A single-channel planar shim coil for a permanent magnet

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Introduction

Magnetic field inhomogeneity produced by main coils of superconducting electromagnets or pole pieces of permanent magnets is corrected using shim coils (active shimming) or magnetic materials (passive shimming). Since the spatial variation of the inhomogeneity is usually complicated, the active shimming requires a number of shim coils (~10<) to produce spatially varying (e.g. z^2, z^3, x^2-y^2) magnetic fields. However, because the bore or gap space of the magnets are limited, the multi-channel shim coils should be installed in a narrow space. To overcome this problem, we designed a single channel-shim coil using the target field approach (1).

Materials and method

A compact MRI system using a permanent magnet (field strength = 0.97 T, gap = 61 mm, pole piece diameter = 140 mm) (2) was used for the shim coil design. The homogeneity of the magnet was measured using a 3D lattice phantom composed of stacked acrylic discs (diameter = 23.9 mm, thickness = 3.0 mm) with square shaped trenches (width = 1 mm, depth = 1 mm) in a cylindrical container (ID = 24 mm, OD = 26.2 mm, length = 61 mm) filled with baby oil (Fig.1). The magnetic field distribution was measured using a 3D SE sequence (TR = 100 ms, TE = 10 ms, voxel size = $(125\ \mu m)^3$) with positive and negative readout gradients. The single-channel shim coil was designed using the target field approach and the field distribution measured in a plane parallel to the pole piece.

Results and discussion

A typical 2D slice of the 3D phantom is shown in Fig. 2. Magnetic field distribution in the central cylindrical region (ϕ20 mm $\times$ 26 mm) was measured using the positional shifts of the landmark points along the readout direction. Figures 3 and 4 show winding patterns at z = -25 mm and +25 mm of the shim coil calculated from the magnetic field distribution in the plane at z = -5 mm using the target field method. Figures 5-7 show the magnetic field distribution measured using the phantom, that calculated from the winding patterns, and the difference between them in the plane at z = -5 mm. The difference represents the corrected field. The maximum, minimum, and RMS of the magnetic field in the plane are 58.3, -2.3, and 22.9, and 9.4, -8.0, and 4.8 ppm for the measured and the corrected magnetic field. Because the RMS of the magnetic field inhomogeneity decreased by about 5 times, this result demonstrates the usefulness of the single-channel shim coil. Although this shim coil cannot be used for correction of inhomogeneity produced by the sample itself, this coil can be used as a powerful alternative to the passive shimming using magnetic materials.

Fig. 1

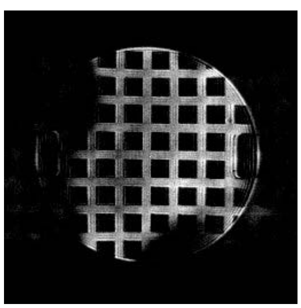

Fig. 2

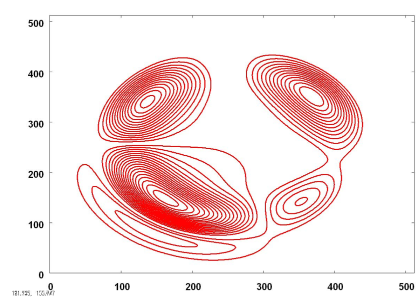

Fig. 3 Winding pattern at z = -25 mm

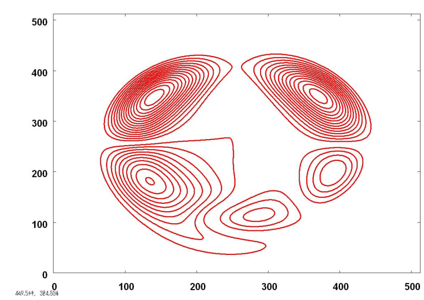

Fig. 4 Winding pattern at z = +25 mm

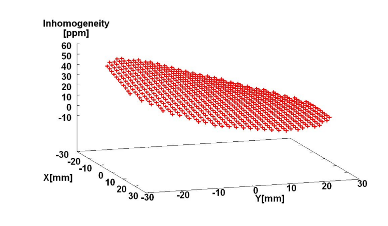

Fig. 5 Measured field distribution

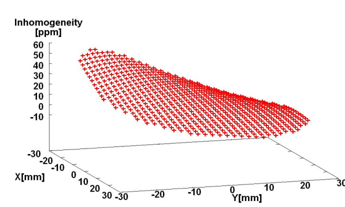

Fig. 6 Magnetic field by the shim coil

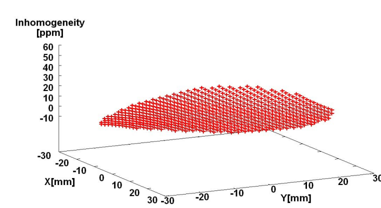

Fig. 7 Corrected field (difference)

Reference

(1) R. Turner, A target field approach to optimal coil design. J. Phys. D: Appl Phys. **19**:L147-151 (1986). (2) T. Haishi, T. Uematsu, Y. Matsuda, K. Kose. Development of a 1.0 T MR microscope using a Nd-Fe-B permanent magnet, Magnetic Resonance Imaging, **19**, 875-880 (2001).