# DESIGN AND CONSTRUCTION OF A HALBACH ARRAY MAGNET FOR PORTABLE BRAIN MRI

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**Introduction:** A portable MR system has the potential to quickly detect brain injury at the site of injury. For example hemorrhage detection is critical for both stroke patients and traumatic brain injury victims. In stroke, rapid distinction between a hemorrhagic and non-hemorrhagic event could allow administration of a clot-busting drug such as tPA (tissue plasminogen activator) in an ambulance prior to transportation to the hospital, perhaps advancing this time-sensitive treatment by up to an hour. Subdural hemorrhage (or hematoma) is a form of traumatic brain injury, in which blood gathers between the dura and arachnoid mater (in meningeal layer) and is likely to be visualized on course resolution (e.g. 5mm) $T_1$ images. Other applications include the potential to construct higher order modes of the Halbach array which can produce strong gradients, For example providing high resolution profile imaging (1) of the brain meninges. A Halbach array of permanent magnets is ideal for portable MRI in that it creates a relatively uniform field transverse to the head without the use of a cryostat or power supplies. To test the feasibility of these magnets for imaging, we have designed, modeled and constructed a small, 20 rung Halbach array with radially magnetized NdFeB N42 magnets, large enough to fit the human head. The modeled field shows a roughly quadratic field profile with a central Larmor frequency sufficient for imaging (~3.3MHz). While the homogeneity is well below that of superconducting magnets, it fits well with our light-weight and portable concept if the inhomogeneities are used in image encoding, either through spatially selective excitation coupled with localization from 32ch parallel reception of the brain signal, or through O-space (2) style encoding induced by rotating the quadratic profile of the magnet around the head. Either case fulfills the portability criteria by eliminating the gradient coil and power supply.

**Materials and Methods:** The major criteria for design of the permanent magnet Halbach array are 1. maximize average field 2. allow small controlled field variation for spatial encoding. COMSOL field simulations were used to manually optimize the field based on the size and quantity of the NdFeB magnets and the radius of the cylinder. The result was a 20 magnet cylindrical array of 14"x1"x1 NdFeB magnets (Fig 1). Two smaller rings of smaller (1" cube) magnets at the top and bottom of the cylinder were added to provide end correction fields to offset the fall-off of the finite array in the z direction. A water-jet cutter was used to create the plastic rings that hold the magnets (fig 2A). In order to create the 14" magnets for the Halbach cylinder, it was necessary to glue to smaller magnets together. The smaller magnets were individually inserted into 1"x1" fiberglass tubes and floated on top of each other as they were repelled in this arrangement. A magnet loader and pushing apparatus was necessary to hold the magnets together during gluing.

**Results:** Figure 1(c-d) shows the COMSOL simulated field variation in 1 KHz contours. Figure 2B shows the field as a function of x, y and z location across the cardinal directions thru isocenter. The field was measured using a Tecmag console and NMR probe tuned to 3.2 MHz. Points were recorded by manually moving the NMR probe and recording FIDs. Frequency drift (Fig. 2C) was also measured by fixing the probe near the center for and tracking the NMR frequency for 20 minutes. This drift is likely due to temperature, which may be mitigated by thermal insulation. These results are shown in Figure 2. Table 1 outlines the resulting parameters of the constructed magnet.

**Conclusion:** The constructed magnet array achieves reasonable homogeneity for our application. It is very portable weighing only 45kg and requires no power to maintain the field. In addition to the cost of building this magnet was less than $6000. The accessibility of this magnet has the potential to offer basic head trauma and hemorrhaging detection to a broad range of applications.

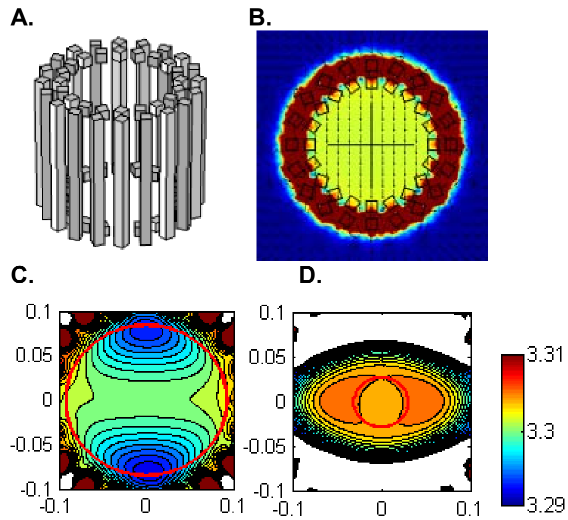


Figure 1: COMSOL simulations (A) magnet geometry, (B) field plot in center slice showing orientation of magnets and the field, (C-D) 1 Khz contour s of center slice and 5 cm above center. Red circle represents brain size.

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| Weight | 45 kg |
| Center Larmor frequency | 3.27MHz (77mT) |
| Homogeneity (over 10 cm^3) | 15,000ppm |
| Drift of B0 over 20 minutes | 586 Hz |
| Array radius | 18cm |
| Array height | 14" |

Table 1: Properties of constructed magnet

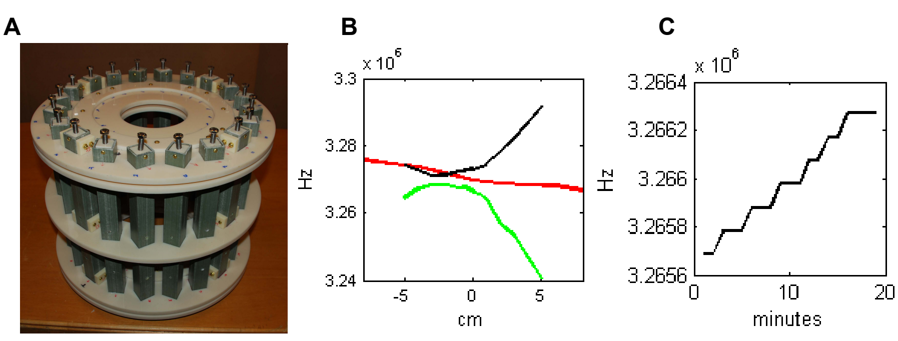


Figure 2: (A) Photo of constructed magnet (B) Measured FID frequency along the z-axis in red (axial), along the x-axis in black, along y-axis in green. (C) Measured FID frequency at one point in magnet for 20 minutes

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