Another step toward making MRI quieter: Along a passive shielding path

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Introduction

Residual eddy currents on the magnet's inside metallic bore diameter are generated by imperfectly shielded gradient coil assemblies. A shielded gradient coil assembly that is enclosed in a vacuum dewar and mechanically isolated still may generate significant acoustic noise due to the interactions of the inner bore eddy currents with the main field [1, 2]. Like all MRI difficulties, this problem grows with MRI field strength and also gradient intensity. One proposed palliative is the partial encapsulation of the gradient assembly outer surface by copper passive shielding [3]. The copper shield may reduce the fringe field at the magnet's inner bore diameter by almost 25 dB [3]. Since the passive screen may be enclosed inside the vacuum chamber along with the gradient assembly, noise generation from its own vibration is not an issue. However, the presence of the metallic shield closer to the imaging volume may increase the residual eddy current effects of the shielded gradient assembly inside imaging DSV. In addition, the use of copper as a passive shielding material can result in the increase of time constants associated with transient eddy currents developed on its surface, and the resistance of the passive shield may change with the temperature of the gradient assembly, possibly resulting in unpredictable spatial and transient behavior for the eddy current fields developed on the passive shield.

We have studied an assembly consisting of an actively shielded gradient coil augmented by additional passive shielding using different combinations of passive copper strips. We have found that an actively shielded gradient assembly including active shielding endcaps, combined with radial and axial passive conductive strips, reduces power deposited on the cryostat's inner bore by 32.5dB from power deposition in a traditional shielded gradient coil assembly. In this circumstance, the maximum fringe field is reduced to less than 11µT.

Methods and Results

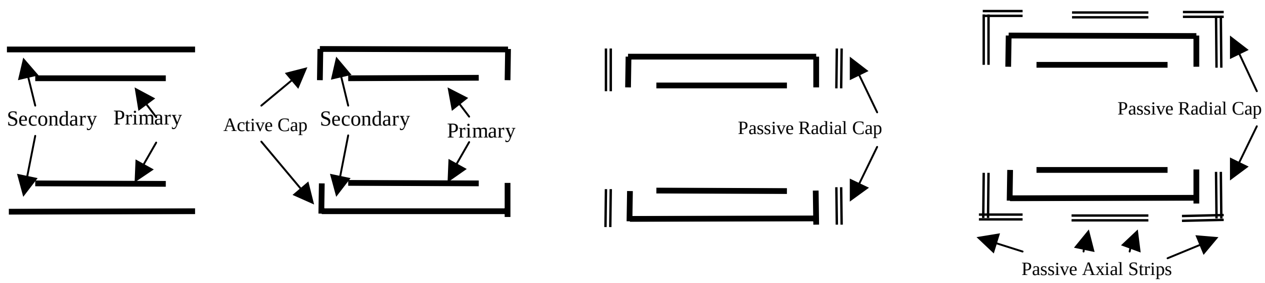

Figure 1. Traditional shielded gradient — Gradient with active endcap windings. — Gradient with active endcap windings and passive rings — Gradient with active endcap windings and passive rings

Figure 1 shows four shielded gradient coil configurations. The first is a traditional gradient coil assembly. The second is an improved shielded gradient coil assembly with active winding end caps. The third contains active caps and a pair of annular passive discs placed on both sides of the shielded cap gradient coil. The fourth is similar to the third with the addition of annular copper strips disposed axially towards the center of the gradient coil assembly. The radius of the primary coil is 0.360m with total length 1.0m. The radius of the secondary coil is 0.440m with total length 1.22m, while the radial dimension of the cap is 0.076m. The axial position of the copper passive annular rings was $\pm$0.80m from the center of the coil with a starting radius of 0.360m. In addition, an annular ring of 0.30m width and 0.45m radius is wrapped around the center of the coil. Table 1 shows calculated results for power deposited in the cryostat's inner bore by a trapezoidal pulse with a width of 1ms, a rise/fall time of 200µs, a flat time of 600µs, and maximum gradient current of 100A. Figure 2 indicates the residual eddy current calculated at the magnet's inner metallic surface.

Table 1. Peak field values at 3 cm outside secondary windings. Peak eddy currents and power deposition in cryostat inner bore.

	Traditional gradient	With active lip	With active lip and passive annular strip	With active lip and lipped passive shield
Fringe field	329.1µT	78.7 µT	78.7 µT	10.2 µT
Eddy current	3.55A	0.759A	0.2363A	0.1682A
Pwr dep. (dBm)	34.661	18.387	7.743	2.09

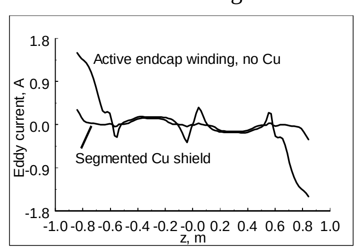

Figure 2. Eddy current comparison.

Discussion and Conclusions

As Table 1 and Figure 2 indicate, the configuration of gradient coil with radially and axially disposed copper conductive strips reduces the electric power deposited by almost 33dB (the acoustic power tracks the ohmic power). For a shielded gradient coil assembly with end cap windings only, the power deposition is reduced by 16.2dB. The addition of two passive annular rings at the end of the structure brings the decrease to 27dB. Such distant conducting rings will not generate harmful eddy currents. The cylindrical Cu surfaces applied to the center of the gradient structure will bring an additional 6dB in power reduction, but they could be a source of transient eddy currents that degrade image quality. By keeping the width and the thickness of these strips to a minimum, such additional effects may be controlled.

References

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