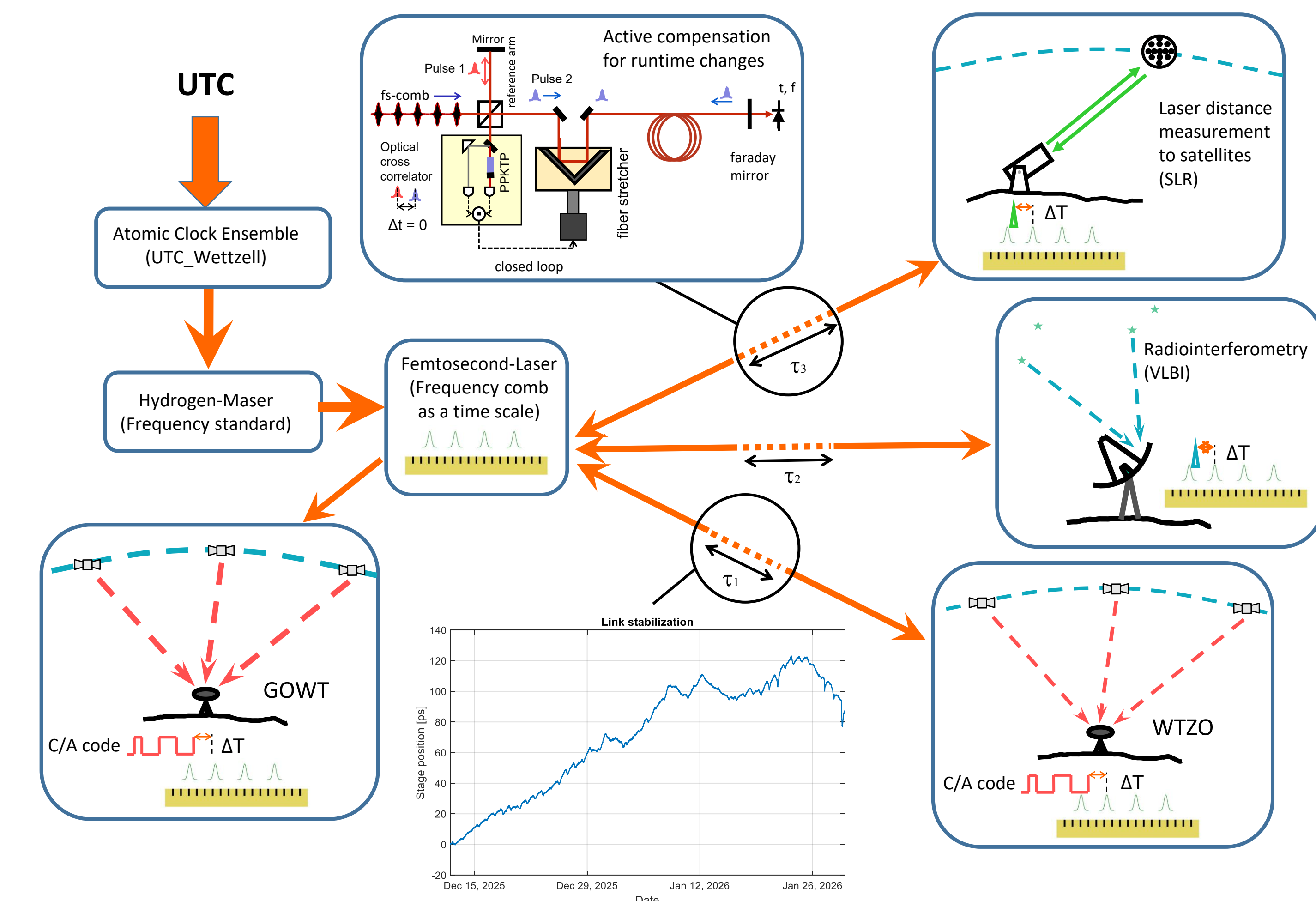


Introduction

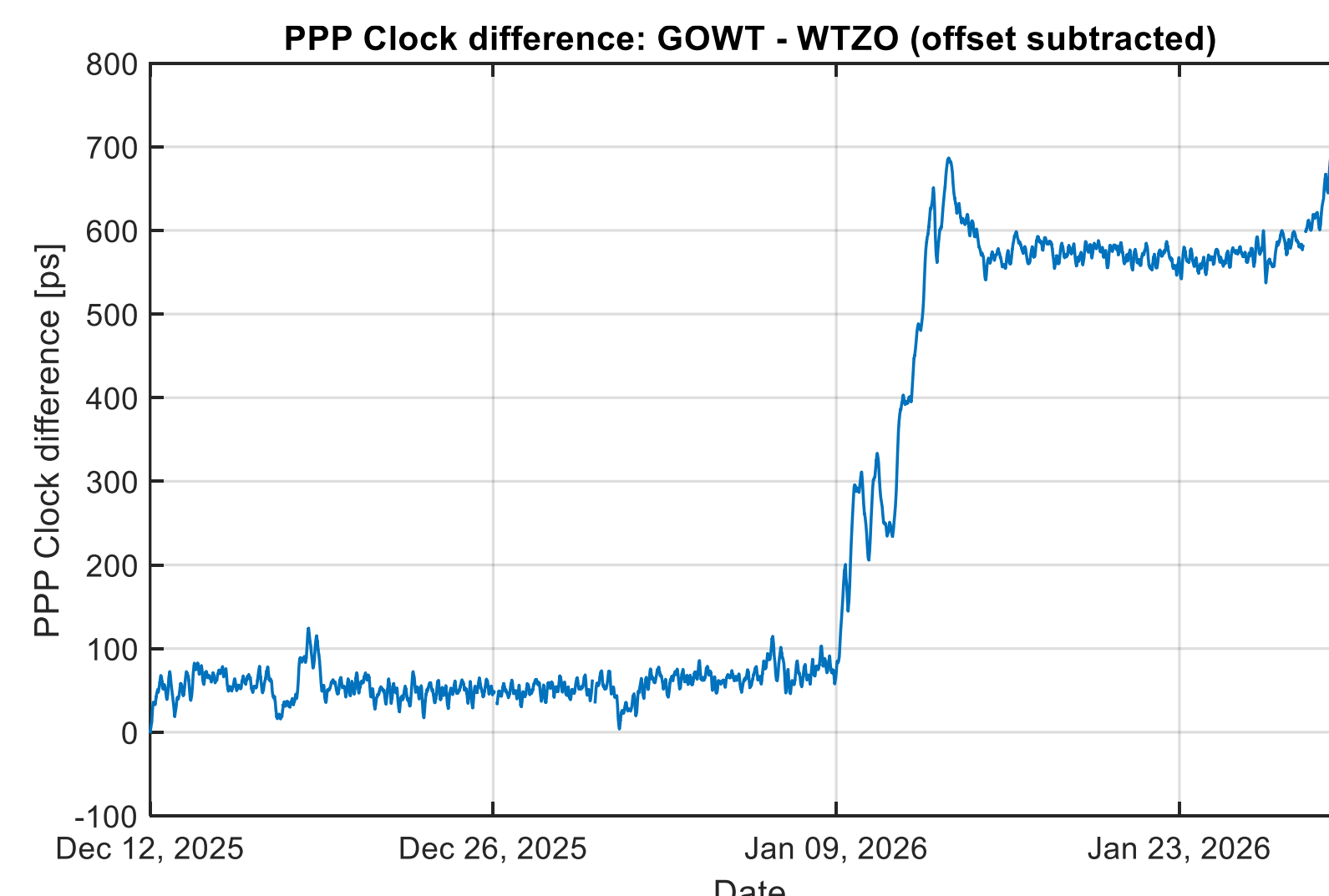
- The quality of ties between space geodetic techniques is one of the major limiting factors for the quality of the ITRS
- We tie SLR, VLBI and GNSS rigidly together, utilizing an actively stabilized delay compensation.
- We establish a station fiducial marker and add phase stability (**Clock Ties**) in order to **remove systematic errors**.
- To integrate this **local time coherence** to GNSS we transmit a **pseudolite signal** from this station fiducial target.
- We propose a **continuous GNSS calibration scheme**

Motivation

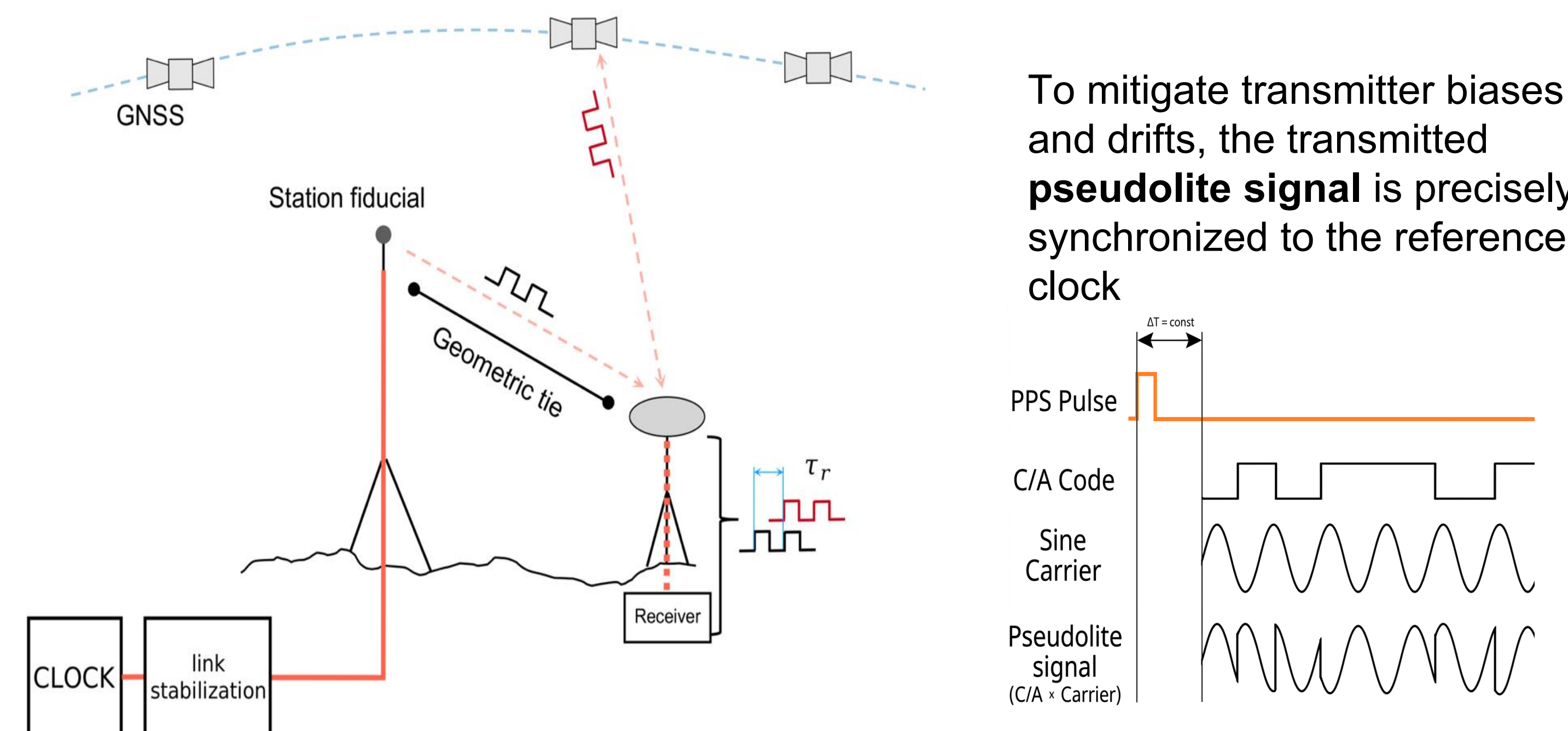
The GOW's novel **time and frequency distribution system** employs optical fs-pulses as a ruler based on time. It is distributed by a **two-way delay compensated optical fiber network**. It provides long-term time coherence for SLR and VLBI.



GNSS carrier-phase measurements do not directly represent the phase of the input clock signal, as they are affected by **variable delays inside the receiver**. These carrier-phase errors propagate into precise GNSS methods such as PPP and IPPP. Despite receiver clock synchronization at the 1 ps level, PPP solutions exhibits discrepancies on the order of 500 ps.

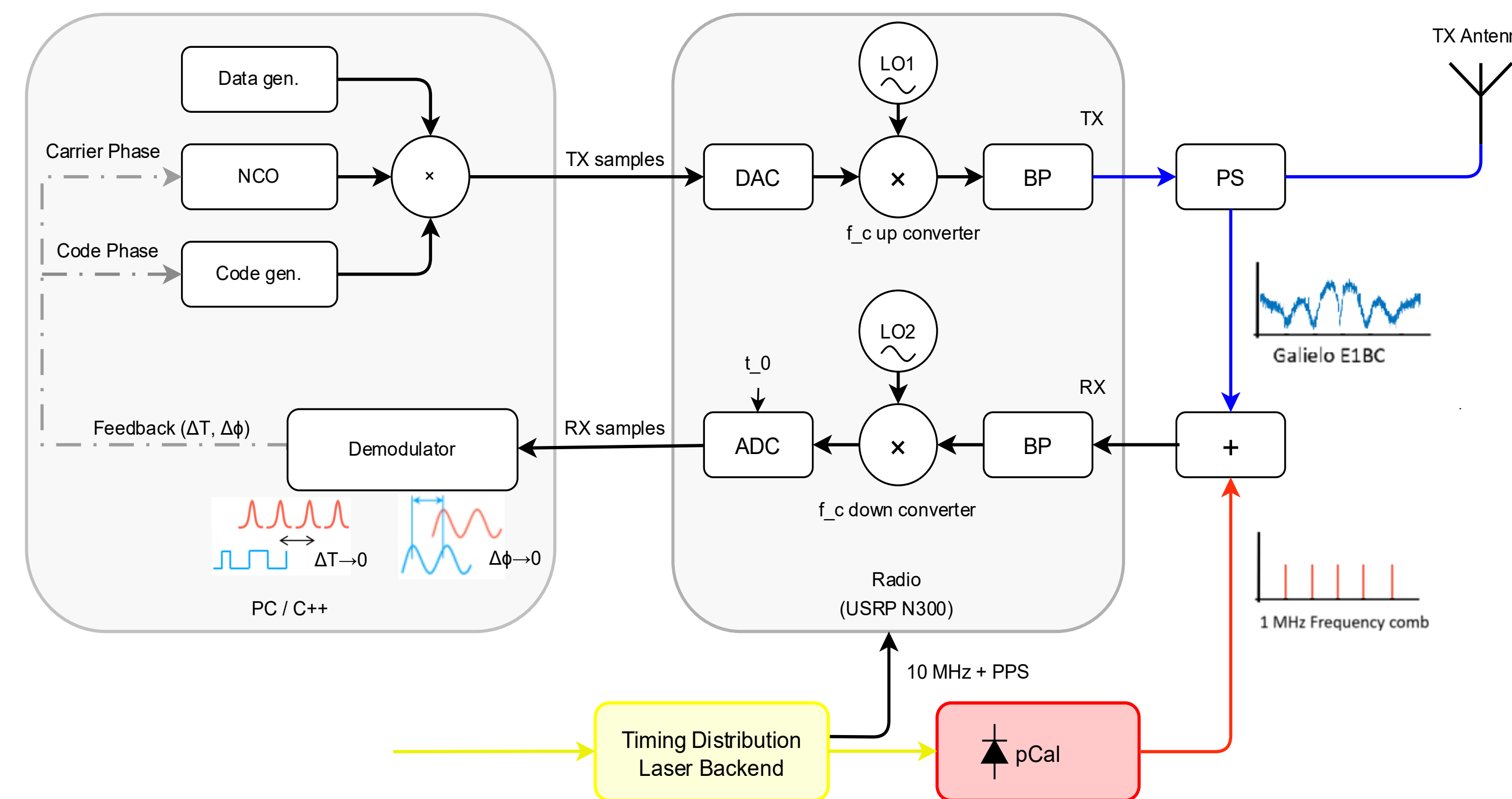


Concept



We develop a **permanent monitoring and correction tool** for the GNSS intra-technique biases based on a precisely **synchronized pseudolite signal**. This correction tool will eliminate receiver hardware-related and temperature-related biases with up to 1 mm precision.

Approach/Design

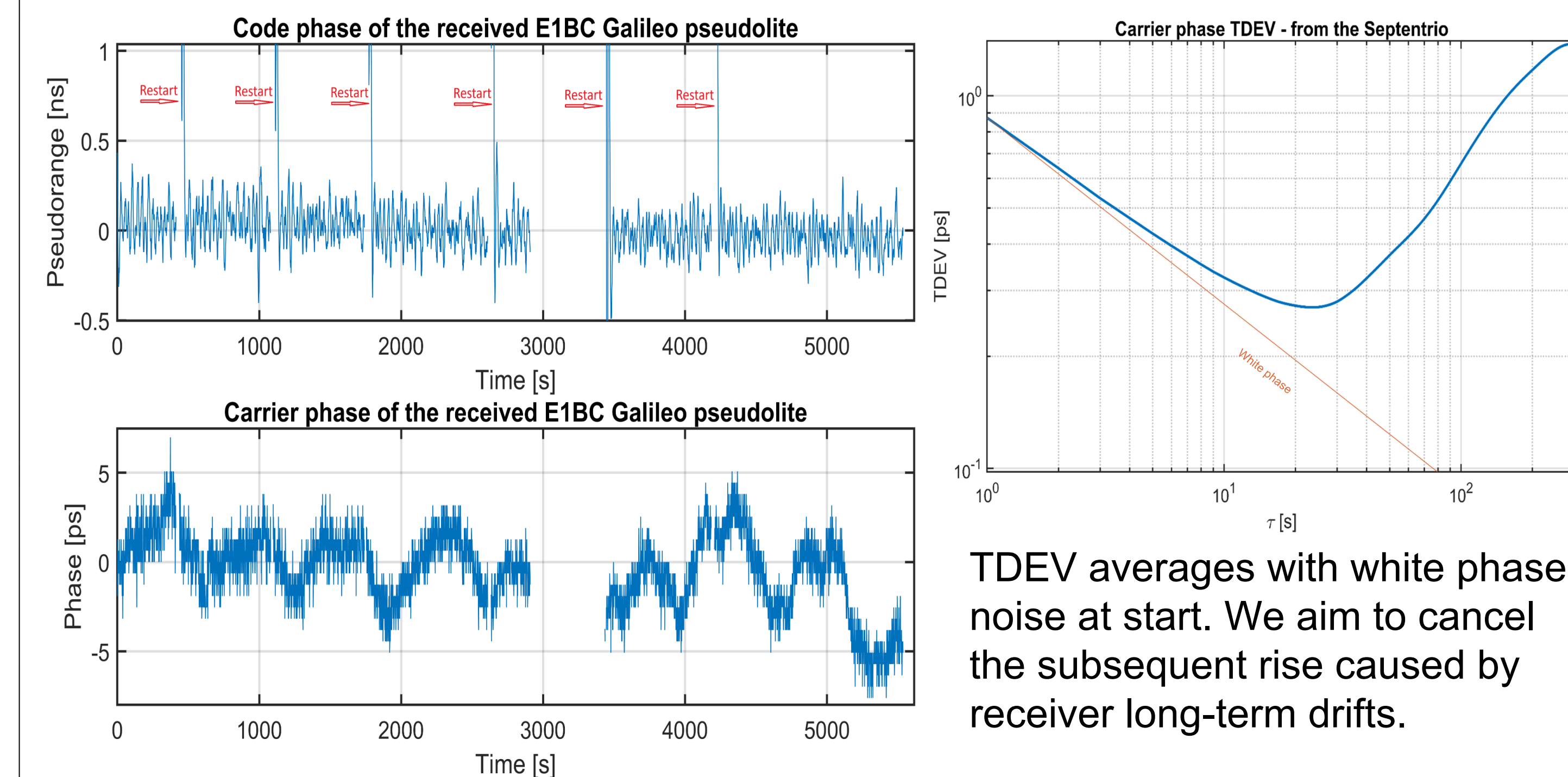


A feedback loop is formed by mixing the **transmitted signal** with a pCal **reference signal** derived from the clock, this signal appears as synchronization tones in the E1 band. **Both signals pass the same receiving RF chain**. The demodulator estimates the phase difference which is then used to adjust the transmitter, so that the transmitted (code and carrier) **phases remain aligned with the reference clock**.

The pseudolite transmits a valid blank Galileo I/NAV Spare word at unoccupied E1BC PRN E20, this signal can be received by conventional GNSS receivers together with other satellites.

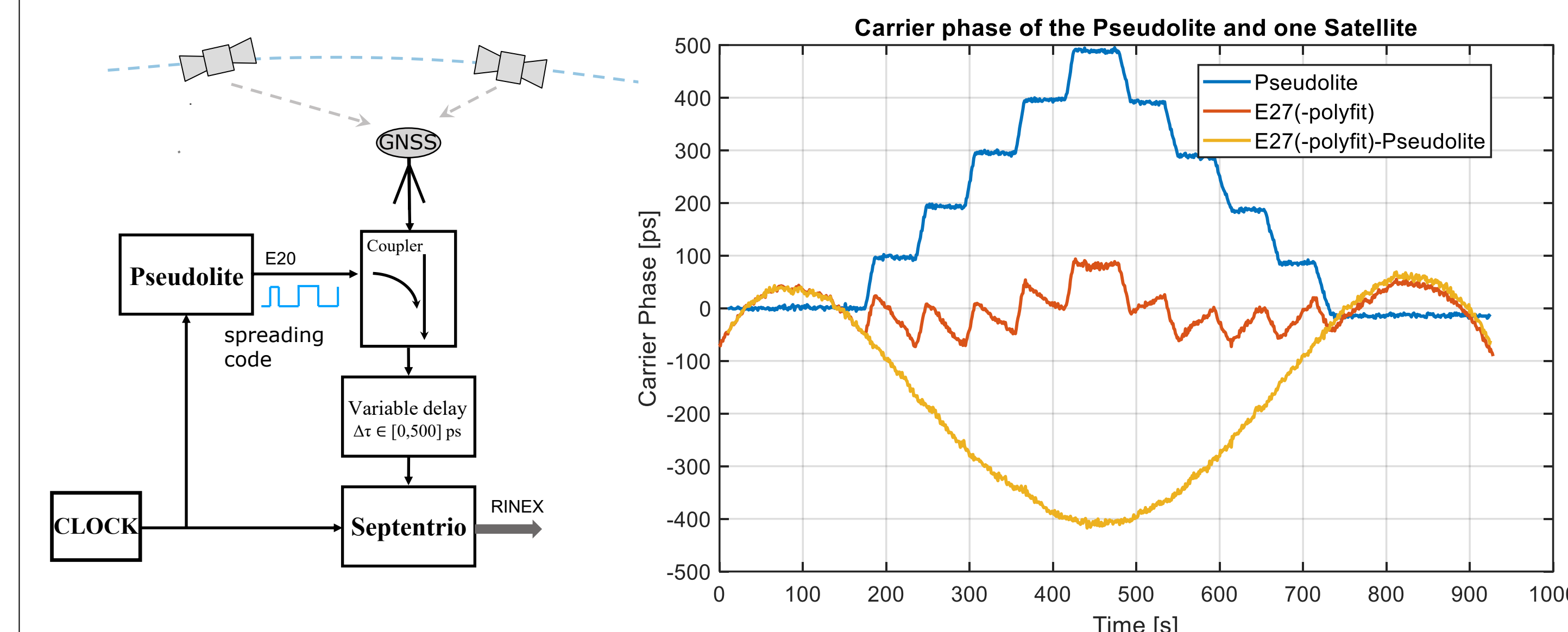
Experiments

Pseudolite signal recorded by a directly-connected Septentrio receiver and stored in the RINEX file. The plot shows a short time segment where the receiver clock drift is negligible, and both the transmitter and receiver are synchronized to the same reference clock. The pseudolite transmits identical phase after it resets or power cycle.



TDEV averages with white phase noise at start. We aim to cancel the subsequent rise caused by receiver long-term drifts.

As a **concept verification**, we incorporated a **tunable delay line** before the GNSS receiver. Adding the **pseudolite signal** coupled before the calibrated delay, we can subtract the delay of the delay line in the RINEX data. The receiver can then determine the additional delay in order of picoseconds. (A fourth-order polynomial fit was subtracted from the E1 satellite carrier phase data to remove the dominant orbit-induced trend, leaving the residual errors for visualization.)



Future work

- Expansion to both **L1 and L2** frequencies
- Pseudolite integration into a **portable solution**
- Concurrent measurements at **multiple observatories**
- GNSS-VLBI Common clock measurements



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