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High-resolution GPR imaging using a nonstandard 2D EEMD technique

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Ground Penetrating Radar (GPR) data are affected by a variety of factors. Linear and nonlinear data processing methods each have been widely applied to the GPR use in geophysical and engineering investigations. For complicated data such as the shallow earth image of urban area, a better result can be achieved by integrating both approaches. In this study, we introduce a nonstandard 2D EEMD approach, which integrates the natural logarithm transformed (NLT) ensemble empirical mode decomposition (EEMD) method with the linear filtering technique to process GPR images. The NLT converts the data into logarithmic values; therefore, it permits a wide dynamic range for the recorded GPR data to be presented. The EEMD dyadic filter bank decomposes the data into multiple components ready for image reconstruction. Consequently, the NLT EEMD method provides a new way of nonlinear energy compensating and noise filtering with results having minimal artifacts. However, horizontal noise in the GPR time-distance section may be enhanced after NLT process in some cases. To solve the dilemma, we process the data two dimensionally. At first, the vertical background noise of each GPR trace is removed by using a standard linear method, the background noise removal algorithm, or simply by performing the sliding background removal filter. After that, the NLT is applied to the data for examining the horizontal coherent energy. Next, we employ the EEMD filter bank horizontally at each time step to remove the horizontal coherent energy. After removing the vertical background noise and horizontal coherent energy, a vertical EEMD method is then applied to generate a filter bank of the GPR time-distance section for final image reconstruction.

Two buried models imitating common shallow earth targets are used to verify the effectiveness of the proposed scheme. One model is a brick cistern buried in a disturbed site of poor reflection quality. The other model is a buried two-stack metallic target that the signal reflected from the lower stack is often masked by the upper one. Compared with the results obtained by using standard processing methods, the proposed approach significantly improves the target resolution. A field example is also provided to demonstrate the competence of the proposed scheme.

Keywords: GPR; 2D EEMD; Logarithmic transform; Horizontal coherent energy