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From Multiresolution to the System-by-Design based GPR Imaging

Francesco Zardi[1], Lorenzo Poli[1], and Andrea Massa[1,2,3]
[1]ELEDIA Research Center (ELEDIA@UniTN - University of Trento), DICAM - Department of Civil, Environmental, and Mechanical Engineering, 38123 Trento - Italy
[2]ELEDIA Research Center (ELEDIA@UESTC - UESTC), School of Electronic Engineering, Chengdu 611731 - China
[3]ELEDIA Research Center (ELEDIA@TSINGHUA - Tsinghua University), 100084 Haidian, Beijing - China

Ground Penetrating Radar (*GPR*) is a technology of high interest due to its many applications [1], requiring to process the collected data to retrieve the shape and/or electromagnetic (*EM*) characteristics of the imaged objects. Such a task can be formulated as an Inverse Scattering Problem (*ISP*), whose solution poses paramount challenges due to the ill-posedness and non-linearity [1]. Therefore, "smart" solution approaches must be developed capable of fully exploiting the available/acquired information to achieve satisfying reconstructions with limited computational resources. In this framework, the development of innovative *GPR* imaging methodologies is an active research area of the ELEDIA Research Center at the University of Trento, Italy. *GPR* microwave imaging strategies based on the Multiresolution (*MR*) paradigm demonstrated significant improvements in terms of reconstruction accuracy and inversion time [2]-[5]. The strength of the *MR* framework stems from balancing the number of unknowns with the amount of available data, reducing the non-linearity of the *ISP*. Moreover, it allows a straightforward exploitation of the "progressively-acquired" information on the imaged domain, resulting in a mitigation of the ill-posedness. Effective *MR* strategies have been recently proposed based on the exploitation of stochastic optimization algorithms [4] to mitigate the risk of false solutions. Recently, an *MR*-based solution strategy has been proposed that exploits an Inexact Newton method developed in L^p spaces to achieve better regularization of the subsurface *ISP* thanks to the joint processing of multiple spectral components of *GPR* data [5]. Another solution paradigm significantly improving the performance of *GPR* data inversion is the System-by-Design (*SbD*) [6][7]. The *SbD*, defined as "*a framework to deal with complexity*" in *EM* problems [6] leverages on the recent advancements in the area of Learning-by-Examples techniques and it allows a proper reformulation of the *ISP* enabling the "smart" reduction of its unknowns and the definition of a fast surrogate model to markedly reduce the computational burden of multi-agent evolutionary-inspired optimization tools [6][7].

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