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Discussions

Interactive comment on “Topologically Optimized Magnetic Lens for MR Applications” *by* Sagar Wadhwa et al.

Anonymous Referee #2

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Sensitivity is the bane of nuclear magnetic resonance spectroscopy and any improvement in the signal to noise ratio (SNR) is welcome. The paper under review is in that vein; it discusses the design, by computer optimization, of a “distributed metal track” (in the words of the authors) to serve as a Lenz lens. A Lenz lens, called so because it uses Lenz’s law of induction and like a lens focusses the magnetic field by a larger coil into a smaller region, when placed between the RF circuit and the sample improves the SNR in MRI and NMR by engineering the distribution of the magnetic field intensity in a region of interest. The paper demonstrates the optimal topology of a Lenz lens, which is then fabricated and its use validated in MR applications at 45 MHz and 500 MHz.

The approach adopted is topology optimization, which answers the question “how to

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Discussion paper

place material within a prescribed design region for optimal performance?" Topology optimization is achieved by the use of an adjustable, spatially varying material property. The authors selected the conductivity of the medium to be a function of the spatial coordinates, which they allowed to vary between that of free space, and Cu, a range of 10^e7. The uniformity of the RF field, which determines the flip angle of the pulse, was the control equation which was minimized subject to a number of constraints. Following the design of two optimal Lenz lenses (one operating at 45 MHz and another at 500 MHz) using a commercial finite element software package, in a second simulation stage called post-processing, the magnetic field distribution in the lenses were characterized by replacing the background field with the magnetic field produced by a realistic coil geometry. Finally, the lenses were fabricated and their performance verified with nutation experiments on a water sample at 45 MHz in a 1 T pre-clinical MRI machine and at 500 MHz in a high resolution NMR spectrometer.

They conclude that topology optimization, using a commercial finite element tool, offers a feasible way to find practical Lenz lens arrangements which can be easily fabricated. They were able to find lenses with a B_1 enhancement of about 1.5, a marginal increase in SNR (1.2 and 1.6), a modest decrease in the $\pi/2$ pulse duration, and that the topologies are a compromise between signal enhancement and field uniformity.

The improvements demonstrated are modest and restricted to 2D, but the approach shows promise. The mechanics of the paper (the English, punctuations, capitalization, etc.) is, however, in need of some serious repair; errors of this nature are too numerous to even list. The authors are also encouraged to consider some other questions/comments given below.

1. In the introduction, the two sentences on filling factor appear to be in disagreement.

2. Chemical elements, such as Cu, are not italicized.

3. The acronym OL is not defined.

4. What are the limitations of restriction to 2D geometry? The sample volumes are much smaller than is practically used so any gain in SNR is compromised because of smaller sample volume. Besides, when you are off-resonance, the trajectory of magnetization is not 2D anyway. Some discussion on this would be welcome. Would having two 2D lenses at the two ends of a solenoid be useful? Was it considered?

5. In Figure 5, what does it mean to have relative length in mm? Would it not be dimensionless?

6. It is BRUKER AVANCE not ADVANCE.

7. Figures 6 c) and 6 f) are not nutation spectra; their Fourier transform is. Why is there an asymmetry (below and above the maximum) in Figure 6 c) with OL?

8. A number of points in the conclusions (3D geometry, Eddy currents, tuning and matching) merit some elaboration in the manuscript. The statement "It is hardly a surprise that the quest for more signal-to-noise from an existing NMR detector arrangement is matter of numerical optimization." is questionable. Pardon my ignorance, but I do not know what a "Pareto front" is.

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