The Effect of Magnet Flanges on Eddy Current Predictions

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Introduction: As design trends for MR imaging systems move towards larger patient bores and stronger gradient strengths, magnetic fields produced by eddy currents play an increasing role on image quality. In gradient coil design, the eddy current surfaces are often modeled as finite length conductive cylinders, coaxial with the gradient coils. This simplification allows for rapid, semi-analytic determination of the eddy current distribution on the cylindrical structures [1]. However, by ignoring other eddy current generating surfaces, such as the magnet flanges, the predicted eddy current response may not accurately reflect the true response. In this study, we evaluate the effect of excluding the magnet flanges on eddy current field predictions using finite element analysis.

Methods and Materials: The eddy current response of an actively shielded transverse gradient coil was simulated using COMSOL (COMSOL, Inc. Burlington MA). When representing the gradient coil with a continuous current distribution, the cos(φ) symmetry in the azimuthal direction can be exploited to reduce the problem to two dimensions [2]. The model was solved for the three scenarios representing a gradient coil in free space, the coil inside a conducting cylinder (Fig. 1b), and the coil inside a conducting cylinder with flanges and the outer cylinder of the magnet (Fig. 1c). A zero-flux boundary condition was imposed at the surfaces of all conducting objects corresponding to the t=0 response to an impulse, also known as an "eddy image." The magnetic field produced by the eddy currents was obtained by subtracting the result of the free gradient simulation from the simulations containing conducting objects. To evaluate the effect of neglecting the flanges in predicting the eddy current response, the flanged simulation was taken as the ground truth, and the rms error was determined with and without pre-emphasis. Results are reported in ppm assuming a 3T magnet. The average mesh resolution was 0.36 cm^2/element, and the total simulation time to compute all three models was 24s on an HP Z800 workstation with 8 cores at 2.67 GHz, and 64 GB of memory.

Results: By neglecting the magnet flanges in the simulation, the rms error in the eddy current prediction was 1.35 ppm before pre-emphasis. This compares to the rms eddy current field for the truth case of 19.51 ppm, corresponding to an average error of 6.9%. Because the contribution to the eddy current field produced by the flanges has significant higher order content, it cannot be completely corrected for with pre-emphasis. The observed error after compensation was 15.8%.

Discussion and Conclusion: Magnet flanges have a non-negligible contribution to the overall eddy current field in the imaging volume. With gradient coils becoming more compact in order to accommodate larger patient bores, active shielding may not be as effective in containing the distorting effects of eddy currents on image quality. It is desirable to include eddy current response surfaces as part of the gradient coil optimization procedure [3], but for truly accurate designs, a geometry more complex than a simple cylinder should be considered.

References: [1] Lopez, H. S. ,Poole, M.,Crozier, S., Eddy current simulation in thick cylinders of finite length induced by coils of arbitrary geometry, *J. Magn. Res.,* **207**, 251-261 (2010) [2] Heins, A. E. Axially-symmetric boundary-value problems. *Bull. Amer. Math. Soc* **71**, 787–808 (1965). [3] Trakic, A., Liu, F., Lopez, H. S., Wang, H., Crozier, S., Longitudinal gradient coil optimization in the presence of transient eddy currents, *Magn, Reson. Med.*, **57**, 1119-1130, 2007

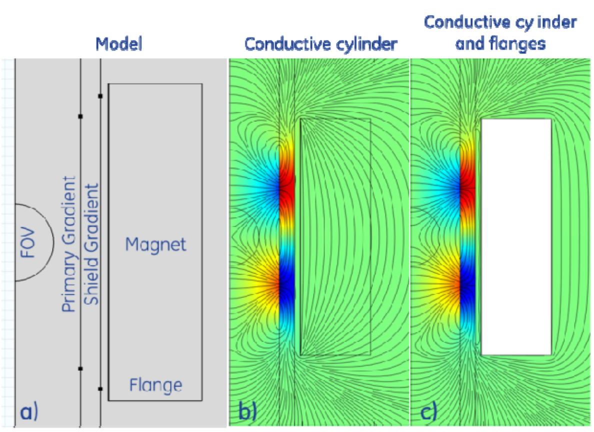

Fig 1. Finite element model (a) of a transverse shielded gradient coil with a conducting cylinder (b) and a conducting cylinder with flanges and outer cylinder (c). The colormap in (b-c) corresponds to the magnetic scalar potential and the lines represent stream traces of the magnetic field.

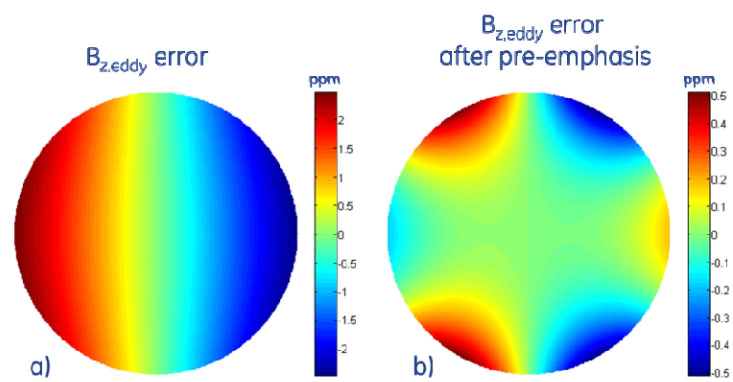

Fig 2. Error in the eddy current field predictions with (a) and without (b) pre-emphasis as a result of excluding the magnet flanges in the model. The error was determined over a 40 cm field of view and reported in ppm of 3T.