Permanent magnet assembly producing a strong tilted homogeneous magnetic field: towards magic angle field spinning NMR and MRI

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Introduction

Metabolism can be studied spectroscopically using the so-called Magic Angle Sample Spinning technique. The sample is placed inside a spinning sample holder, and the axis of rotation makes an angle of ~54.7 degrees with respect to the main magnetic field B_0. This rotation eliminated the effects of anisotropic interactions from the spectra and leads to high-resolution, high-sensitivity isotropic signatures of metabolites. There are many cases where sample rotation is not possible, nor practical, in particular when living animals are involved. Here we explore the alternative proposal [1] of spinning the magnetic field at the magic angle around a static object or subject.

Methods

We use an approach to magnet design based on symmetry considerations and an analytical theory of 3D magnetostatics that allows the design of arbitrary magnetic fields inside (in-situ) and outside (ex-situ) permanent magnets with particular emphasis on the orientation of the magnetic field [2,3]. These magnetic fields can be optimized to achieve the required field homogeneity inside the sweet spot. The control of the field profiles can be mastered at any order, which leads to large regions of interest and deep object-penetration distances.

We have designed a cylindrical pure permanent magnet structure, which generates a homogeneous magnetic field pointing along a direction that makes the magic angle with respect to the axis of the cylinder. Mechanical rotation of this cylinder around its axis, would lead to a rotation of the magnetic field in a conical trajectory, eliminating anisotropic interaction from the spectra. This system was built.

Results

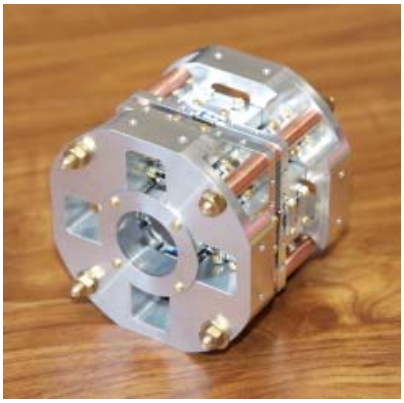
We will present the first pure permanent magnet system producing a homogeneous field tilted at the magic angle [4]. Measurements show that the magnitude of the field is ~0.22 T and its profile is homogeneous up to 50 ppm as measured on an oil phantom of 1.5 mm^3. The angle of the tilt is 54.7 degrees, ±0.3 degrees inside a 10 mm diameter spherical volume at the center of the magnet.

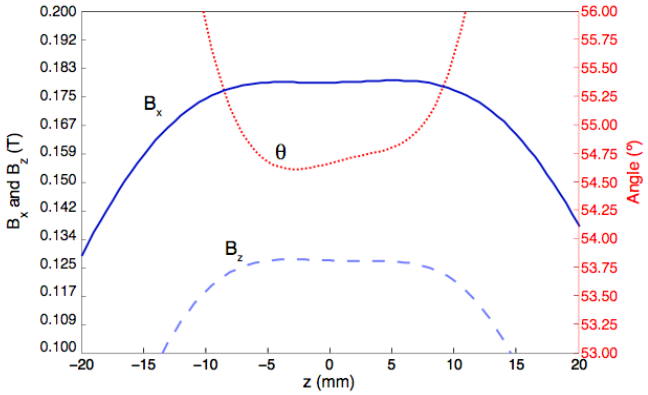
Conclusions

The analytical theory we describe is a powerful tool for designing portable MRI magnets using permanent rare earth materials since it allows the control of the magnitude, homogeneity and orientation of the magnetic field. The introduction of solid-state methodology in MRI could in principle be combined, by magnetic field rotation. This is certainly a difficult task, but possibly attainable through the use of permanent magnet technology. This work is currently underway in our Laboratory and some preliminary ideas will be presented.

References

[1] E. R. Andrew and R. G. Eades, *Discuss. Faraday Soc.* **34**, 38-42 (1962).
[2] C. Hugon, P. M. Aguiar, G. Aubert and D. Sakellariou, *C. R. Chimie* **13**, 388-393 (2010).
[3] C. Hugon, F. D'Amico, G. Aubert and D. Sakellariou, *J. Magn. Reson.* **205**, 75-85 (2010).
[4] D. Sakellariou, C. Hugon, A. Guiga, G. Aubert, S. Cazaux and P. Hardy, *Magn. Reson. Chem.*, (2010), in press.





Figures (Left) Pure permanent magnet system producing a uniform magnetic field tilted at the magic angle. (Right) Field profiles along the z axis of the longitudinal, the transverse and the resultant magnetic field. The angle of the tilt is also shown.