Modernization and Characterization of the Riga SLR Timing System

Evan Hoffman (GFZ Potsdam)
Kalvis Salmins (Institute of Astronomy Univ. of Latvia)
Jorge R. del Pino (Institute of Astronomy Univ. of Latvia)
Aivis Meijers (Institute of Astronomy Univ. of Latvia)

Abstract

A huge push towards modernization is underway at the Riga SLR station. One of the systems under refurbishment is the timing system. This presentation compares the past and present timing systems. A new documentation effort has been started to facilitate traceability and easier maintenance. The new frequency standard is a GPS steered rubidium. A stability analysis of this source was completed using a cesium clock equipped with a high-performance tube, and compared to measurements of the previous standard. Measurements have been performed to validate the timing offset relative to the event timer measurement. These changes should greatly improve confidence in the quality of the data collected. Most of the timing equipment is located in a separate building from the telescope and ranging equipment. The time signals are delivered via a run of coaxial cable. There are plans to replace these cables with fibers in the future to reduce jitter and any temperature dependence. A measurement and analysis of the variation in signal delay with respect to temperature is also presented.

Introduction

Several structural and systemic improvements are being carried out at the Riga SLR station. These include improved telescope driving systems with encoder feedback, laser alignment and measurement techniques, and general modifications and upgrades to improve the performance and reliability of the system. The timing system forms an important part of this effort as the basis for all measurements performed and data collected. An otherwise excellent system with a poor timing setup will produce unreliable data. As such, particular attention was paid to the refurbishment of the timing system during these upgrades.

A Brief History

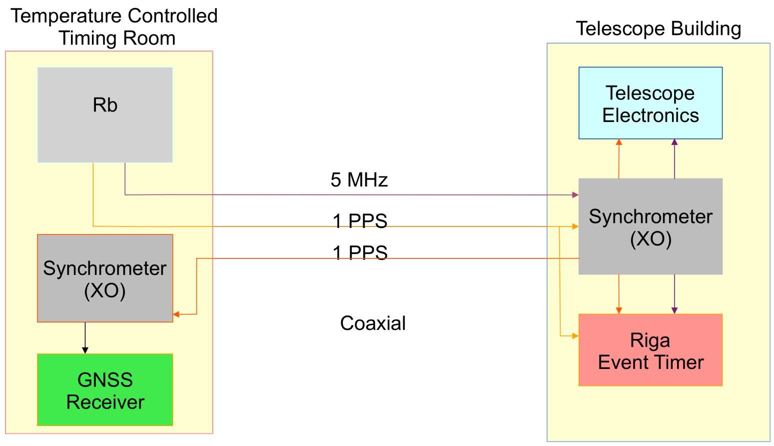

Figure 1: Simplified Old Timing System Setup

Figure 1 shows the setup of the old timing system. Most of the major timing equipment is located in a separate building, as the telescope building is not climate controlled. A 5 MHz sine wave and 1 PPS is generated by an unsteered rubidium standard CH73 secondary time standard and delivered to a synchrometer CH37 (tertiary time standard) located in the telescope building. This synchrometer then provides timing signals to the telescope control electronics, the event timer gets 1PPS and 5Mhz straight from the rubidium standard. A 1 PPS signal is sent from this synchrometer to an additional synchrometer located in the timing room. The rubidium is compared to a GNSS receiver to keep the 1 PPS relatively close to UTC, knowing the cable signal delays in the coaxial cable connecting the two synchrometers. The rubidium 1 PPS was adjusted in order to match the GPS 1PPS. The redundancy was built into the system to protect against equipment failure and power outages, as a second slip would otherwise not be noticed until tracking began. Additionally, BCD encoded time was transmitted to the telescope and displayed on a separate clock to assist in setting the proper time on the synchrometer at the telescope in case of a power outage.

Over the years, the system developed a few problems. Documentation for the system was poor or nonexistent, which caused issues with maintenance. Much of the equipment, such as the rubidium and the frequency source, was obsolete, more than twenty years old, and difficult to service.

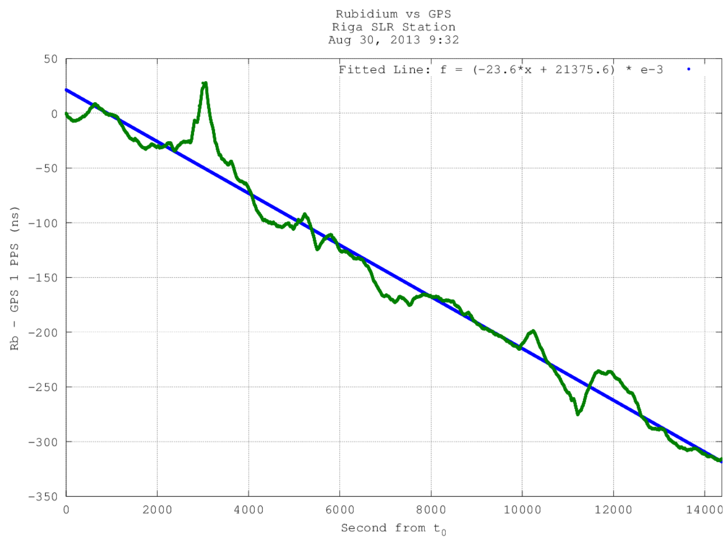

Figure 2: Long Term Drift Shown by old Rb

Figure 2 shows the drift of the rubidium over the course of several hours, as compared to a standard GPS receiver. A line of best fit has been plotted showing a large drift greater than 2 µs per day, which would require the operator to synchronize the 1 PPS multiple times during the day. Longer passes would cause even bigger problems. The advanced age of the device (over 20 years) also reduced confidence in its medium and short term stability.

The coaxial running between the two buildings was also a concern, as it was exposed to the environment and had seasonal and diurnal temperature fluctuations.

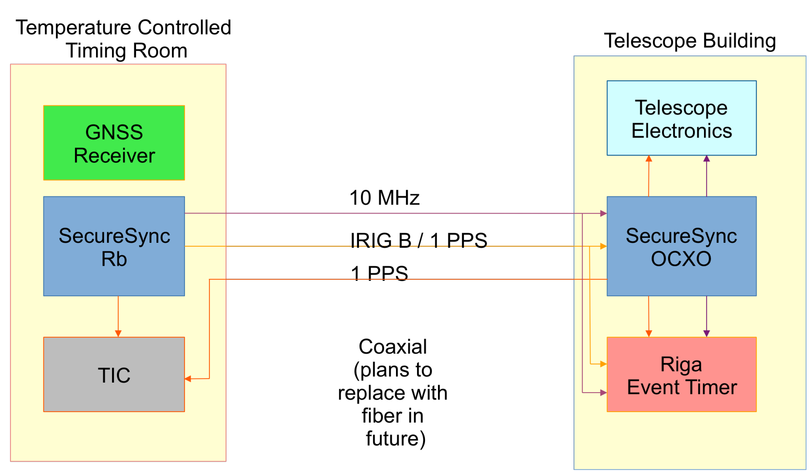

Figure 3: Planned Timing System

New Timing System

Figure 3 shows the planned setup for the new timing system. The base of the time keeping and signal generation is provided by the Spectracom Securesync synchronization system, replacing the old rubidium and the synchrometers. A Securesync unit equipped with an internal rubidium oscillator is our primary frequency source. The rubidium oscillator in this unit is steered by GNSS. A second Securesync with a oven controlled crystal oscillator is placed in the telescope room with synchronization to the primary source provided by an IRIG-B/1 PPS setup. This has an advantage of passing epoch information as well. Coaxial lines will be replaced with optical fibers to deliver time signals. This has the advantage of lower signal jitter as well as greatly reduced temperature dependence for the signal delay.

Vetting and Verifying

Tests are ongoing to test and validate the system in terms of function and performance. The 1 PPS of the Securesync was compared to a 1 PPS generates by a cesium clock with a high performance tube over the course of several days. A third GPS disciplined oscillator was used in parallel to verify the measurement.

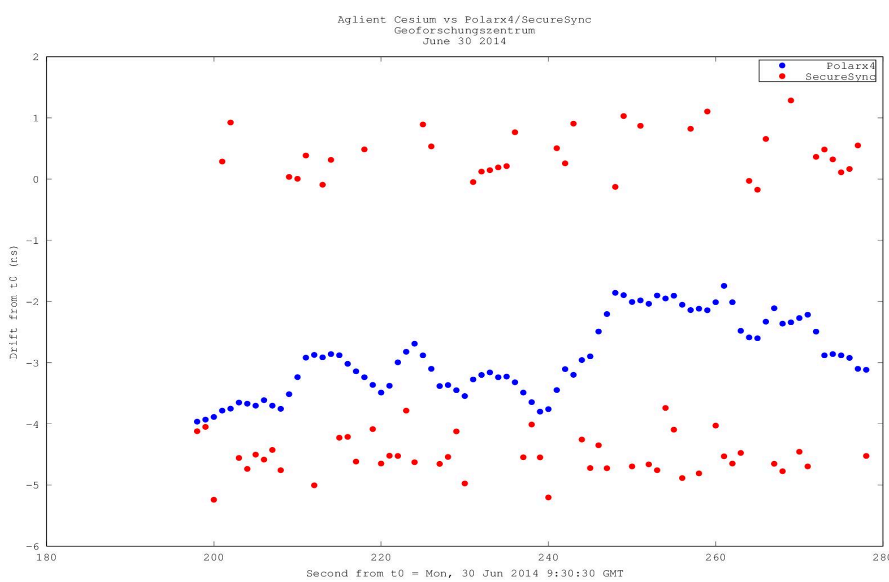

Figure 4: 3 Way Test

Figure 4 shows a short section of the test. The red data points represent the SecureSync, while the blue data points are obtained from the other GPS receiver. Both represent drift relative to an arbitrary starting time versus the cesium. There was an oscillation between small groups of 1 PPSs generated by the SecureSync roughly 5 ns in magnitude. It is not present in the GPS receiver, showing the problem resides with the SecureSync. Further tests conducted on the 10 MHz revealed no jumps in phase in relation to the 10 MHz of the cesium that would suggest a problem with the rubidium oscillator itself, pointing to the 1 PPS generation being an issue. These findings were reported to the manufacturer, who subsequently discovered a software bug causing the issue. A software update is expected in early 2015.

This test underlines the importance of redundancy in testing and knowing your hardware.

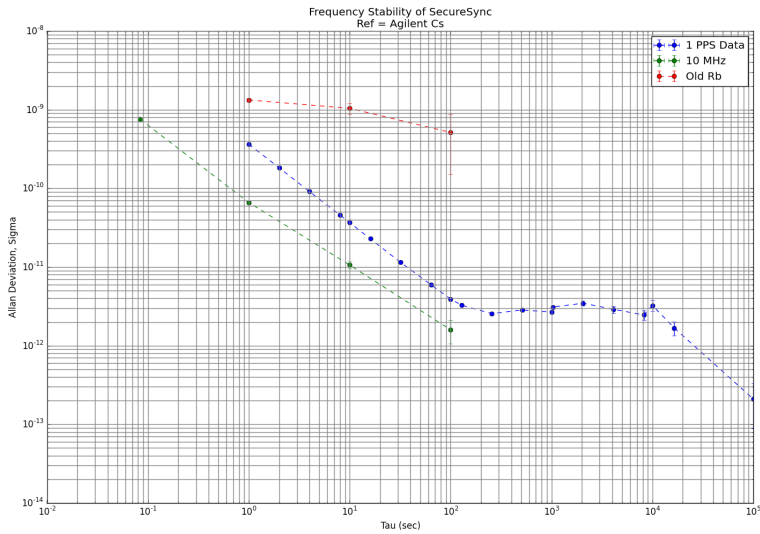

Figure 5: Allan Deviation of Frequency Sources

Figure 5 shows an Allan deviation analysis of the old and new frequency sources. The red line shows the old unsteered rubidium. The blue line was an analysis performed using the 1 PPS from the SecureSync. The green line used the 10 MHz from the SecureSync. The reference clock used was the high performance cesium. Despite its errors in 1 PPS generation, there is a significant improvement in frequency stability by several orders of magnitude. Using the 10 MHz gives even better results, meeting the specification set by the manufacturer.

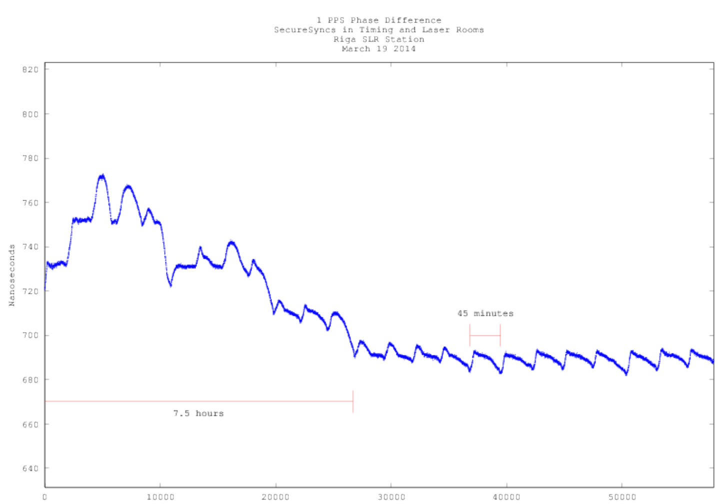

Figure 6: IRIG-B Test

Figure 6 shows tests performed on the IRIG-B. Phase error measurements were performed on the remote and local SecureSync units in the timing room and the telescope building. The unit showed about a 7.5 hour settling time after power-on of both units. A saw-tooth pattern was also visible in the error with a period of about 45 minutes, and an amplitude of about 10 ns. It is unclear whether this will improve after the software update, however further tests are planned.

In summary, our tests have discovered some issues with the setup currently (mainly equipment), but they are believed to be correctable via further analysis and software updates. Indeed, the SecureSync software update release notes from February, 2015 (1) states that the 5 ns 1 pps jump issue has been corrected.

Temperature Dependence Tests

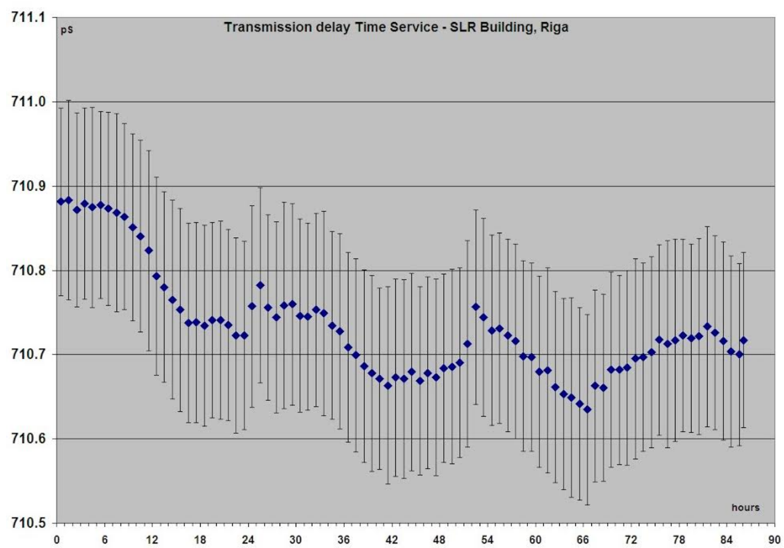

Figure 7 Signal Delay Measurements, Winter

Figure 7 shows a signal delay test that was performed on the coaxial cables running from the timing building. A pulse was applied to one end of the cable, with the other end disconnected. The open circuit round-trip reflection time (y-axis) of the pulse was measured at a sample rate of 0.20 Hz over a period of several days. Data were noisy due to limitations in measuring equipment, but a slight diurnal trend was shown, with a noticeable 12 hour lag when correlated with outside temperature. The trend is weak enough (<100 ps one way) that it should not have a significant effect on the overall stability on a day to day basis. More tests are being analyzed with data taken during the summer to establish seasonal effects. Installation and testing of fiber is also planned, which should make the effect even smaller.

Conclusion

The measurements show that the new system fits timing requirements for the SLR as indicated in [2].

Our results show the value and necessity of independent tests and crosschecks for critical equipment. These tests may reveal otherwise hard to detect problems and anomalies, and are helpful in understanding device operational nuances.

Acknowledgments

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References

[1] Spectracomcorp.com, 'SecureSync 5.2 Release Notes', 2015. [Online]. Available: http://www.spectracomcorp.com/Desktopmodules/Bring2Mind/DMX/Download.aspx?EntryId=428&PortalId=0. [Accessed: 05- Mar- 2015].

[2] L. Combrinck, "Satellite Laser Ranging," in *Sciences of Geodesy - I*, G. Xu, Ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010, pp. 301–338.