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Discussions

[MRD]

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

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The manuscript describes the design and implementation of a technique to increase the amount of RF power delivered to the sample region in magnetic resonance experiments. The B1 coils in MR experiment do a two fold job: a) Creating a homogeneous magnetic field pulse along a direction perpendicular to the main magnetic field direction (taken to be the z -direction in general), b) Detecting the flux induced by the larmor precession of sample magnetisation, the main signal in a MR experiment. The signal to noise measured in any MR experiment thus critically depends on the efficiency of this coil to do both its jobs. In this manuscript a magnetic lens design is computationally optimised such that it focuses more of the rf power from the B1 coil into the sample volume. The optimal design is also fabricated and tested to check for power enhancement at the sample.

Improving signal to noise(S/N) and resolution are a constant objective of new techniques introduced in MR. This manuscript provides a way to augment the hardware in exciting MR set-ups to increase S/N by about a factor of two. The technique derives its working principle from the Lenz lens used to enhance the effective filling factor of sample in receiver coils in MR. The manuscript shows a way to computational optimise the lens design to get the most out of the system. Though the enhancement achieved in the end is not very different from the standard Lenz lens design, given the constrains of construction, it demonstrates the possibility to use such a software optimisation for building coils with specific deliverables. They use commercial finite element analysis software for the task. The method can be modified to design coils with other specification such as broad tunability or homogeneity over a specified region of interest etc. Thus the manuscript demonstrates the possibility to use this technique for hardware improvements in MR receiver coil design.

The article starts by introducing the need for S/N improvements in MR and describes some of the hardware techniques that have been used in literature for enhancing sample filling factor and rf power at the sample. **It would be nice to also talk about typical homogeneity in rf fields of the various coils current in use.** The Lenz lens(LL) is introduced and the need to optimising the LL lens to achieve specific goals is mentioned. The background of topology optimisation for inverse material design is also introduced with relevant references.

The main aspects of the new design concern the electromagnetic wave propagation through medium and the electrodynamics involved in magnetic induction and wave propagation through interface. The relevant electromagnetic equation: Maxwell equations and its modifications for the problem are properly introduced. The boundary conditions under which the equations are solved for also explained. **The parameter**

called penetration factor p **needs to explained.** They provide a comprehensive list of constrains and conditions under which they solve for the optimisation. **It would be nice to know if these conditions are sufficient in themselves, may be with some representative examples from literature.**

The optimisation protocol basically creates a region of metal (Cu) and air and finds the profile of Cu that would give rise to the required field strength and uniformity at the sample region. A design variable γ is used to define free space or Cu [0 or 1]. They use a hyperbolic tangent function, defined by a parameter β, to define the material contrast between the Cu and air regions such that construction of the coil would be practical without region defined in multiple grayscale. The numerical algorithm is set up in a commercial software - COMSOL. The various steps for calculating the optimal lens (OL) by iterating over γ and β is explained starting from a initial shape with uniform γ and linearly boundaries (β =1). **The β values are course grained as each increment of β doubles its value. Would a 'slower' increment give better optimisation or the boundary shape change is still sufficiently slow with this step size?**

The details of the procedure for obtained a OL lens at 45MHz and 500 MHz are explained. Post processing simulations to check the field enhancements given the OL are also performed and the results are explained well. The enhancement obtained are compared to standard receiver colis in their MR instruments for OL and LL and the results are well tabulated in Table 2. The inhomogeneity in the magnetic field are also simulated and compared. They also justify the fact that the amplification achieved was not very different between OL and LL due to practical constrains.

They go ahead and fabricate the LL and perform NMR nutation experiments to demonstrate the rf field enhancement and the results are well tabulated in Table 3.

The paper successfully demonstrates that commercial finite element software can be used to find practical, optimal LL lens with set goals even if the OL does not show much difference from LL.

The theory, the numerical algorithm, simulation and the NMR experiments are all explained well and figures and tables are well presented. The language of the text though requires to be improved. There are many grammatical and typographical errors in the article that need to be taken care of. I will attempt to list a few below.

Technical Corrections

1. Abstract: Line 4 current *"...designs that delivers..."* change to "*designs that deliver..."*

2. Abstract: Line 5 current *"...an RF circuit..."* change to *"a RF circuit..."*

3. Introduction: Line 13 current *"... and also leads to a reduction in ...."* change to *"... and also a reduction in ...."*

4. Introduction: Line 43 current *"... by Jauga et. al that by tuning and matching ...of operation, this improved...."* change to *"... by Jauga et. al that tuning and matching ....of operation, improved..."*

5. Methodology: Line 103 current *"....blue region in te centrerepresents ...."* change to *"....blue region in tne center represents ...."*

6. Methodology: Line 124 current *".. any values..."* change to *" any value"*

7. Post processing: Line 212 current *"...magnetic field. it focuses..."* change to *"........magnetic field. It focuses..........."*

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8. Post processing: Line 219 current *"...while the protrusions maintains the uniformity of the field..."* change to *".......while the protrusions maintain the uniformity of the field.........."*

9. Post processing: Line 223 current *"... the geometry similar to as shown in ..."* change to *"....... ageometry similar to that shown in ...."*

10. Fabrication: Line 278 current *"...... solution was placed was in a bubble ....."* change to *"...... solution was placed in a bubble ...."*

11. Conclusions Line 307 current *"......The found topologies form a ....."* change to *"......The topologies found by optimization form a ...."*