Transversal Gradient Compensation in Three-sided MRI Magnets

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Introduction

A previous work [1] has proposed an open magnet configuration based on a three-dimensional finite configuration that completely confines the field and contains a closed cavity where the field is perfectly homogeneous. When the cavity is opened on three sides to allow patient access some stray field arises and distortions of the field are induced, the most important being a strong gradient in the direction of the opening.

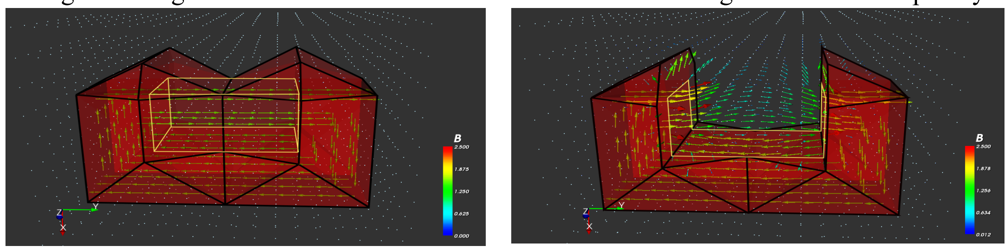

Fig. 1 - a) (left) a closed magnetized structure that confines a uniform field within itself and an enclosed cavity (outlined in light color); b) (right) the same structure in which the cavity has been made accessible by removing portions that do not carry

An in depth analysis of the contributions of the individual elements making up the structure suggests a compensation strategy that cancels the gradient without sensibly affecting the overall structure efficiency.

Method

The structure depicted in Fig. 1a) is composed of flat face uniformly magnetized polyhedra. The continuity conditions for the normal and tangential components of $\boldsymbol{B}$ and $\boldsymbol{H}$ at each interface between different materials can be expressed [2,3] by simple relations among the current densities (or magnetic charges) and the face normals. This allows finding a solution to the problem of completely enclosing the homogenous volume (i.e. the magnet cavity) with blocks of uniformly magnetized material or, what is equivalent, with electrical windings. Patient access is obtained by removing one or more of the blocks, chosen among those that do not support a magnetic flux, as in Fig. 1b). By substituting each magnetized block with its equivalent surface currents it can be shown that the structure in Fig. 1b) is equivalent to the one shown in Fig. 3, which can be partitioned in two independent windings: A and B. The individual contributions of the two windings to the field and their sum, along the vertical axis, are shown in Fig. 2 as continuous and dash-dot lines. It is easily seen that just by moving winding B farther apart in the z direction it is possible to oppose the strong gradient generated by winding A. A heuristic search gives the optimal dimensions and location of the B' winding that result in the structure depicted in Fig. 4, and in the fields represented by the continuous and dashed lines in Fig. 2. The raw homogeneity obtained in a structure having w=1 m, h=1.5 m, d=1 m is 2400 ppm over a sphere of 10 cm diameter[4], mostly determined by a second order harmonic that can be easily corrected with conventional means.

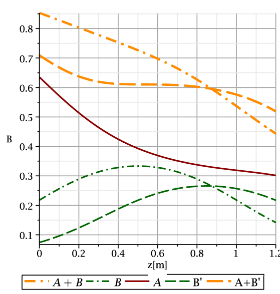

Fig. 2 - Field generated by structures in Fig. 3 and 4

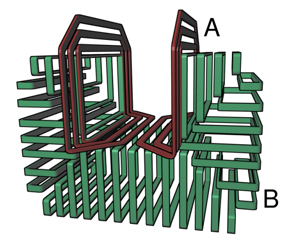

Fig. 3 - Current structure equivalent to Fig. 1b

Conclusion

An effective way of compensating the transversal gradient arising from the asymmetric opening of an ideal, closed, uniform field structure has been presented. Contrary to many compensation strategies, the correction also increases the field intensity thus adding to the overall structure efficiency.

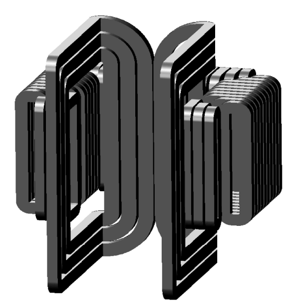

Fig. 4 – The final structure

Acknowledgments

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References

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