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Challenges and Strategies for Quantitive Ground Penetrating Radar Diagnostics of Cultural Heritage

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High resolution non-invasive surveys based on Ground Penetrating Radar are exploited in many different applications, including cultural heritage diagnostics. In this framework, the interaction of the probing wave with an inaccessible region is useful for instance to provide information on the inner status of a structure, so to call for maintenance, or to characterize an underground scenario, so to address the following excavations.

While the large part of GPR surveys is still based on "traditional" radar-like techniques, which require a significant interpretation stage by an expert user, microwave tomography (MT) strategies based on inverse scattering have been recently gaining an increasing attention. As a matter of fact, these techniques are capable of achieving images which are stable with respect to measurement noise and uncertainties on the scenario, therefore being minimally dependent on the end-user's interpretation.

So far, MT strategies adopted in GPR surveys are based on an approximated formulation which neglects the underlying non-linearity of the inverse problem. Such a circumstance, that greatly simplifies their practical application, limits the achievable performances, as it prevents one from achieving a quantitative assessment of the scenario under test in terms of location, shape and electormagnetic parameters of the embedded "anomalies". Obviously, the potential advantage resulting from such a completely objective assessment is apparent, since an imaging method able to deliver quantitative information entails a dramatic reduction of costs and a definite improvement in the effectiveness of maintenance operations. Therefore, a stimulating challenge is to proceed towards the development of imaging strategies that rely on *full-wave* models and which are thus capable of providing these added-value results.

However, such an aim is not a trivial one pursue, since one has to tackle the inverse problem in its fully non-linearity and ill-posedness. Indeed, such a task needs the adoption of suitable regularization strategies and sophisticated inversion tools which account for multiple scattering effects, in order to ensure the reliability and accuracy of the reconstructions. Moreover, it requires to develop increasingly sophisticated electromagnetic models of the scenario under test and processing strategies able to take advantage of a priori information (when available) and "diversity" in data (multi-frequency/multi-static/multi-view acquisition), while being computationally effective.

Some of the recent advancements achieved in the last years at CNR-IREA will be discussed in this communication, showing their relevance to the realm of to cultural heritage diagnostics.