Design Strategy for Shielded Open MRI Magnets

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Introduction

The essence of the design of a MRI magnet is a struggle between the contrasting requirements of a substantial homogeneous volume together with a wide magnet opening to ease patient and operator access. In addition a minimum stray field level is required. [1]
Magnet designers have traditionally addressed these needs by selecting two-dimensional configurations that satisfy the homogeneity requirement when infinitely extended in the third dimension, and by truncating them to a finite length. Thus cylindrical magnets can be seen as derivations of the infinite solenoid and "C" magnets as derivations of the parallel plate capacitor configurations.
We propose a different approach in which the starting point is 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 one or more sides to allow patient access distortions are induced and a stray field arises, but the three-dimensional starting point introduces a new degree of freedom that would be otherwise absent.

Method

The starting point is the definition of the shape and size of the homogeneous volume. If a cartesian frame of reference is chosen the volume will have a prismatic shape and we can assume, without loss of generality, that the field is oriented along one of the axes. Being the field static, the problem can be solved in terms of magnetic charges and scalar magnetic potential. If the structure is composed of flat face polyedra 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 between the current densities or the 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. The ensuing field distortions will have to be compensated, in a way not too different from what is done in the traditional approach. Figure 1 shows an example configuration: in a) the cavity is closed and the field is everywhere homogeneous, in b) three sides have been removed and, although the field leaks out, it still remains essentially confined within the structure. The compensation can be effected with elements (coils or permanent magnets) affixed to the faces of the cavity.

Conclusion

A strategy for the design of self shielded, open magnets for MRI imaging has been presented. It is based on the transformation of an exact 3D closed solution to an open one. The initial choice of a three-dimensional (rather than 2D) configuration affords new degrees of freedom to the design, like the choice of a field path that does not flow in the portions of the structure that will be removed.

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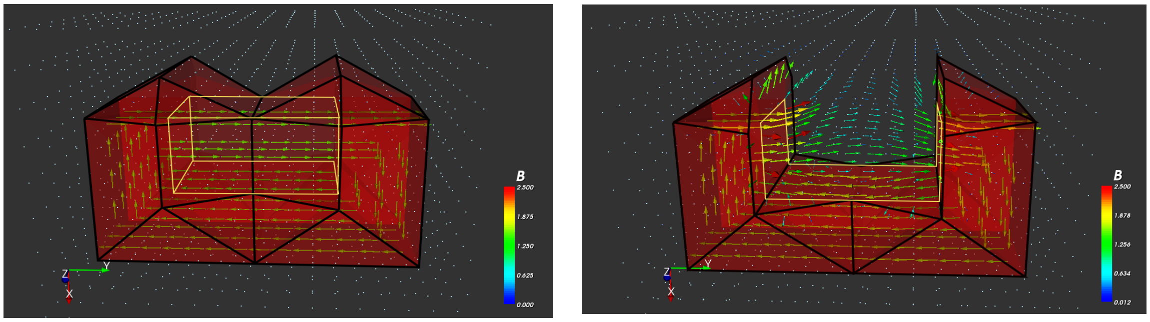

Figure 1 – a) (left) a closed magnetized structure that confines a uniform field within itself and an enclosed cavity (outlined in light color); b) (right) the same structure in which the cavity has been made accessible by removing portions that do not carry flux**.**

References

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