FORWARD MODELING CONTRIBUTION IN THE GPR SIGNATURES INTERPRETATION OF URBAN HETEROGENEITIES.

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INTRODUCTION

BRGM and the french Projet National Microtunnel funded a research project where Ground Penetrating Radar (GPR) was used to characterize the test-site of the Laboratoire Central des Ponts et Chaussées (France). The objective of this project was to find a method to better interpret the radar signatures by combining data processing to forward modeling, especially in the case of urban heterogeneities. We focused a large part of our work to adapt a sufficient quick and accurate algorithm to be efficient in industrial applications. Modeling algorithm, adapted from radar waves propagation theory in 2D heterogeneous dispersive media, is based on the upward extrapolation of a downgoing field in the frequency-wavenumber domain. Like for other modeling techniques such as ray-tracing (Goodman, 1994; Cai and McMechan, 1995; Powers, 1995), FDTD (Moghaddams et al., 1991; Roberts, 1994) or pseudo-spectral methods (Carcione, 1996; Casper and Kung, 1996) some compromises have been introduced and must be kept in mind. In the following, we will first recall the modeling method, and after an example description from the LCPC test site, where real processed data are compared to synthetics, we will insist on the advantages and the weakness of the method.

MODELING METHOD

The modeling method is based on wavefield extrapolation in the frequency-wavenumber (f,k) domain, from the solution of the 2D Maxwell's equations (Bitri and Grandjean, submitted). The wavefield is extrapolated by a phase-shift (Gazdag, 1978; Claerbout, 1985) technique using constant relative permittivity K and quality factor Q ,

then it is modified by a correction term to handle lateral K and Q variations (Stoffa et. al, 1990). The radar wave dispersion and attenuation, induced by relaxation processes (Jonsher, 1977), are taken into account by a linear-frequency dependent Q model (Turner, 1994), and expressed by a complex wavenumber in the propagation equation (Bano, 1996).

DATA PROCESSING AND MODELING

The LCPC test site is composed by 4 different medium, representative of geotechnical material, where targets, such as pipes, voids, cables, are buried. A total of 14 GPR profiles were selected to cover the site; they were recorded with 300, 500 and 900 MHz antenna frequencies in order to obtain wide ranges of penetration and resolution. To complete the study, a borehole to surface GPR device was set up to estimate the different medium velocities from tomographic inversion.

After conventional data processing, a comparison between processed sections and synthetics can be made. Some typical radar signatures are presented on figure 2. This example shows the field data recorded at 900 MHz (Fig.1a), the dielectric model in term of K and Q distributions (Fig.1b), and the synthetic (Fig.1c.). Positive results are clear: all the targets, dipping reflector (P), big pipe (G), drains (d1-d2), small pipes (L1-L8) are well modeled on the synthetic. In the same way, the K and Q values, explaining the field data, are in good agreement with the nature of lithologies. Unfortunately, some weakness related to the fundamentals of the method remains: numerical artefacts as noise interference (X3) cannot be removed and multiples (X1, X2) cannot be modeled.

CONCLUSION

Modeling radar wave propagation in a 2D dispersive heterogeneous medium has been successfully implemented. The produced GPR synthetics can be compared to field data until to converge to a realistic geotechnical model, giving the spatial distribution of dielectric parameters. By referring to tables (Olhoeft, 1981), these values can be related to a geotechnical and geological material. Furthermore a good match between data and synthetic guarantees the ground structure has been well understood. Modeling GPR data becomes a necessary way to approach quantitative interpretation. Even if it is a weighty task for common studies, it remains crucial in some commercial projects where a precise diagnosis is requested. To make this method easy to use, we gathered the modeling and processing routines in the same computing platform from which a case histories database can be consulted during the processing or the modeling. The resulting software appears as a new GPR data interpretation tool where the three modules, processing, modeling and GPR images database, can be interactively used.

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Fig.1: data recorded at the LCPC test site (a), model of K and Q parameters (b) and resulting synthetic (c). geological materials are indicated. Targets are: G=big pipe filled by air; d1-d2: plastic drains filled by air; L1-L8: small pipes of metal filled by air, plastic filled by water and plastic filled by air. The K,Q values are indicated beside the targets.