SOP-based DSP Blind Anomaly Detection for Sensing on Deployed Metropolitan Fibers

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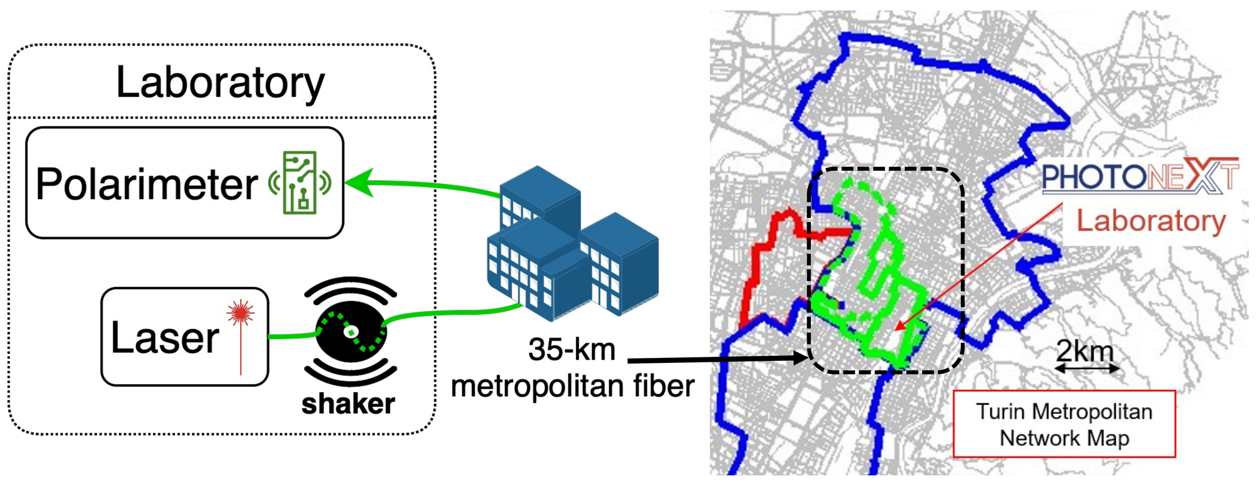
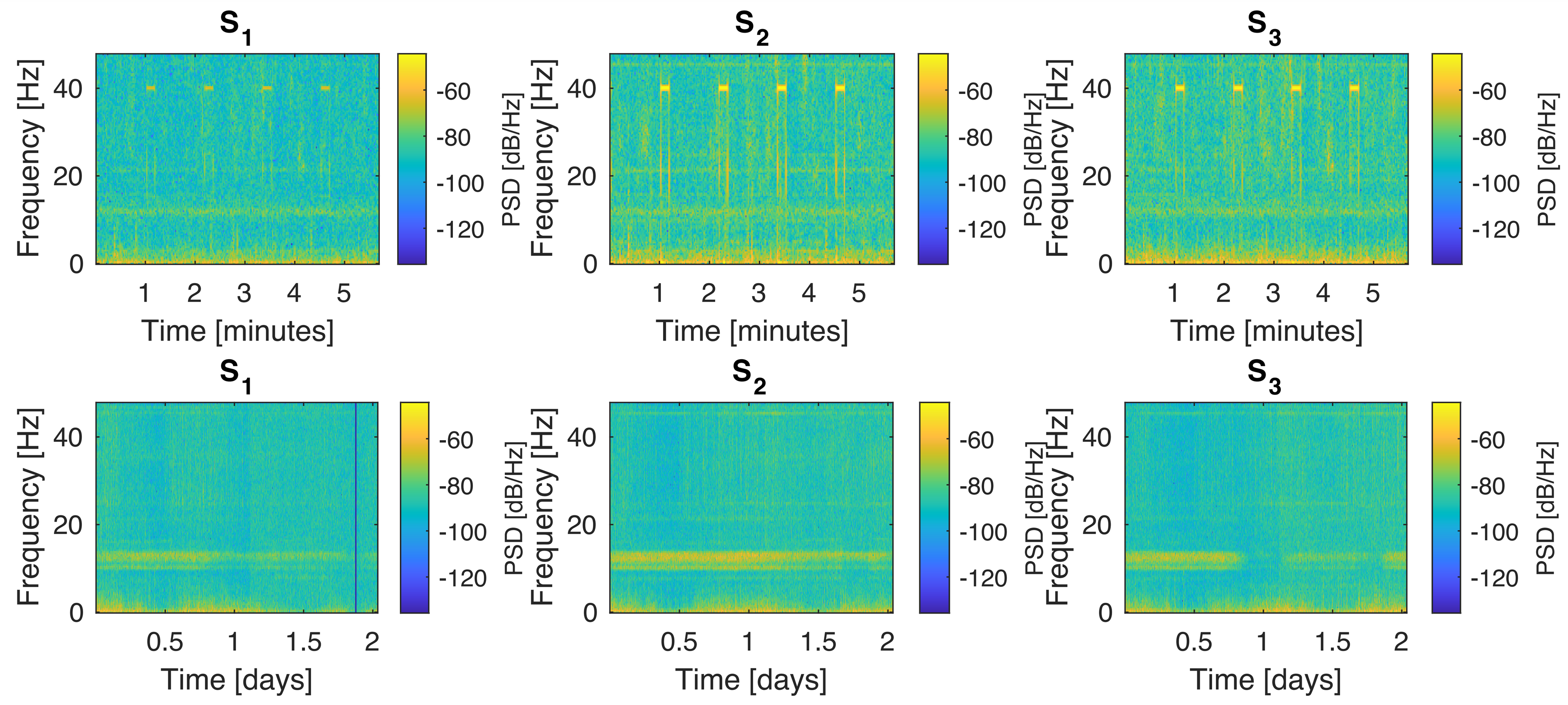
Monitoring fiber State-of-Polarization (SOP) to detect anomalies in metropolitan areas

- Construction and maintenance works can commonly lead to **fiber cuts or damages**, weighting on **reinstallation costs**.
- It is fundamental to perform a **"blind" detection** of hazardous fiber health conditions (in particular, anomalous vibrations along the deployed fibers).
- We can exploit a **State of Polarization (SOP)** based DSP detection algorithm (applicable in principle to both direct-detection and coherent systems).
- **SOP is insensitive to laser linewidth →** commercial TLC transceivers could be perfectly suitable.



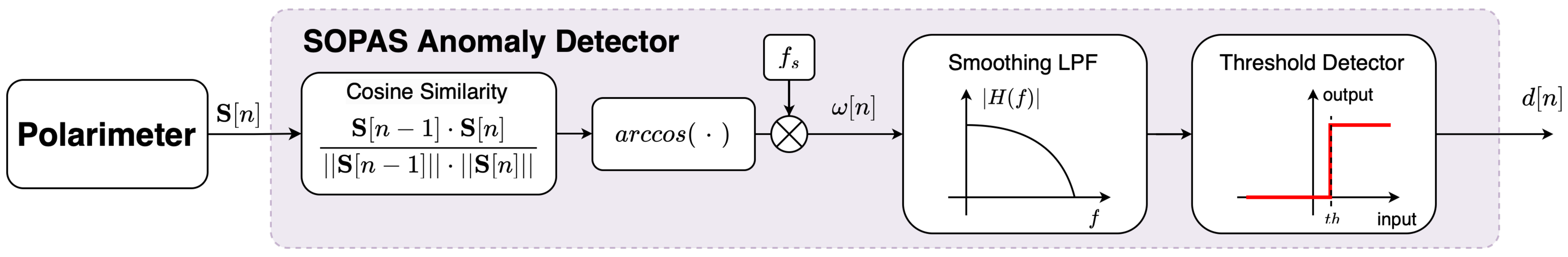


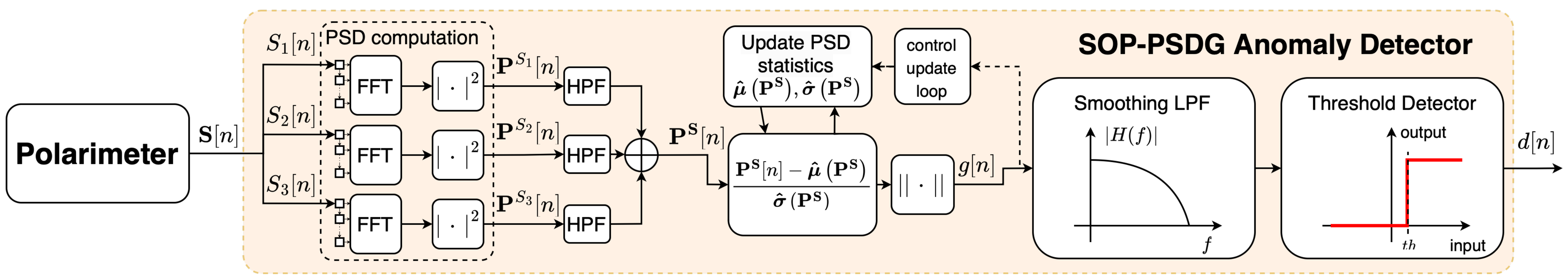
- We propose two DSP algorithms and experimentally validate them over a **35km-long metropolitan fiber deployed in Turin downtown area.**
- We emulate hazardous mechanical vibrations by means of a **mechanical shaker** applied on a few meters of the fibers.
- We found that Stokes parameters are **non-stationary** in this scenario, when observed over long acquisitions (several days).

The developed SOP-based Digital Signal Processing schemes

We propose and compare two different algorithms:

- The SOPAS DSP scheme detect anomalies by monitoring the **SOP Angular Speed** (SOPAS).
- SOPAS evaluates the change-rate between consecutive SOP samples over the Poincaré sphere.
- Anomalies are detected when the SOPAS exceeds a given threshold.

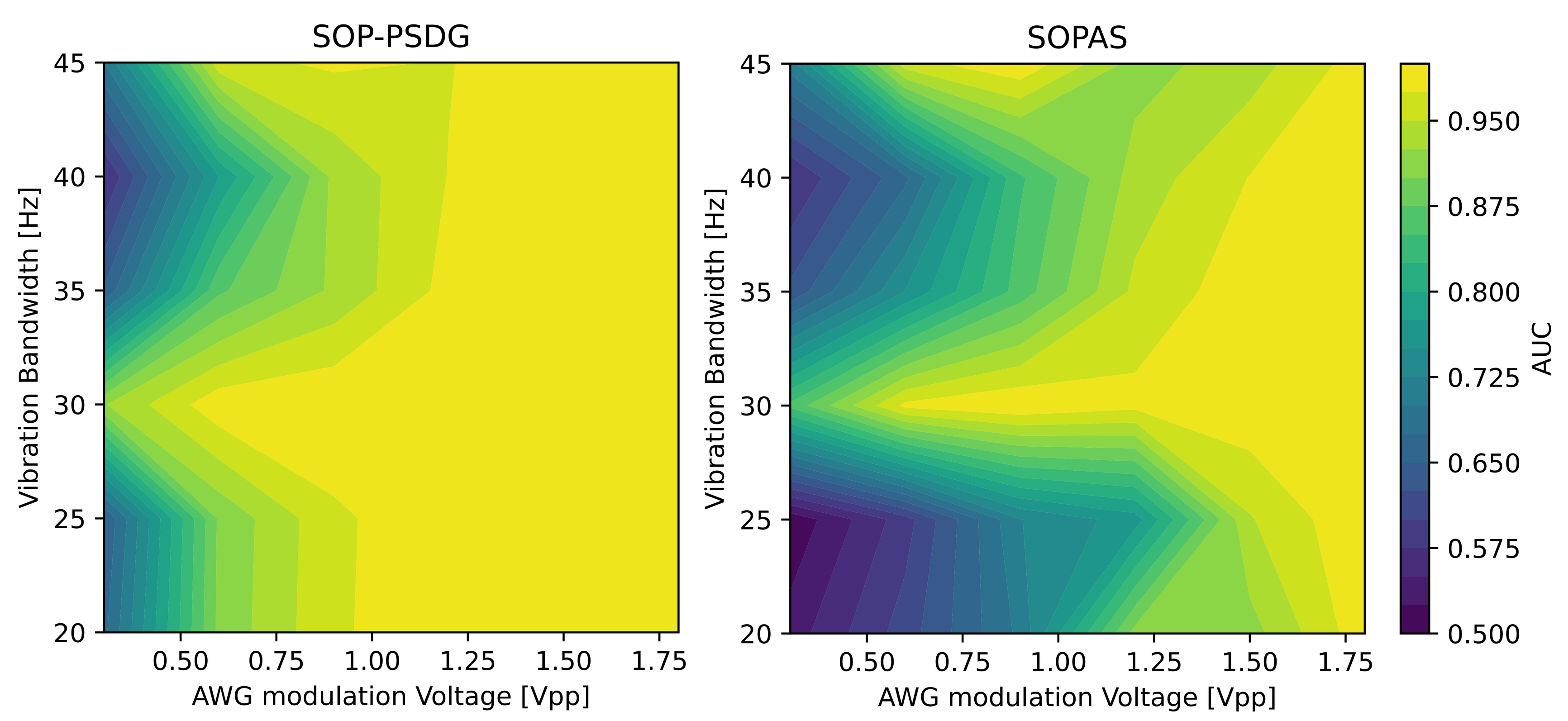




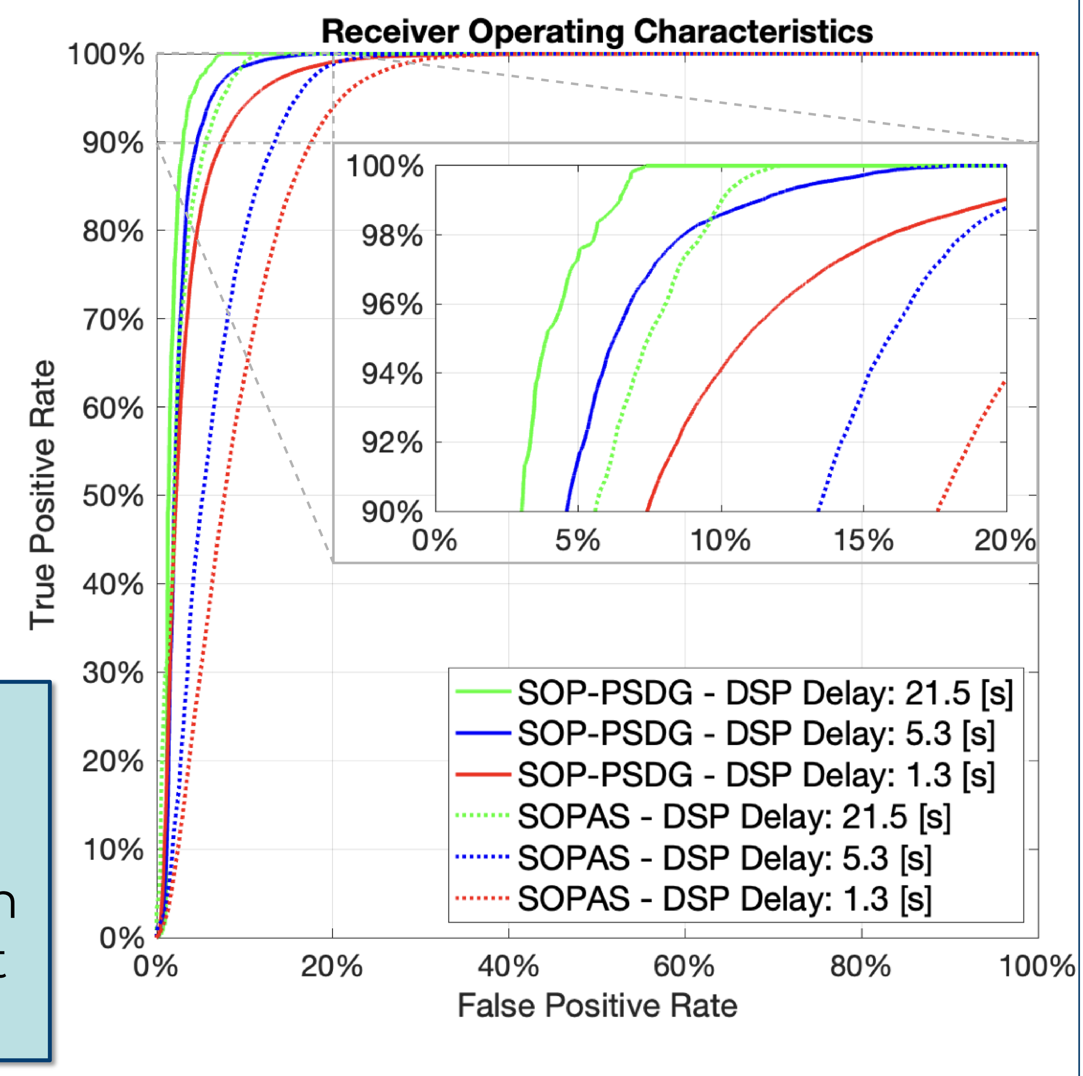
- The SOP-PSDG anomaly detector monitors how the **SOP Power Spectral Density** evolves in time.
- Anomalies are detected when the **Gap** between *current* and *average* PSD exceeds a given threshold.
- The average PSD statistics are *dynamically* updated over time.

Experimental Results on a 35-km deployed metropolitan fiber

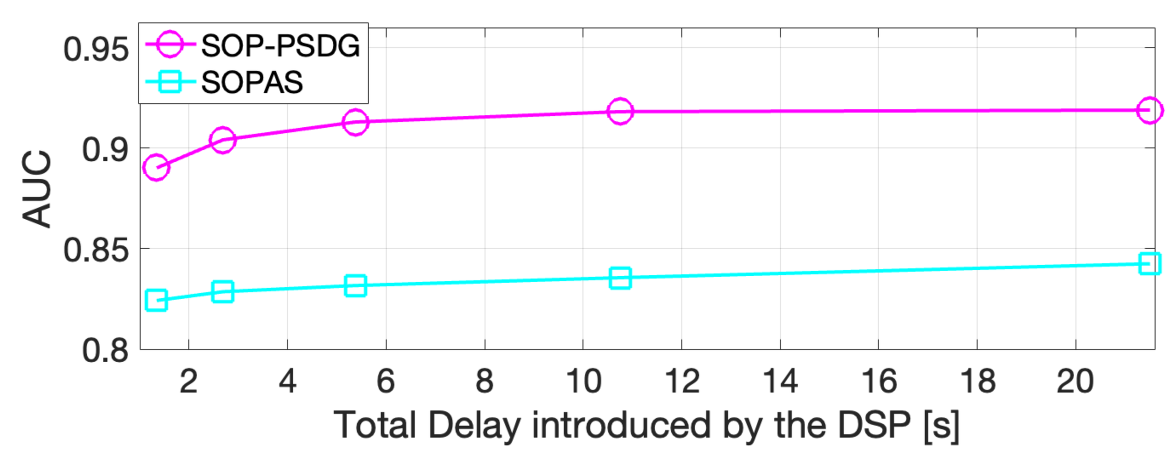
- During the experiments, several types of Gaussian vibrations are induced by the mechanical shaker along few meters of the 35 km of deployed metropolitan fiber.
  - We intentionally changed amplitude and frequency range of the mechanical vibration.
- The **Receiver Operating Characteristics (ROC)** performance is evaluated for both DSP anomaly detection schemes.
  - ROC curves track the *correct detection probability* (**True Positive Rate**) as function of the *false alarm probability* (**False Positive Rate**).



> ➢ Performance improves as the LPF smoothing window (and DSP Delay) increases.
> ➢ A trade-off between detection accuracy and DSP delay must be taken into account.



- The **Area Under the ROC Curve (AUC)** quantifies the overall detector performance
  - AUC = 0.5 → *Random detector*, AUC = 1.0 → *Perfect detector*



In general, *SOP-PSDG demonstrates to be a better anomaly detector than SOPAS.*