Selective Passive Shielding

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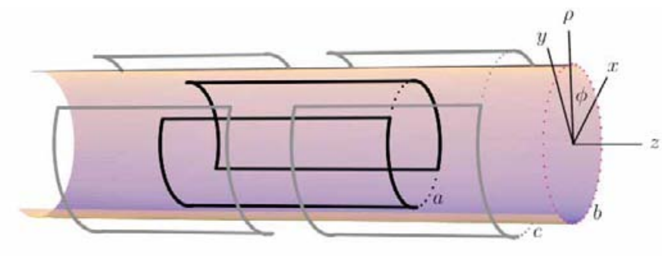
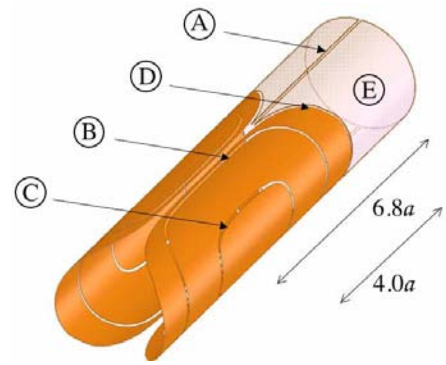
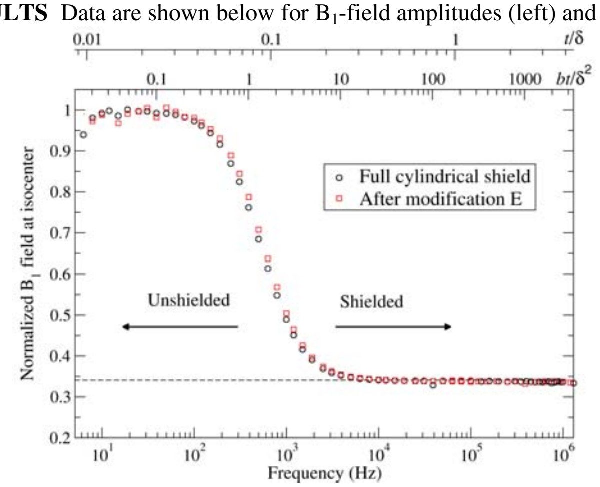
INTRODUCTION The main challenge in applying passive RF shielding techniques to very low field implementations of MRI is illustrated by the diagram to the left: a metallic shield (on $\rho = b$, cut-away) of sufficient thickness to contain the RF field from the B_1-coil (on $\rho = a < b$) may also screen fields from gradient coils (on $\rho = c > b$). To get around this problem, one may resort to active shielding techniques [1,2]. Or, as we demonstrate here, one may use a passive shield that has been judiciously segmented to frustrate the flow of eddy-currents driven by gradient coils while leaving those associated with the B_1-coil largely unperturbed. This can be achieved by segmenting the shield along the flow lines of the latter, since they are not, in general, confluent with those of the former. The Green function method outlined in Refs.[1,2] is used to calculate flow lines and hence shield patterns.



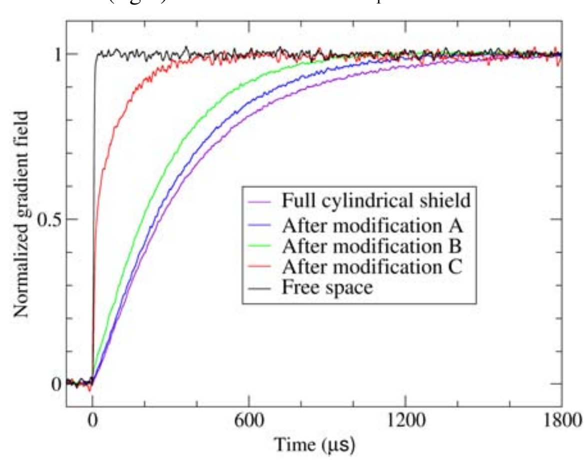
EXPERIMENT A prototype of the coil and shield geometry shown above was designed and tested. We chose $a{:}b{:}c$ = 9:11:13 as a reasonable set of ratios typical of an MRI setup. The B_1-coil was wound on a PVC tube (a = 3.7 cm). The gradient coils, both transverse and axial (not shown above), were made from copper tape applied to a cardboard tube (c = 5.3 cm). The shield was constructed from copper foil (thickness t = 250 μm) on a PVC tube (b = 4.5 cm) using a single solder seam along $\phi = 90^o$; the resulting copper tube had a length of 50 cm (half-length 6.8a), sufficient to behave as an ideal (*i.e.,* infinitely-long) passive shield for the B_1-coil. The shield was subsequently modified with incisions (A) through (D) and excision of the end-pieces (E), as shown to the right. All incisions were made along the theoretical eddy-current flow lines for the B_1-coil. These modifications were chosen for the following reasons: Incision (A), made along $\phi = \pm 90^o$**,** disrupts azimuthal eddy currents from y- and z-gradient coils; incisions (B) and (C) disrupt axial and azimuthal eddy currents from all gradient coils; incision (D), made along a contour beyond which only 1% of the (theoretical) B_1-coil eddy currents exist, allows the shield to be shortened with removal of the end-pieces (E). We measured B_1-field amplitudes and gradient-field rise-times under the following conditions: (i) in free space, (ii) with the full cylindrical shield, and (iii) after each modification (A) through (E) of the shield.



RESULTS Data are shown below for B_1-field amplitudes (left) and gradient-field rise-times (right) inside the shielded B_1-coil.



The B_1-field at the isocenter normalized to free-space values for each frequency. The high frequency limit for the full shield (circles) agrees with theory (dashed line) [2]; results are very similar following all modifications (A) through (E) (squares). The data clearly show (see top axes) that the onset of shielding occurs when the electromagnetic skin depth (δ) satisfies $\delta^2 < bt$ and not $\delta < t$ as is commonly assumed [3]. This was corroborated by measurements of B_1-field transmission through the shield (not shown here).



The magnetic field at $|x|$ = 3cm from the isocenter produced by the x-gradient coil. The rise-time decreases after each modification (A) through (C). No further decrease was observed following modifications (D) and (E) (not shown here). Fields produced by y- and z-gradient coils (not shown here) exhibit shorter rise-times, since eddy currents for these coils are more strongly frustrated by all axial incisions in this shield. Additional incisions (within (b) or (c)) are expected to further decrease field rise-times from all gradient-coil geometries.

SUMMARY A selective passive shield for a saddle-shaped B_1-coil was designed and tested. The results clearly indicate that such shields would be of use in very low field implementations of MRI where the RF frequency may be comparable to, or even lower than, gradient-field switching frequencies. We also point out that selective passive shielding could be used to decouple receive coils from external noise sources.

REFERENCES [1] R. Turner and R.M. Bowley, J. Phys. E **19**, 876 (1986). [2] C.P. Bidinosti, I.S. Kravchuk, and M.E. Hayden, J. Magn. Reson. **177**, 31 (2005). [3] S. Fahy, C. Kittel, and S.G. Louie, Am. J. Phys. **56**, 989 (1988).