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Forward and Inverse Modeling for Through-the-Wall Imaging Applications

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Through-Wall (TW) radar is a technique with interesting applications in the surveillance, rescue, and detection of humans or objects, both in civilian and military fields, thanks to penetration of microwave fields through buildings materials [1]. Despite the significant advancements achieved in the scientific community, most of the approaches for the analysis of the measured data are still usually based on simplified propagation models (e.g., using far-field assumptions or ray propagation). Methods based on the exact characterization of the scattering phenomena are still limited, although in principle they would allow the development of more sophisticated imaging techniques, e.g., aimed at obtaining quantitative reconstruction of the inspected scenarios. Such algorithms have been mainly developed and validated for free space targets, and their extensions to a TW layout is still challenging. Indeed, it is necessary to suitably model in the inversion scheme the field propagation through the wall and the effects of multiple interactions of the scattered field with the wall. The same issues apply to the forward scattering problem, since electromagnetic solvers plays an important role in providing both a better physical insight of experimental data as well as a reliable benchmark for inversion algorithms.

In this framework, the aim of this paper is twofold. On one side, an accurate solver for the forward problem is provided. On the other one, a new imaging method, based on an inverse-scattering procedure applied to a scattering model fully incorporating through-wall propagation, is adopted. In the considered TW layout, a 2D investigation domain is illuminated by means of a multi-view multi-static illumination/measurement setup in which the antennas are modeled by line-current sources and ideal probing points. The tool used for the solution of the scattering problem is developed on an analytical basis through expansions into cylindrical waves, a technique known as Cylindrical Wave Approach [2]. In its implementation for a TW environment, all the multiple interactions between the field scattered by the target and the wall are modelled, and numerical solution is accurately performed. The synthetic data returned by this approach are employed to test an inversion scheme implementing the layered background of the TW problem. The inverse scattering method is based on a regularization procedure in variable-exponent Lebesgue-space [3-4] incorporating the exact Green's function for the through-wall scenario. Such approach has been found to provide solutions endowed with less oversmoothing than classical Hilbert-space methods, thus allowing a better shaping of the targets in the inspected scenario.

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