Studies on system stability and calibrations of H-SLR station

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Abstract
The paper concerns on the calibration and the system stability of the Satellite Laser Ranging station (SLR) at Helwan. The geometrical setup of the calibration method, applied at the H-SLR station, is explained. The calibration constant produced from the calibration of the system is computed and the results are summarized for two periods using two kinds of Photo multipliers (PMT). The average root mean square values of the calibrations carried out during the period from the year 1991 to the year 2008 are computed. The stability of the H-SLR station are studied for two different years before and after the upgrading. To clarify the precision of the Helwan-SLR station, the results of its calibration are compared with the results of the calibrations of the other SLR-Stations.

1. Introduction and System Configuration

The satellite laser ranging (SLR) is a space geodetic technology, which can measure the distance between a ground station and a satellite most precisely in current methods. The absolute time of flight of photons so that the geometry of satellite and laser station can be determined precisely as long as the system calibration error is controlled in a negligible level, equivalent to the accuracy of 1 cm or less. For this end, brief information about the Helwan SLR station is given. The mount configuration is Azimuth/Elevation with a coude system of mirrors for the transmitted beams as shown in fig. 1. The guiding of the mount is a computer controlled. The receiving system of the mount is a spherical mirror lens of diameter 40 cm, and optical filter of 6 nm with 80 % transmission. The type of the used detector is a Photomultiplier (PMT) manufactured by Hamamatsu model H6533. The quantum efficiency of this PMT is 10 % at 532 nm and of normal gain equal 5.6 million. The mode of the PMT is single photoelectron detection (Cech, M., et.al, 1998).

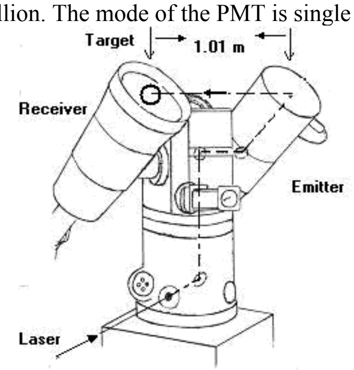
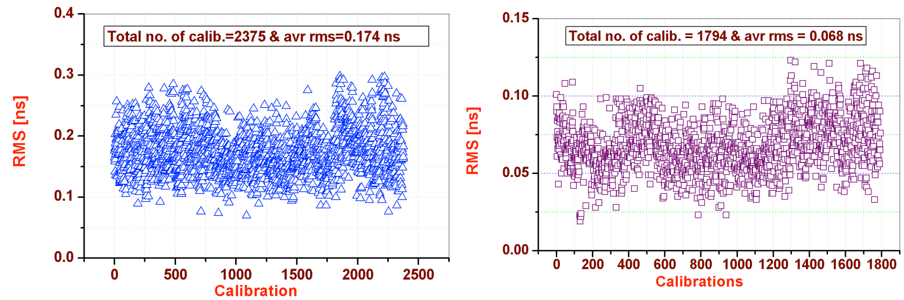


Fig 1.Three coude mirrors inside the mount to guide the laser beam and the fourth mirror is outside the mount for calibration.

The used laser is composed of Nd: YAG oscillator, pulse selector, three amplifiers system and a Second Harmonic Generator (SHG); it produces a semi train of pulses (Jelinkova, J., 1984, Prochazka, I., 1989). The wavelength of the laser pulses is 0.53 μm with pulse width of 20 psec and of repetition rate of nearly 5 Hz with 80 mj in energy. The divergence of the laser beam is adjustable and can reach to 0.1 mill radians. The laser transmitter is placed outside the mount and then the laser beam is directed to the satellite through the mount via a four coude mirrors. The ranging electronics of the system consists of a time interval counter of type a Stanford SR620 of resolution equal 4 psec. The start channel is a special optoswitch and the stop channel discriminator Ortec is a constant fraction (Cech, M., et.al, 1998). The time and frequency system is GPS Time/Frequency standard, manufactured by Helwlett-Packard of model 58503B, which is providing the 1pps epoch signals with accuracy better than 110 ns. The meteorological station (MET-3) is installed to improve temperature, humidity and atmospheric pressure s' measurements. The pressure sensor model is a Digiquartz MET3 and it measures with accuracy of 0.1 mbar. The temperature sensor model is Platinum resistance temperature probe and it measures with accuracy ~ 0.5 deg C. As for the model of the humidity sensor, it is a capacitance probe and its accuracy is 2 % at 25^{o}c. To study the system stability we will carry out calibrations of the station and from the studies we will concern on the measurements of the resulted calibration delays.

2. The calibration method

The Helwan - SLR station is calibrated using internal calibration method. It is accomplished by ranging on a fixed target placed at a distance of 1.01 meter from the laser. A detailed description of the calibration method is shown in Fig 1. For the purpose of the calibration, both the emitter and the receiver are covered. The cover of the emitter has a hole followed by mirror to reflect the beam to the direction of the target. The computation of the calibration constant is the average of nearly 100 returns (echoes) by using the counter SR620, but it was the average of 150 echoes by using the time interval counter of type HP5370B. The first channel is used for processing the signal from the start detector; the second channel is used for discriminating pulses from the PMT. The time delays of both, i.e. the start and stop channel were adjusted to the lowest time jitter. The first results show the mean value of the system calibration is about 85 nsec and time jitter is about 50 psec where the counter HP5370B is used for ranging (Cech, M., et.al, 1998). There are some parameters are affecting the calibration results. By fixing all except the PMT in some cases and the time interval counter in others, it will easy to describe the result. For the purpose of this study, we concerned on the results of the calibration, which is applied to the Helwan SLR-station in two periods. The first period is from Aug. 1991 to Sept. 1997. During that time the photomultiplier (PMT) of type RCA 31034A has been used. Due to the long operating time of that PMT, its sensitivity had been decreased by approximately 3 times (Cech, M., et.al, 1998) .In May, 1998 the receiver package was completely upgraded and the PMT RCA 31034 was replaced by the PMT Hamamatsu H6533 box with PMT tube 4998. It consists of a PMT tube and high voltage (HV) with precise divider. The Tennelec TC 952A high voltage power supply with stable 2500 volts was used as a source for the PMT, to obtain standard parameters. On the other hand, the old pre-amplifiers HP8447A (400 MHz) and HP8447D (1.3 MHz) have been replaced by EG & G Ortec1 GHz pre-amplifier Model 9306. It is a four-stage preamplifier based on Hewlett Packard MMIC chips. Hence, the second period is from May 1998 till December 2008, in which this new PMT are in use.



(a) (b)

Fig. 2. The calibrations vs. the RMS values for all the calibrations carried out using the old PMT in (a) and the new PMT in (b) .

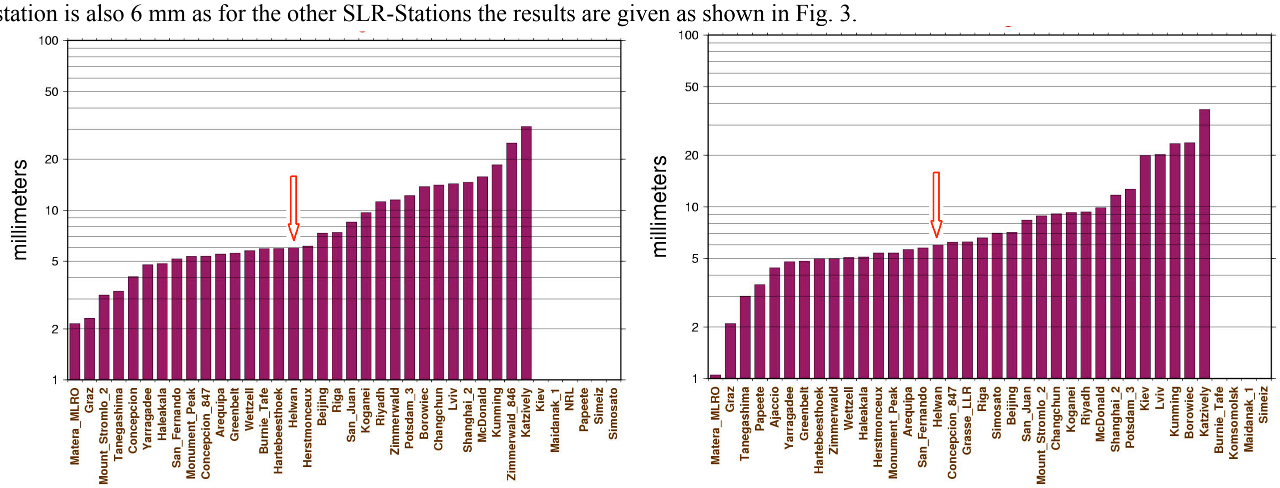
For all the calibrations, the RMS value are computed in which the root mean square value is selected corresponding to rejection criteria of 2 Sigma (Hamal, K., 1978). The calibrations applied to the station within the whole period from 1991 to 2008 are computed and the results are shown in Fig. 2. During the first period, there are 2375 calibrations, have been applied. The RMS values of these calibrations are computed and the results are shown in Fig.2 (a). The average RMS value of the calibrations is found to be 0.174 nsec. Similarly, the results of the calibrations of the system applied during the second period, in which the new PMT package is used, are shown in Fig.2 (b). The total number of calibrations occurred in that period are 1794 and the average precision is found to be 0.068 nsec, which is nearly 2.6 times better than the precision of the calibrations produced by the old PMT. It is also agree with the results produced by reference (Cech, M., et.al, 1998). For comparison purposes, the numbers of calibrations as well as the average root mean square value are computed for each year individually and the results are given in Tab.1.

Tab. 1. The calibrations applied to the station in the period from 1991 to 2008, the average RMS value of the calibration per year is given as well.

Year	Nr. of calibrations	Average RMS
1991	307	0.177
1992	401	0.181
1993	453	0.168
1994	389	0.160
1995	282	0.171
1996	214	0.198
1997	329	0.175
1998	428	0.064
1999	418	0.066
2000	320	0.061
2001	119	0.068
2002	-	-
2003	-	-
2004	120	0.075
2005	226	0.077
2006	55	0.079
2007	77	0.077
2008	31	0.074

In the first period of the Tab.1, it is clear that the worst precision of the calibrations occurred at the year 1996 with RMS value of 0.198 nsec and the best one is during the year 1994 with RMS value of 0.160 nsec. However in the case of the second period, using the new PMT, the worst precision of the calibrations occurred at the year 2006 with RMS value of 0.079 nsec and the best one is at the year 2000 with RMS value of 0.061 nsec. Actually, this reason is not only refer to the PMT but also to other parameters such as the method of measurements of metrological conditions. As it is mentioned in section 2, there is a new instrument for measuring the temperature, humidity and pressure with a high precision, which has not been available in the year 1996. It is also clear from the table that the average RMS value of the years from 1998 to the year 2002 is below 0.07 nsec while from the year 2004 till 2008 the average RMS values are higher than 0.07 nsec.

The precision of the measurements of the Helwan SLR station is compared with the precision of the other SLR stations, and the results are given in Fig. 3(a) for the satellite Starlette in the period from October 1, 2007 through December 31, 2007 (http://ilrs.gsfc.nasa.gov/images/2007_12_cal_rms.html) . It shows that the root mean square value of the calibration measurements is 6 mm as measured for the H-SLR station. As for Fig.3 (b), it shows the results as measured for the satellite Starlette in the same period of 2008 (http://ilrs.gsfc.nasa.gov/images/2008_12_cal_rms.html). It shows that the root mean square value of the calibration of H-SLR station is also 6 mm as for the other SLR-Stations the results are given as shown in Fig. 3.

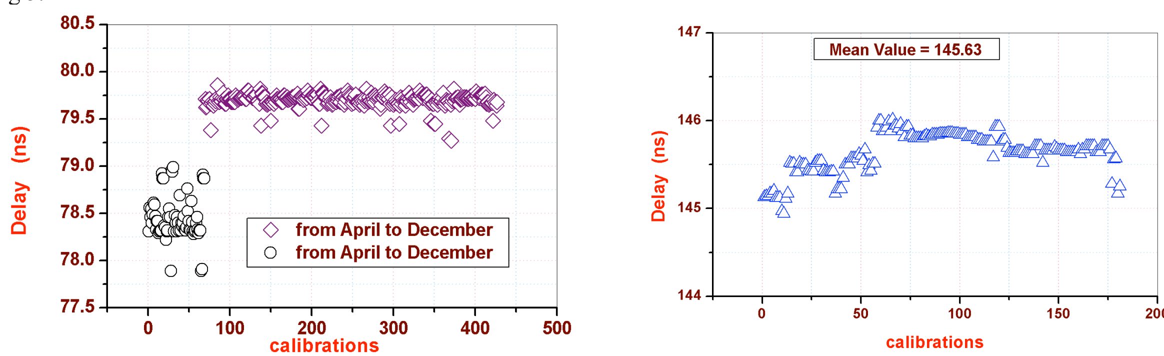


(a) (b)

Fig. 3 The deduced precision of the average single-shot calibration RMS, in millimeters, during the last quarter of 2007 in (a) and during the last quarter of 2008 in (b) .

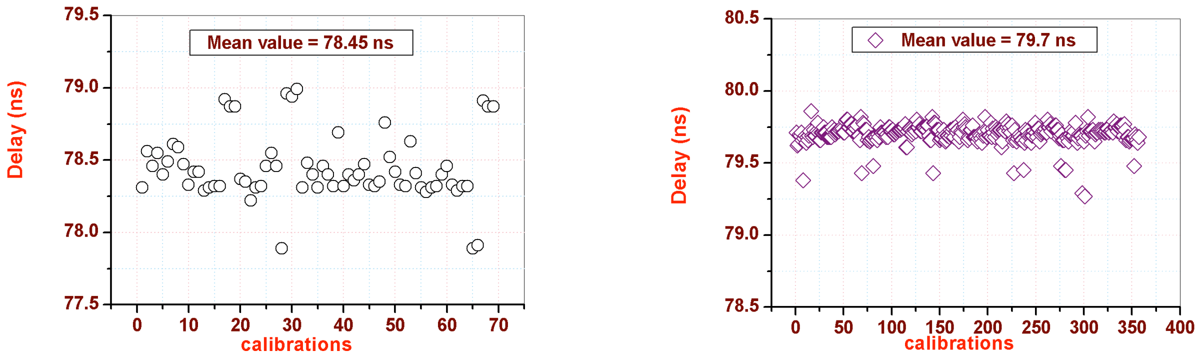
3. Calibration constant and system stability

The calibration constant of the system or the system delay is one of the important parameters, has been carried out before satellites ranging. Changes in calibration value indicate that something has happened and may be bias the range data. The calibration constant has been computed for two different periods (as of the availability of the data), one of them after using the new PMT at the year 2000 and the other by using the old PMT during the year 1996. The results show that, the system delay is much more stable at the year 2000 than that at the year 1996, as shown in fig. 4. However in fig. 4 (a) the data symbol by circles are produced using the old time interval counter of type HP5370B, since the new time interval counter SR620 has not been yet installed at the station. The data obtained by the new interval counter is shown in fig.5 (b). This also proves that the stability of measurements of the system delay obtained using the new time interval counter is better than the measurements of the system delay obtained using the old counter as shown in Fig 5.



(a) (b)

Fig. 4. The calibration constant obtained by calibrating the system during the year 2000 in (a) and 1996 in (b)



(a) (b)

Fig. 5. The system delay produced by using the time interval HP5370B in (a) and SR620 in (b) during the year 2000.

4. Conclusion

The calibrations which have been carried out at the Helwan-SLR station during the period from 1991 to 2008 are studied. There are 4196 calibrations carried out with two kinds of photomultipliers. In the first period from 1991 to 1997, there are 2375 calibrations are carried out using the old PMT. The second period which carried out from May 1998 till 2008 in which the new PMT is in use there are 1794 calibrations are carried out. The average RMS value of the calibration for using the old PMT is found to be 0.174 nsec, while for the new PMT is 0.068 nsec. It means that the calibrations produced using the new PMT package are nearly 2.6 times better than that of the calibrations produced using the old PMT.

It is also clear that the average RMS value of the calibration data obtained through the years from 1998 to the year 2002 is below 0.07 while from the year 2005 till 2008 the average RMS values are higher than 0.07 ns. From the measurements of the system delay, it is found a much more stability at the data obtained after upgrading the system than that of the stability of the data obtained before the upgrading. By the way, the system stability of using the new time interval counter SR620 is better than that of using the old counter HP5370B.

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