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Information content in frequency-dependent, multi-offset GPR data for layered media reconstruction using full-wave inversion

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Water lost through leaks can represent high percentages of the total production in water supply systems and constitutes an important issue. Leak detection can be tackled with various techniques such as the ground-penetrating radar (GPR). Based on this technology, various procedures have been elaborated to characterize a leak and its evolution. In this study, we focus on a new full-wave radar modelling approach for near-field conditions, which takes into account the antenna effects as well as the interactions between the antenna(s) and the medium through frequency-dependent global transmission and reflection coefficients. This approach is applied to layered media for which 3-D Green's functions can be calculated. The model allows for a quantitative estimation of the properties of multilayered media by using full-wave inversion.

This method, however, proves to be limited to provide users with an on-demand assessment as it is generally computationally demanding and time consuming, depending on the medium configuration as well as the number of unknown parameters to retrieve. In that respect, we propose two leads in order to enhance the parameter retrieval step. The first one consists in analyzing the impact of the reduction of the number of frequencies on the information content. For both numerical and laboratory experiments, this operation has been achieved by investigating the response surface topography of objective functions arising from the comparison between measured and modelled data. The second one involves the numerical implementation of multistatic antenna configurations with constant and variable offsets in the model. These two kinds of analyses are then combined in numerical experiments to observe the conjugated effect of the number of frequencies and the offset configuration.

To perform the numerical analyses, synthetic Green's functions were simulated for different multilayered medium configurations. The results show that an antenna offset increase leads to an improvement in the response surface topography, which is more or less marked according to the initial information content. It also highlights the theoretical possibility of significantly reducing the number of frequencies without degrading the information content. This last statement is confirmed with the laboratory experiment which incorporates measurements done with a Vivaldi antenna above a medium composed of one or more sand layers characterized by different water contents. As a conclusion, the offset and frequency analyses highlight the great potential of the model for improving the soil parameter retrieval while reducing the computation time for a given antenna(s) – medium configuration.

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