Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Ioannis Georgakis

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Fast integral equation methods and performance bounds of modern magnetic resonance coils

Supervisor: Prof. Maxim Fedorov

Co-advisor: Prof. Athanasios Polimeridis

Chair of PhD defense Jury: Prof. Ivan Oseledets *Email: I.Oseledets@skoltech.ru*

Date of Thesis Defense: 28 November 2019

Name of the Reviewer: Dmitry Dylov

I confirm the absence of any conflict of interest	**Signature:** **Date: 28-10-2019**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

PhD candidate demonstrates application of analytical methods along with new numerical approach to modeling interactions between electromagnetic waves and biological tissue. Calculation of the theoretical boundaries of the operating characteristics of RF coils is carried out in accordance with basic electrodynamics laws. The corresponding optimal RF excitation patterns which are derived for a particular phantom of human body are extremely promising in finding remedies for the inhomogeneities of the ultra-large-field MR imaging systems. It is possible that the research effort presented in this thesis will lead to appearance of unprecedented details in the MRI scans of the future. The newly developed apparatus for solving integral volume equations for the exact calculation of electromagnetic field distributions in the framework of highly heterogeneous realistic models of the human body is an impressive accomplishment on its own.

The subject of optimization, however, seems not to be sufficiently robust in terms of mathematical formulation presented in (5.50)-(5.55). Perhaps, a more robust approach to the computational derivation of an optimal shape of the excitation pattern would be beneficial to completing the story. The numerical part, however, is sufficiently robust and sound.

The rationale behind choosing a new performance metric, UITXE, which is claimed to provide the largest theoretical response for a given coil design is not covered sufficiently well in the introduction part to the section 3. The claim itself could be elaborated to clarify the cases when the theoretical considerations fail to depict experimental observations. How well does this relate to the real magnets today?

Even after reading the thesis, this jury member was left dubious with regard to the most important question: should we continue increasing the RF magnitude in hopes to see greater detail in the images? There is room for improving the relevant description.

Pages 166-168 contain post-editing gibberish and should be removed.

How about tackling the SNR "hot spots", caused by the absorbance difference (SAR), with simple digital artefact removal pipelines? Perhaps, the future plans section could be written in such a way that the theoretical sections preceding the conclusion should naturally lead towards the future of MR imaging.

What are the outcomes expected from an imaging system capable of generating MR echo and and the complex excitation sequences in time? Will detectors keep up with the excitation sequences? Can the ultra-strong component of the magnetic field introduce strong nonlinear response with the second-order relaxation effects in the biological tissues?

The prospect of improved signal to noise ratio (SNR), higher spatial / spectral resolution and shorter imaging time are well described to provide motivation for the reader. Although patient safety is mentioned, the literature search with regard to the highly oscillatory and compensatory component of the RF magnetic field is not presented.

As a suggestion to re-unite the reader with the Data Science, it is recommended to add a short speculation on the subject of modern Image-to-Image translation approaches that attempt to generate ultra-high filed MR imagery from the low-detail images. See, for example, this work and explain how your approach relates to this work:

https://link.springer.com/chapter/10.1007%2F978-3-319-46976-8_5

With regard to strict derivation of the solver of the integral equation, phrases like "surprisingly stable convergence" should be avoided or, alternatively, a justification of why the expectations had been below the obtained ones should be provided. Overall, it is a rather strong work which shows that the education at Skoltech is like drinking from a fire hose which you first have to unfold from a coil.

Good luck!

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*