An FDFD-based Simulation Concept for Stochastic Investigations on Improvised Explosive Devices in Colombia:

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The detection and neutralization of anti-personnel landmines and explosive devices is a major challenge in many countries worldwide, Colombia for instance. In contrast to conventional landmines, Improvised Explosive Devices (IEDs), the most frequently used mine-type in Colombia, are constructed and installed in varying manner. Furthermore, most IEDs contain only a small portion of metal parts, namely the detonator and battery pack, making it difficult to trace them reliably and to distinguish them from other buried objects.
Ground Penetrating Radar (GPR) is a recognized method for the detection of buried objects, which has been used with great success in many cases as an alternative to other methods, like metal-detectors for example.
Frequently used methods to counter the weak signal strength of mines are migration algorithms, also known as synthetic aperture radar (SAR) algorithms, compensating the range migration of the ground echoes and therefore focusing the image. An enhanced approach concerning object identification is the utilization of certain resonance behavior of the IEDs. This includes the resonances of metallic parts, like the detonator or the battery pack, as well as internal resonances caused by the reflected bouncing waves inside the dielectric bodies.
Nonetheless, the measurement data strongly depends not only on the configuration of the IEDs itself, but also on different parameters of the surrounding soil structure, like its moisture content, homogeneity and the surface roughness.

To analyze this diversity of influences on the results under realistic conditions, a fast and accurate simulator for stochastic investigations is needed.

Simulating a complex environment, including the antenna, ground environment and the IED itself, using an entire three-dimensional simulation, leads to long simulation times, making it impractical for this purpose. In this contribution we present a simulator based on a twodimensional finite-difference method in the frequency-domain (FDFD), which is capable to handle this parameter-diversity.

Even though not as popular as the finite-difference time-domain method (FDTD), the FDFD has considerable advantages for this application, since the lossy and dispersive behavior of the soil structure can be treated more easily in the frequency-domain. Furthermore, the resonances of certain components within the IED may cause long simulation times in timedomain implementations. At the same time the FDFD is a stable and rigorous numerical technique leading to accurate results, which is the reason why it is used with success for simulating photonic crystals and periodic structures, for instance.

Ground clutter is a major problem for the detection of shallow buried objects. In this context we present simulation results concerning the influence of the surface roughness on GPR measurements.

In order to improve the results in terms of signal-to-noise ratio and resolution, we applied a backprojection algorithm on the obtained dataset. This algorithm is based on the successive summation of the phase-corrected and interpolated data at each point in the pixelmap, allowing a pulse-by-pulse image generation. Because of these properties the algorithm is very promising in real-time signal processing of GPR measurements.