Event Timing System for Riga SLR Station

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Abstract

The new Riga Event Timing System (RTS) is designed and built in 2006 for SLR station Riga-1884 to improve its measurement equipment in precision, functionality and reliability of operation. The RTS is a multimode instrument for satellite ranging at 10 Hz repetition rate with parallel measurement of PMT-pulse amplitudes for the range bias correction. The RTS can support millimetre accuracy of SLR although the overall system accuracy is limited by the other equipment of Riga SLR station. As compared to the previous version of Riga timing system, the RTS offers considerably better performance and functionality and provides a good basis for further improving the Riga SLR station as a whole.

Introduction

The Riga Event Timing System (RTS) is designed and built in 2006 for Riga SLR station to upgrade its measurement equipment. The RTS maintains the basic functional possibilities of the previous Riga timing system but is advanced in many essential respects. Specifically, the RTS is based on employment of the latest Riga Event Timer A032-ET [1]. As compared to the previously used instrument, the A032-ET provides much better single-shot resolution (8 ps RMS instead of the previous 25 ps) and much smaller “dead time” (60 ns instead of the previous 400 ns).

A new hardware design is made to integrate the most of specialized hardware means within a single stand-alone device. There are new functional possibilities of digital signal processing and system control that have to increase the SLR efficiency. Some optional functional capabilities are added for experimental investigations with the aim to improve the performance of Riga station as a whole.

A special feature of the RTS is that it provides pre-processing of STOP pulses coming from either traditional single or special doubled receiver based on Photo Multiplier Tubes (PMT). The doubled receiver generates the pulses overlapping only when the true STOP pulse is being received [2]. It makes possible to reduce the noise influence when the satellite ranging is performed by day. Like the previous Riga timing system, the RTS performs PMT pulse amplitude measurement to correct the range bias [3].

Principles of operation

The RTS supports the following operational modes:

- SLR system calibration in the range from 9 to 375 m with parallel measurement of STOP-pulse amplitudes;
- Satellite ranging to 25,500 km at 10 Hz repetition rate with parallel measurement of STOP-pulse amplitudes;
- Integrated mode when the SLR system calibration and satellite ranging are performed simultaneously (for optional use);
- Measurement of pulse noises.

Structurally the RTS combines the RTS hardware and a PC with the RTS software (Fig.1).

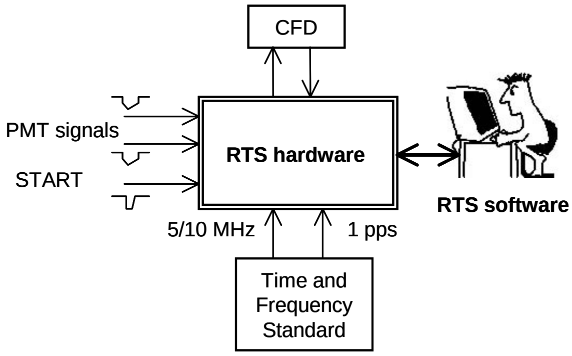

Figure 1. *RTS architecture*

Additionally the RTS includes two commonly used external devices: Time and Frequency Standard and Constant Fraction Discriminator (CFD).

The RTS hardware

The RTS hardware contains three functional units: Signal Processing block, Event Timer Block and Master Clock; each implemented as a separate board. These boards and their power supply are housed in 19’’ 2U rack module (Fig.2).

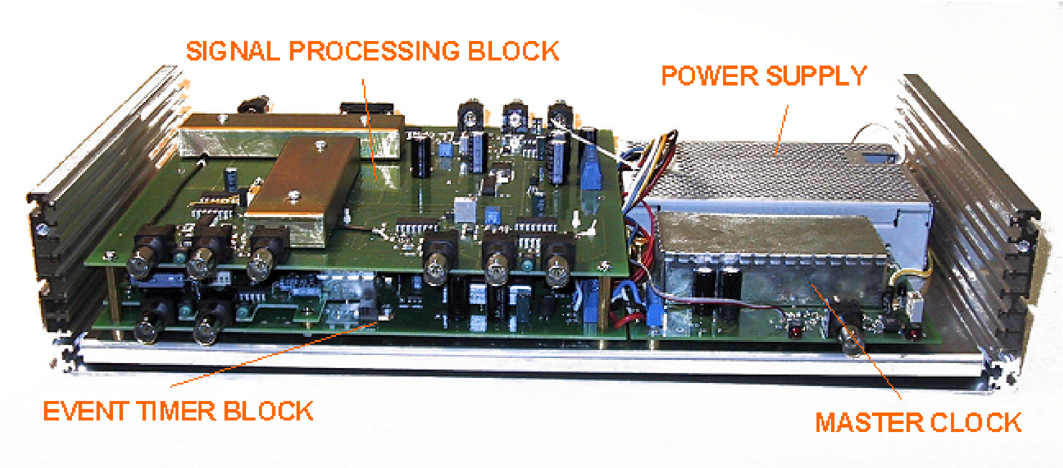

Figure 2. *RTS hardware assembly*

The Signal Processing Block receives the PMT pulses (3 to 7 ns width range; -0.1 to -3.0 V amplitude range) and, in interaction with the CFD, produces normalised NIM pulses for the Event Timer Block. The Event Timer Block measures time instants of these pulses and START pulses coming. Then the measurement results come to PC for further data processing, displaying and memorizing. The Master Clock represents a voltage-controlled crystal oscillator disciplined by an external high-stable 5 or 10 MHz reference frequency using PLL circuit. It generates a low-jittered 100 MHz clock signal required for precise event measurement and synchronization of Signal Processing Block operation as a whole.

Signal Processing Block

The Signal Processing Block performs a few basic operations with PMT pulses before their measurement by the Event Timer Block (Fig.3).

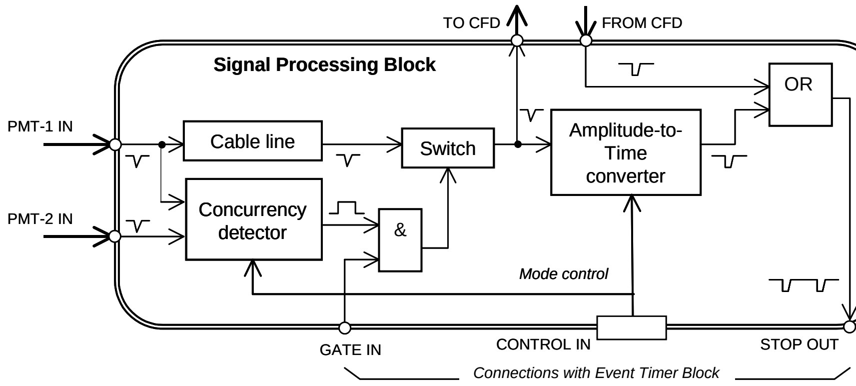

Figure 3. *Functional diagram of the Signal Processing Block*

At first it selects PMT pulses which probably conform only to the returned laser pulses. To do that either single (“PMT-1 IN”) input or two (“PMT-1 IN” and “PMT-2 IN”) inputs for PMT pulses can be used. In the last case it is supposed that the PMT pulses overlap only when the true return is being received. In the case of concurrency of these pulses one of them (“PMT-1”) is selected using the wideband switch. Such selection acts together with the online programmable gating provided by the Event Timer Block.

The selected pulses from the switch output come to the CFD. The CFD generates normalized NIM pulse in response to each input PMT pulse. This NIM pulse comes to the input “FROM CFD” of the Signal Processing Block. However the CFD cannot fully avoid the time-uncertainty of PMT pulse coming. For this reason the amplitude of each PMT pulses is additionally measured as the amplitude values are related to the range bias. To do that, the Amplitude-to-Time converter generates the NIM pulse in response to the same PMT pulse with some delay proportional to the PMT pulse amplitude. In this way every selected PMT pulse is being converted into two NIM pulses where the first one represents directly the returned signal and time interval from the first pulse to the second one reflects its amplitude (Fig.4). Resolution of such amplitude measurement is about 9 bits.

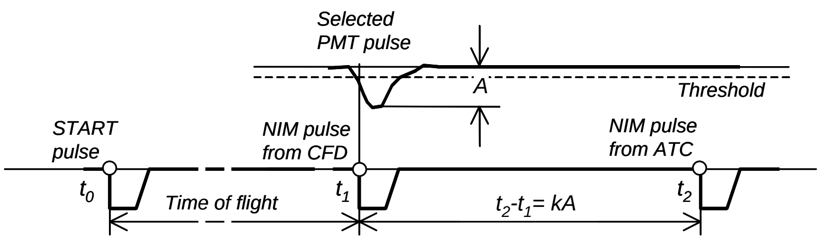

Figure 4. *Time diagram illustrating PMT pulse amplitude conversion*

Then the Event Timer Block measures time instants of these pulses and START pulse coming at each ranging cycle so as to give out complete data for further satellite ranging. As shown in [3], the mentioned technique of PMT signal amplitude measurement makes it possible to effectively correct the range bias caused by the PMT features.

Event Timer Block

The Event Timer Block precisely measures the instants at which input events occur. Every event is associated with certain fixed point on the leading edge of input NIM pulses. Used method of event timing is untraditional in many respects. Specifically, it supports not only high precision but high speed as well. Using 100 MHz internal clocks this method provides each single measurement with 7-8 ps RMS resolution during 60 ns only.

The event measurement is performed in two stages. At first, the Event Timer Block transforms every input event into single 80-bit timing data block (subsequently referred to as TD-block) and sequentially accumulates them in a FIFO memory. Each TD-block contains the counting data (39 bits; 10 ns resolution) and interpolating data (40 bits), as well as one-bit mark specifying the kind of measured event (either Start or Stop). The interpolating data are presented initially in an intermediate redundant form.

At the next stage the PC takes out TD-blocks from the FIFO memory and processes them to obtain the corresponding epoch time-tags in a unified form. Further these time-tags are additionally processed to display the ranging results in real time. To achieve the best precision, processing of TD-blocks takes into account the actual physical characteristics of time interpolation under actual operating conditions; these characteristics are defined through so called scaling (hardware calibration) before the measurement.

The Event Timer Block is flexibly controllable and allows writing TD-blocks in the FIFO memory and reading them by the PC in different order. Specifically, the RTS provides cyclical measurement of events. In the beginning of each cycle the RTS measures a single Start-event, and only then - a number of Stop-events. According to the modes of RTS operation, the Event Timer Block measures up to 3 events in the System calibration and Satellite ranging modes, up to 5 events in the “Integrated mode” and up to 10000 events when pulse noise is measured. In all cases the Event Timer Block at first accumulates TD-blocks in the FIFO memory during some defined waiting period, starting from Start-event registration. During this time the PC processes TD-blocks that have been read out from the Event Timer Block in the previous cycle. Then the PC stops the event registration, reads the currently accumulated TD-blocks and allows starting the next similar cycle. The waiting period is strictly adapted to the repetition rate (10 Hz) of RTS operation. Optionally the RTS can provide the repetition rate up to 30 Hz.

In addition to the event measurement the Event Timer Block generates NIM pulses, which come to the input “GATE IN” of the Signal Processing Block to provide online programmable PMT pulse gating.

The RTS software

The RTS software performs real-time procedures which depend on the selected operating mode, current user control, etc. There are also various auxiliary procedures to prepare the system to operation (clock synchronization, calibration of measurement hardware, system checking, etc). For example, in the conventional Satellite ranging mode the RTS software performs in real time the following procedures:

- periodically checks the RTS hardware to detect the START pulse coming;
- when the START pulse is detected, triggers the internal time-out and begins processing of the previously taken data;
- when the time-out is finished, stops the measurement, reads the data from the RTS hardware, writes to it a new data concerning the STOP pulse gating and makes next cycle available.

Correspondingly the data processing performed during the time-out includes:

- conversion of TD-blocks to the unified form of epoch time-tags;

- calculation of the gate delay and residual, time interval reflected the STOP pulse amplitude and new data concerning the STOP pulse gating in the next cycle;
- displaying (Fig.5) and memorizing the measurement results.

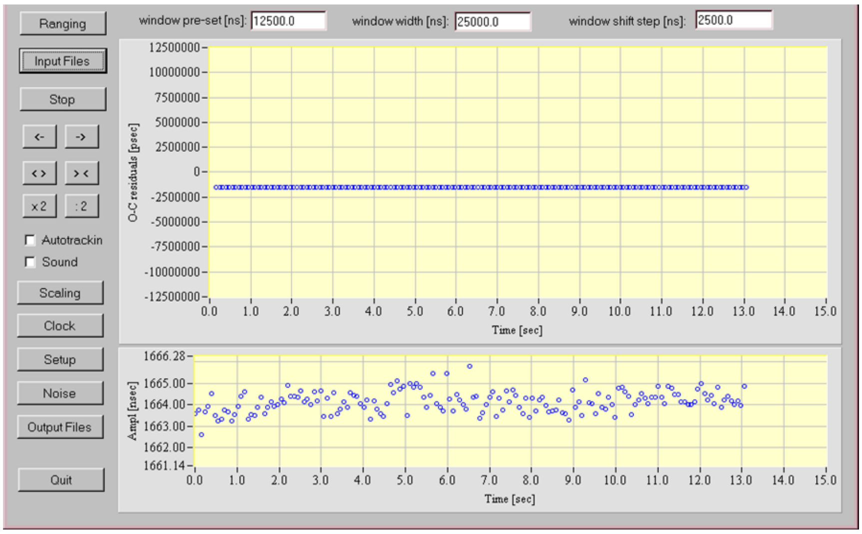

Figure 5. *Example of displaying the measurement results. Upper plot shows residuals; bottom plot indicates amplitudes of PMT pulses*

The RTS software offers optionally an autotracking of satellite in range after its initial acquisition. When the autotracking is on, possible trend of the residuals is actually excluded due to the automatic gate delay correction. Algorithm of the autotracking is based on median selection of current residuals to exclude their possible abnormal values, and continuous generation of a special piecewise-linear function for gate delay correction. Every piece of this function is being determined using regression analysis of the current fraction of residuals. In this case the gate delay correction is performed at 1 Hz rate approx., allowing considerable errors in initial predetermination of the function "RANGE vs. START TIME".

The RTS software is written in *C* language for LabWindows/CVI ver.6.0 and works under Windows XP.

Conclusion

As compared to the previous version of Riga timing system, the RTS offers considerably better performance in terms of accuracy, functionality, and reliability in operation. This provides a good basis for further advancing the Riga SLR Station as a whole. In 2006 the RTS was involved in trial operation; the first series of successful SLR results has been obtained.

Reference

[1] V. Bespalko, E. Boole, V. Vedin. The Model A032-ET of Riga Event Timers. Proceedings of the 15th International Workshop on Laser Ranging, Canberra Australia, October 16-20, 2006.

[2] ILRS 2003-2004 Annual Report, p. B-38.

[3] Yu. Artyukh, V. Bespalko, K. Lapushka, A. Rybakov. PMT signals caused range-bias correction at the SLR Station Riga-1884. Proceedings of the 12th International Workshop on Laser Ranging. Matera, Italy, November 13-17, 2000.