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DETERMINATION OF THE DIFFERENTIAL TIME CORRECTION BETWEEN GPS TIME RECEIVERS LOCATED AT THE COMMUNICATIONS RESEARCH LABORATORY AND THE OBSERVATOIRE DE PARIS

by

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Abstract

We report here the results of a comparison of GPS time receivers organized by the Communications Research Laboratory of Tokyo with the support of the Bureau International des Poids et Mesures. The comparison of the receivers located at the Communications Research Laboratory (CRL) and the Paris Observatory (OP) was effected by means of a portable GPS Sony time receiver. The large uncertainty of this comparison, due to systematic effects in the portable receiver, provided only a rough check of the accuracy of GPS time transfer between the two laboratories.

Resumé

La méthode de comparaison des horloges en utilisant les satellites du GPS observés en vues simultanées peut, à ce jour, atteindre une exactitude de quelques nanosecondes. Un mauvais étalonnage des récepteurs du temps du GPS constitue l'un des facteurs limitant cette exactitude. La méthode qui permet le mieux d'éliminer les erreurs d'étalonnage consiste à comparer des récepteurs distants par transport d'un récepteur portable. Nous rapportons ici les résultats d'une telle campagne d'étalonnage organisée par le Communications Research Laboratory de Tokyo avec l'aide du BIPM. La comparaison des récepteurs situés au Communications Research Laboratory (CRL) et à l'Observatoire de Paris (OP) a été effectuée à l'aide d'un récepteur de temps portable Sony. Cette comparaison, affectée d'une large incertitude due à des variations systématiques du récepteur portable, ne permet qu'une verification approchée de l'exactitude des comparaisons horaires par GPS entre ces deux laboratoires.

INTRODUCTION

The method of clock comparison using GPS satellites in common view can now reach an accuracy of a few nanoseconds. Wrong calibration of GPS time receivers is one of the limiting factors to this accuracy. The method which best permits removal of calibration errors is the comparison of remote receivers by transfer of a portable receiver from one location to another.

We report here the results of a comparison of GPS time receivers organized by the Communications Research Laboratory of Tokyo with the support of the Bureau International des Poids et Mesures. The comparison of the receivers located at the Communications Research Laboratory (CRL) and the Paris Observatory (OP) was effected by means of a portable GPS Sony time receiver. The large uncertainty of this comparison, due to systematic effects in the portable receiver, provided only a rough check of the accuracy of GPS time transfer between the two laboratories.

The present comparison was realized following the method described in the BIPM report 91/6 [1].

RECEIVER CHARACTERISTICS

All three receivers involved in this exercise are single-channel, C/A code receivers. Their principal characteristics are:

Portable receiver:	Maker: Sony, Type: GTT 3000, Ser. No: 861004, Adopted receiver internal delay + antenna cable delay: 99 ns,
CRL:	Maker: Allen Osborne Associates, Type: NBS/TTR5A, Receiver Ser. No: 184, Ser. No of antenna and downconverter: 185, Adopted receiver internal delay + antenna cable delay: 155 ns,
OP:	Maker: Allen Osborne Associates, Type: NBS/TTR5, Receiver Ser. No: 051, Ser. No of antenna and downconverter: 019, Antenna cable length: 34 m (delay 168 ns), Adopted receiver internal delay: 50 ns.

The NBS type receivers downconvert the L1 frequency (1575,42 MHz) at the antenna level to 75 MHz and the Sony receiver to 63,42 MHz. For NBS type receivers, the models used to estimate ionospheric and tropospheric delays are known: for the Sony receiver they have not been communicated by the manufacturer.

The NBS receiver uses a trigger level of 0,5 V, but the Sony receiver trigger level is unknown to the user. This can produce an unknown differential delay depending on the rise time of the local time-reference pulses.

CONDITIONS OF COMPARISON

The portable equipment consisted of the receiver, its antenna and a calibrated antenna cable. The laboratories visited supplied a) a 5 MHz reference signal, b) a series of 1 s pulses from the local reference, UTC(lab), via a cable of known delay. In each laboratory the portable receiver was connected to the same clock as the local receiver and the antenna of the portable receiver was placed close to the local antenna (less than 5 meters away). The differential coordinates of the antenna phase centres were known at each site with uncertainties of a few centimetres.

During the comparison at the Communications Research Laboratory, before the visit to Paris, the receivers were programmed for the period February 4-8 with 11 tracks of the *BIPM Common-View International Schedule No 18* for East Asia , which includes only Block I satellites, and for the period February 9-13 with 28 tracks of the Block I and Block II satellites from the same schedule. During the comparison at the Paris Observatory, the receivers were programmed with the *BIPM Common-View International Schedule No 18* for Europe, of 37 tracks, which included Block I and Block II satellites.

During this exercise the Block II satellites were subjected to Selective Availability (SA), so strict common views were required. All common views retained for the comparison fulfilled the following conditions: 0 s common-view tolerance, 780 s minimum duration of the track, 11° minimum elevation angles for satellites. From 5 to 36 common views were available for the comparison at each site.

Comparisons at short distances allow cancellation of a number of errors. If the software of the involved receivers are identical, no error should arise from satellite broadcast ephemerides, antenna coordinates or imperfect modelling of the ionosphere and troposphere. During this comparison these conditions may not be fulfilled as we do not have information on the Sony receiver software.

Just after the comparison of receivers at the CRL, the AOA TTR5A receiver failed so it was impossible to carry out a repeat comparison with the portable Sony receiver after its return to Japan.

RESULTS

The time differences $dt(i)_{loc.rec.}$ obtained at each laboratory for each track i are defined as:

$$dt(i)_{loc.rec.}=[UTC(lab)\text{-}GPS\ time(i)]_{Sony}-[UTC(lab)\text{-}GPS\ time(i)]_{loc.rec.}$$

They are analysed by the computation of modified Allan variances. As illustrated for the comparison at the CRL during the period February 8 - 13, 1992 in the figure below, the values $dt(i)_{loc.rec.}$ are affected by white phase noise up to an averaging interval of one day.

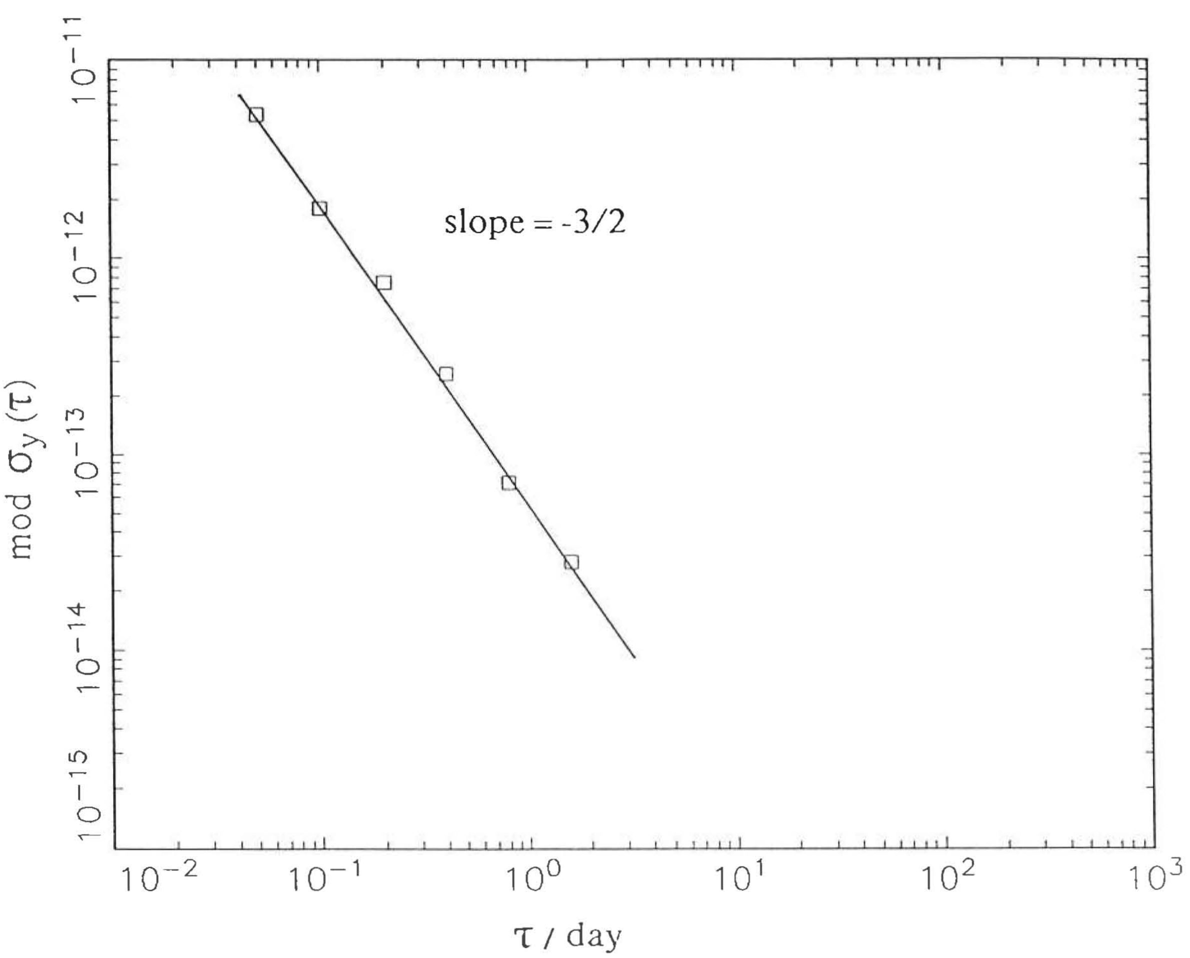

Figure 1. Square root of the modified Allan variance of the differences $dt(i)_{NBS184}=[UTC(CRL)\text{-}GPS\ time(i)]_{Sony} - [UTC(CRL)\text{-}GPS\ time(i)]_{NBS184}$ for the period February 8-13, 1992.

This justifies computation of a mean offset for one-day periods and of the standard deviation of the mean as an expression of confidence of the mean. It should be noted that the standard deviation of the mean reflects only the physical conditions during the one-day period of the comparison and gives no indication of the day-to-day reproducibility of the measurements.

The daily results of the comparisons are as follows:

Lab	Date 1992	Number of individual common views	Mean offset /ns	Standard deviation of individual common view /ns	Standard deviation of the mean /ns
CRL	Feb. 4	5	3,60	13,63	6,10
	Feb. 5	9	-2,78	6,87	2,29
	Feb. 6	9	-1,89	6,19	2,06
	Feb. 7	10	-6,70	7,94	2,51
	Feb. 8	9	-1,22	13,02	4,34
	Feb. 9	21	-1,10	6,10	1,33
	Feb. 10	16	4,44	7,18	1,80
	Feb. 11	23	3,35	6,78	1,41
	Feb. 12	19	2,58	6,59	1,51
	Feb. 13	23	-5,35	6,46	1,35
OP	March 4	21	2,67	8,01	1,75
	March 5	36	2,56	8,19	1,36
	March 6	31	0,74	5,79	1,04
	March 7	33	1,67	7,35	1,28
	March 8	15	-0,93	6,57	1,70

These offsets exhibit an unusually large discrepancy, up to 11 ns at the CRL and 3,5 ns at the OP. Usually during differential calibrations of GPS time receivers daily means are consistent to within 2 ns [1]. Figure 2 shows a strong relation between external temperature and the results of the comparison of receivers at the Paris Observatory.

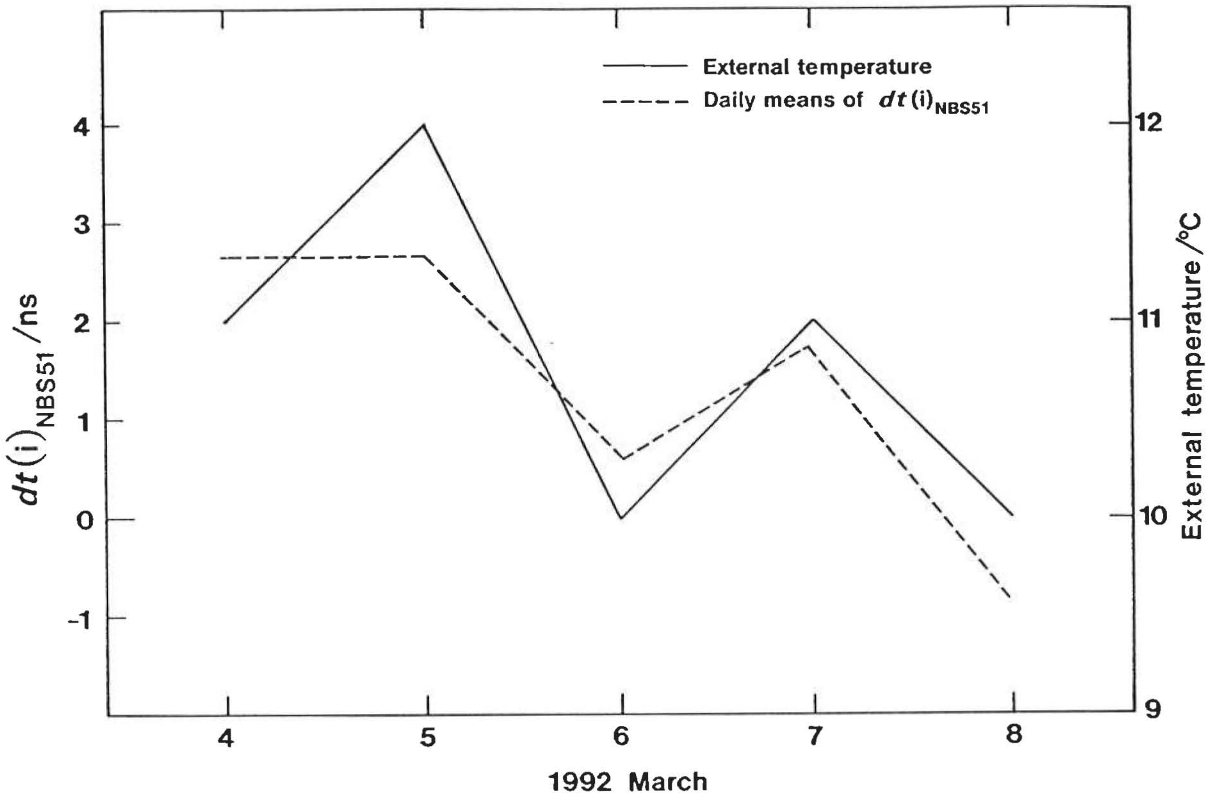

Figure 2. Relationship between $dt(i)_{NBS51}$ and external temperature at Paris Observatory.

As early experiments show that NBS type receivers are not sensitive to temperature [2], we suspect that the Sony receiver may be temperature sensitive.

We have computed the means of the daily values of the comparisons of the portable receiver with the local receivers for the whole period of comparison at each location. The corresponding uncertainties cannot be estimated through computation of the standard deviations of the means because these daily values show systematic effects. We adopt the root mean square of the residuals to the average as an estimation of the confidence of the mean.

Lab	Period 1992	Total number of common views	Mean offset /ns	Estimated uncertainty /ns
CRL	February 4-13	144	-0,5	5,0
OP	March 4-8	136	1,3	2,0

The practical purpose of comparisons of this type is to estimate a differential correction which may be added to the GPS comparisons of the time scales kept by the laboratories concerned. Observed systematic effects during this comparison do not allow us to provide a definitive differential time correction for the receivers at the CRL and the OP. Also, the unknown trigger level of the Sony receiver does not allow us to estimate a possible additional differential delay. We are able however to give a rough estimation of this differential correction for the period of comparison. We stress that a seasonal effect could give rise to a very different correction for an other period of the year.

UTC(i)-UTC(j)	Differential time correction /ns	Estimated uncertainty for the period of comparison /ns
UTC(CRL)-UTC(OP)	-2	5

CONCLUSION

The results of the determination of differential time correction between the GPS time receivers located at the CRL and the OP provide a rough check of the accuracy of time transfer between the two laboratories. The large uncertainty of the present comparison, due to systematic effects in the portable Sony receiver, calls for another comparison using a more stable receiver.

This kind of comparison should, in any case, be repeated from time to time in order to check the ageing of the local receivers. Environmental conditions such as temperature, humidity and multipath reflections also require investigation.

Acknowledgements

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References

[1] W. Lewandowski, "Determination of differential time correction between the GPS time receivers located at the Observatoire de la Côte d'Azur and the Technical University of Graz," *BIPM Report 91/6, November 1991.*

[2] W. Lewandowski and R. Tourde, "Sensitivity to the External Temperature of some GPS Time Receivers," *Proc. 22nd Annual Precise Time and Time Interval Applications and Planning Meeting,* 307-316.