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Electromagnetic imaging methods in Lebesgue spaces for nondestructive testing and biomedical diagnostics

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Microwave imaging, although being the subject of research from decades, is still considered an emerging field. One of the key points of microwave imaging techniques is the solution of an inverse problem, which is ill-posed and nonlinear in its general form. A large variety of solution strategies has been proposed by the scientific community, both qualitative and quantitative. Despite the potential advantages of microwave imaging, only a limited subset of these techniques has been implemented in commercial systems, due to the difficulties in dealing with the problem complexity in real-world applications. On the one hand, this can be seen as a potential limitation; on the other hand, it strongly stimulates the scientific and engineering research in the field.

Taking into account the challenging problem of the quantitative characterization of the dielectric properties of unknown structures, an attractive class of deterministic inversion methods is represented by inexact-Newton approaches [1]. This kind of problem solution, which is based on an iterative Newton linearization, has been found to be very effective, and has been applied to several different contexts [2]. Furthermore, significant improvements in the retrieved solutions have been noticed by moving outside from the conventional Hilbert-space framework, and considering Lebesgue spaces L^p with different exponent parameters [3]. More recently, Lebesgue spaces with variable exponents have also been explored, to devise adaptive strategies that address the practical absence of a-priori information about the configuration under test [4].

In this contribution, an overview of quantitative inexact-Newton microwave imaging techniques in Lebesgue spaces is presented. A particular attention is paid to the recent inverse-scattering strategies in the mathematical framework of variable-exponent spaces. These methods will be evaluated in two possible applications. The first one is related to the nondestructive investigation of buried structures, whereas the second one is brain stroke detection. The description of the inverse-scattering algorithms is supported by several validation results, obtained in numerically simulated scenarios, as well as in the presence of real data acquired with specific microwave system prototypes.

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[2] F. Boero *et al.*, "Microwave tomography for the inspection of wood materials: imaging system and experimental results," *IEEE Trans. Microw. Theory Tech.*, vol. 66, no. 7, pp. 3497–3510, Jul. 2018.

[3] I. Bisio *et al.*, "Brain stroke microwave imaging by means of a Newton-conjugate-gradient method in L^p Banach spaces," *IEEE Trans. Microw. Theory Tech.*, vol. 66, no. 8, pp. 3668–3682, Aug. 2018.

[4] C. Estatico, A. Fedeli, M. Pastorino, and A. Randazzo, "Quantitative microwave imaging method in Lebesgue spaces with nonconstant exponents," *IEEE Trans. Antennas Propag.*, vol. 66, no. 12, pp. 7282–7294, Dec. 2018.