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Matched Field Processing of train vibrations for opportunistic surface wave tomography

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Railways are exposed to geotechnical hazards such as sinkholes or subsidence because they encounter many geological settings. Railway subsurface imaging is thus important in order to detect small anomalies in the elastic properties of the upper 50 meters of soils. Seismic interferometry applied on train induced signals is a promising technique, and previous works have shown clear Rayleigh waves and reflections in the retrieved Green's functions. However, extracting the dispersion curves of the reconstructed Rayleigh waves in a automated and robust way with high-resolution is challenging.

We study a continuously acquired dataset consisting of a dense array of five lines of accelerometers deployed parallel to 120 m of track. We use Matched Field Processing (MFP) to recover a high-resolution S-wave velocity model of the subsurface. The workflow begins by correlating signals in time windows when the train is outside the array, to ensure nearly planar wavefronts before the interferometry step. However, using only trains far from the array discards the measurements associated to the train crossing the array which have a very high signal-to-noise ratio but are difficult to model. We observe experimentally that train crossings the array generate correlations compatible with the isotropic and uncorrelated source distribution hypothesis used in passive seismology. Under this assumption, we correlate signals when the train is directly next to the sensors. Combined with correlations for the train in the far-field, this allows to track the Rayleigh dispersion curve in the very high frequencies (> 50 Hz). This broadband dispersion curve extraction, along with the balanced azimuthal coverage of our image due to the source diversity, is helpful for reliable imaging of shallow structures ranging from the bottom of the ballast to the bedrock. Since array methods are robust, and trains are repeatable sources, this paves the way for reliable monitoring of the subsurface with unprecedented temporal and spatial resolution.