On the Reconstruction Capabilities of Microwave Tomography Imaging

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Ground Penetrating Radar (GPR) systems are non-invasive diagnostic tools able to provide high resolution images of the inner structure of the probed spatial region. Owing to this capability, GPR systems are nowadays more and more considered in a large number of applications as geology, archaeology, civil engineering, demining, and so on. In particular, beyond the most common down-looking systems, airborne and forward-looking GPR are gaining attention as subsurface imaging tools able to survey wide, possibly non accessible, areas and/or to assure a standoff distance between the operator and the targets.

Whatever is the adopted measurement configuration, a key issue for the improvement of the GPR impact in operative conditions is the availability of advanced data processing approaches. These approaches have to be capable of providing well focused images, whose interpretation should be easy and free from the operators' expertise.

Among the other state of art GPR data processing procedures, Microwave Tomography approaches based on the Born Approximation face the imaging as a linear inverse scattering problem, which is solved by using the truncated Singular Value Decomposition (SVD) as a regularized inversion scheme [1]. In particular, these approaches require to solve, in the frequency domain, a linear integral equation which relates the scattered field (i.e. the data) to the unknown electric contrast function. The contrast function accounts for the target as an anomaly in terms of electromagnetic properties with respect to the ones of the background medium. The incident field and Green's function are the key ingredients of the linear integral equation and define the linear scattering operator to be inverted.

In this communication, Microwave Tomography formulation is considered as a unified logical frame to tackle different scenarios and measurement configurations. Moreover, we review some recent theoretical studies aimed at assessing the achievable reconstruction capabilities when down looking, forward looking and airborne GPR systems are considered [2,3,4]. These studies are performed by taking into account the spectral content of the object space and the regularized Point Spread Function (PSF), whose expressions are given in terms of the SVD of the scattering operator. Therefore, the SVD is adopted as a powerful tool to analyze the spatial filtering properties of the involved scattering operator and to investigate how the retrievable spatial variations of the unknown electric contrast depend on the measurement configuration. In addition, theoretical bounds for the range and cross-range resolution limits are recalled as well as guidelines to select the extension of the measurement lines according to the spatial size and position of the investigated domain, once the working frequency range has been set.

[1] F. Soldovieri, J. Hugenschmidt, R. Persico and G. Leone, "A linear inverse scattering algorithm for realistic GPR applications, *Near Surf. Geophys*., vol. 5, pp.29–42, 2007.

[2] R. Persico, "Introduction to ground penetrating radar: inverse scattering and data processing, IEEE Press Series on Electromagnetic Wave Theory". New York: Wiley, 2013.

[3] I. Catapano, F. Soldovieri, M.A. González-Huici, "Performance assessment of a microwave tomographic approach for the Forward Looking Radar configuration", Sensing & Imaging: An International Journal, Apr. 2014.

[4] I. Catapano, L. Crocco, Y. Krellmann, G. Triltzsch, F. Soldovieri, Tomographic airborne ground penetrating radar imaging: Achievable spatial resolution and on-field assessment, ISPRS Journal of Photogrammetry and Remote Sensing, vol.92, pp. 69–78, 2014.