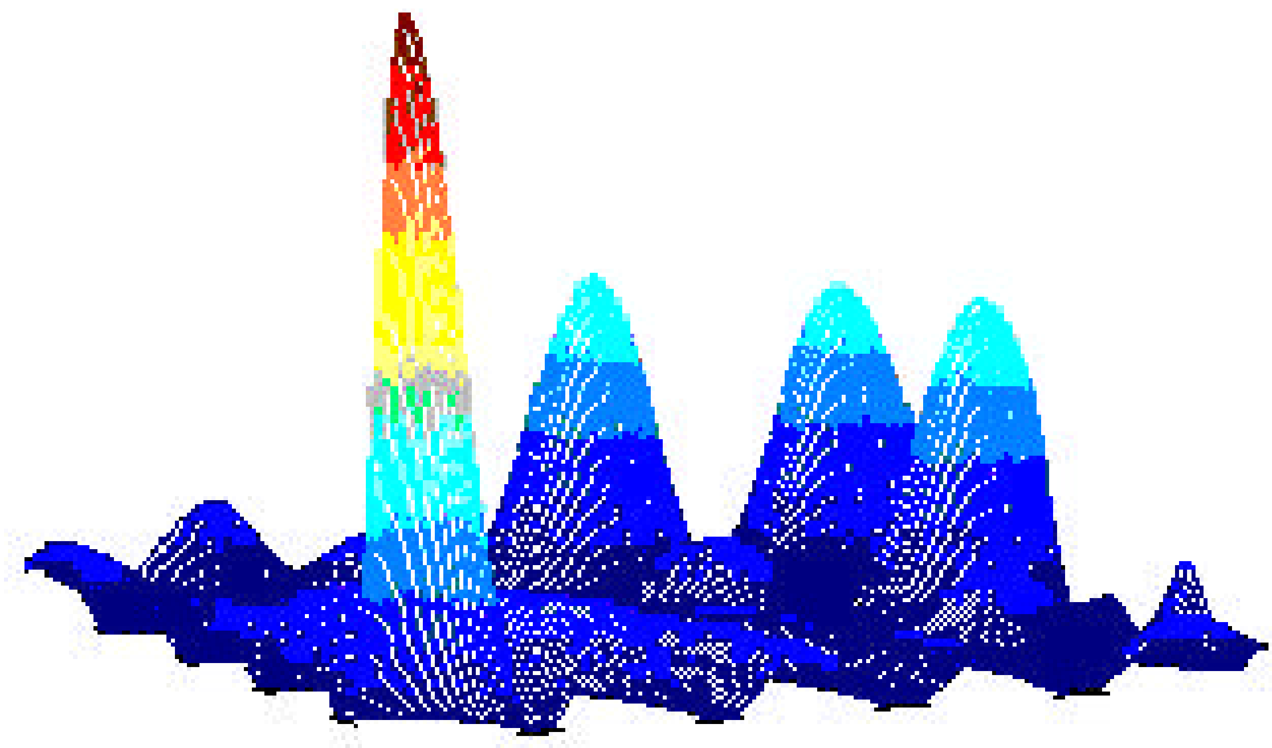
ADVANCED SIGNAL PROCESSING METHODS APPLIED TO ENGINEERING ANALYSIS OF SEISMIC SURFACE WAVES



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ADVANCED SIGNAL PROCESSING METHODS APPLIED TO ENGINEERING ANALYSIS OF SEISMIC SURFACE WAVES

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Dedicated to Sara

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Summary

Analysis of seismic surface waves offers nondestructive methods to determine the dynamic material properties of the near-surface earth. The primary engineering estimates of interest are the Rayleigh wave phase velocities and material attenuation coefficients as a function of frequency.

Traditional spectral analysis of seismic surface waves techniques rely on simplistic signal processing methods and suffer from several limitations. This research discusses the primary problems associated with seismic surface wave analysis, determines their impacts on engineering estimates, and introduces optimum phase velocity and material attenuation estimators.

Traditional phase velocity estimators suffer from several major limitations. The primary problem is a model incompatibility, i.e. estimating plane wave parameters from a cylindrically spreading wavefield. An additional limitation is an inability to handle multimodal wave propagation. Advanced signal and spatial array processing methods, including signal-noise subspace techniques, are introduced to yield optimum, multimodal phase velocity estimates. Cylindrical beamformers are developed to implement the correct physical model during wavenumber estimation, allowing estimates of phase velocities for much larger wavelengths than attainable with traditional methods. Synthetic linear arrays are derived, allowing the extraction of multimodal phase velocities from the efficient integration of several two-sensor measurements.

Traditional material attenuation estimators also suffer from several limitations, including an incorrect geometric energy spreading model, inability to handle multiple modes, and inability to optimally remove noise. A complete spectral representation for geometric spreading, as a function of temporal frequency and wavenumber, is introduced. The results show that geometric spreading is a function of the cylindrical wavenumber, and the correct Hankel function solution for the cylindrical wave equation leads to multiple mode attenuation coefficient estimates. Noise is optimally removed through use of the eigenvalue extremal property of the spatiospectral correlation matrix.