TESTS OF THE STABILITY AND LINEARITY OF THE A031-ET EVENT TIMER AT GRAZ STATION

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Abstract

The event timer A031ET (made by the Institute of Electronics and Computer Science, University of Latvia, Riga) offers an interesting alternative to the widely used SR620 time-of-flight counters. In order to check for the linearity and stability of this instrument, a series of intercomparisons between the A031 and the „E.T." at Graz SLR station (consisting of top-level Dassault modules) was performed. The obtained data covers the full range of time intervals which is of interest for SLR measurements (70 ns – 200 ms) and shows both excellent linearity and stability of the Riga Instrument. The different test methods and the results of the intercomparison between both event timers are discussed and some hints for the optimum operation of the A031 are given.

Introduction

It is well-known that the widely used SR620 time interval counters display a sample- and range-dependent non-linearity of the measured time intervals within the range of intervals used for Satellite Laser Ranging [Gibbs, 2002]. Those non-linearities can amount up to several 10 ps and have to be taken into account in order to avoid time-dependent range biases (cf. Fig. 1).

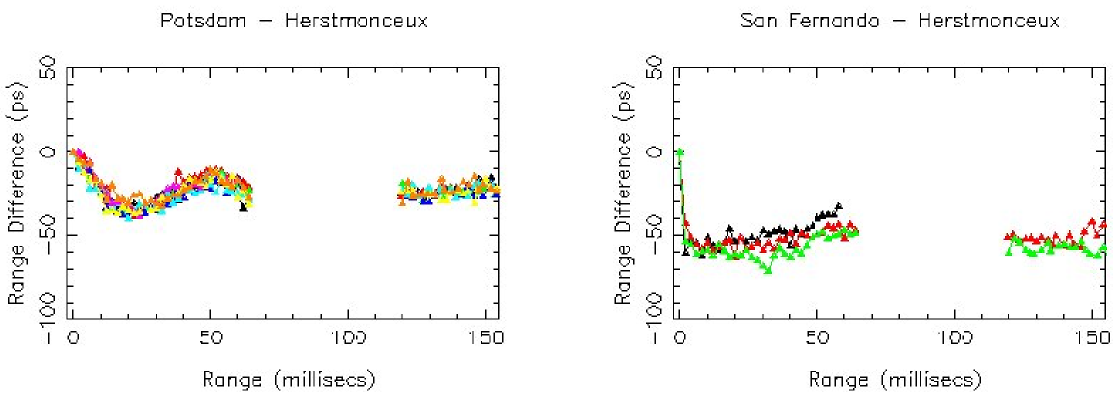

Figure 1. Examples of non-linearities for two different samples of SR620 counters (adapted from [Gibbs, 2002])

While this range-dependent non-linearity appears to be fairly stable within 10-20 ps and can thus be corrected for in post-processing, it would be desirable to use timing devices which are virtually free of such effects. Event timers based on the commercially available Dassault modules are claimed to display non-linearities of ≤ 2.5ps but are rather expensive. The newly developed event timer A031-ET (University of Riga, Latvia) is far less expensive and might offer an interesting alternative to the SR620 in case the non-linearity was far below the values found for the Stanford counters. The intention of our experiments was to investigate the stability and linearity of the A031-ET as compared to an event timer based on Dassault modules.

The A031-ET Instrument

The A031-ET is the most recent development within the family of timing instrumentation from the Institute of Electronics, University of Riga [Artyukh et al., 2002]. It is a rather compact unit with NIM inputs for start/stop events and an optional electronic gate, and requires a 10 MHz external timebase and a 1PPS timing signal (both TTL level) for means of epoch synchronization. The application software is running under Windows® on a PC interfaced via EPP to the event timer. This PC is to be connected to a local network via TCP/IP for fast data exchange.

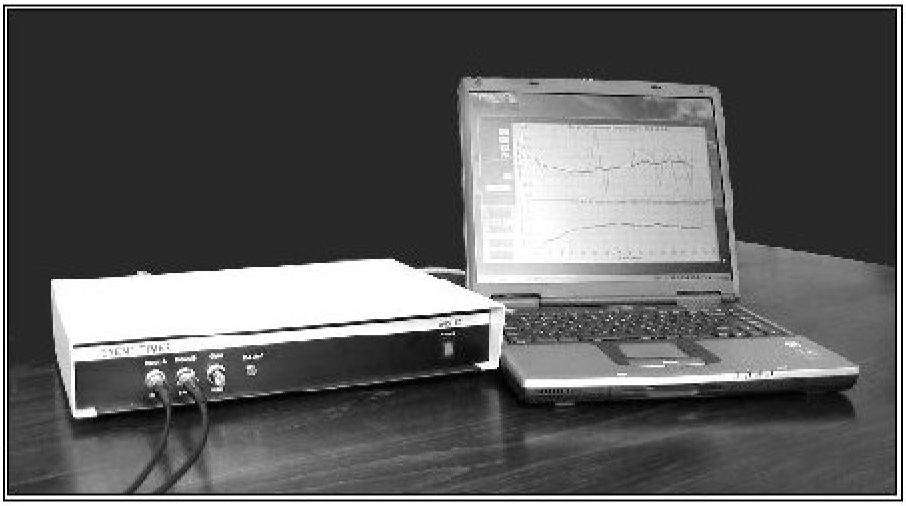

Figure 2. The A031-ET instrument with the interfaced PC for the application software

The single-shot RMS is typically in the order of 10-12 ps, the dead time is about 70 ns. Up to 6550 time tags per operating cycle may be registered before the internal buffer has to be dumped to the host PC via the parallel port. The A031-ET can be operated both the AT (event timing on both inputs A and B) and TI mode (advanced time interval measurement with A arming B, but with B capable of registering multiple stops, taking into account the dead time). Triggering can be performed both externally or internally.

Test Setup at Graz SLR Station

Tests of linearity and stability were performed in February 2004 at the SLR station 7839 Graz (Austria) against the „E.T." [Kirchner and Koidl, 2000] which is made from Dassault modules and exhibits a non-linearity of < 2.5 ps. The A031ET was supplied with the clock- and time-reference of the SLR station and registered data from calibrations, satellite trackings and simulations in parallel. Because target and satellite data yield only a limited range of time intervals, dedicated simulations were performed in order to cover the full range of time intervals between 1 ... 200 ms. For this purpose the tracking software was modified in a way that the delay of the range gate was increased in ms-steps every 2 seconds, and the first noise pulse after opening the gate was taken as stop pulse. For checking the range of 100ns...1ms, a pulse generator with manual stepping of delay time was used because the range gate could not be set to values of less than 1 ms. This range is important because the typical SLR calibration time interval is in the order of 100 ns for short-way links and several µs for remote targets.
A certain constraint was caused by the above-mentioned fact that the A031-ET in its present hardware configuration can only record max. 6550 events/cycle in full speed AT mode (this

corresponds to a registration time of about 1.6 s at 2 kHz laser repetition rate at the Graz station) followed by a gap for data transfer of about 1 s. Therefore only 60% of events could be recorded in parallel between the "E.T." and the A031, but this was sufficient for this test. The data processing was performed by LabVIEW-programs created in situ. They were written for searching such data that both event timers had registered. For a detailed analysis of nonlinearity the difference values of simulation measurements were processed as follows:

- 2.2 sigma filtering
- computing the mean values for each ms-step (red curve in Figure 3)
- low pass filtering with $f_u = 0.02$ Hz (the scan rate of stepping was about 0.5 Hz) (blue curve in Figure 3)

This way the noise of the individual samples was much reduced, and possible trends could be visualized in a more simple way.

Test Results

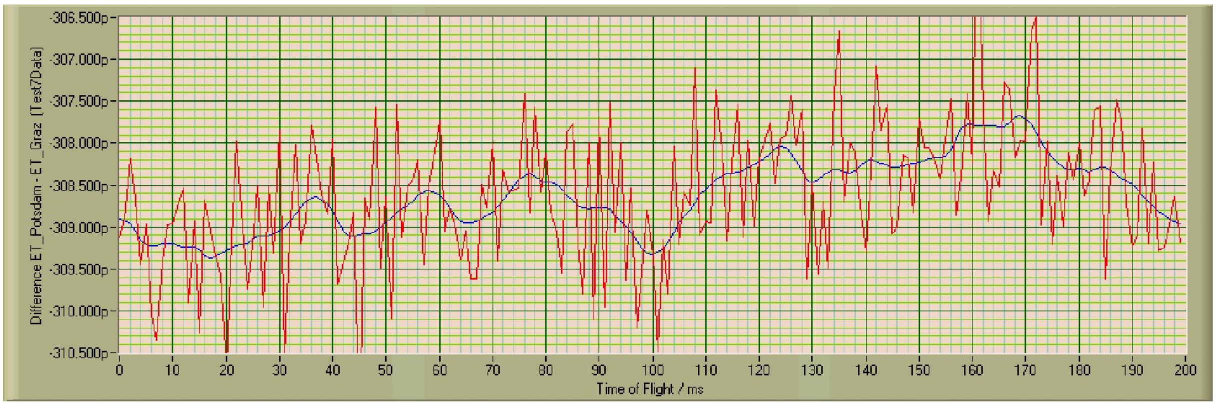

Figure 3. Results of a simulation measurement (obtained at 500 Hz, 11 February 2004)

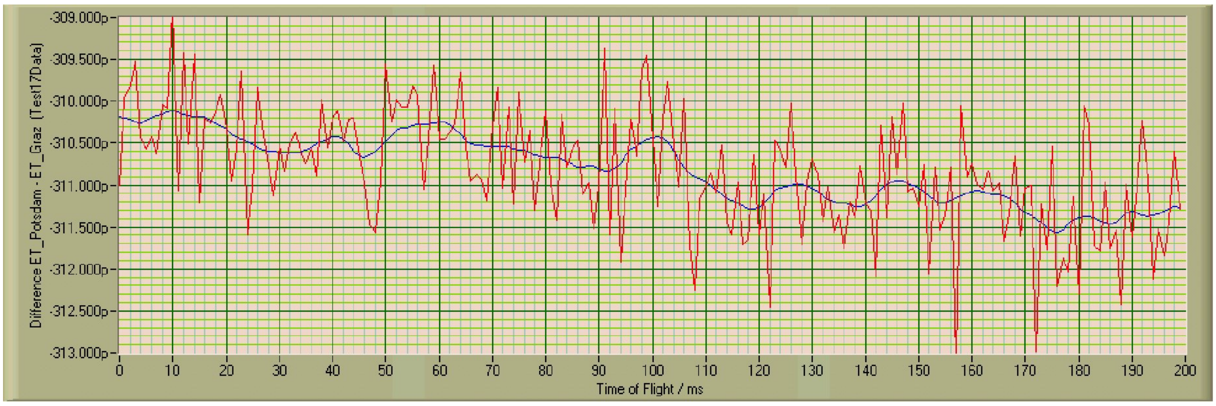

Figure 4. Results of a simulation measurement (obtained at 2000 Hz, 12 February 2004)

In Figures 3 and 4 the results of simulation measurements within the range of 1 ... 200 ms are shown. The full vertical scale is 4 ps. The scatter of the mean values (red curce) is slightly higher in the data obtained on 11 February due to the lower number per point at a reduced rate of data taking (500 Hz vs. 2000 Hz), but there is neither nonlinearity nor drift observable. The variation of the low-pass filtered data (blue curve) is less then 3 ps in both diagrams.

Figure 5 shows a summary of all measurements in a logarithmic scale. This way the range between 100 ns...1 ms is much better resolved. The linearity is excellent over the full scale.

The data from simulation measurements are filtered (blue curves in Figures 3, and 4), the data from satellite trackings are plotted without any additional filtering and thus show a certain scatter as expected. The RMS of target data is 10...11 ps, that of satellite data about 9 ps. Because the RMS of the Graz "E.T." is about 4ps, the main part of measured RMS is caused by the A031ET which is in excellent agreement with the RMS data as specified by the manufacturer.

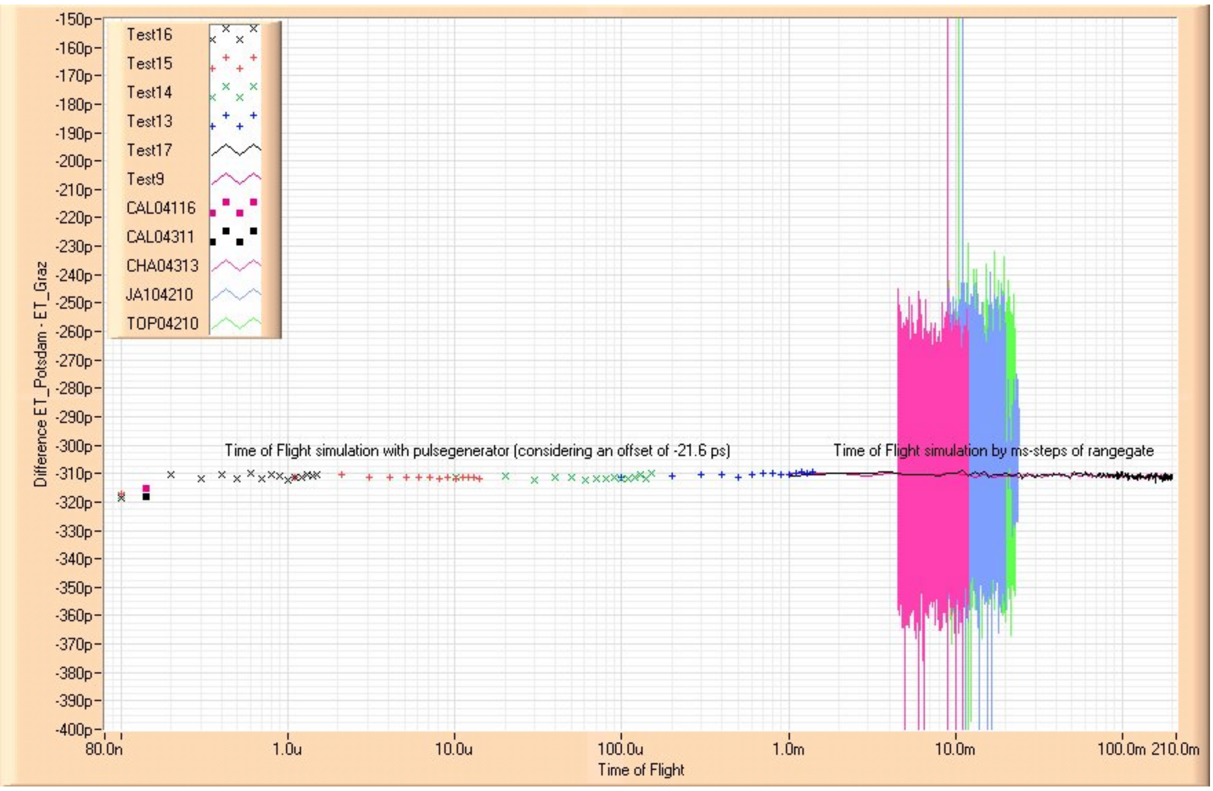

Figure 5. Combined results from all types of linearity measurements

Assuming that the event timer of the Graz station was well within its linearity specification (<2.5 ps) during the tests, it can be stated that both the temporal stability and non-linearity of the A031-ET instrument are excellent over the full range of SLR ranging intervals. A small offset (in the order of 5 ps) may be present for very short time intervals just exceeding the dead time of the event timer. Already for intervals of >150 ps there is no more sign of such an effect.

This high performance makes the A031-ET an interesting alternative to the SR620 at a comparable price but with much better stability and linearity than the Stanford instrument.

A031-ET Settings for Routine Operation

As already mentioned above, the present hardware layout of the A031-ET with the need of data dumping via EPP poses a certain problem for the use at systems with very high repetition rates which have to operate the A031-ET in the AT (event timer) mode. This was realized by the manufacturer meanwhile, and upcoming versions of the event timer will take into account the special needs of such stations, e.g. by the use of a cyclic internal buffer and a faster PC interface as USB [Lapushka, 2004].

For the present 10 Hz SLR systems the Riga instrument can readily be adapted without such modifications already now. The operation software allows for settings of the data taking which satisfy all needs of a 10 Hz system. As a simple way to implement the A031-ET into an existing system we suggest to use the advanced TI mode with a number events/cycle set to a value of 2 and the number of cycles as high as 100.000. These settings allow the data to be dumped from the internal buffer after the pass, and this way even very long passes of satellites as Lageos, Glonass or Etalon can be observed without overwriting the memory of the A031-ET. The data is internally recorded in binary format which results in relatively small files. Start and stop channels can easily be distinguished within the raw data by the opposite signs which are assigned to A (negative) and B (positive).

References

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