be explained only by the pole pieces.

In conclusion, the enhancement phenomenon of the gradient coil set in a permanent magnet was quantitatively explained with the pole pieces of the magnet. Therefore, imaging pulse sequences should be designed by considering the magnetic properties of the pole pieces.

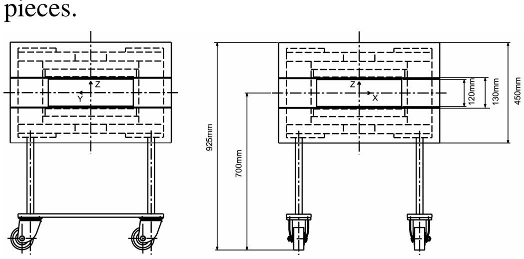

Fig.1 Permanent magnet

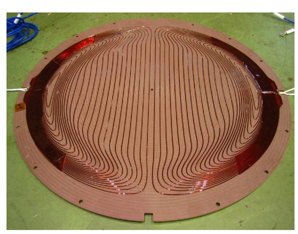

Fig.2 Gx, Gy

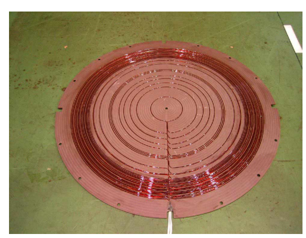

Fig.3 Gz

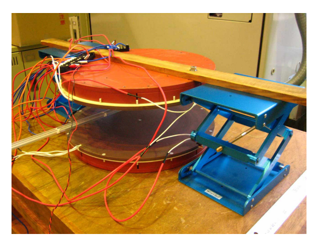

Fig.4 Experimental setup

	Numerical calculation		Measuement results	
	Free space (G/cm/A)	With PP (G/cm/A)	Free space (G/cm/A)	With PP (G/cm/A)
Gx	0.094	0.184(1.96)	0.095(1.01)	0.180(1.91)
Gy	0.096	0.185(1.93)	0.097(1.01)	0.180(1.88)
Gz	0.200	0.290(1.45)	0.202(1.01)	0.286(1.43)

Table 1. Efficiencies of the gradient coils. Numbers in the parentheses are values normalized by those numerical calculations in a free space.

REFERENCES

[1] S.Handa ,K.Kose, T.Haishi, E.Sugiyama, M.Aoki. Proc of the 15th ISMRM, Berlin, submitted.
[2] R.Turner, A target field approach to optimal coil design. J Phys D: Appl Phys 1986;19:147-151.
[3] ED.Goldberg, Genetic Algorithms in Search, Optimization and Machine Learning. Reading MA:Addison-Wesley
[4] S.Handa, F.Okada, K.Kose. Effects of magnetic circuits on magnetic field gradients produced by planar gradient coils. 13th ISMRM Proc p851, 2005.