PhD Dissertation Review

Ilja Merunka

Feasibility Study of Microwave Differential Tomography for Medical Diagnostics and Therapy

Topic of the dissertation

When searching for keywords microwave & differential & tomography in *IEEE Xplore* and *Web of Science*, I found publications related to:

1. Microwave tomography based on differential equations [A];
2. Multi-frequency differential linearized techniques conferring the performance to the UWB tomography [B];
3. Differential imaging in field of the diffraction tomography [C];
4. Differential tomography used in satellite techniques [D].

Since COMSOL models are used, the term differential tomography in the title emphasizes that thesis belongs to the first group, I guess. On the other hand, I do not see the reason for using terms the feasibility study and the therapy in the title. A brief clarification is welcome

No matter, the microwave tomography is topical and the dissertation thesis is up to date.

Objectives & methods used

In the thesis, following objectives are defined:

1. Design of an antenna system for microwave tomography
2. Measurement of complex permittivity of human tissues
3. Study of performance of reconstruction algorithms for microwave tomography
4. Brain stroke detection and classification
5. Temperature dependent model of agar phantom for testing microwave tomography

PhD thesis is conceived as a combination of conventional thesis (chapters 1 to 5) and selected journal papers (chapters 6 to 9).

Dealing with the **conventional chapters**:

1. A microwave tomography is introduced. The state-of-the-art is focused on the solution of the inverse problem by stochastic approaches (the objective no. 3 only), and other objectives are not considered.
2. An iterative solution of an inverse problem related to microwave imaging is discussed, and Gauss Newton optimization is reviewed. Hence, fundamentals for the objective 3 are given.
3. Antenna elements for an experimental microwave imaging system are compared. Four existing antennas are reviewed (Fig. 3.1) and a novel bowtie element is proposed (Fig. 3.7). For the antennas, frequency responses of |S11| and |S21| are provided (Fig. 3.3, 3.9), and loss density contours are given (Fig. 3.4, 3.12).

- Description of compared antennas is insufficient and does not allow an independent verification of presented results.
- No details related to results are provided (if simulated or measured, under what conditions performed, what way verified).

The chapter is related to the **objective no. 1**.

4. Practical implementation of the experimental microwave imaging system is described. Attention is turned to the hardware (including bowtie antennas), and the Gauss-Newton iterative reconstruction allowing the detection of strokes.

   The chapter is related to the **objective no. 4**.

5. Measurement of complex permittivity of an agar phantom at different temperatures is described. Exploitation of a genetic algorithm for fitting measured agar parameters to Debye model is presented.

   The chapter is related to the **objective no. 5**.

Dealing with **journal papers**:

6. LA GIOIA, A.; PORTER, E.; MERUNKA, I. et al. Open-ended coaxial probe technique for dielectric measurement of biological tissues: challenges and common practices. *Diagnostics*, 2018, 8, 40. DOI: 10.3390/diagnostics8020040

   The paper is related to the **objective no. 2**.

7. SALUCCI, M.; VRBA, J.; MERUNKA, I. et al. Real-time brain stroke detection through a learning-by-examples technique – An experimental assessment. *Microwave and Optical Technology Letters*, 2017, 59, 2796–2799. DOI: 10.1002/mop.30821

   The paper is related to the **objective no. 4**.

8. SALUCCI, M.; GELMINI, A.; VRBA, J. et al. Instantaneous brain stroke classification and localization from real scattering data. *Microwave and Optical Technology Letters*, 2019, 61, 805–808. DOI: 10.1002/mop.31639

   The paper is related to the **objective no. 4**.

9. MERUNKA, I.; MASSA, A.; VRBA, D. et al. Microwave tomography system for methodical testing of human brain stroke detection approaches. *International Journal of Antennas and Propagation*, 2019, article ID 4074862

   The paper is related to the **objective no. 4**.

Since the papers 6 to 9 were deeply reviewed by the editorial staff of journals, I consider the contents being novel and valid.

I can summarize that **all the objectives of the dissertation were met**.

Only the **objective 3** needs additional clarification. I the abstract, the author states: *I decided to concentrate mostly on the quantitative deterministic iterative approaches [20] using forward solver*. Nevertheless, those approaches are discussed in the state of the art only.

Formal aspects

The dissertation is written in good English. The ideas are expressed clearly and accurately. Figures are well-readable. On the other hand:

- When reviewing Maxwell equations on page 8, the numbering of relations is incorrect and there is a mistake in Gauss law.
- On page 14, the right-hand chart in Fig. 3.3 is not |S11|; an incorrect description of the vertical axis. Were the frequency responses simulated or measured? What way the responses were verified?
- The links are missing on pages 20, 23, …

Impact

According to Web of Science, 34 papers are associated with the name of Ilja Merunka. Those papers have 96 citations without self-citations, and the h-index of the author is 5. The paper on measuring biological tissues in *Diagnostics* has 44 citations, and the paper on the brain stroke detection through learning-by-examples was cites 23 times. Obviously, the related research is of a significant impact.

Conclusion

Considering the above evaluation, the dissertation thesis authored by Ilja Merunka is definitely

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to being defended.

Brno, the 2nd of January, 2021

Zbynek Raida

Questions

1. When designing an antenna for the experimental microwave imaging system, following objectives were defined (page 12):

    1.1 The active element is separated by the ground plane from the surroundings;

    Is your monopole perpendicular to the wall of the imaging system? Then there is no radiation in the direction of the axis. Other antennas have the main lobe there.

    1.2 A coaxial feeding is preferred;

    Can you explain the principle of feeding your bowtie dipole? And can you compare it with a conventional feeding by a coplanar waveguide?

    1.3 Symmetric radiation pattern is preferred;

    Can provide the bowtie antenna symmetrical radiation pattern around the direction perpendicular to the wall?

    1.4 Small dimensions of an antenna are requested;

    All the antennas are resonant antennas. Can be their dimensions minimized?

1.5 As good impedance matching as possible;

Is impedance matching the property of an antenna or a matching circuit?

1.6 As high transmission to the most distant antenna as possible.

In the far field, the objective is equivalent to the maximum realized gain in a given direction. Does the situation in the microwave imaging system differ?

2. For the first time, I became familiar with the experimental microwave imaging system in [E]; even bowtie antennas were exploited. Can you provide a brief overview what features were adopted from the existing system and what is the novel development? And why [E] is not referenced in the thesis?
3. Why a genetic algorithm was used when fitting measured agar parameters to Debye model? For such a task, a local optimization should be sufficient, I guess. And is there any comparison from open literature available?
4. What was your percentage contribution to papers from chapters 6 to 9?
5. What way the quartile of journals was determined? According to *Web of Science, Microwave and Optical Technology Letters* are in Q4 both in electrical engineering and optics.

References

[A] AFSARI, A.; ABBOSH, A.M; RAHMAT-SAMII, Y. A rapid medical microwave tomography based on partial differential equations. *IEEE Transactions on Antennas and Propagation*, 2018, vol. 66, no. 10, p. 5521-5535. DOI: 10.1109/TAP.2018.2855642

[B] GUARDIOLA, M.; CAPDEVILA, S.; JOFRE, L. Robust differential multi-frequency microwave imaging for breast cancer detection. *European Conference on Antennas and Propagation* (EuCAP 2013). Gothenburg (Sweden): EurAAP, 2013.

[C] DILMAN, I.; AKINCI, M.N.; ÇAYÖREN, M.; AKDUMAN, I. Differential microwave imaging of the stroke-affected brain via diffraction tomography. *The 25th Telecommunication Forum* (TELFOR 2017). Belgrade (Serbia): IEEE, 2017. DOI: 10.1109/TELFOR.2017.8249382

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[E] VRBA, J. *Perspective Medical Diagnostics Methods Based on Microwave Measurement of Dielectric Properties of Biological Tissues*. Habilitation Thesis. Czech Technical University of Prague, 2016.

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