TESTING MOTOROLA ONCORE GPS RECEIVER AND TEMPERATURE-STABILIZED ANTENNAS FOR TIME METROLOGY

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Abstract

With GPS now fully operational, the market for GPS navigation receivers is booming and one can purchase a multichannel GPS pocket-sized receiver for only a few hundred dollars. One of them, the Motorola Oncore eight-channel one-frequency receiver, is of special interest for timing because it provides a 1 pps output. Preliminary results of tests with the BIPM international GPS common-view schedule are given in this paper.

One identified source of instability in GPS time receiver hardware is a dependence on external temperature. This is typically of about 0.2 ns/°C and can approach 2 ns/°C for some types of receivers. In this paper it is shown that this problem can be resolved by enclosing antennas in temperature-stabilized ovens. Results are reported for Motorola and TTR6 Allen Osborne antennas.

INTRODUCTION

This paper treats two distinct topics. The first is a test of the low-cost Motorola Oncore GPS receiver for the use in time metrology. The second is a test of temperature-controlled antennas. However, the two tests were conducted together, as for a period the classic GPS time receiver, which served to test the Motorola, had its antenna covered by an oven with stabilized temperature, and for another period the Motorola antenna was covered by an oven. For this reason the paper, initially scheduled to report only on the use of the Motorola receiver, was extended to the second topic.

MOTOROLA RECEIVER

In the time-metrology community the GPS time receivers most commonly used are C/A code, one-channel, one-frequency devices. They were developed in the early 1980s and their high price, about twenty thousand dollars, has not changed. But with GPS now fully operational, the market for GPS navigation receivers is booming and one can purchase a multichannel GPS pocket-sized receiver for a few hundred dollars. One such receiver, the Motorola Oncore eight-channel one-frequency receiver, is of special interest for timing because it provides a 1 pps output.

At the Observatoire de Besançon (OB) and the Bureau International des Poids et Mesures (BIPM) tests were made with Motorola Oncore receivers connected to local HP5071A cesium clocks with an external time intervallometer and a microcomputer. The setups at the two laboratories are shown in Figures 1 and 2.

At Observatoire de Besançon the first series of tests were carried out using two co-located XT Oncore receivers. The objective of the tests was to verify that a low-cost device of this kind could be used for the synchronization of the Auger Observatory, a cosmic ray project designed to observe ultrahigh energy particles. The time offset between the 1 pps signal from the receiver and the corresponding signal from a HP5071A cesium clock was measured. Data were acquired every second (the Auger application requires this) for each receiver. No schedule was used for this series of tests. Sessions were performed using the highest satellite in view. Scanning of the constellation was repeated every 10 minutes. Figure 3 shows the differences between two receivers at 1-second intervals over 1 hour. The data show a standard deviation of about 7 ns. This plot is typical of what was observed during sessions of up to 4 days.

At the BIPM the test of a VP Oncore receiver was carried out under conditions as close as possible to those which obtain during GPS common-view clock comparisons for the generation of International Atomic Time (TAI). The 1-second observations of the VP Oncore receiver were statistically treated following a standard procedure[1] using tracks which have a duration of 13 minutes. However, all corrections added to the pseudorange measurements were provided by the VP Oncore receiver software. It is not yet known if this software uses standard formulae and constants. This will be checked in coming tests and, most probably, software which includes standards for time metrology will be developed. All one-channel "classical" time receivers, AOA TTR5, AOA TTR6, and Sercel, participating in this test, and one of the eight channels of the VP Oncore receiver was programmed with BIPM international GPS common-view schedule No. 27. Differential antenna coordinates of those receivers are known with an uncertainty of a few centimeters.

Having 13-minute tracks in standard format for the VP Oncore receiver allowed on-site comparison in common view (0 km baseline) with "classical" GPS time-transfer receivers. Differences between the VP Oncore and the TTR5 and the standard deviation of individual "common view" are shown on Figure 4. For reference, a comparison of two "classical" GPS time receivers, TTR5 and Sercel, is reported on Figure 5. The performance of the VP Oncore receiver is not quite so good, the difference, perhaps, being due to the use of nonstandard software. The noise exhibited by the time series of Figures 4 and 5 was analyzed by the use of a modified Allan variance. Both exhibit white phase noise up to an averaging interval of about 12 days (Figures 6 and 7).

To examine the possibility of a correlation with external temperature, daily averages of the differences between the receivers were computed. On Figure 8 we report results on the comparison of the VP Oncore receiver with the TTR5 and a comparison of the TTR5 and the TTR6. No significant difference between two pairs of comparisons can be observed except during the first period, when the antenna of the TTR6 was protected by a temperature-stabilized oven. This is explained in more detail below. No improvement of the VP Oncore results was observed when its antenna was enclosed in an oven.

TEMPERATURE-STABILIZED ANTENNAS

During last decade the performance of GPS common-view time transfer has improved by one order of magnitude through the use of high-accuracy ground-antenna coordinates, postprocessed precise ephemerides, and double-frequency ionospheric measurements. In good cases the uncertainty of this time transfer can approach 2 ns, but further progress is limited by the performance of the receiver hardware. One identified source of instability is a dependence on external temperature.[2] This is typically about 0.2 ns/°C and can approach 2 ns/°C for some types of receivers. This maximum value results in a diurnal effect of about 20 ns and a seasonal effect of several tens of nanoseconds.

The sensitivity to external temperature suggests an effect linked to the parts of time equipment located in the open air, that is, to the antenna and its cable. The receiver itself is usually located in an air-conditioned room. For several years different hypotheses were considered to explain the temperature dependence of timing equipment. All linked the problem to the electronics of the antenna, but none were verified by experiment.

As no practical way was found to resolve the problem electronically, another approach was suggested: the antenna should be protected by an oven with a stabilized temperature. Such ovens are easy and cheap to construct, and are within the capabilities of any time laboratory. Detailed descriptions of the ovens built at the BIPM are shown in Figures 9 and 10. The temperature of the oven used at the BIPM was set at 38°C. This is the highest temperature recorded at Sèvres, which implies that only heating is required: cooling systems are much more complicated. Initial observations show that temperature stabilization of the antenna assembly reduces or even eliminates the diurnal delay variation. It is thought that the observed stabilization results from control of the temperature of the filters and amplifiers rather than of the antenna element itself. The results are reported on Figures 8, 11, and 12.

Although at the time of completion of this study a second oven had been constructed, only the first was used for the results covered here. Comparisons of two receivers with two protected antennas will be reported in a future study.

CONCLUSIONS

1) Tests of the GPS Motorola Oncore receiver reported in this paper demonstrate the metrological quality of this device and confirm the results of earlier work.[3] Further effort is necessary to improve the operation of this receiver, mainly the application of standard procedures.

2) Preliminary results show that the use of temperature-stabilized enclosures for GPS time receiver antenna electronics reduce daily hardware delay variations. Further investigations are necessary.

REFERENCES

[1] D.W. Allan, and C. Thomas 1994, *"Technical directives for standardization of GPS time receiver software,"* **Metrologia, 31,** pp. 67-79.

[2] W. Lewandowski, and R. Tourde 1991, *"Sensitivity to the external temperature of some GPS time receivers,"* Proceedings of the 22nd Annual Precise Time and Time Interval (PTTI) Meeting, 4-6 December 1990, Vienna, Virginia, USA (NASA CP-3116), pp. 307-316.

[3] R.P. Giffard, L.S. Cutler, J.A. Kusters, M. Miranian, and D.W. Allan 1996, "*Continuous, multi-channel, common-view, L1-GPS time-comparison over a 4,000 km baseline,*" Proceedings of the 1996 IEEE International Frequency Control Symposium, 5-7 June 1996, Honolulu, Hawaii, USA, pp. 1198-1205.

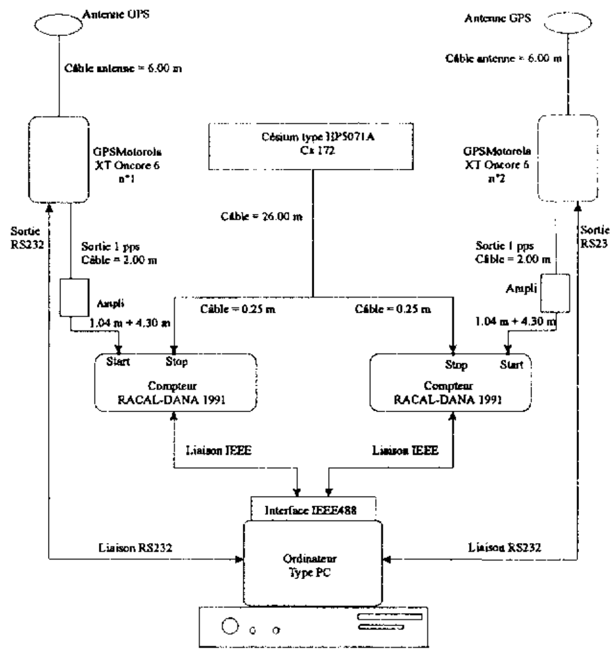

Figure 1. Experimental set-up at the Observatoire de Besançon.

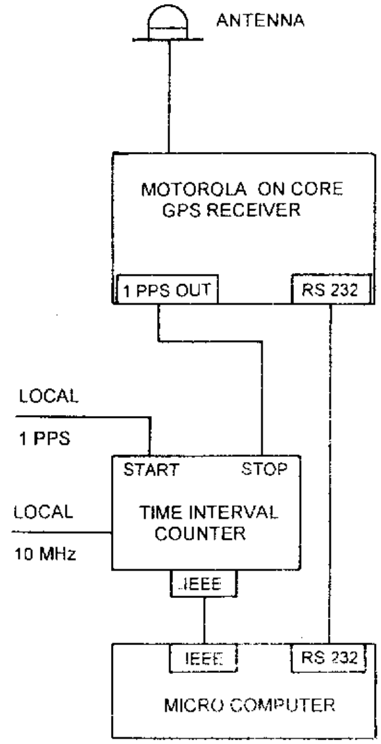

Figure 2. Experimental set-up at the BIPM.

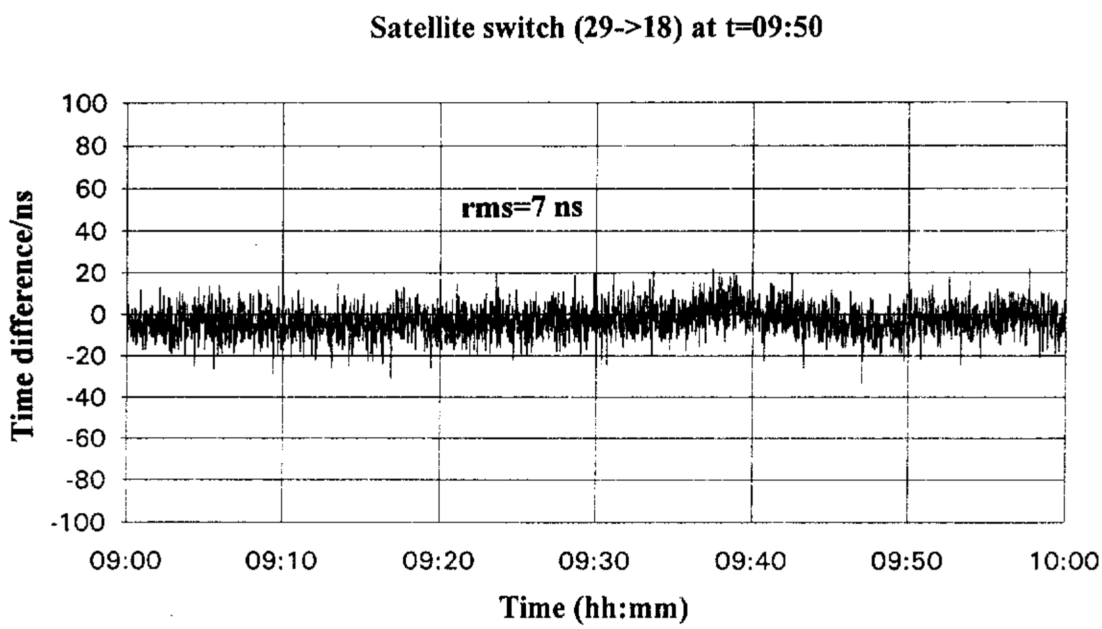

Figure 3. [*OB HP5071A - GPS time*]$_{\text{XT ONCORE No 1}}$ - [*OB HP5071A - GPS time*]$_{\text{XT ONCORE No 2}}$ every second over 1 hour.

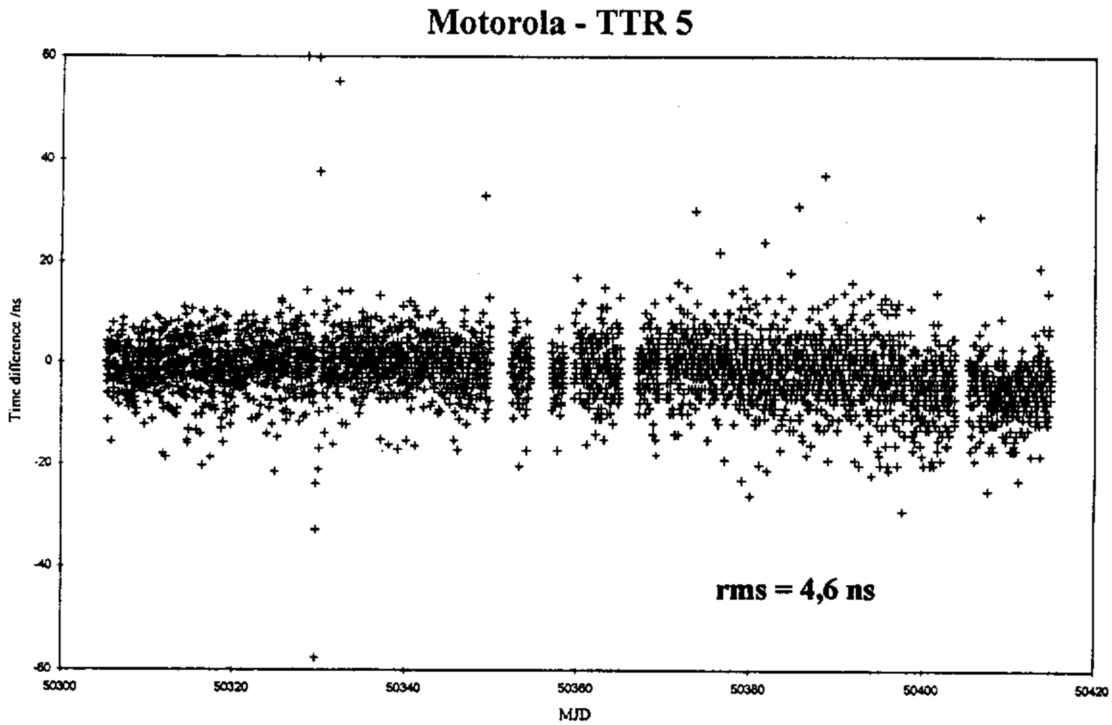

Figure 4. [*BIPM HP5071A - GPS time*]$_{\mathrm{VP\ ONCORE}}$ - [*BIPM HP5071A - GPS time*]$_{\mathrm{TTR5}}$ for individual 13-minute tracks and corresponding standard deviation.

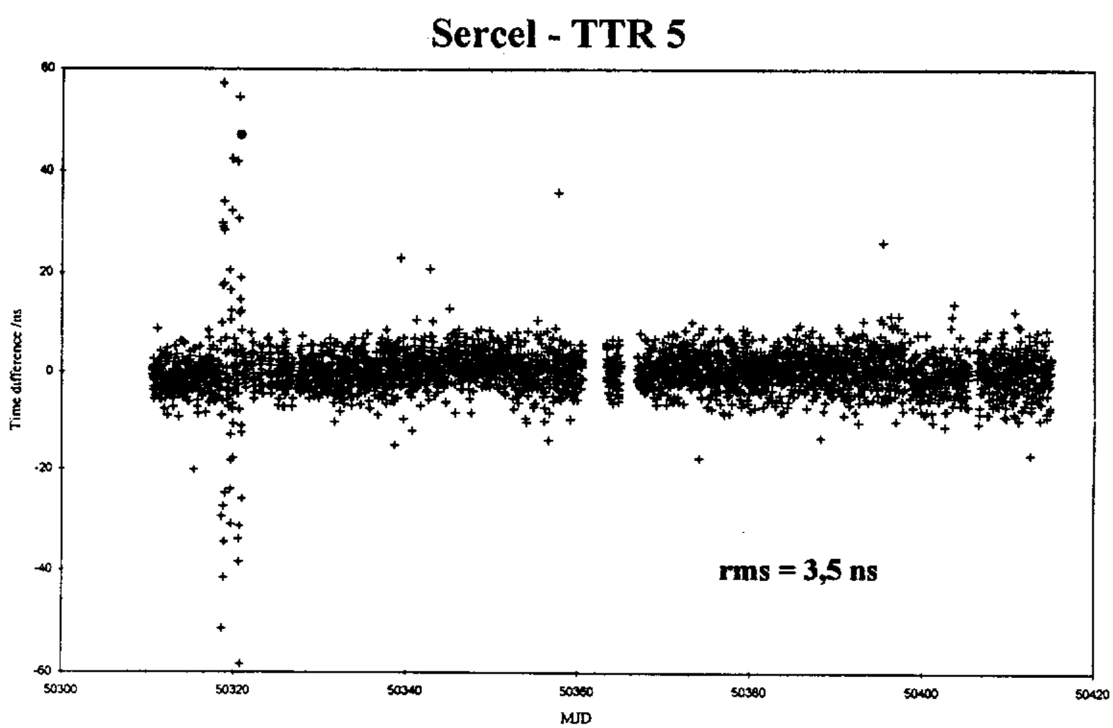

Figure 5. [*BIPM HP5071A - GPS time*]$_{\mathrm{SERCEL}}$ - [*BIPM HP5071A - GPS time*]$_{\mathrm{TTR5}}$ for individual 13-minute tracks and corresponding standard deviation.

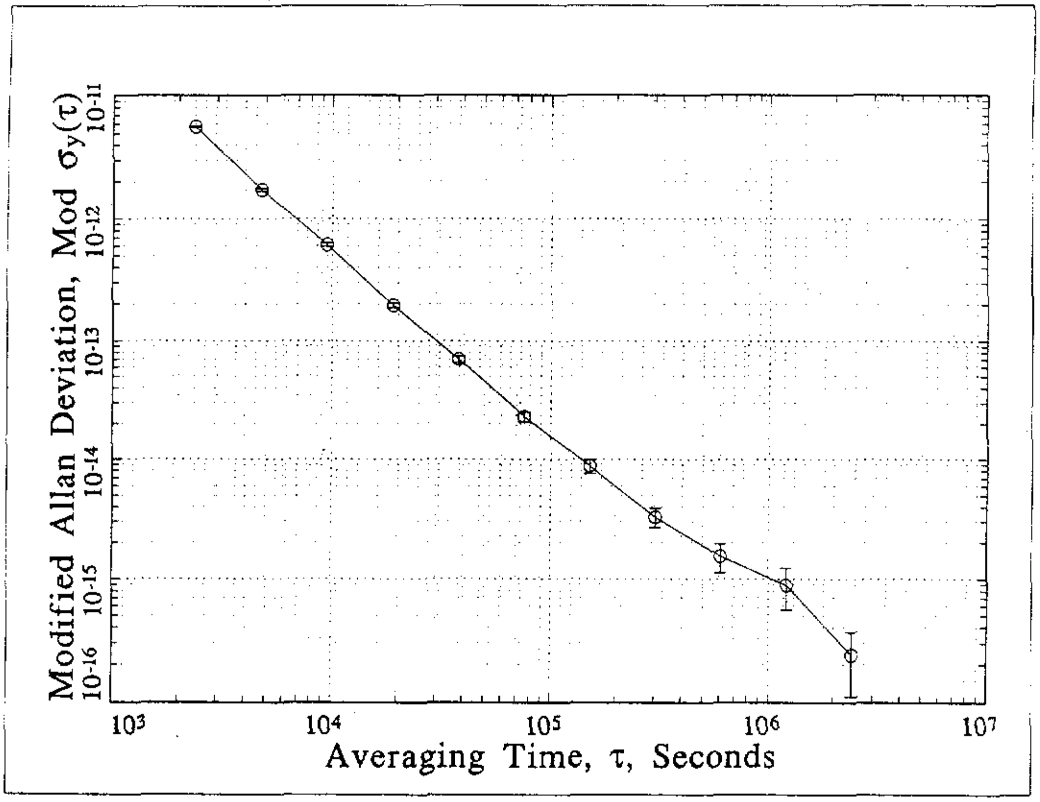

Figure 6. Square root of the modified Allan variance of the time series [*BIPM HP5071A-GPS time*]$_{VP\ ONCORE}$-[*BIPM HP5071A - GPS time*]$_{TTR5}$ reported on Figure 4.

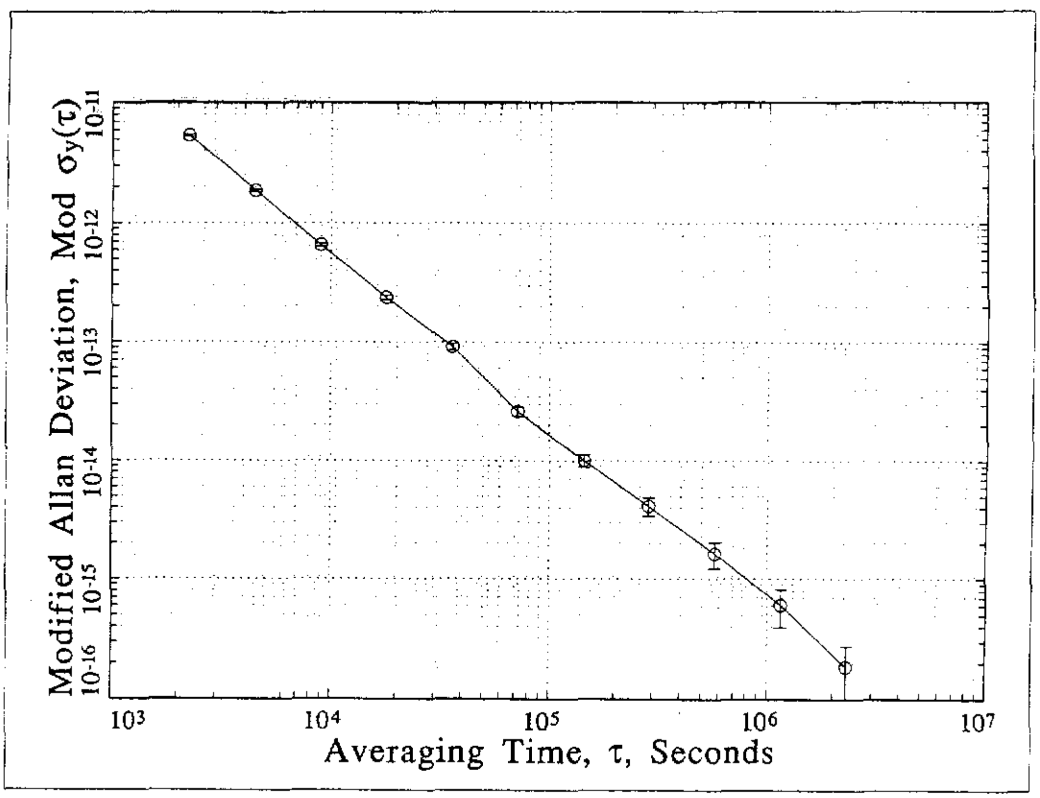

Figure 7. Square root of the modified Allan variance of the time series [*BIPM HP5071A - GPS time*]$_{SERCEL}$ - [*BIPM HP5071A - GPS time*]$_{TTR5}$ reported on Figure 5.

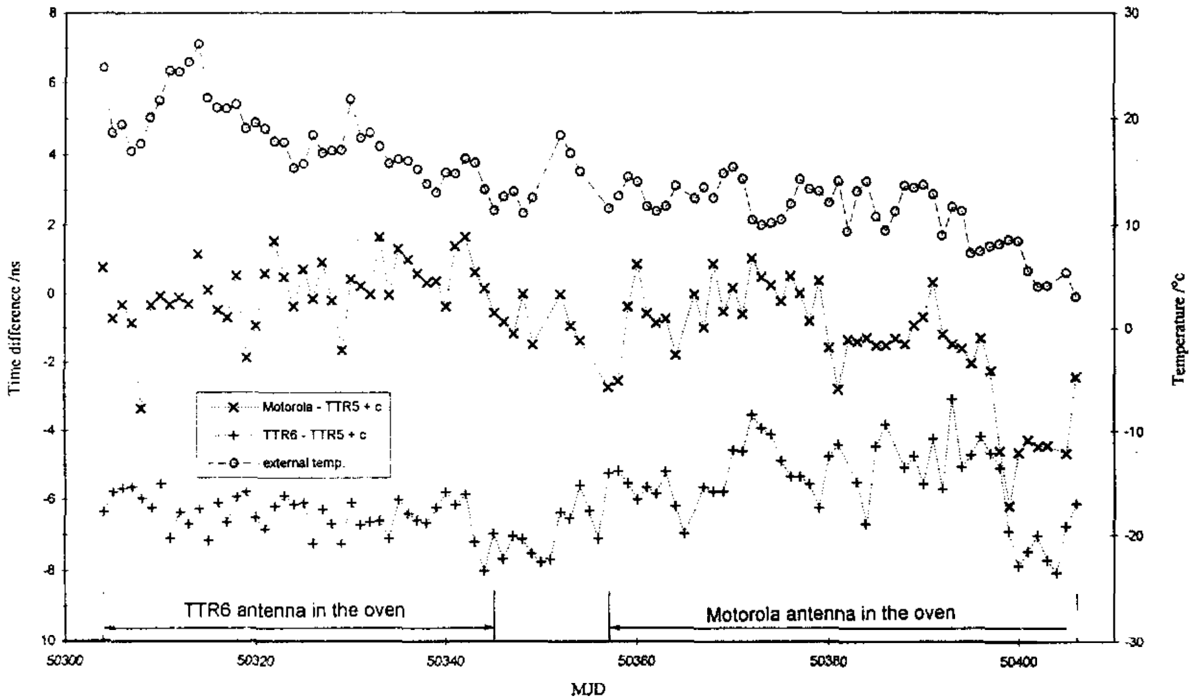

Figure 8. Daily averages of external temperature and daily averages of [*BIPM HP5071A-GPS time*]$_{VP\ ONCORE}$-[*BIPM HP5071A-GPS time*]$_{TTR5}$ and [*BIPM HP5071A-GPS time*]$_{TTR6}$ - [*BIPM HP5071A-GPS time*]$_{TTR5}$.

Figure 9. GPS and GLONASS antennas at the BIPM. Two GPS antennas are covered by ovens.

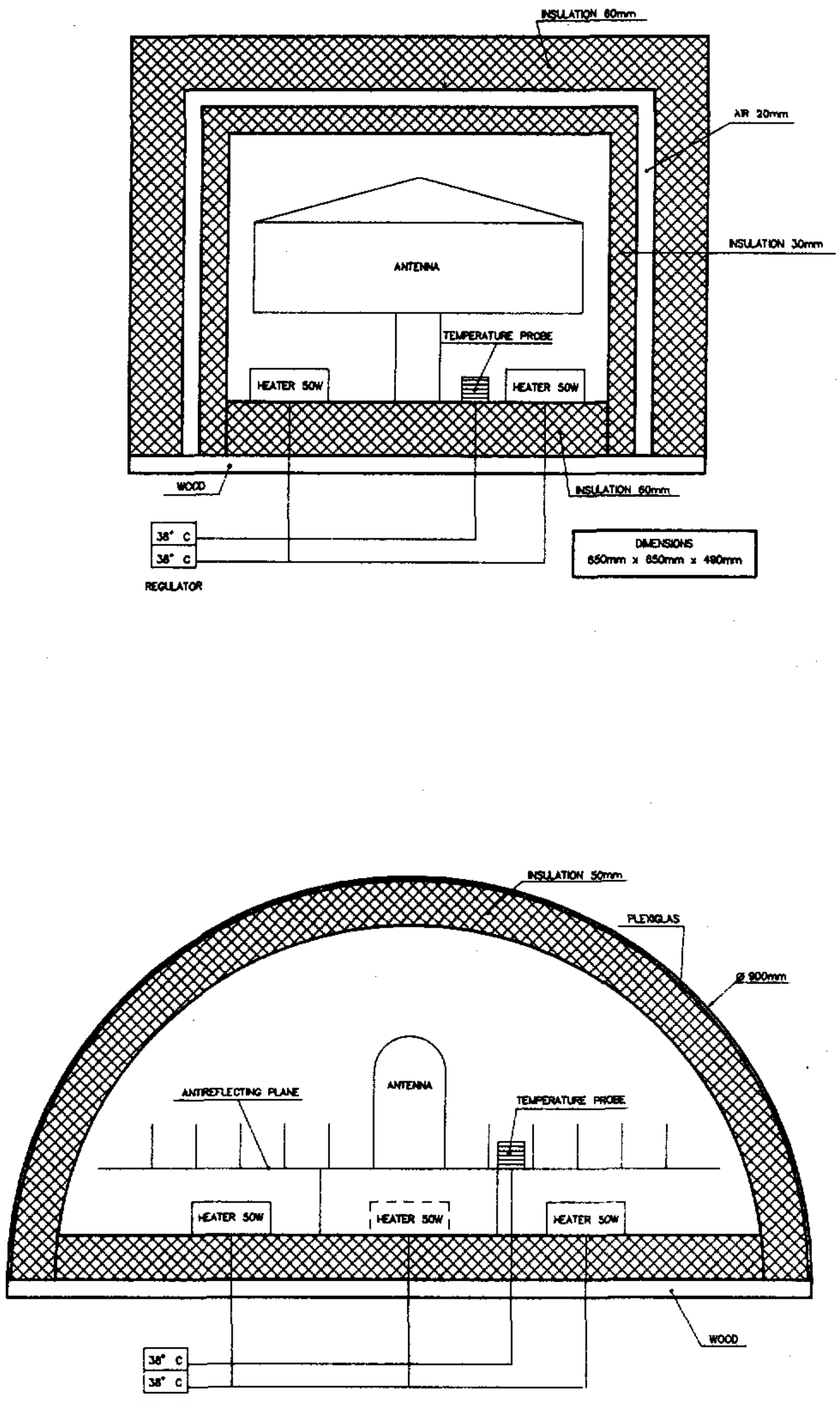

Figure 10. Two ovens built at the BIPM.

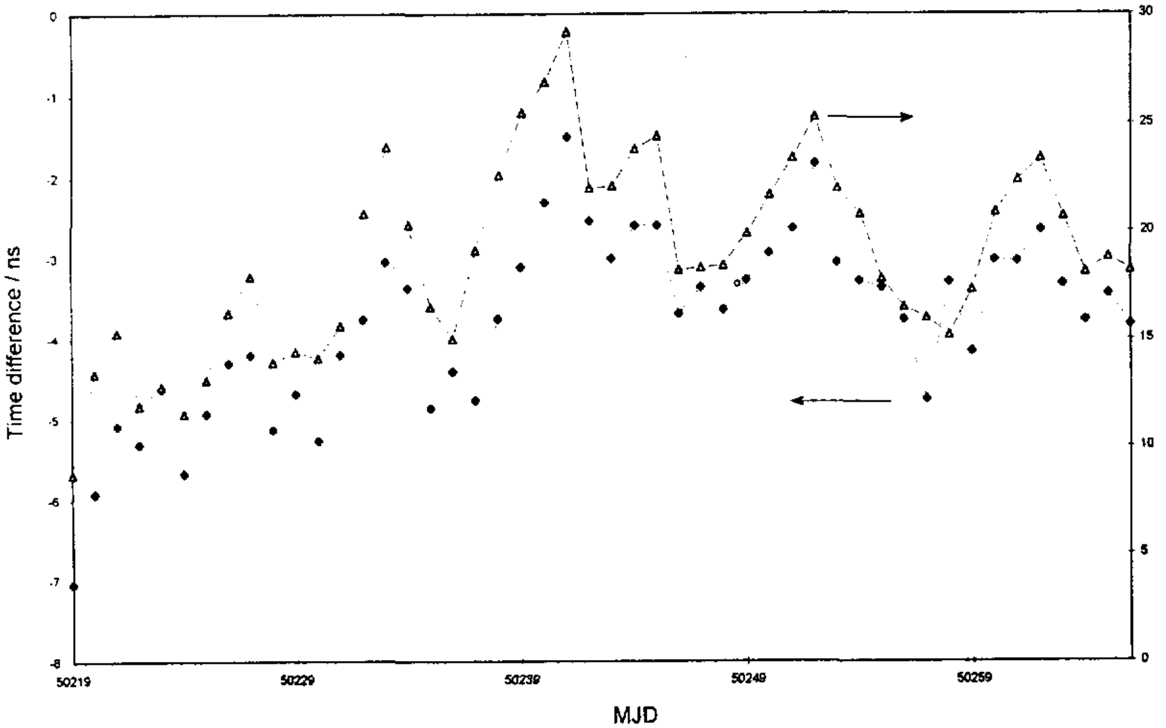

Figure 11. Daily averages of [*BIPM HP5071A - GPS time*]$_{TTR5}$ - [*BIPM HP5071A - GPS time*]$_{TTR6}$, with TTR5 and TTR6 antenna no-protected by the oven, and daily average temperature at BIPM.

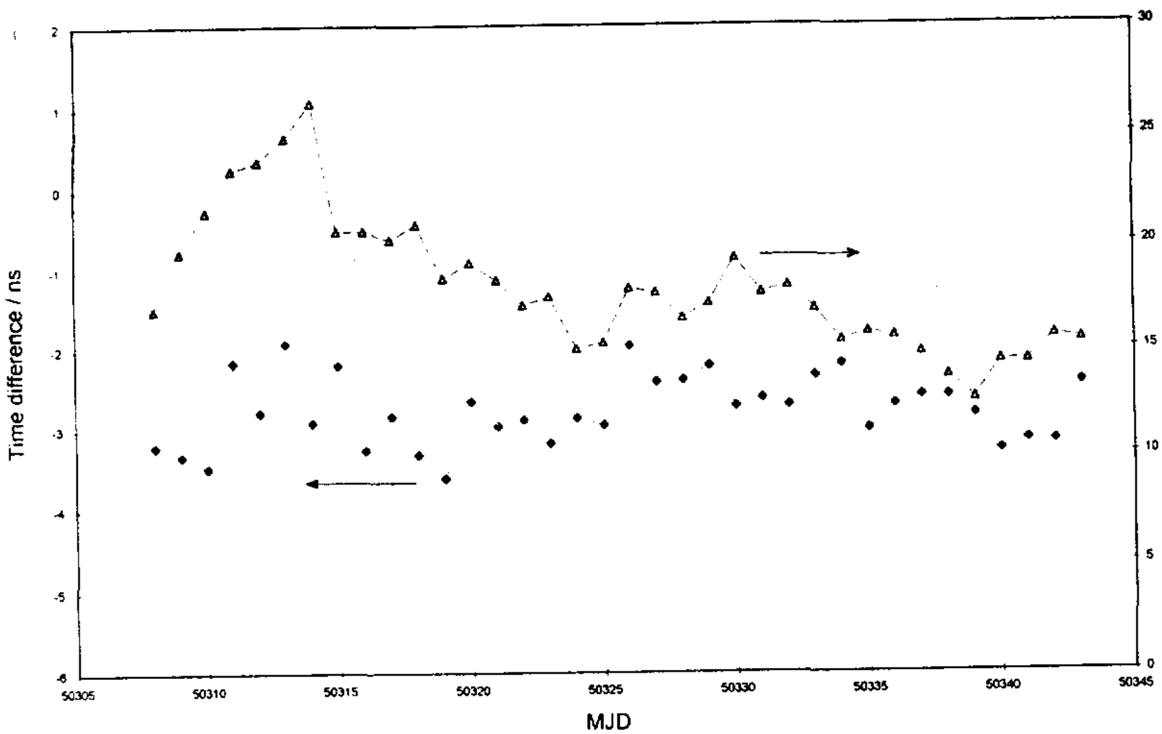

Figure 12. Daily averages of [*BIPM HP5071A - GPS time*]$_{TTR5}$ - [*BIPM HP5071A - GPS time*]$_{TTR6}$, with TTR6 antenna protected by the oven, and daily average temperature at BIPM.