Application Note

Remote Synchronization of Time Taggers

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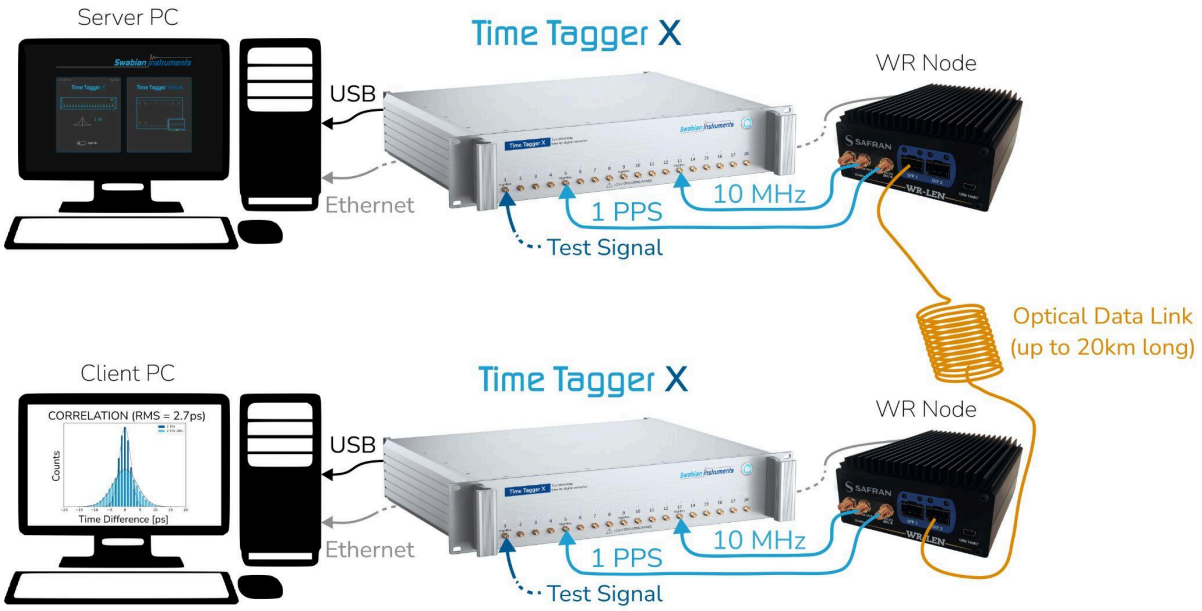

Figure 1. Setup for the remote synchronization of Time Taggers to enable measurements over long distances. Remote synchronization is demonstrated with a White Rabbit (WR) layer using 300 m of single-mode optical fiber. The measured timing jitter is only σ_{2TTX} = 4.0 ps, slightly above the intrinsic jitter of Time Tagger X in HighRes mode of σ_{1TTX} = 1.8 ps, corresponding to a synchronization-induced jitter of just σ_{WR} = 3.5 ps.

INTRODUCTION

Key breakthroughs in quantum networking, science, telecommunications, finance, and computing rely on precise synchronization of time measurements across multiple locations. Examples include quantum key distribution (QKD) and detector synchronization, which involve event detection with very high fidelity time-to-digital conversion (time tagging) at different sites many kilometers apart, sharing a common time base (synchronization).

Swabian Instruments has demonstrated remote synchronization of Time Taggers leveraging Safran White Rabbit network nodes to achieve measurements with high timing resolution and picosecond precision.

MEASUREMENT

Swabian Instruments' Time Tagger X features class-leading hardware with a single-channel jitter of just 2 ps RMS (root-mean-square, $\sigma/\sqrt{2}$) and 1.5 ps RMS in HighRes mode. The outstanding data acquisition hardware and a powerful software engine streamlining data acquisition and analysis enable researchers to perform measurements with a few lines of code in their desired programming language.

The `setSoftwareClock()` function locks the Time Tagger to an external clock (typically 10 MHz), allowing multiple Time Taggers to operate on the same time base. For precise synchronization over long distances, the White Rabbit (WR) protocol is used [1]. WR is a network standard for the synchronization of instruments over conventional fiber-optic networks up to 20 km in length with subnanosecond accuracy and picosecond precision. WR nodes distribute a common clock via optical fiber and locally generate output signals (1PPS, 10 MHz), which the Time Taggers take as input for synchronization. Simultaneously, the optical 1 Gbit/s link transfers the time tags, which are then transmitted between the node and PC using an Ethernet interface. Swabian Instruments' `TimeTaggerNetwork` is started on a remote server, so the client addresses the local and remote Time Taggers as if they were both present locally (Figure 1).

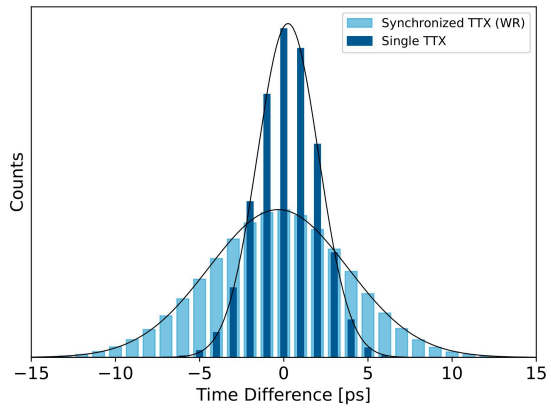

Figure 2. Correlation measurement of two Time Tagger X synchronized with White Rabbit nodes, connected with 300 m-optical fiber (dark blue, σ_{2TTX} = 4.0 ps), compared to the same measurement performed using a single Time Tagger X (light blue, σ_{1TTX} = 1.8 ps).

RESULTS

A single 10 MHz test signal is measured by both remote and local Time Taggers synchronized with Safran WR-LEN network nodes. The resulting time tag streams are stored on the local client PC using the `FileWriter`, combined via `mergeStreamFiles()`, and evaluated by a `Correlation` measurement. The additional jitter σ_{WR} introduced by the White Rabbit system using 300 m of single-mode optical fiber is calculated from the jitter of the synchronized system σ_{2TTX} = 4.0 ps RMS (dark blue in Fig. 2) and the measured jitter of a single Time Tagger X in HighRes configuration σ_{1TTX} = 1.8 ps RMS (light blue in Fig. 2):

$$\sigma_{WR} = \sqrt{\sigma_{2TTX}^2 - \sigma_{1TTX}^2} = 3.5 \text{ ps}.$$

Remote synchronization of Time Taggers can also be achieved in other ways, such as with GPS-disciplined oscillators. However, the advantage of using WR is that it provides both the synchronization tool and the communication layer in a single solution. This powerful combination makes it an ideal companion for Swabian Instruments Time Taggers. WR networks can, in principle, be extended to hundreds of nodes, and thanks to the open-source nature of its implementation, this approach is not tied to any particular hardware vendor.

REFERENCES

[1] White Rabbit Project
https://ohwr.org/project/white-rabbit/wikis/home

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