A THROUGH-THE-WALL IMAGING PROCEDURE BASED ON A LEBESGUE-SPACE INVERSION METHOD

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ABSTRACT
A novel through-the-wall imaging method is presented in this paper. The approach is based on a linearized scattering model, which is inverted by means of an efficient algorithm performing a regularization in the framework of Lebesgue spaces. Some preliminary numerical results are reported for assessing the capabilities of the approach.

INTRODUCTION AND OVERVIEW OF THE DEVELOPED APPROACH
In the last years, microwave imaging has acquired an ever growing importance in several fields, such as nondestructive testing and biomedical diagnostics (Pastorino and Randazzo 2018). In this framework, an important applicative scenario is represented by through-the-wall imaging (TWI), in which the aim is to retrieve information (e.g., position, size, dielectric properties) about targets hidden behind dielectric structures such as walls (Amin 2011). Indeed, microwaves represent a good candidate for such an application, since they are able to penetrate inside building materials (e.g., concrete, cinderblocks, and so on). However, the relationship between the wanted information and the quantities that can be measured (i.e., the electric field) is in general severely ill-posed, requiring the use of properly designed inversion algorithms.
In particular, assuming a monostatic setup, the scattered electric field can be expressed by using a linear approximation of the full scattering equations as (Solimene et al. 2009)

$$E_{scatt}(\mathbf{r}_{ant}) \cong \int_D I(\mathbf{r}')g_{ml}(\mathbf{r}',\mathbf{r}_{ant})g_{ml}(\mathbf{r}_{ant},\mathbf{r}')d\mathbf{r}',\ \mathbf{r}_{ant} \in M \quad (1)$$

where is the inspected region, is the position of the antenna in the probing line, and is the Green's function for the considered scenario. Starting from measurements of the scattered electric field, an image showing the support of the target can be obtained by inverting (1) in order to retrieve the function, which assumes high values on the target.
In this work, in order to address the ill-posedness of the problem, the inversion is performed by means of a novel procedure developed in the framework of the spaces (Estatico et al. 2012), which has been found to provide very good regularization capabilities in microwave imaging problems. The main difference with respect to standard inversion procedures commonly adopted in microwave imaging is related to the use of the more general norm to weight the residuals and errors instead of the common least square norm. Such a choice allows the introduction of an additional parameter (the norm of the adopted space), which can be tuned for increasing the reconstruction quality. For instance, low values of enhance the sparsity of the solution, thus allowing cleaner reconstructions of localized targets (Bisio et al. 2018).

RESULTS AND CONCLUSIONS
The developed procedure has been preliminarily tested by means of numerical simulations. A single circular metallic cylinder of radius 10 cm located at a distance of 1 m from a lossless wall of thickness 0.2 m and relative dielectric permittivity, 4 has been considered. Monostatic measurements, with the antenna scanning a probing line of length 1 m located 1 m away from the wall, have been simulated by using a finite-difference time-domain solver. A ricker

pulse with center frequency of 2 GHz has been used to feed the antenna. In order to apply the inversion procedure, 41 frequency samples between 1 and 3 GHz has been extracted from the simulated signal by means of the fast Fourier transform. The inversion procedure has been executed with the following parameters: Maximum number of iterations, 100; threshold on the relative variation of the residual, 0.01. The result obtained assuming 1.3 is shown in Figure 1. As can be seen, the reconstructed image allows to correctly identify the location and position of the target, although the size of the target is slightly underestimated. Moreover, the image is characterized by a very clean background and no artefacts are present. Further numerical and experimental results will be shown in the presentation for assessing the capabilities of the approach with different targets and in more realistic operating conditions.

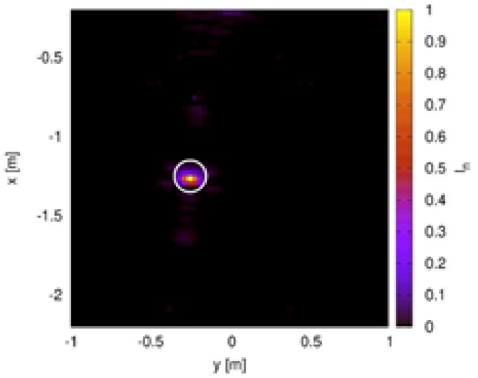

Fig.1 Reconstructed scenario with 1.3. Single PEC cylinder behind a dielectric wall.

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