Book Review

A Maxwellian Look beyond Opaque Interfaces

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Preamble

I wonder if James Clerk Maxwell, Scottish mathematical physicist and father of the classical theory of electromagnetic radiation, could have imagined being included on the cover of a book dealing with a sensing technology used to locate the position of buried pipes, to analyze the integrity of buildings, and to uncover ancient archaeological sites

The idea is by Raffaele Persico, the author of "Introduction on Ground Penetrating Radar: Inverse Scattering and Data Processing" (Persico, 2014 [1]).

Aware of the fact that his work is not just for beginners, Raffaele Persico guides us to the fascinating, as well as complex, world of the physics of Ground Penetrating Radar (GPR) data processing, with the competence of the researcher, the teacher, the technologist and, let me just say, the sensibilities of a humanist.

I know the author and his passion for Dante and the Divine Comedy, which could have inspired him in the structure of the work and the communication method chosen for the contents. The reader feels the presence of the author (Virgilius) who guides them (Dante), tests his/her understanding, invites him/her to reflect on how to maximize the retrieved amount of information, and other typical 'obsessions' of remote sensing scientists.

Review

The books starts from the basic concepts of GPR (Chapter 1) and mathematical physics by facing the characterization problem of the host medium (Chapter 2) with particular reference to the issues linked to the measure of the propagation velocity from masonry to homogeneous soil, considering different targets (from point-like to circular ones), data configurations (interfacial and non-interfacial) and offsets. It is worth highlighting some interesting notations on the conductivity-loss influence on the wave velocity propagation in soil.

In Chapter 3, the author gets to the heart of the 'GPR-problem': the data sampling from frequency to time steps. Raffaele Persico deals with the problems of aliasing for both stepped frequency and pulsed GPR systems in a general framework, considering different investigation scenarios.

In Chapters 4 and 5, the author 'takes the bull by the horns' with the 2D-scattering equations, not only for dielectric but also for magnetic targets, and in the general framework of a possibly magnetic soil. The mathematical and theoretical basis of GPR transmission, including Maxwells's equations, are showed and discussed.

Finally, in Chapter 6 the Born series of inverse scattering problem are introduced by focusing on the associated mathematical uncertainties related to the ill-posedness and nonlinearity. I personally found the discussion about the influence (in terms of resolution) of the distance between two targets and the losses in the soil on the non-linear effects interesting.

Chapter 7 and 8 gets to the heart of data processing approach, which typically is employed to improve the raw GPR data. The research experience of Persico in such a field, from back ground removal to Born approximation, makes these chapters among the most exhaustive and it is full of starting ideas for further discussions.

Chapter 9 provides the theoretical basis and the application of Diffraction Tomography (DT) for both dielectric and magnetic targets. All the aspects and features characterizing the problem and the configuration, including the horizontal and vertical resolution, spatial, frequency and time step, the radiation characteristics of antennas, the DT relationships for Differential Configuration, and in the presence of Background Removal, are exhaustively described.

In the next chapter (10), two-dimensional migration in the frequency and time domain is described. The treatment is limited to the case of dielectric soils and targets and considering common offset data gathered at the air–soil interface.

The following three chapters face the 3D problem, beginning from the 3D scattering equations (Chapter 11, coauthored by L. Lo Monte and R. Solimene) and going on to 3D diffraction tomography and 3D migration algorithms (Chapters 12 and 13, respectively).

3D radar imaging is currently one of the most exciting fields of application of GPR. With regard to this, particular attention has been paid to the sampling parameters required for the 3D. The 3D problem has been analyzed and discussed in a comparative way with the 2D one as in the case of the migration algorithms in time and frequency domain.

Chapter 14 completes the theoretical part of the GPR treatment, dealing with the singular vale decomposition technique that allow the obtaining of tomographic inversion by means of linear models.

Finally, Chapter 15, written with the contributions of I. Catapano, M. Ciminale, G. Leucci, and L. Matera, provides a variety of exercises and applications of some concepts and approaches described in the previous chapters, such as the Measure of the Propagation Velocity for different configurations, host medium and offsets, the role of the sampling parameters, the effects of the height of the observation line, the extent of the investigation domain, and background removal.

In conclusion, the book invites us to reflect on the importance of the knowledge of the theoretical basis in order achieve the best of the GPR potential capabilities for different uses, from engineering to archeology. For the authors, the latter is the most important application in the field.

GPR applied to archaeology is one of the most complex and challenging fields of application due to the varied nature of the anomalies to identify: a mix of weak and strong targets, which impose the

adoption of different data processing choices and strategies for which a robust knowledge of Maxwell's equations is mandatory, but in the context of a holistic approach to the problem.

Reference

1. Persico, R. *Introduction on Ground Penetrating Radar: Inverse Scattering and Data Processing*; Wiley/IEEE Press: Piscataway, NJ, USA, 2014.