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Numerical GPR Imaging through Directional Antenna Systems in Complex Scenarios

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The capability of imaging hidden targets and interfaces in non-accessible and complex scenarios is a topic of increasing interest for several practical applications, such as civil engineering, geophysics, and planetary explorations [1]. In this frame, Ground Penetrating Radar (GPR) has been proven as an efficient and reliable technique, also thanks to the development of effective imaging procedures based on linear modeling of the scattering phenomenon, which is usually considered as activated by ideal sources [1],[2]. Actually, such modeling simplifications are rarely verified in typical operative scenarios, when a number of heterogeneous targets can interact each other and with the surrounding environment, producing undesired contributions such as clutter and ghosts targets. From a physical viewpoint, these phenomena are mainly due to multipath contributions at the receiving antenna system, and different solutions have been proposed to mitigate these effects on the final image reconstruction (see, e.g., [2] and references therein).

In this work we investigate on the possible improvements achievable when the directional features of the transmitting antenna system are taken into account in the imaging algorithm. Following and extending the recent investigations illustrated in [2] and [3], we consider in particular arrays of antennas, made by arbitrary types of elements, as activating the scattering phenomenon: hence, the effects of neglecting or accounting for the inherent directional radiation of the considered array are investigated as regards the accuracy of the final reconstruction of targets. Taking into account the resolution losses linked to the relevant synthetic aperture, we analyze the possibility of improving the quality of imaging, mitigating the presence of spurious contributions.

By implementing a ‘synthetic setup’ that analyzes the scenarios under test through different electromagnetic CAD tools (mainly CST Microwave Studio and gprMax), it has been possible to simulate numerically the spatial distribution of the incident and scattered fields for both ideal and realistic sources, gathered in a suitable grid of points in two-dimensional or three-dimensional regions of interest. In such environments, a number of reference tests have been performed, emphasizing the improvements achievable by the proposed advanced numerical procedure. Various reconstruction cases are presented and discussed in detail, considering examples of GPR systems placed on a ground interface to detect different buried scatterers in challenging operative conditions (e.g., target size comparable to the operative GPR wavelengths, antennas placed in near-field conditions, presence of ground roughness, etc.).

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[2] G. Gennarelli and F. Soldovieri, “Multipath ghosts in radar imaging: Physical insight and mitigation strategies,” IEEE J. Selec. Topics Appl. Earth Observ. Remote Sens., 8(3), pp. 1078-1086, 2015.

[3] D. Comite, A. Galli, I. Catapano, and F. Soldovieri, “The role of the antenna radiation pattern in the performance of a microwave tomographic approach for GPR imaging,” IEEE J. Selec. Topics Appl. Earth Observ. Remote Sens., doi 10.1109/JSTARS.2016.2636833, 11 pp., 2017.