A032-ET Experimental Test on Changchun SLR

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Abstract

This paper introduces the experimental test of A032 Event Timer on Changchun SLR. First, the pulse delay generator DG535 is used to generate two path signals to simulate the start and stop signal, and the A032-ET to measure the intervals. Then, it also gives out the system hardware connection diagram, analyzes signal time sequence and shows the software flow chart. Finally it shows the results of ranging the ground target and the satellites.

Key Words: Event Timer, A032-ET, Satellite Laser Ranging (SLR), Simulation

Introduction

Satellite Laser Ranging (SLR) is the most accurate satellite tracking technique available with single shot positional accuracy under a centimeter and normal point corrected data able to claim precision of just a few millimeters. The SLR tracking method requires a pulsed laser source and a telescope which is used to collect the reflected laser light on its return. The laser provides a detectable link between a fixed station and a distant satellite moving in the space. The telescope and associated equipment determine a very precise location and velocity for both the satellite and station from the data provided by the laser beam. Time interval from station to the satellite and back can be calculated by counters, which is transferred into the range we want.

The SLR data are used to improve the orbital predictions for the tracked satellites which, in turn, make the satellites easier to track. In other words, the more data we get the better precision of orbit prediction we can calculate. Increasing the firing frequency is a convenient way to increase data, and there are many stations around the world trying to do KHz SLR system. SLR, in essence, is a method of satellite tracking. The key equipment for increasing the firing frequency are the counter and laser source. But now the KHz laser source is available in the world. And here we put the emphasis on the counter. There are two kinds of counters: the Time Interval counter and the Event Timer counter. The interval counter measures the time the laser flight from the station to satellite and back. HP5370 and SR620 are the most popular used interval timers in the global SLR society. The Event Timer records the epochs of signals received by both channel A (start) and B (stop) and puts them into buffer. Then the epochs are matched by range gate prediction. Event Timer calculates intervals with epochs, and in theory, with no rate limits but reading and processing data.

While using Event Timer, sending range gate is the most important technical difficulty, and the match of start and stop signals is also very important. Many stations in the world are adopting Event Timer as counter to advance their systems. PET4 has been used in Wettzell station, which is assembled by Dassualt model; P-PET 2000 begun to work in San Fernando in 2004, and Graz station have already completed KHz system; the KHz system in Herstmonceux is on developing stage, and almost finished. A032-ET developed by Latvia University using EET method also fits for KHz system in theory.

Status In Changchun

There are two interval counters in Changchun station: HP5370B is used routinely and SR620 as a standby. The observation in Changchun is excellent these years and the system is steady. The single shot precision is less than 2cm, and the passes observed every year are more than 4,000. However, the laser fire frequency is not very high: 8Hz for low orbit satellites and 5 Hz or 4Hz for high orbit satellites. We plan to use the Event Timer to increase firing frequency to 10Hz and even higher so as to increase the quantity of data. After analyzing all Event Timers, the A032-ET was chosen for Changchun experiment, and the purpose is to increase the firing frequency for all satellites to 10Hz, and even higher. As an Event Timer, A032-ET is superior to interval counter; some specifications are shown in Table 1.

Table 1: *A032-ET specifications*

Single shot RMS		<10 ps
Dead time		60 ns
Nor-linearity error		< 1 ps
Offset temperature stability		<0.1 ps
FIFO depth		1,200
Measurement rate	Option 1	Up to 10KHz continually
	Option 2	Up to 500Hz cycle repetition rate

Figure 1. *Hardware of A032-ET*

There are two currently available options of the A032-ET, which use the same specialized hardware (Figure 1 shows the hardware of A032-ET) but differ by the software. These options provide alternatively two basic kinds of measurement: The option A032.1 provides continuous (gapless) measurement of events at high (up to 10 KHZ) mean measurement rate. It is well suitable to measure the overlapped time intervals between Start and Stop events that come at the separate inputs (either A or B) of the Event Timer in any order. Specifically this is the case of advanced SLR at KHz repetition rate. The option A032.2 provides cyclical measurement of events that come at the separate inputs of the ET-device in the strict order. Specifically this is the case of conventional SLR where the measured Start-Stop time intervals do not exceed the repetition period of Start events. Considering our purpose, we choose A032.1 option to do the experiment, and the range gate has to be redesigned to fit for the new counter.

Experiment test and real observation on Changchun SLR

Before experiment we redesign the range gate control circuit, and the scheme is represented in Figure 2.

Range gate control circuit is assembled by three circuits, which are designed by the same module. The three circuits generate gate signal circularly and then are imported into an OR gate. Finally, the RG_out is transmitted as the range gate we want.

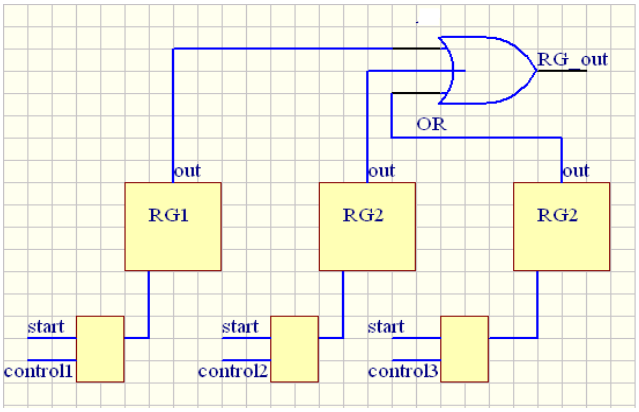
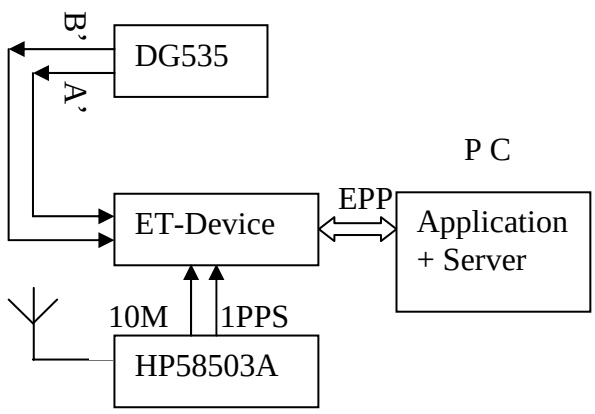


Figure 2. *Range gate control circuit*

Simulation

In this simulation, we use pulse generator DG535 as a signal source. It generates two NIM signals, and the interval was measured by A032-ET. The rate is set to 10Hz for the purpose is increasing the frequency to 10Hz. The interval sent by DG535 is static and the trigger is interior. The hardware connection scheme is shown in Figure 3, and the software flow chart is showed in Figure 4. All through the test, A032-ET worked normally, it measured the interval with the precision of ps under the condition of 10Hz



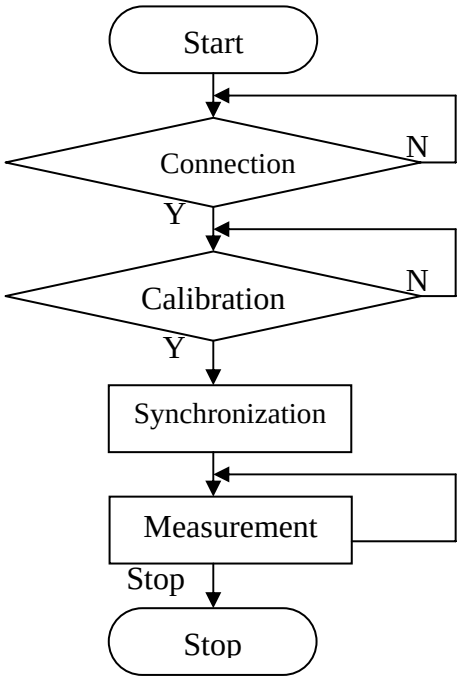


Figure 3. *Simulation scheme*

Figure 4. *Software flow chart*

Range gate measurement

Range gate is measured with A032-ET to find out the matching of start and stop signals. In this experiment, the start pulse is generated by DG535, which is triggered by laser firing, and output of the range gate is used as the stop pulse. Range gate measurement is to simulate observation condition and make some improvement for the software. The main function written in VC++ language is compiled as Dynamic Link Library. The data received by A032-ET is transferred into control software written in VB for

calculating the time interval. The data transferred into VB with the form of an array included time-tags that the events happened in channel A, B. The time-tags are matched well with range gate prediction.

Real Observations

The firing frequency is increased to 10Hz for all satellites and A032-ET is used as a new timer to calculate the time interval instead. The hardware connection scheme is presented in Figure 5. The main pulse is imported into channel A as start signal and the return pulse as stop signal. A032-ET could distinguish only NIM pulses; the 10MHz and 1pps signals are given by GPS HP58503A. Figure 6 shows the time sequence of Changchun SLR system. In the scheme, T1 and T4 is laser fire time, T2 is the epoch time of the main pulse, and T3 is the epoch time of the return pulse.

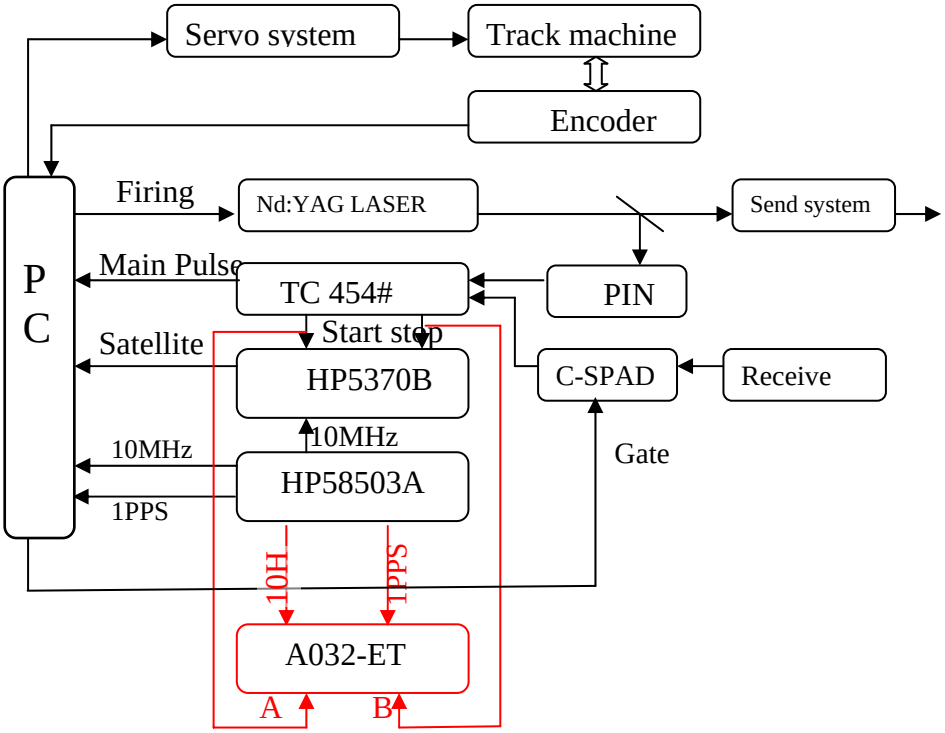


Figure 5. *Hardware connection*

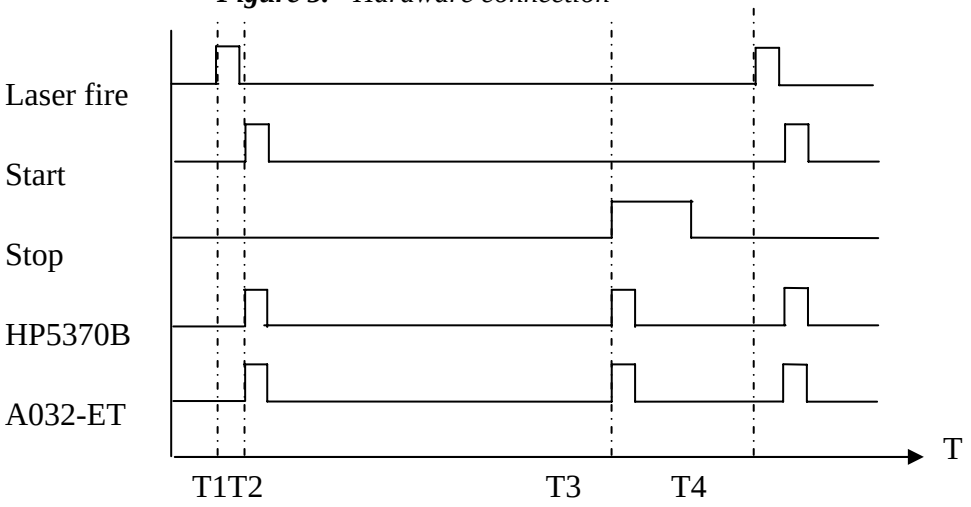


Figure 6. *Time sequence of Changchun SLR system*

Figure 7 shows the Etalon-2 measurement interface. The firing rate is 10Hz. From this picture, the return signal line can be clearly seen. From the satellite observation, we can see that the system works very well with A032-ET under the condition of 10Hz firing frequency. The return signal rate of high orbit satellites is increased.

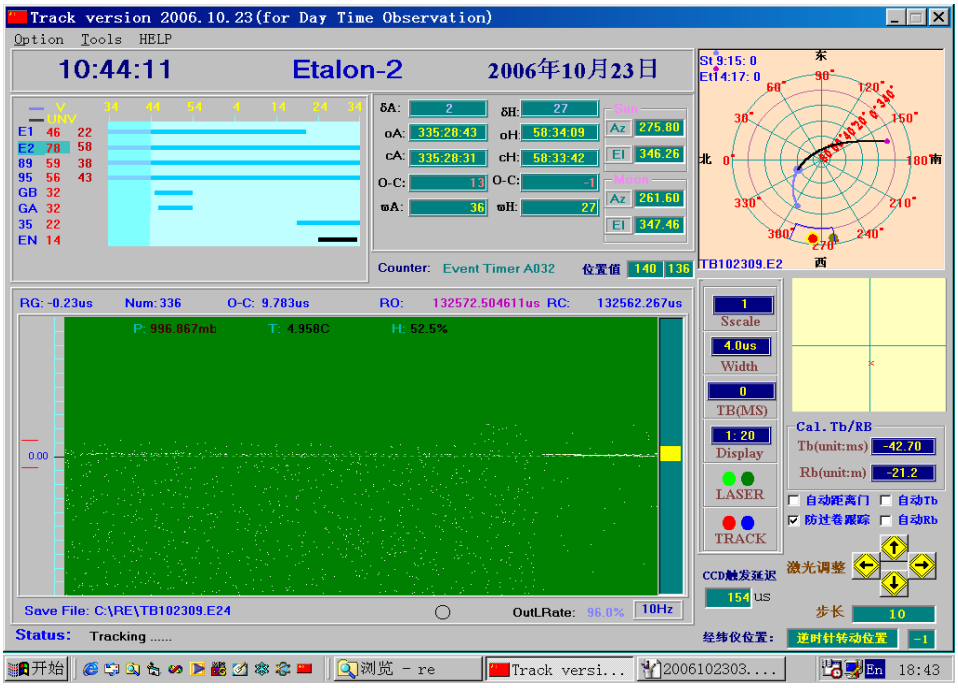


Figure 7. *Etalon-2 measurement interface*

Conclusion

From analysis report such as Toshi's report, we can see A032-ET works well as Event Timer. The precision is 1cm more or less. It could be used in SLR system normally. Because the laser pulse is about 200ps in Changchun station, the precision of the whole system does not increase obviously after the event timer is used. Since Oct.23 of 2006, A032-ET has been used in the satellite laser ranging routinely for the all satellites tracked with the firing frequency of 10Hz in Changchun station. Table 2 shows the data quantity from 2006-10-23 to 2006-12-31. There are too many passes. Now, it works very well and the experiment is very successful. Next, we plan to increase to KHz observation if the laser source is available.

Table 2: *Data of Changchun SLR Station (2006-10-23 to 2006-12-31)*

Site Information		Data Volume			
Column 1	2	3	4	5	6
Location	Station Number	LEO pass Tot	LAGEOS pass Tot	High pass Tot	Total passes
Changchun	7237	1095	153	209	1457

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References

[1] Yu. Artyukh: "Selective Time Interval Counter for SLR Applications", Proc. of 11th International Workshop on Laser Ranging, Deggendort, Germany, 1998.

[2] Yang, F.M.: "Current status and future plans for the Chinese Satellite Laser Ranging Network", Surv. Geophys. 22 (6): 465-471 2001.

[3] P. Gibbs: "Comparisons of a single SR620 timer against a variety of timers from the Eurolas network", Proceedings of 13th International Workshop on Laser Ranging, Washington D.C. 2002.

[4] P. Gibbs: "Inter-comparison of Various Timing Devices Against a Single SR Timer", Proceedings of 13th International Laser Ranging Workshop, Washington D.C., USA. 2002.

[5] Yu. Artyukh, V. Bespal: "A New Line of Timing Systems for Satellite Laser Ranging", Proceeding of the 8th Biennial Electronics Conference, Tallinnl, Estonia, 2002, pp. 239-240.

[6] Yu. Artyukh, V. Bespal: "A010 Family of Time Interval Counter Adapted to SLR Application", Proceedings of the 13th International Laser Ranging Workshop, Washington D.C. 2002.

[7] Liu Chengzhi, Zhao You, Fan Cunbo, etc.: "The Performance of Changchun Satellite Laser Ranging Station", Proceeding of 14th International Laser Ranging Workshop, San Fernando, Spain, 2004, pp. 175-177.

[8] Yu. Artyukh, V. Bespal: "A Version of the A032-ET Event Timer for KHz SLR", Proceedings of KHz SLR Meeting, Graz, Austria, 2004.

[9] C. Selke, F. Koidl, G. Kirchner: "Tests of the Stability and Linearity of the A032ET Event Timer at Graz Station", Proceeding of 14th International Laser Ranging Workshop, San Fernando, Spain, 2004, pp. 337-341.

[10] G. Kirchner, 2004, SLR Graz: The RGG (Range Gate Generator), Proceedings of KHz SLR Meeting, Graz, Austria.

[11] G. Appleby, P. Gibbs: "SGF Herstmonseux: Current Status and Future Upgrades", Proceeding of 14th International Laser Ranging Workshop, San Fernando, Spain, 2004, pp. 213-216.

[12] K. Hamal, I. Prochazka: "Portable Pico Event Timer 2 KHz", Proceeding of 14th International Laser Ranging Workshop, San Fernando, Spain, 2004, pp. 333-335.

[13] G. Kirchner, F. Koidl: "Graz KHz SLR System: Design, Experiences and Results", Proceeding of 14th International Laser Ranging Workshop, San Fernando, Spain, 2004, pp. 501-505.

[14] G. Kirchner: "Riga A032-ET in Graz", ILRS 2005 Workshop, Eastbourne, England, 2005.