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Instantaneous attribute profiling of GPR data using the HHT technique

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The analysis of instantaneous attributes (IAs) is a useful tool for interpreting ground penetrating radar (GPR) data. However, the conventional Hilbert transform used for deriving the IAs is controversial because it cannot provide the full IAs of the data. The conventional method only leads to an apparent spectrogram. A newer analysis method, the Hilbert-Huang transform (HHT), consisting of empirical mode decomposition (EMD) and the Hilbert transform is applied in this study for seeking a better resolution of IAs.

In this study, we decomposed the original GPR data into a series of intrinsic mode functions (IMFs) with ensemble empirical mode decomposition (EEMD), and then applied the Hilbert transform to generate the imaginary part of each IMF component. As a consequence, the IMF can be expressed in complex form after the Hilbert transform, and the IAs of each IMF component is obtained by simple trigonometry calculation and differentiation accordingly. With the aid of the EEMD technique, the Hilbert transform is well-behaved; therefore, it renders full IAs of each decomposed component as functions of time. We display the IAs of the GPR section in separate profiles to demonstrate the interpretation of their physical significance.

A controlled experimental study was performed on a site of known buried targets to acquire sample data for testing this new method and establishing the basic data processing sequence. We also conducted a pseudo-3D GPR survey with 50 MHz antennas along the channel bed of the Chingshui River in Ilan County, northeastern Taiwan to collect real data for further evaluation. To compare the HHT with the conventional Hilbert transform, we applied both techniques to the GPR stacked section. The IAs are displayed in amplitude, phase, and frequency profiles. The residue resulting from the EEMD is normally excluded to remove the bias. The signal can further be enhanced by removing noisy components before applying the Hilbert transform. For some cases, only the IMF component representing the most significant physical meaning is selected to approximate the faithful representation of IAs. The IA profiles derived from the real data demonstrate more details of the channel-bed deposits that are not resolved with other standard methods such as the conventional Hilbert transform.

The success of deriving IA profiles by using the HHT method is impressive, and gives us confidence for applying the new IA processing scheme to other engineering and geophysical data. The IAs of the HHT do not include spurious harmonics so that they generate more results with physical significance.