Vol. 46 No. 1 Journal of the Communications Research Laboratory March 1999
Printed in Tokyo, Japan pp. 207−211

8.4 COLLOCATION EXPERIMENT ON FOUR ELECTRONICS/OPTICAL PACKAGES FOR THE KSP SLR SYSTEM

By
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ABSTRACT

To demonstrate the accuracy and stability of SLR's ranges to within a few millimeters, we set up the optics for collocation to calibrate four Electronics/Optical (E/O) packages for the Key Stone Project (KSP)and connected to a single telescope at Kashima. A common drift could be removed by applying real time calibration and we demonstrated a stability of 1.5mm rms. The mini-collocation experiment using four E/O packages and three ground targets ensured the inconsistency between geodetic survey and the system delay by the order of within ± 3mm and detected a possible error of 1mm in the local survey.
Keywords: Collocation, SLR, Accuracy, Range bias, Survey

1. Introduction

The Key Stone Project (KSP) system monitors the crustal movements at station in Tokyo Metropolitan area through measuring their displacements by a combination of space geodetic techniques, VLBI (Very Long Baseline Interferometer) and SLR (Satellite Laser Ranging)(1). The SLR system was installed in 1996 and test observation started at Kashima in February 1997. The SLR system includes the dome building in which the telescope is set and trailer box housing laser and electronics(2).

Before delivery to the four KSP sites, we conducted the collocation experiments with four trailer boxes (Electronics/Optical (E/O) packages) during in July, 1997 to verify the ranging accuracy at a millimeter level. This paper describes the method of calibration, configuration of the experiment and results of range stability through simultaneous observation to multiple ground targets by four E/O packages. Figure 1 shows the picture of KSP Kashima site, where SLR dome building surrounded by four E/O packages and VLBI antenna are located.

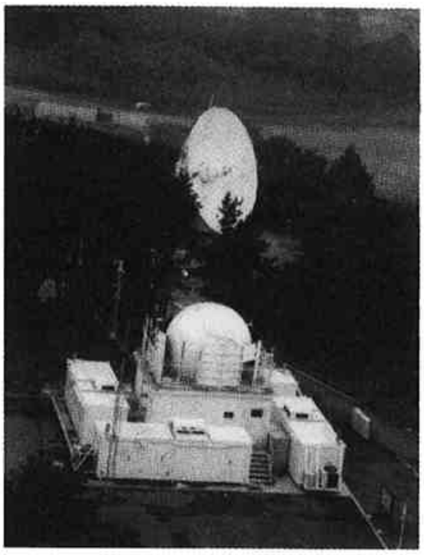

Fig. 1 The view of the Kashima station (The SLR dome building surrounded by four Electronics/Optical are seen. The VLBI antenna behind the SLR dome is also seen.)

2. Method of Calibration used in the Experiment

Among space geodetic techniques, the SLR has unique capability of measuring the absolute distance to the target. However, the accuracy is affected by many factors(2). One of the most directive factor is a system delay that often causes range bias. The instability of range bias will affect the solution of coordinates of the station and will be mixed not only with a long term tectonic change but also with a short term site displacement.

The system delay is defined by the sum of the elapsed time (or equivalent to the distance for the laser pulse to travel in the time) both for the laser pulse from a start detector to the telescope reference point and for the returned pulse (from a target) passing again the reference point to a stop detector. The telescope reference point which is invariant when a telescope is pointing to any direction, is defined on an intersection of azimuth and elevation axes. The system delay is normally evaluated both by SLR's range to a ground target and by the distance from the telescope reference point to the target which have been accurately measured by a geodetic survey. Since KSP SLR systems were installed, local surveys have been periodically conducted and reported(3).

The difference between the laser ranging value and the survey value is applied to the satellite ranging measurements.

2.1 Real time calibration

If a retroreflecor is put on a telescope aperture so that the laser pulse is returned simultaneously with that from a target outside, the system delay variation in a short term can be evaluated. Figure 2 shows the concept of the real time calibration.

2.2 Mini-collocation

To evaluate stability of the system delay and to

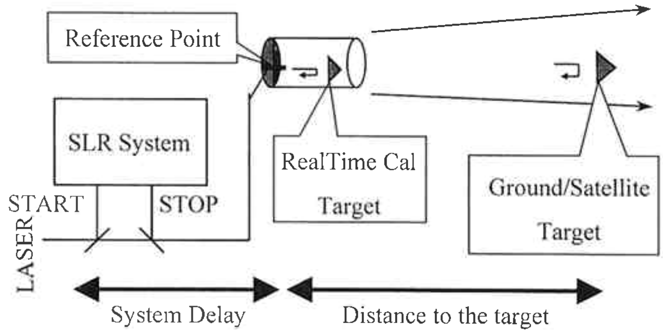

Fig. 2 The concept of the real time calibration.

validate the consistency between survey and SLR results, a test ranging to multiple ground targets which are distributed uniformly in azimuth are conducted. Figure 3 illustrates the concept of mini-collocation in case of using four E/O packages and three ground targets. The system delay of each package is the solved-for-parameter and is assumed to be stable during the experiment. If two or more targets are put in vertically, the vertical component of the telescope reference point will be estimated[4].

3. The Configuration of the Collocation System

Figure 4 illustrates the optics design for collocation of four E/O packages (T2, T3, T4 and T5) in order to use the common telescope located at Kashima. The ground targets used are called the East, West and South long pillar. It sends the laser light from the T2 to the telescope through Coude path and divides the receiving light to all the four packages. The mirror in front of each E/O package acts as a beam splitter whose reflection efficiency is set at 33, 50, 75 and 100%, respectively by dielectric coating. From the E/O package, T2, a common start pulse signal is distributed to other E/O packages.

Each receiving system is composed of an silicon SPAD (Single Phone Avalanche Diode), an epoch timing system, a GPS receiver, and signal distributor.

4. The Result of Ranging to the Ground Targets

Figure 5 shows the ground ranging result to the East target for four hours. Each point is calculated by the mean of 15 seconds. The return rate was set 15% or less by neutral density filters to ensure the signal strength was at a single photoelectron level so that any bias was not produced by amplitude correction. The stability of range for each package was shown to be within 2-3mm rms. However, the small but common drift was seen in the plots.

We applied the real time calibration to one of the package. Figure 6 shows an example of ground ranging data which is improved by 1 mm in about 12 minutes. It means that the common effect between on the target for real time calibration and the target outside was cancelled out. It is suggested that the small common effect cycled at about every 10 minutes is due to the variation of laser pulse shape or other effects caused by air-conditioning cycle. The stability of range after applying real time calibration achieves 1.5mm rms.

Figure 7 shows the result of mini-collocation in which the estimated system delay (deviated from the grand mean) , placed by order of each E/O package number and each target name (East, West and South). Considering that the deviation of system delays from the mean is systematic, the ground survey results up to 1mm accuracy is in question and is to be re-examined.

5. Conclusion

We have demonstrated the accuracy of range and its stability of all KSP SLR E/O packages by applying multiple calibration techniques. During the experiment period, we tried to get simultaneous returns of the four packages

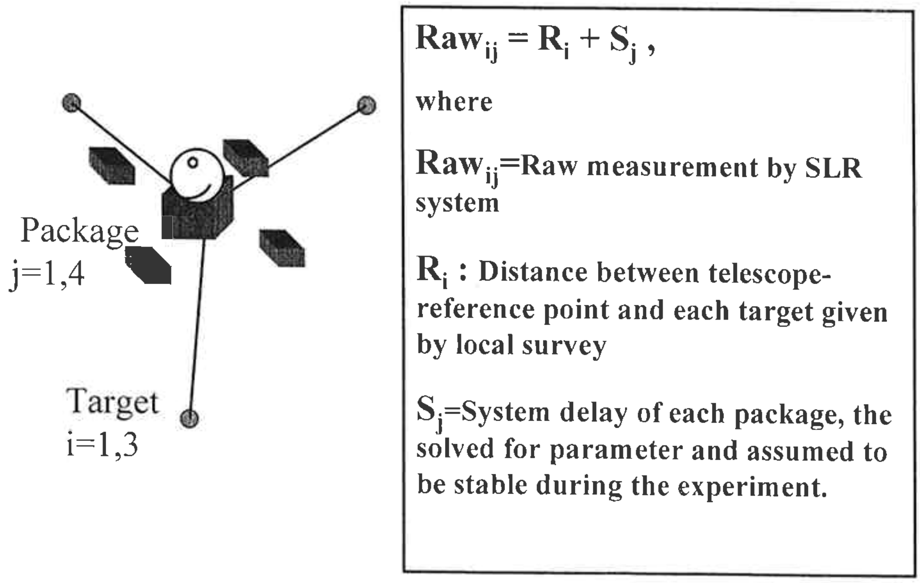

Fig. 3 The schematic diagram of mini-collocation in case of three targets and four SLR E/O packages.

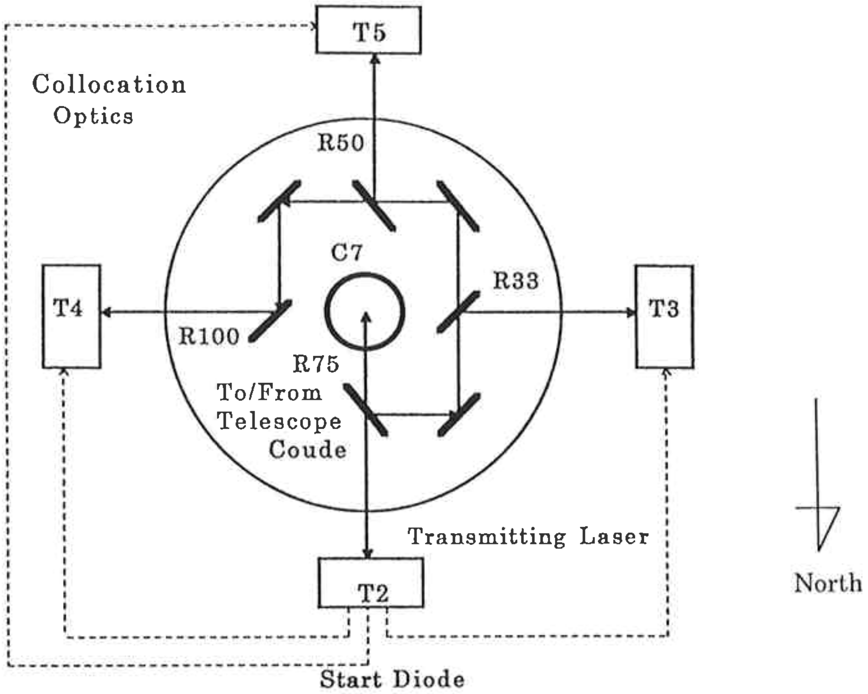

Fig. 4 The design of optics for collocation of four E/O packages at Kashima. (The number in R# # means reflective efficiency of the beam splitter)

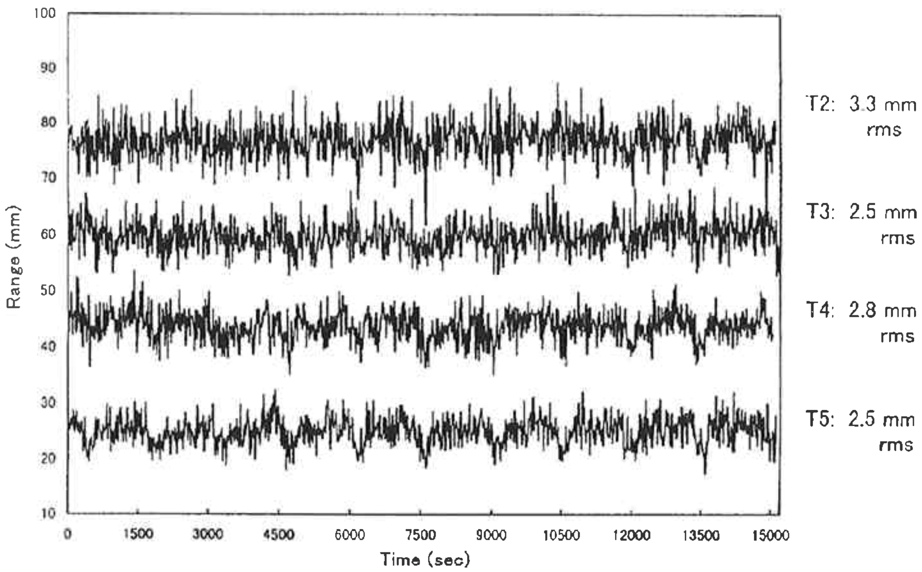

Fig. 5 Ranges simultaneously measured by each E/O package (T2-T5) to the East target for 4 hours. (Data was taken at 50Hz, in a single photoelectron level and averaged in every 15 seconds)

from the satellite, but not enough data ware obtained because of the bad weather. Although demonstration was for ground targets, it was proved to be sensitive to the precision of 1mm.

Acknowledgement

In conducting E/O packages collocation at Kashima, we would like to thank the staff of the contractors, Hitachi Co. ltd. and Electro Optic Systems Pty Limited (EOS), namely Mr. Koushou Aikawa, Toshihide Oyama and Mr. John Guilfoyle for their professional efforts in a tight schedule.

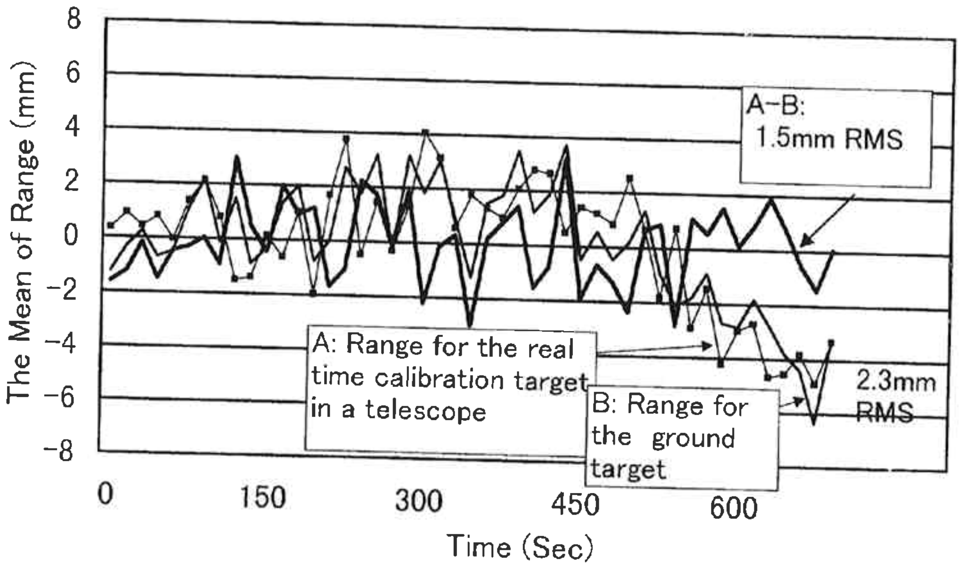

Fig. 6 The example of the application of real time calibration to the ground target in 12 minutes.

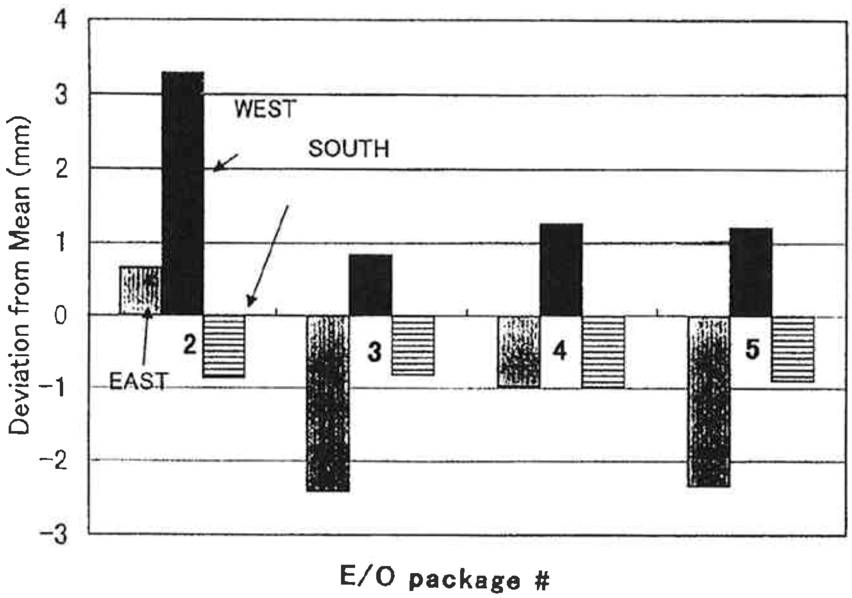

Fig. 7 Mini-collocation : the consistency of survey and system delay, August, 1997 placed by order of E/O package number (T2, T3, T4 and T5) and ground target name (East, West and South).

References

(1) Y. Yoshino, "2. Overview of the Key Stone Project", J. Comm. Res. Lab., **46**, 1, pp.3-6, March 1999.

(2) H. Kunimori, "4.1 Design Concept of the KSP SLR System", J. Comm. Res. Lab., **46**, 1, pp.97-102, March 1999.

(3) S. Xia, H. Tamura, H. Hasegawa, J. Ooizumi, J. Amagai and H. Kikukawa, "Local Tie at the Key Stone Sites", International workshop on Geodetic Measurements by the collocation of Space Techniques on Earth (GEMSTONE), Tokyo, Jan. 1999 (in press).

(4) F. Katsuo, T. Otsubo, J. Amagai, and H. Nojiri, "4.8 A concept of monitoring the telescope reference point by using multiple ground targets", J. Comm. Res. Lab., **46**, 1, pp.135-140, March 1999.

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