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HDTomoGPR: Ground Penetrating Radar System and Algorithms for Fine Root Analysis

Gerald Sabin,[1*] Jamar Robinson,[1] Michael Wicks,[2] Andrew Bogel,[2] and Nihad Alfalsaye,[2]

[1]RNET Technologies, 240 West Elmwood Drive, Dayton, OH 45459;
[2]University of Dayton, 300 College Park, Dayton, OH 45469

Contact: gsabin@RNET-Tech.com

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The HDTomoGPR is a mobile, field-deployable high-resolution subsurface 3D data collection platform for below ground imaging. The system can be used in any situation where an accurate underground visualization is required. Potential use cases include fine-grained root analysis, concrete analysis, archeology, and geological survey of construction sites. The primary benefits, as compared to other GPR systems, are improved resolution and improved 3D images for easy survey analysis. The 3D imaging benefits are derived from the increased data collection (via multiple antenna look angles collected from a stable data collection platform) that supports state-of-the-art GPR tomography to generate high-resolution images.

HDTomoGPR utilizes novel radar processing technology of data from an unconventional radar platform using COTS RF and compute technology. The HDTomoGPR radar system operates from 1GHz to 12 GHz and utilizes an Ultra-Wide Band (UWB) radar and data processing suite to balance resolution and penetration depth. The high frequency bands provide superior resolution at shallow depths of penetration, while the lower frequency bands allow greater subsurface penetration. The system uses a nonlinear stepped FM (frequency modulated) signal, and is designed to compensate for the frequency selective and site specific attenuation exhibited by soil and rock formations.

In order to increase the resolution and generate high quality 3D images, HDTomoGPR processes the phase measurement data tomographically (i.e., from a variety of viewing angles, e.g. geometric diversity). The data is then adaptively combined coherently to produce the high-resolution 3D image. A major advantage of this novel adaptive tomographic signal/image processing techniques is that the target is viewed from multiple look directions, which overcomes the effect of dominant scattering (strong reflections) from the front surfaces (leading edges) of the target and subsequent shadowing (weak reflections) of the back surfaces of targets. In addition, the resolution of the target image is enhanced as a result of multi-static tomographic signal processing. The computed images can achieve the Rayleigh resolution limit of $\lambda/3$.

In order to collect data over a variety of look angles (i.e., GPR antenna positions), the trailer includes a 1000mm by 1200mm scanning platform and houses a precision antenna placement system, RF equipment (1 to 12 GHz scan capabilities using a stepped FM waveform), and a compute platform. A prototype HDTomoGPR scanner has been developed, fabricated and deployed. Experimental results to date include indoor laboratory experiments and outdoor tests with a commercial agricultural partner.