A Magnet for a Compact MRI Scanner Designed for the International Space Station

Krzysztof Turek

AGH University of Science and Technology
Al. Mickiewicza 30, 30-059 Krakow; turek@uci.agh.edu.pl

A long-term living in the microgravity environment is accompanied by complex changes in a human body. Some of these changes like the bone mass and strength loss or the shift of body fluids could be accurately monitored by a MRI scanner installed at the International Space Station (ISS). The data from the MR scans in the Space could effectively help to find means of preventing problems with the astronaut health. The current MRI scanners based on superconducting or permanent bulk and heavy magnets could not be transported to ISS by existing cargo spacecrafts. Moreover, gradient systems of the scanners are power hungry and the energy consumed by them could hardly be incorporated into the ISS energy budget. This is why a new concept of a compact MRI scanner was developed (1), (2). This scanner adopts two existing technologies: the light permanent magnet based on Halbach cylindrical structure (3) and the space information coding by specially constructed rf coils (4) these make the gradient coils and the driving them power hungry amplifiers needless.

To design a suitable magnet a set of mathematical tools for the analysis of magnetic field produced by the Halbach dipole cylinder were developed or adopted. The analytical equations for the magnetic flux density at the axis of the various variants Halbach dipole magnet (5) are the most important of them since they allow to develop time efficient procedures for computing the homogeneity of the field. The harmonic analysis based on these equations gives a clear intuitive insight into the dependency of the homogeneity on magnet geometry and integration of the magnetostatic Coulomb law in Mathematica is a very accurate method of computing the magnetic flux density at the axis and out of it. In the first case the results were used for verification of the complex analytical equations (see Fig.1). An analytical formula and the integral procedure was used to minimize the magnet weight and size to meet the requirements put on a payload transported to the space in the Standard International Payload Rack (6). All three methods can be combined to find a detail structure of the magnet that would generate magnetic field of homogeneity required for the high resolution MR imaging. In this way it was shown that the classical, truncated Halbach dipole geometry must be substantially modified to generate the magnetic field of the requested quality.
Fig. 1. A comparison of the magnetic flux density at the axis of a truncated, segmented Halbach dipole, calculated from the analytical equation (solid line) and by integration of the magnetostatic Coulomb law. There is the conformity of results within 0.02 ppm.

References


5. Homogeneity of Magnetic Field Generated by Truncated Halbach Dipoles, Turek K., Liszkowski P., to be published.