Detection and analysis of anthropogenic patterns in a phase-stabilized optical fiber network

Dominik Husmann[1], Serge Zaugg[1], Jacques Morel[1]

[1] Photonic, Time and Frequency Laboratory, Swiss Federal Institute of Metrology METAS, Bern-Wabern, Switzerland

Email: dominik.husmann@metas.ch

Phase-stabilized fiber networks for state-of-the-art optical frequency dissemination promise versatile application as environmental sensors, being sensitive to seismic waves[1], temperature variations or anthropogenic acoustic noise. Specifically, the phase correction signal applied to stabilize the optical frequency carries the information of the fiber noise, integrated along the full extent of the fiber. Its spectral analysis allows to separate specific phenomena: Seismic events are typically in the sub-Hz range, temperature variations are on time scales of hours, and anthropogenic events are in the range of few Hz to tens of Hz. The latter are a principal source of fluctuations in the noise baseline of fiber networks in urban areas, and a better understanding of their origin can provide information for improved network designs.

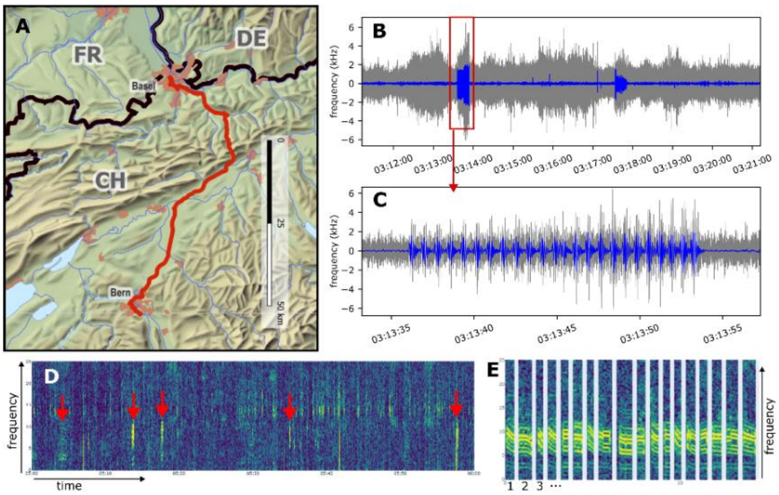

Fig. 1: A. Geographic overview of fiber link. B. Time trace of phase correction signal, with zoom (C) showing anthropogenic pattern. D. Time resolved Fourier transform of frequency correction data, measured over 1 hour. Singular events (red arrows) are visible as high intensity peaks at distinct frequency bands. E. Collection of spectra of detected events, exposing well-defined spectral components.

Here we analyze the phase correction signal on a 126 km long fiber connecting METAS in Bern to the University of Basel[2] (see Fig. 1A) in the frequency range attributed to anthropogenic effects. The fibers are installed underground and follow mainly roads and train tracks. In addition to broadband noise fluctuations following day-night cycles, we also observe sporadic signals that indicate to be originating from well-defined localized sources along the network (Fig. 1B-E). We attribute these to small set of points where the fiber couples strongly to a noise source, such as fibers crossing railway tracks. We apply unsupervised clustering to group these events and identify regularity in the schedule of similar events, that is indicative of railway activity.

Our work provides a descriptive analysis of the observed signals and identifies possible exploitations for application in terms of optimization of metrology networks. Further, the demonstrated sensitivity to singular events along the fiber could have applications in remote sensing, in places where distributed acoustic sensing is limited in distance.

[1] S. Noe et al., "Long-range fiber-optic earthquake sensing by active phase noise cancellation", Scientific Reports, vol. 13, p. 1-7, 2023

[2] D. Husmann et al., "SI-traceable frequency dissemination at 1572.06 nm in a stabilized fiber network with ring topology", Optics Express, vol. 29, p. 24592-24605, 2021.