Mechanically adjustable shielded insert gradient for experimental evaluation of construction tolerances

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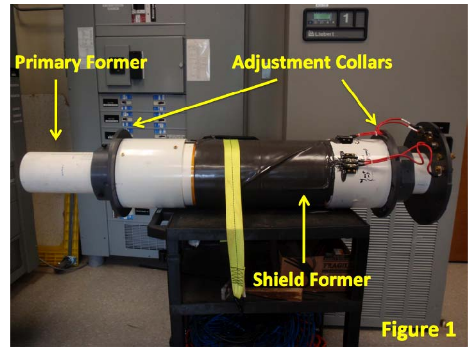
Introduction: Virtually all applications in MR require the rapid switching of gradient fields within the scanner, and many emerging applications take advantage of rapidly switched shim coils; eddy-currents generated in the surrounding structures of the system are therefore a constant challenge. Mitigation of coupling between an insert coil and the MR system is typically accomplished using active shielding; however, the construction tolerances required for these shielded systems are not well known. Our goal is to examine the eddy-currents generated in a 7.0 T system by driving a very special shielded insert gradient coil of our own design. This coil is unique in that we have constructed it such that the active shields can be purposely misaligned with respect to the primary coil by predetermined amounts in all directions. In this study we present initial results with this test system for the impedance of the shielded gradient insert as a function of shield positioning error, both inside and outside an idealized scanner bore.

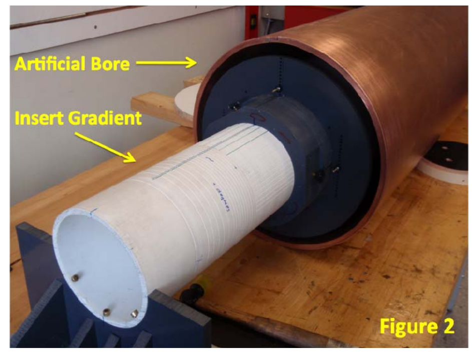
Methods: A two axis shielded gradient set was designed using a minimum power Fourier series method [1]. The gradient set consisted of one shielded Y-gradient coil and one shielded Z-gradient coil. The Z and Y gradient coils had radii of 7.0 cm and 7.5 cm, respectively, and the Z and Y shield radii were: 11.0 cm and 11.5 cm. The shielded coils had inductances (1 kHz) of: 99.7 μH for the Z-axis and 116.9 μH for the Y-axis. The shields were connected in series with the primary coils, but were mechanically isolated using separate formers to allow for independent movement (Figs 1,2). The shields can be offset in the longitudinal, azimuthal, and radial directions, or any combination simply by adjusting the position of the collars that connect the primary coils to the shields. The impedance of each shielded axis was measured as a function of shield offset in all three directions. This was done inside and outside of a continuous copper cylinder with radius 17.5 cm (figure 2), which mimics the bore of our 7.0 T system.

Results and Discussion: Resistance at 1 kHz was found not to vary significantly across any primary-shield offset combinations. As expected, in all cases it was found that the inductance of each axis increased as the shields were offset from their correct positions. This effect was still present when the measurements were repeated inside the artificial bore (figure 3); however, the effect was reduced due to the presence of a mutual inductance between the gradient insert and the bore. As an example of the data, Figure 3 shows the measured inductance of the shielded Y-gradient coil as the shield is continuously misaligned along the z-direction. The difference between inductance values inside and outside of the bore are plotted in figure 4 for this same case. The results suggest that the shield would have to be misaligned by a significant amount (~7.0 cm) before the inductive coupling to the bore would become as large as for an unshielded primary coil. Previous work [2] has shown that unshielded insert coils with similar radial scaling to the scanner bore will generate significant eddy-currents in a MR system. If eddy current magnitude scales with coil inductive coupling to the bore, then this result would suggest that induced eddy currents for a coil with a shield misaligned by a few cm would approximate those produced by an unshielded coil. These results provide a “bench-top” means of investigating gradient coupling to an MR scanner, and are currently being verified by experiment with the shielded insert gradient inside our 7.0 T system.

References:

[1] Carlson J W et al. 1992 Magn. Reson. Med. **26**:191-206
[2] Chronik B A et al. 2000 Magn. Reson. Med. **44**:955-963





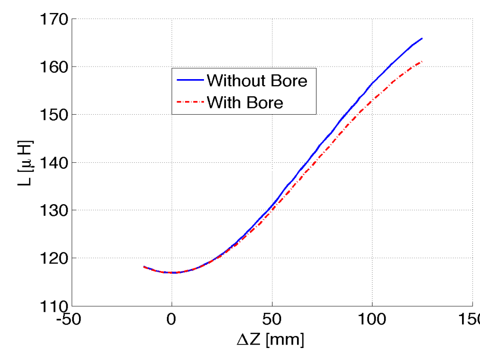


Fig. 3 (above) shows inductance of the shielded Y-coil as a function of shield offset along the z-direction with and without the bore. Fig. 4 (below) shows the difference in inductance values inside and outside of the bore for the same case as figure 3. The horizontal line indicates the unshielded case.