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Data processing of ground-penetrating radar signals for the detection of discontinuities using polarization diversity

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In civil engineering, ground penetrating radar (GPR) is used to survey pavement thickness at traffic speed, detect and localize buried objects (pipes, cables, voids, cavities), zones of cracks and discontinuities in concrete or soils. In this work, a ground-coupled radar made of a pair of transmitting and receiving bowtie-slot antennas is moved linearly on the soil surface to detect the reflected waves induced by discontinuities in the subsurface. The GPR system operates in the frequency domain using a step-frequency continuous wave (SFCW) using a Vector Network Analyzer (VNA) in an ultra-wide band [0.3 ; 4] GHz. The detection of targets is usually focused on time imaging. Thus, the targets (limited in size) are usually shown by diffraction hyperbolas on a Bscan image that is an unfocused depiction of the scatterers. The contrast in permittivity and the ratio between the size of the object and the wavelength are important parameters in the detection process. Thus, we have made a first study on the use of polarization diversity to obtain additional information relative to the contrast between the soil and the target and the dielectric characteristics of a target. The two main polarizations configurations of the radar have been considered in the presence of objects having a pipe geometry: the TM (Transverse Magnetic) and TE (Transverse Electric.

To interpret the diffraction hyperbolas on a Bscan image, we have used pre-processing techniques are necessary to reduce the clutter signal which can overlap and obscure the target responses, particularly shallow objects. The clutter, which can be composed of the direct coupling between the antennas and the reflected wave from the soil surface, the scattering on the heterogeneities due to the granular nature of the subsurface material, and some additive noise, varies with soil dielectric characteristics and/or surface roughness and leads to uncertainty in the measurements (additive noise). Because of the statistical nature of the clutter, we have considered and quantified the performance of the Principal Component Analysis (PCA) and the Independent Component Analysis (ICA) in remove or minimizing the clutter using the receiver operating characteristics (ROC) graph. The study has been focused in the preferred polarization on simulated and experimental scenarios of soil structures with a few parameters such as the presence of a different target depths which are capable to perturb the first arrival times made of clutter components, and different dielectric characteristics (conductive or dielectric) of a given target (pipe).