Investigating the interactions of active magnetic shielding systems with high-permeability materials.

Niall Holmes[1], James Leggett[1], Tim Tierney[2], Elena Boto[1], Ryan M Hill[1], Gillian Roberts[1], Vishal Shah[3], Stephanie Mellor[2], Paul Glover[1], Gareth R Barnes[2], Matthew J Brookes[1] and Richard Bowtell[1]

[1] Sir Peter Mansfield Imaging Centre, University of Nottingham, Nottingham, NG7 2RD, UK
[2] Wellcome Centre for Human Neuroimaging, University College London, London, WC1N 3AR, UK
[3] QuSpin Inc., 331 South 104th Street, Suite 130, Louisville, CO 80027, USA.

Magnetoencephalography (MEG) measurements using optically pumped magnetometers (OPMs) have the potential to revolutionise the field through the production of wearable systems [1]. Crucial to the design of OPM-MEG devices so far has been the development of electromagnetic coils for additional field cancellation inside a magnetically shielded room (MSR) to create zero-field environments [2,3]. Coils which produce homogeneous magnetic fields and magnetic field gradients are placed around the subject, with the current carried in each coil determined by feedback loops. However, several layers of high-permeability material (e.g. mu-metal) are used in the construction of a MSR, and the fields produced by these coils are affected by an interface between the air (where the relative permeability μ_r is ≈ 1) and the mu-metal ($\mu_r \approx 80{,}000$). This impacts upon the efficiency of the coils (field or field gradient per unit current), the spatial homogeneity of the produced magnetic fields and therefore the shielding performance. Here, we employ a method of images based approach to investigate these interactions, modelling the system as an infinite series of recursive reflections of current elements in the planes of the MSR [4]. Simulations of these effects in a bi-planar coil system are compared with experimental measurements. Characterisation of these interactions will allow their incorporation into the design of active shielding systems optimised for use inside a MSR; the design of lighter and cheaper MSRs will hopefully be facilitated by such systems.

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[3] J. Iivanainen et al., On-scalp MEG system utilizing an actively shielded array of optically-pumped magnetometers, Neuroimage (2019).
[2] Q. Cao et al., Optimization of a coil system for generating uniform magnetic fields inside a cubic magnetic shield, Energies (2018).