Experimental Analysis of Time Deviation on a Passive Localization System

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Clock statistics

A **clock** can be modeled as a device producing a **sine wave**:

$$V(t) = V_0 \sin\left(2\pi f_0 t + \boldsymbol{\phi(t)}\right)$$

Two parameters can be identified: ← **Phase fluctuation (noise)**

- **Time fluctuation**: $\boldsymbol{x(t)} = \phi(t)/2\pi f_0$
- **Frequency fluctuation**: $\boldsymbol{y(t)} = \frac{1}{2\pi f_0}\frac{d\phi(t)}{dt}$

$\phi(t)$ is **non-stationary**, these quantities cannot be analyzed through traditional statistics but the **Allan variance** $\sigma_y^2(\tau)$ can be used. It measures the variance of the difference of two values of y spaced by a time τ. Other versions of the Allan variance were developed, like the **modified Allan variance**, whose estimates converge more quickly and are capable to distinguish between more types of noise. Its expression in terms of time data is:

$$Mod\ \sigma_y^2(\tau) = \frac{1}{2m^2\tau^2(N-3m+1)} \times \sum_{j=1}^{N-3m+1}\left[\sum_{i=j}^{j+m-1}(x_{i+2m} - 2x_{i+m} + x_i)\right]^2$$

where **τ is the time horizon** on which the variance is calculated, x_k the k^{th} sample of a dataset containing N values of $x(t)$ sampled every T_s, and $m = \tau/T_s$ the number of samples of $x(t)$ contained in the time horizon τ (m must be an integer such as $m \geq 1$).

Time Variance is a metric characterizing efficiently time fluctuations of a clock. It is based on the modified Allan variance:

$$\sigma_x^2(\tau) = (\tau^2/3)\cdot Mod\ \sigma_y^2(\tau)$$

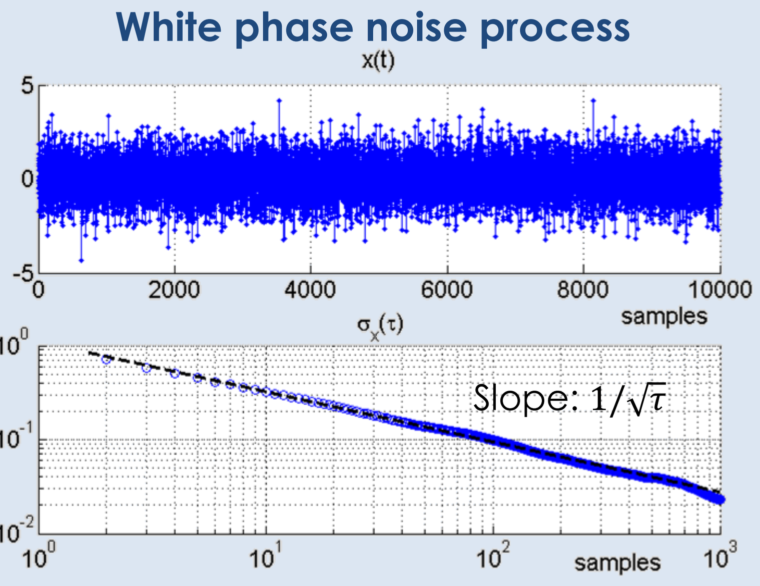
In practice x represents the fluctuation of a clock **relative** to another reference clock.

Interpretation

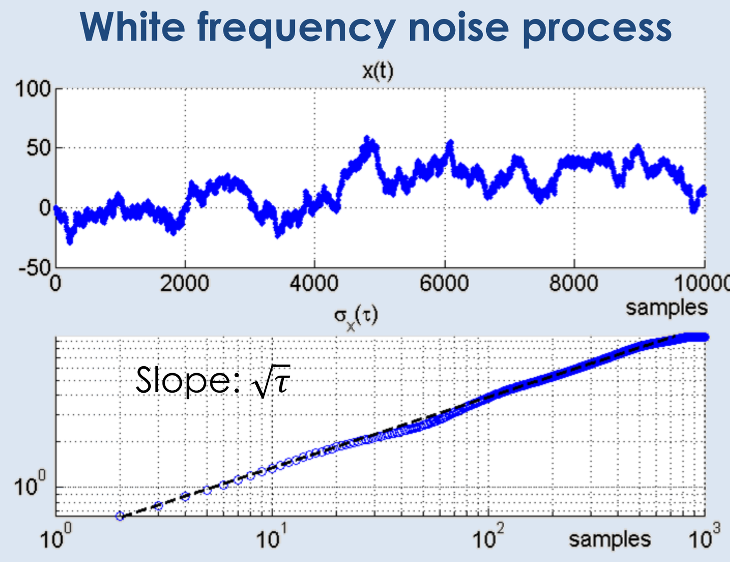
$\sigma_x(\tau)$: standard deviation of the time error between the clocks considering an averaging time of τ.

Computations of $\sigma_x(\tau)$ on simulated scenarios with different types of noise found in oscillators:

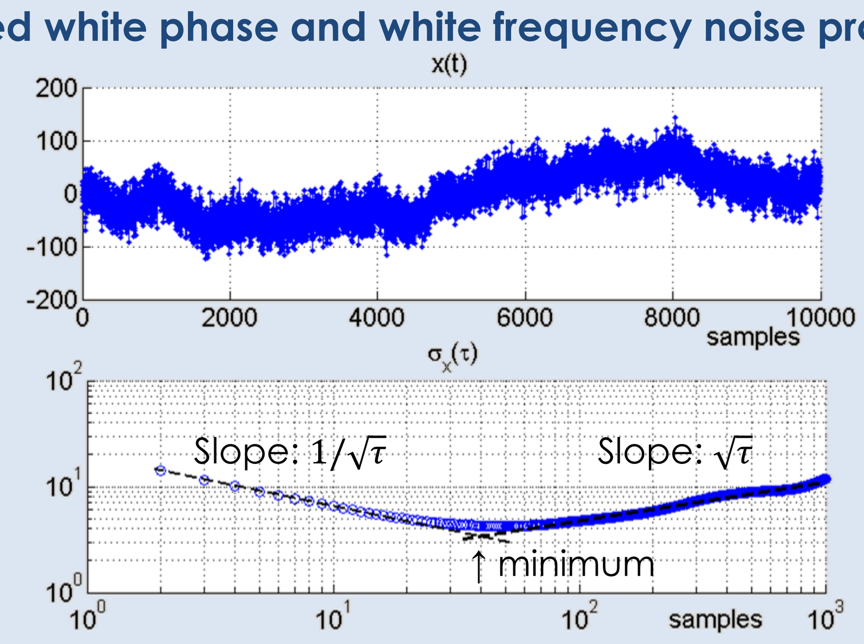
White phase noise process



White frequency noise process



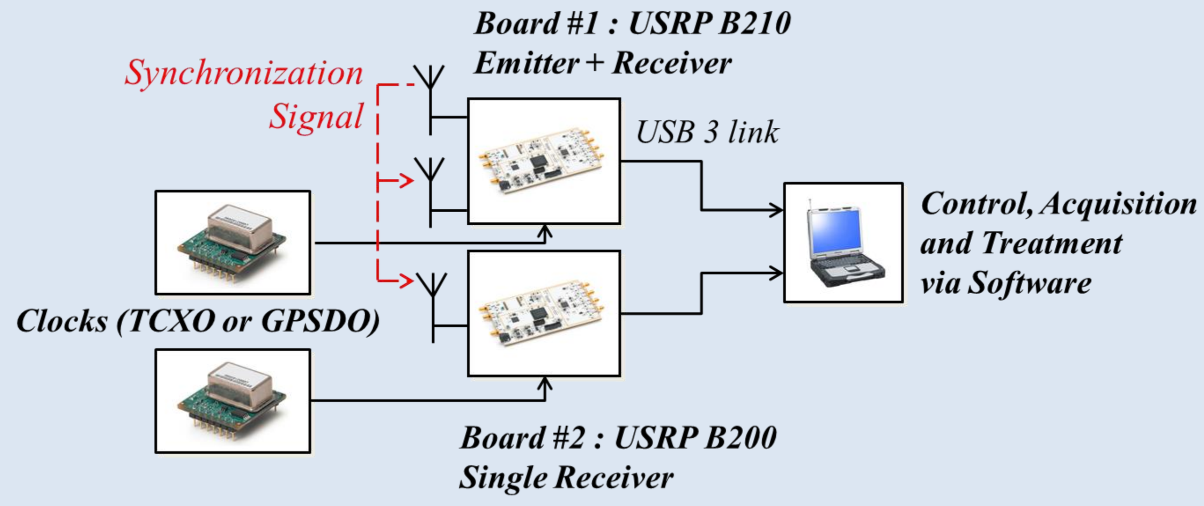
Mixed white phase and white frequency noise process



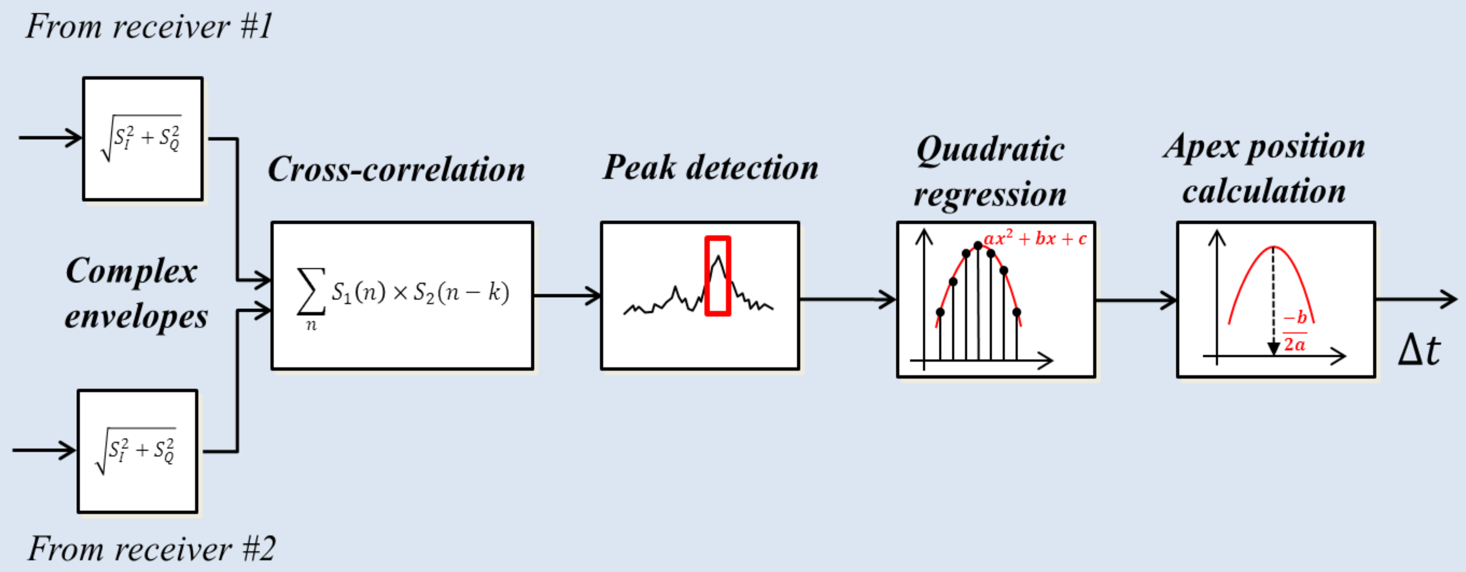
Experimental setup

Goal: evaluate the overall time synchronization performance of a whole passive system.

The platforms are **synchronized** via a custom protocol based on the emission and reception of a **RF signal**.

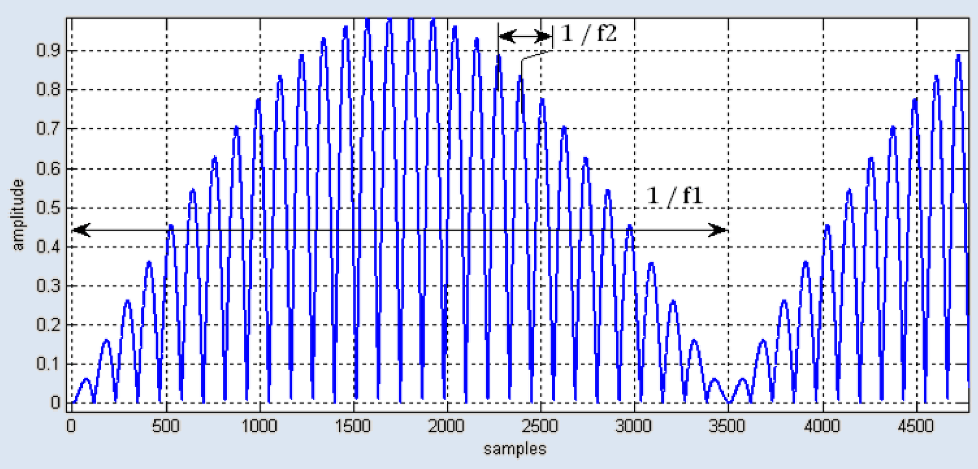


This signal is **cross-correlated** between platforms to evaluate the **delay** between their clocks:



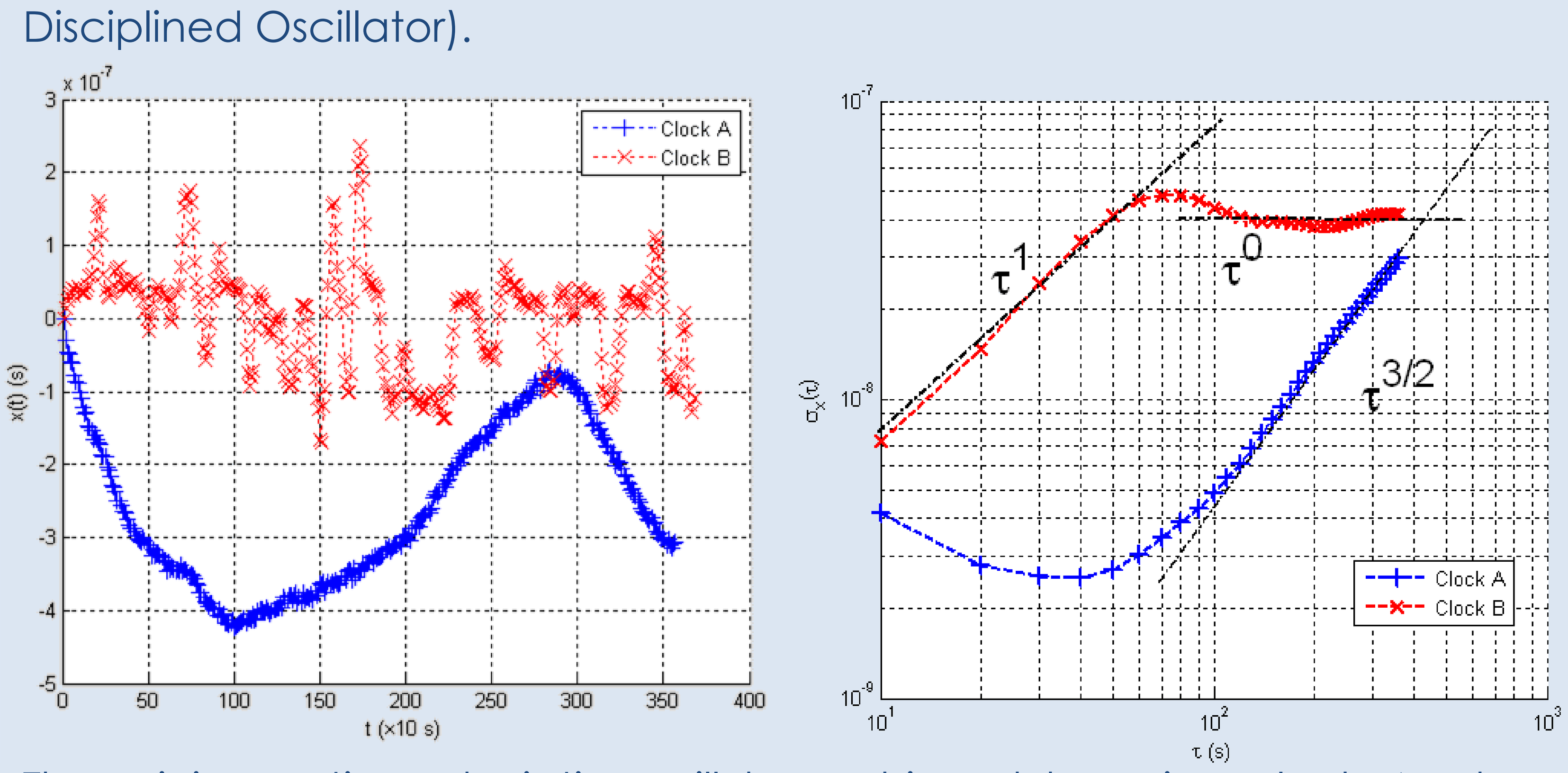
This signal is designed to have an correlation function with a **narrow** and **unambiguous** primary lobe.

$$s(t) = \sin(2\pi f_1 t)\sin(2\pi f_2 t)e^{j2\pi f_{LO}t}$$



Results

Two experiments have been carried out, each featuring a different type of clock (A or B). The same clock type is mounted on both receivers on an experiment. Clocks type A are **TCXO** and clocks type B are **GPSDO** (GPS Disciplined Oscillator).



The minimum time deviation will be achieved by using clock A when $\tau < 350$ s and clock B when $\tau > 350$ s. So if the system is in a hostile zone and has a poor (high) synchronization period or no sync signal exchanged, because of **jamming** or for **stealth purposes**, a GPSDO appears to be the best choice. If a short period synchronization signal is available, a standard TCXO seems to be a better option.