A practical insert design for dreMR imaging in the human head

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Introduction

Delta relaxation enhanced magnetic resonance ("dreMR") is a new technology that allows for greatly enhanced specificity between targeted contrast agents in the bound and unbound states [1,4]. This method utilizes an electromagnet insert coil in order to alter the main magnetic field as a function of time over a region of interest by more than +/- 0.1 T in an otherwise standard MR scanner. By modifying the main magnetic field during longitudinal relaxation, the signal obtained from tissue in the presence of a bound contrast agent can be separated from that produced in the presence of an unbound agent. This is possible when the relaxivity of a targeted contrast agent in the bound state is strongly dependent on field strength. An example of such an agent is the FDA-approved, albumin-targeted agent MS-325 ("Vasovist"), whose relaxivity changes significantly when bound to serum albumin [2,3]. Previously, we have developed dreMR insert coils specifically for small animal imaging [4]. We have previously reported on the feasibility of dreMR insert coil designs for human-scale systems [5]; however, those designs did not fully consider active shielding and practical engineering constraints such as minimum wire spacing or cooling. In this study, we describe a practical, actively shielded, insertable dreMR coil design suitable for human head imaging.

Methods

The insert coil was designed as a primary coil plus active shield. The primary was modeled by two thick solenoids separated by a gap of 4.2 cm. Each solenoid was composed of wire of cross section 5.3 mm, with 30 turns along z, 4 radial layers, and an inner diameter of 36.5 cm. The 5.3 mm square wire is the thickness of commercially available hollow wire with a 3 mm circular hole for the flow of coolant. We have used this wire previously for gradient and magnet construction projects similar to this. The shielding layer was created using the boundary element (BE) method, with a cylindrical finite element mesh with a diameter of 51 cm and length (z-direction) of 60 cm. 900 radially symmetric target points were created over a diameter of 80 cm extending +/- 60 cm in the z-direction so as to cancel the field produced by the primary coil. The number of wires on the shield was chosen so that the current flow through the shield and primary could be in series.

Results

The actively shielded head insert coil produces a field efficiency of 0.30 mT/A, resistance of 413 mΩ, and inductance of 8.40 mH. Because a dreMR coil does not need to be switched on/off rapidly (rise times of 10 – 20 ms being perfectly acceptable), the relatively high inductance can be tolerated. The efficiency translates to a 0.10 T field shift for 333 A. This level of current is achievable with current generation gradient amplifier systems. The peak power dissipation at this field would be 44 kW. Assuming a 50% duty cycle, the rms power dissipated in the coil (~ 22 kW) can be managed with relatively standard water-cooling systems. As described in [1], a dreMR coil is not required to produce a highly uniform or temporally stable magnetic field, as the field-shifts are not applied during signal acquisition. Non-uniformities can be easily corrected for in the final dreMR image. Figure 1 shows a human head superimposed over a coronal view of the field homogeneity. This coil produces better than 10% uniformity over a cylindrical region 20 cm long and 30 cm in diameter. Figure 2 displays a schematic cross-section of the full dreMR insert system. We are currently investigating the use of the BE method to design a shield with shoulder cutouts which would further increase ease of access to the imaging region.

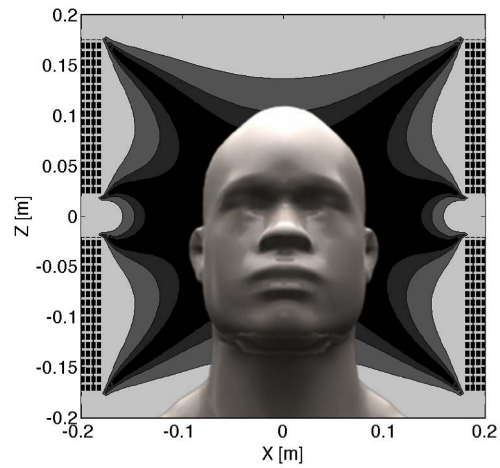

Figure 1. Field homogeneity map (in the xz-plane) of the electromagnet insert coil super-imposed onto a human head. The regions are defined as follows: less than 5% uniformity (black); less than 10% (dark gray); less than 20% (lighter gray); more than 20% (lightest gray). Black dashed lines represent primary coil windings.

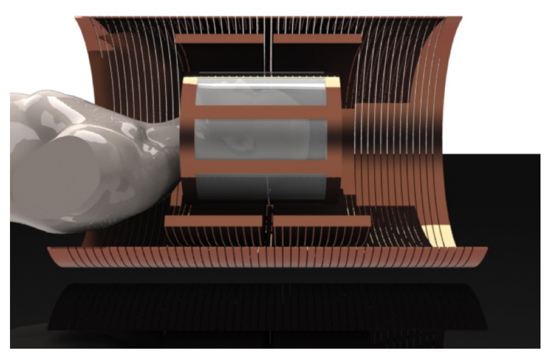

Figure 2. Cut-out image of dreMR actively shielded electromagnet with human head and specialized head-only RF coil inside.

Conclusion

A practical, actively shielded dreMR coil design for human head imaging has been described. This coil would be constructed for implementation on a 1.5 T platform, as the contrast agents of interest display the strongest relaxivity field dependence around that field. Our previous results in phantom and small animal tests indicate that the proposed coil will be capable of demonstrating useful dreMR contrast in the human head.

References and Acknowledgements

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