

# High resolution imaging using a high-field yokeless permanent magnet

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## Introduction

Temperature drift of the magnetic field is a serious problem in MRI systems with high-field (1 T<) yokeless permanent magnets using Nd-Fe-B magnetic materials, because they have a large temperature coefficient (~1000 ppm/deg) of the residual magnetization (1). The field stability can be improved using temperature control of the magnet. However, because the thermal conductivity of the Nd-Fe-B material is very poor (~7 W/m/K: about 1/60 of that of Cu) and openness of the magnet gap is highly desired, the temperature control of the whole magnet is a complicated problem. In this study, we solved this problem using a thermal insulation of a yokeless permanent magnet and an NMR lock technique, and performed high resolution imaging of several samples.

## Materials and method

A homebuilt compact MRI system using a 1.0 T yokeless permanent magnet (Hitachi Metals Co., Japan) installed in an office room (~18 m<sup>2</sup>) was used for the experiment. The specification of the permanent magnet is: field strength = 1.04 T, gap width = 40 mm, pole piece diameter = 96 mm, homogeneity = 20 ppm over 20 mm dsv, size = 238 mm (W) × 252.4 mm (H) × 184 mm (D), weight = 85 kg (Fig.1). The magnet was thermally insulated using polyurethane foam (thickness = 30 mm) and FRP plates (thickness = 2 mm). Gradient coils were thermally insulated using 2.0 mm thick FRP plates from the pole pieces. Temperature of the magnet and NMR frequency of a spherical water phantom (diameter = 8 mm) were simultaneously measured every minute for about 68 hours. To demonstrate the performance of the thermal insulation, several samples were imaged using 2D or 3D SE sequences with a time-sharing NMR lock mode implemented in an MRI data-acquisition software package (Sampler 6, MRTechnology, Japan).

## Results and discussion

Figure 2 shows temperature of the room and the magnet measured with time. This graph clearly shows that whole-day temperature change of the magnet (~0.5 degree) is about 1/4 of that of the room (~2 degree). Figure 3 shows temporal change of the Larmor frequency of the water phantom. This graph shows that the largest frequency change is about 50 Hz/min. Figure 4 shows a correlation of the magnet temperature and the Larmor frequency offset (-42.57 kHz/degree, -950 ppm/degree). Figures 5 and 7 are 2D slices of an okra and a small tomato. The okra was acquired with a 2D SE sequence (TR/TE = 1000 ms/32 ms, NEX = 128, 1 mm slice, 1024<sup>2</sup> matrix, (20 μm)<sup>2</sup> pixel) and the tomato was acquired with a 2D SE sequence (TR/TE = 400 ms/16 ms, NEX = 512, 1 mm slice, 512<sup>2</sup> matrix, (40 μm)<sup>2</sup> pixel). Since the NMR lock sequence was applied before every phase encoding (128 s interval for okra, 204.8 s interval for tomato) and the pixel bandwidth was 48.8 and 97.7 Hz, these images may be affected by the drift of the magnetic field. Figure 8 shows a 2D slice selected from a 3D image dataset of a middle finger. The finger was acquired with a 3DSE sequence (TR/TE = 200 ms/12 ms, NEX = 1, 256<sup>2</sup> × 32 matrix, voxel size = (80 μm)<sup>2</sup> × 0.8 mm). Since the internal NMR lock sequence was applied before every outer phase encoding (51.2 s interval) and the pixel bandwidth was 195 Hz, this image was not affected by the drift of the magnetic field. In conclusion, if we carefully choose the NMR lock interval and the pixel bandwidth, we can acquire high resolution images without temperature control of the yokeless permanent magnet.

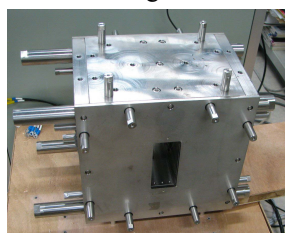


Fig.1 Permanent magnet

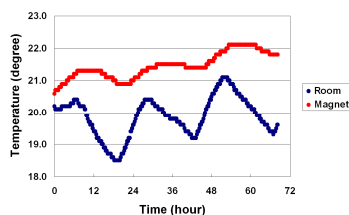


Fig.2 Magnet and room temperature

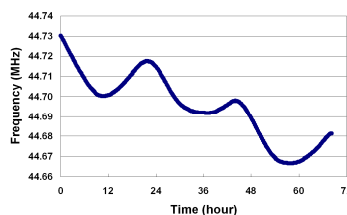


Fig.3 Larmor frequency drift

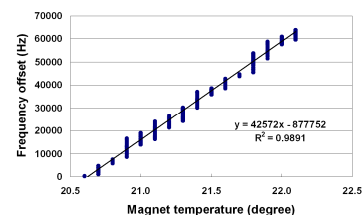


Fig.4 Magnet temperature vs frequency

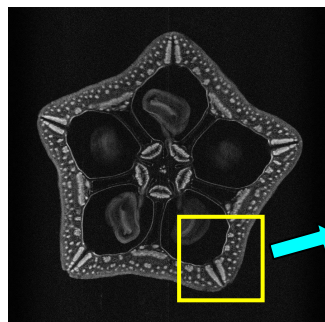


Fig.5 Okra (1024 x 1024 matrix)

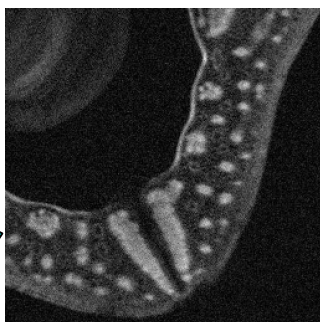


Fig.6 (20 μm)<sup>2</sup> resolution



Fig.7 Gumi tomato, (40 μm)<sup>2</sup>

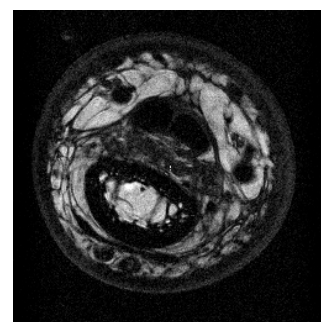


Fig.8 Middle finger (80 μm)<sup>2</sup>

References: (1) <http://www.hitachi-metals.co.jp/prod/prod03/pdf/hg-a22-b.pdf>