TIME TRANSFER WITH GPS MULTI-CHANNEL MOTOROLA ONCORE RECEIVER USING CCDS STANDARDS

J. Nawrocki*, W. Lewandowski**, J. Azoubib**

*Astrogeodynamical Observatory, Space Research Center, Polish Academy of Sciences, Borowiec, Poland
**Bureau International des Poids et Mesures, Sèvres, France

Abstract

Most of the standard receivers used for the common-view time transfer are of the single-channel, single-frequency, Coarse/Acquisition code type. They all are built according to the "NBS standard" prototype from the early 1980's. The uncertainty of the common-view time comparisons varies between 2-3 ns RMS for the best of them. The new generation of the unexpensive, multi-channel C/A code receivers which are now available seems to make the old standard obsolete.

One of the interesting new solutions, proposed for the time transfer, is the 8-channel Motorola VP Oncore receiver combined with a time-interval counter and a microcomputer (Gifford et al., 1996), (Lewandowski et al., 1996).

Such a measurement system was tested for several months at the Time Section of the Bureau International des Poids et Mesures (BIPM) in Sèvres, yelding very interesting results (Lewandowski et al., 1997).

To maintain the compatibility with the old "NBS type" receivers, still in use at the majority of time laboratories, and to make use of the Motorola multi-channel capabilities, special software driving the receiver and the counter was developed at BIPM in 1997.

The results of tests in time transfer between BIPM in Sèvres and AOS in Borowiec (Astrogeodynamical Observatory in Borowiec, Poland) at the baseline of about 1200 km give the uncertainty of results in the range of 1-2 ns RMS when applying recommendations of CCDS (Allan, Thomas, 1993).

Introduction

The common-view method of GPS time transfer is one of the most precise and accurate methods for time comparison between remote clocks. The main aim of the method, proposed at the beginning of the '80s (Allan, Weiss, 1980) was to increase the accuracy of the comparisons into the range of a few nanoseconds. The method became especially important after the implementation of SA (selective availability). The observations of the same GPS satellite are carried on simultaneously at different laboratories according to the schedule published, usually twice a year, by the BIPM. Up to now, the common-view method is applied for single-frequency receivers which enable observation of up to 48 satellite passes per day.

New, inexpensive, multichannel receivers, enable observation of several satellites simultaneously. Motorola VP Oncore is especially interesting among them, because of the information available through the RS-232 communication port of the receiver. It is possible to relate the Motorola's 1 pps pulse with nanosecond accuracy to the internal time scale of the receiver. Full observed satellite information (raw satellite dispatch) and raw pseudorange measurements are also available.
It is possible to prepare the receiver independently of time comparisons, where all the computations are carried according to rules recommended by the CCDS (Comité Consultatif pour la Définition de la Seconde (Rapport BIPM-93/6). The essential advantage of such observations is the compatibility with old, single-channel, NBS-type receivers, still in use at the majority of time laboratories.

Setup of the equipment

The organization of the measurements is very similar to the setup applied at BIPM and Besançon in the experiment carried out in 1996 (Lewandowski et al., 1997). The Stanford SR-620 time-interval counter (Fig. 1) is started by the 1 pps pulse from the local UTC clock driven by the Oscilloquartz EUDICS 3020 cesium frequency standard. The counter is stopped by the 1 pps pulse from the Motorola Oncore VP receiver, working in the GPS synchronization mode. Both the counter and the receiver are controlled by the software installed on a PC computer. COM1 port is used for the communication with the counter: for sending commands and for gathering the readings 1PPS(local clock) - 1PPS(receiver). Serial COM2 port is used for the communication with Motorola. Set up of the experiment at BIPM in Sèvres is almost identical, the only difference is that Racal-Dana counter is controlled using HPIB interface instead of a serial one. The Racal-Dana counter is driven by the 5MHz frequency signal from HP5071Acesium time and frequency standard, also generating a laboratory 1pps pulse.

Software driving the measurements

The block diagram of the applied software is presented in Fig. 2. During the startup procedure the Motorola Oncore VP receiver is set up in the position-hold mode, with antenna coordinates known with cm accuracy in the ITRF reference frame. The 1pps signal output is formed by the internal GPS time scale of the receiver.
The reception of the measurement 1PPS(local clock)-1PPS(receiver) from the counter triggers the gathering of the following data from the Motorola:

- pseudoranges for each of the observed satellites,
- corrections connecting internal software GPS time scale of the receiver to its 1pps pulse.

Every 6 seconds the orbital data of the observed satellites (raw satellite frames) are also received. Satellite clock parameters, Keplerian elements of the orbit, and their reference time are decoded. The basic condition for the proper functioning of the software was to tie the internal time scale of the receiver to that generated by the receiver 1pps pulse. The work-out of the data during the pass is done exactly

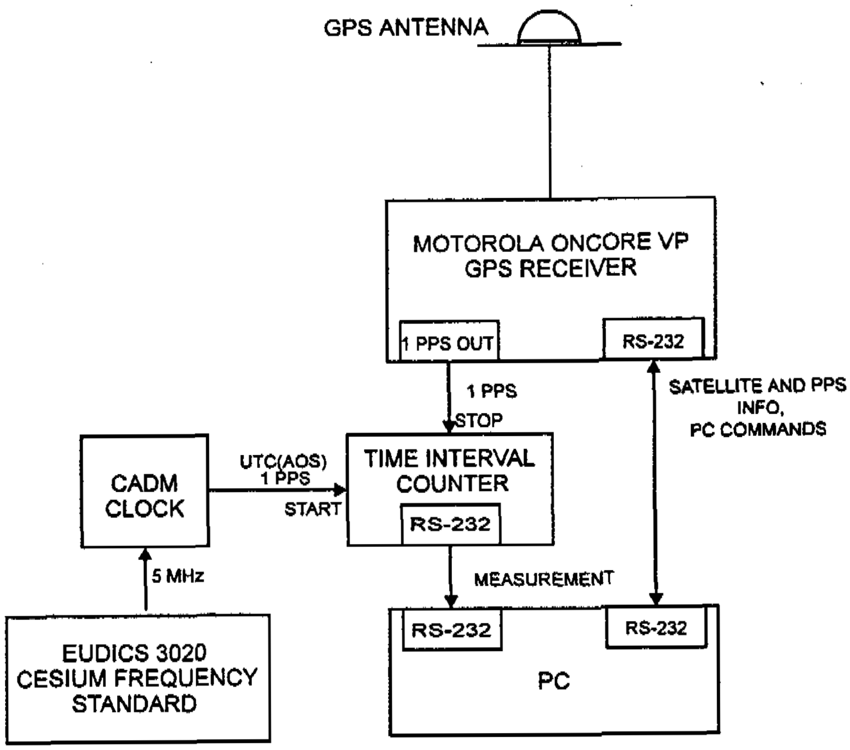

Fig. 1. Setup of the Experiment at Borowiec Observatory.

according to the recommendations of the CCDS (Rapport BIPM 1993/6). The 780 measurements carried in the period of time defined by the BIPM schedule are divided into 15 s intervals. The differences between the second of the local clock and i-th satellite time second are pseudoranges. The connection between Motorola internal second and the output 1pps pulse can be written as: 1pps + $\Delta\tau$, where $\Delta\tau$ can be computed from the corrections transmitted one second before and one second after the 1pps pulse. The pseudorange for the i-th satellite can be thus written as:

$$psd_i = UTC(loc) - 1pps(Motorola) + 1pps(Motorola) - T(sat_i),$$

so:

$$psd_i = UTC(loc) - T(sat_i).$$

For each of the 15 s intervals, the pseudoranges are square fitted for the center of the interval. Satellite position, geometric delay as well as ionospheric, tropospheric, Sagnac, periodic relativistic, L1-L2 corrections are computed. Then the clock corrections foraccess to GPS time, using the broadcasted second-order polynomial are evaluated. The values obtained in this way are linear-fitted. The results for each satellite are stored in the standard format on the hard disk, ready for the transfer to the other laboratory participating in the experiment.

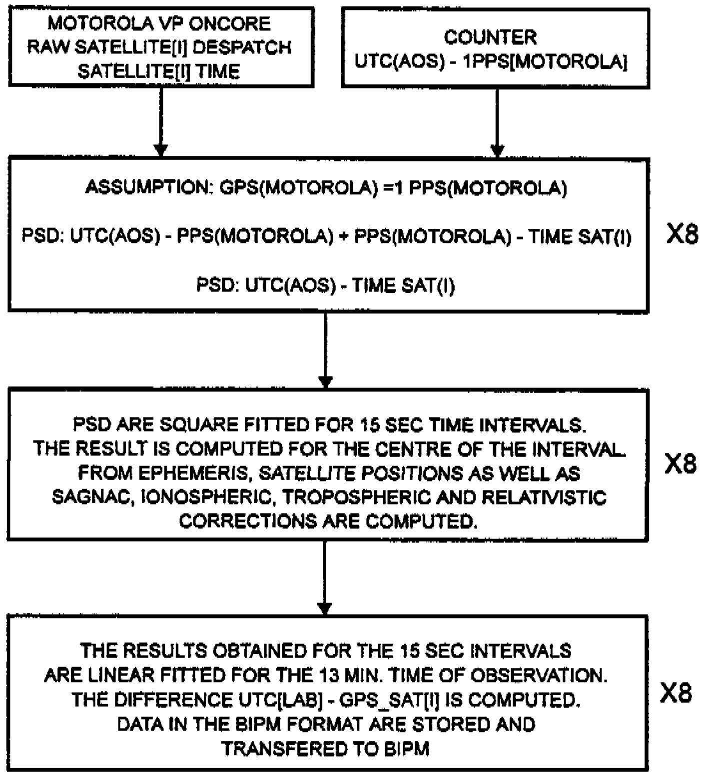

Fig. 2. General diagram of the software applied to the work-out of the Motorola VP Oncore data.

Common-view results of the experiment

In the experiment pariticipated two Motorola Oncore VP receivers working simultaneously at BIPM (Sèvres,France) and AOS (Borowiec, Poland). The approximate baseline is about 1200 km. The results of the observations come from the period of MJD: 50679 - 50683 (19.08 - 23.08.1997) and present the time scales comparison between the BIPM and the AOS. The comparisons were obtained using both multi-channel and single-channel observations. Fig. 3 presents raw differences BIPM - AOS obtained for multi-channel observations between the two laboratories. One-channel comparisons are presented in Fig. 4. The results of the removal of slope are shown in Fig.5 and Fig.6 respectively. The period of observations is relatively short because of the quite significant drift of the clock at AOS. The EUDICS 3020 cesium frequency standard is at least by an order of magnitude less stable then the HP5071, equipped with high performance tube used at Sèvres.

Fig. 7 presents the modified Allan deviation computed for the BIPM - AOS multi-channel observations. Similar computations obtained for the one-channel observations are shown in the Fig. 8. The results of the time stability of the multi-channel and one-channel observations are analyzed in Fig. 9 and Fig. 10. The multi-channel results are more stable. The uncertainty of the comparisons (RMS) varies between 1.2 to 1.5 ns;

for one-channel observations it is by 1 ns worse. The certainty problem for all GPS receivers are the changes of internal receiver delay caused by the changes of external temperature (Lewandowski and Tourde, 1991). Fig.11 presents the zero-baseline, one-channel comparisons between Motorola and Sercel receiver working at the BIPM time laboratory. The same 1pps pulse from local clock was used for the two receivers. The Sercel was equipped with the temperature-stabilized antenna; the Motorola was equipped with typical, unstabilized antenna. For the period of MJD: 50670 - 50721 the daily average of external temperature varied between 12° to 33° C. The changes in the difference Sercel - Motorola follow the pattern of the external temperature. The temperature coefficient is equal ζ=-0.27 ns/deg.

Conclusions

The best single-channel, C/A code receivers built especially for timing purposes, e.g. Allen-Osborne TTR6, NBS TTR5, or Sercel, used for common-view observations for baselines 1000-2 000 km give the uncertainty of 2-3 ns. They observe up to 48, 13 min. satellite passes per day. The results obtained with the set of equipment consisting of an inexpensive, multi-channel Motorola VP Oncore receiver, a time counter with the 1 ns resolution, and the PC computer with especially prepared software are significantly better. As it was presented above, the obtained uncertainty is well below the 2 ns level. The Motorola at Borowiec observes about 650 satellite passes per day. Moreover, the results of the multi-channel satellite observations obtained with the software used at Sèvres and Borowiec are compatible with the old single-channel receivers widely used for timing purposes. The significant problem still concerns the relatively high dependence of Motorola observations on outside temperature,which can be resolved by thermal protection of its antenna.

References

1. D. W. Allan, A. M. Weiss, Accurate Time and Frequency Transfer During Common-View of GPS Satellite, Proc. 34th Ann. Symp. on Frequency Control, pp. 334 - 346, 1980.
2. The Group on GPS Time Transfer Standards, Technical Directives for Standardization of GPS Time Receiver Software, Rapport BIPM 1993/6.
3. W. Lewandowski, P. Moussay, P. Guerin, F. Meyer, M. Vincent, Testing Motorola Oncore GPS Receiver for Time Metrology, EFTF '97.
4. W. Lewandowski, R. Tourde, Sensitivity to the External Temperature of Some GPS Time Receivers, Proc. 22nd PTTI Meeting, pp. 307-316, 1990.

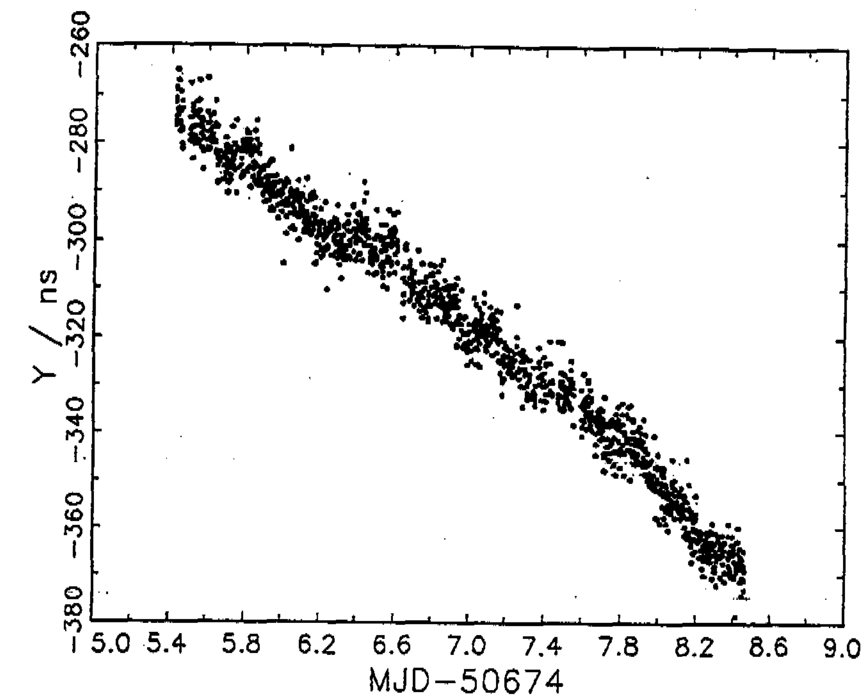

Fig. 3. Raw [BIPM clock - AOS clock] differences by Motorola multi-channel, common-view observations.

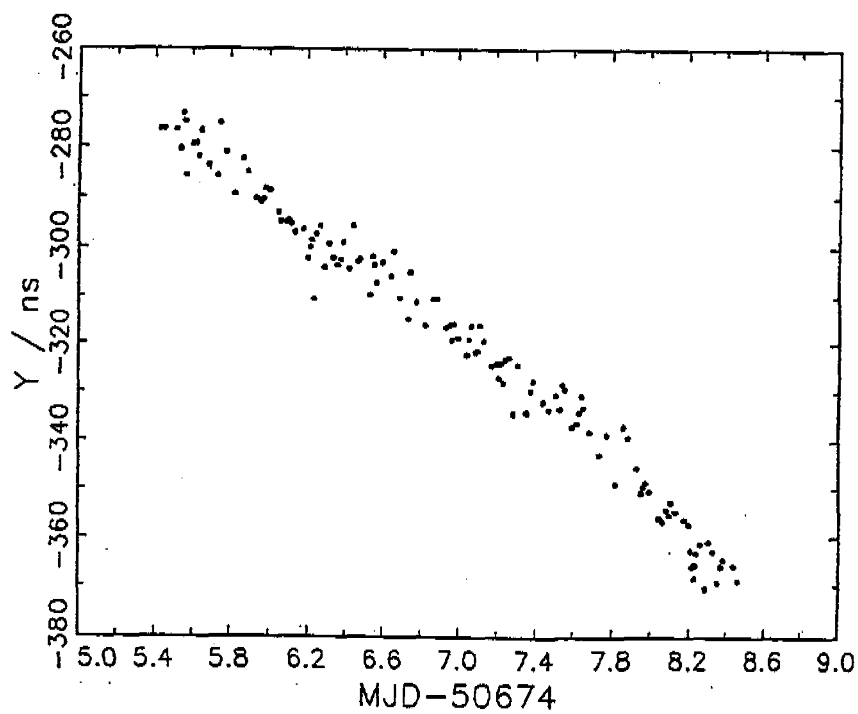

Fig. 4. Raw [BIPM clock - AOS clock] differences by Motorola one-channel observations.

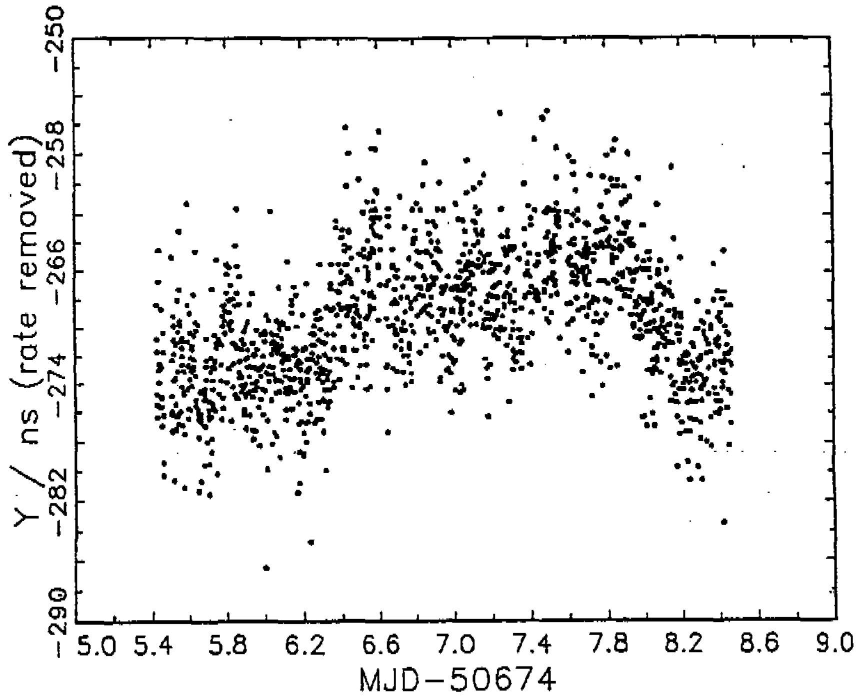

Fig. 5. Data of Fig. 3 after slope removal.

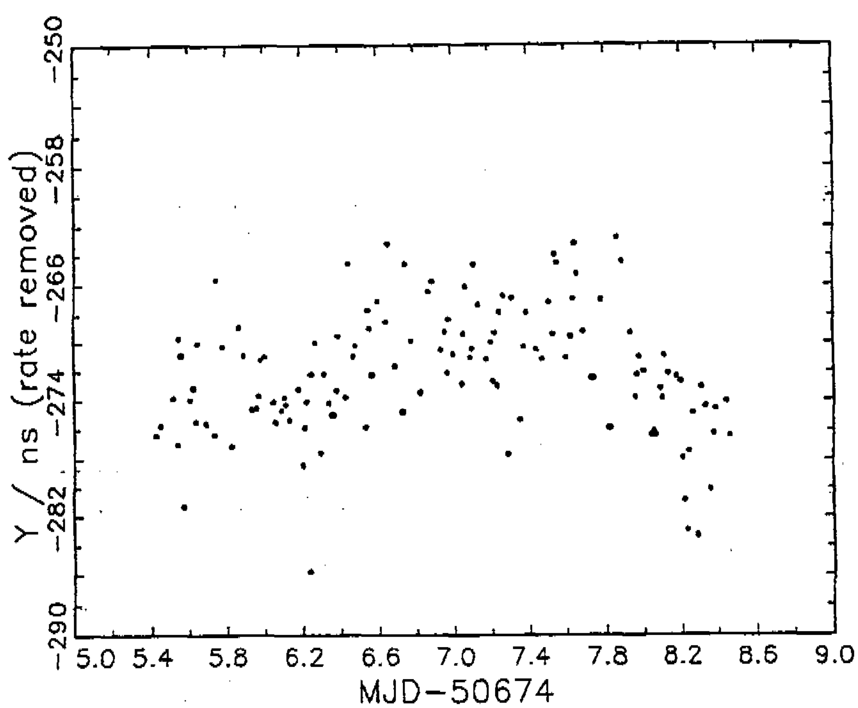

Fig. 6. Data of Fig. 4 after slope removal.

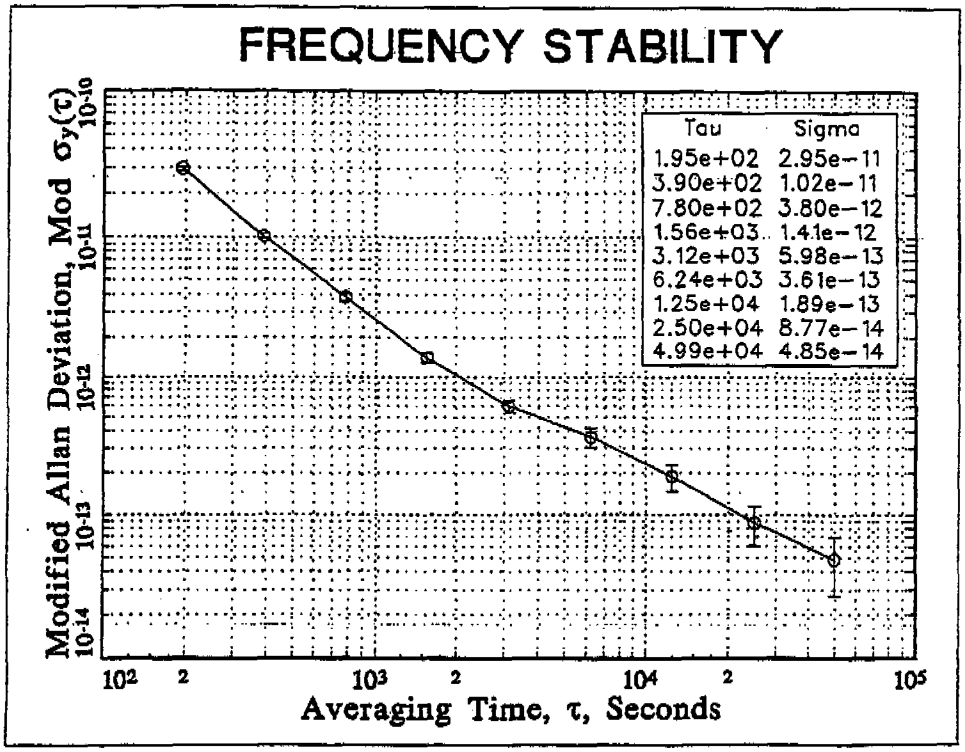

Fig. 7. Modified Allan Deviation of the [BIPM clock - AOS clock] differences from Motorola multi-channel observations.

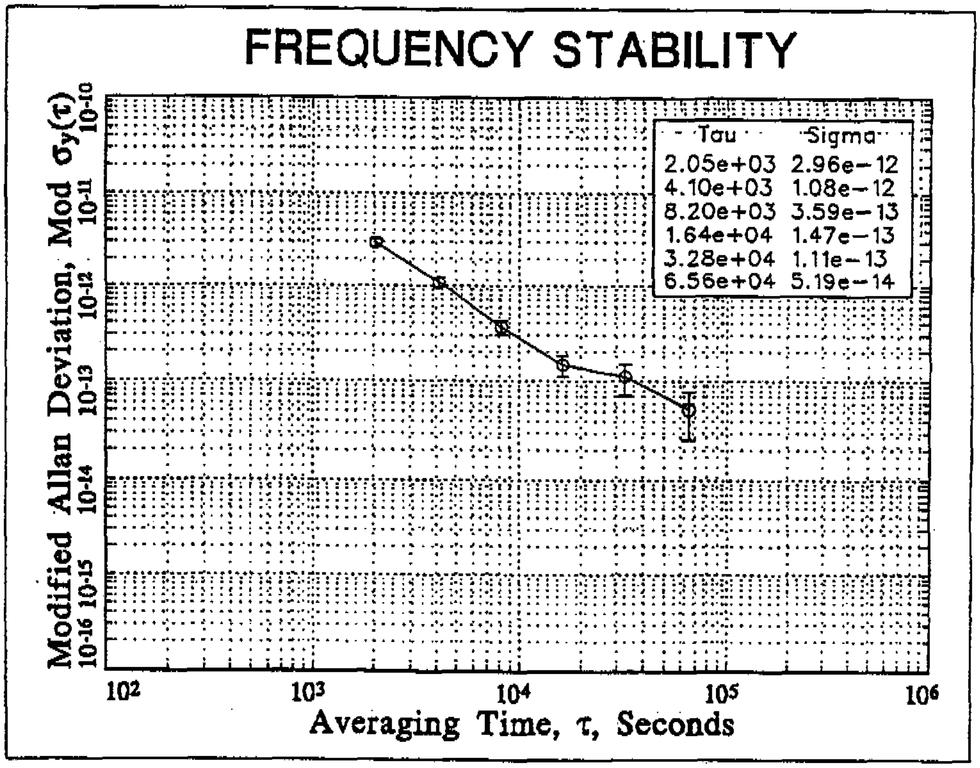

Fig. 8. Modified Allan Deviation of the [BIPM clock - AOS clock] differences from Motorola one-channel observations.

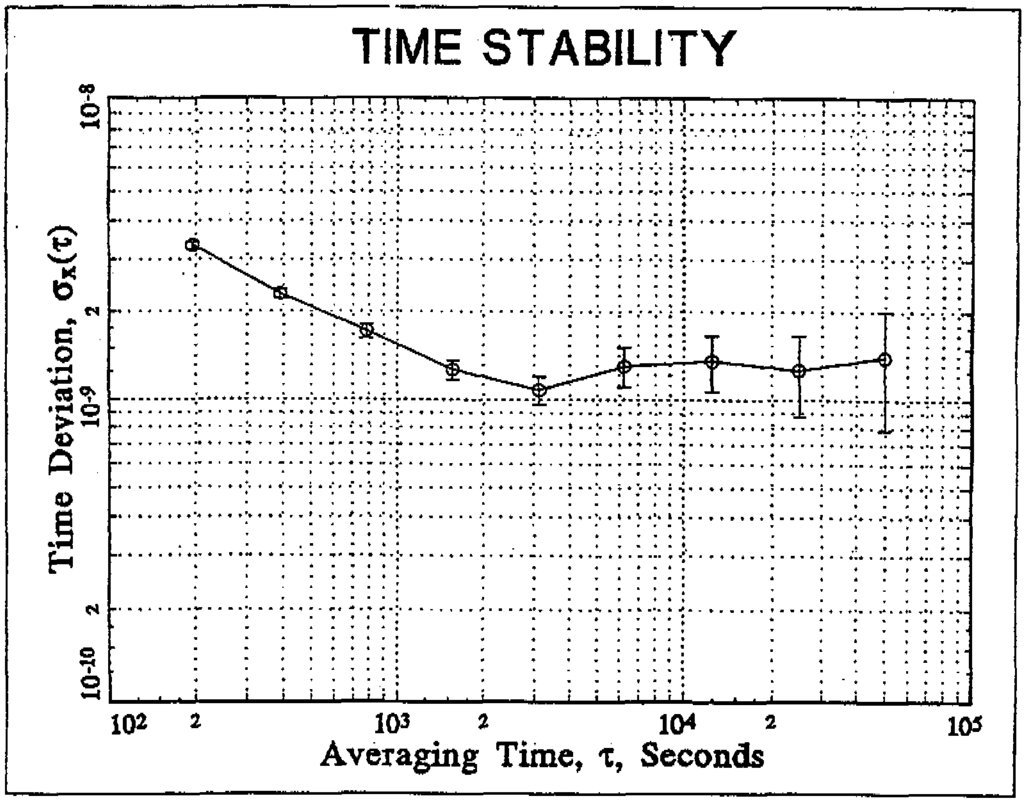

Fig. 9. Time deviation of the [BIPM clock - AOS clock] differences from Motorola multi-channel observations.

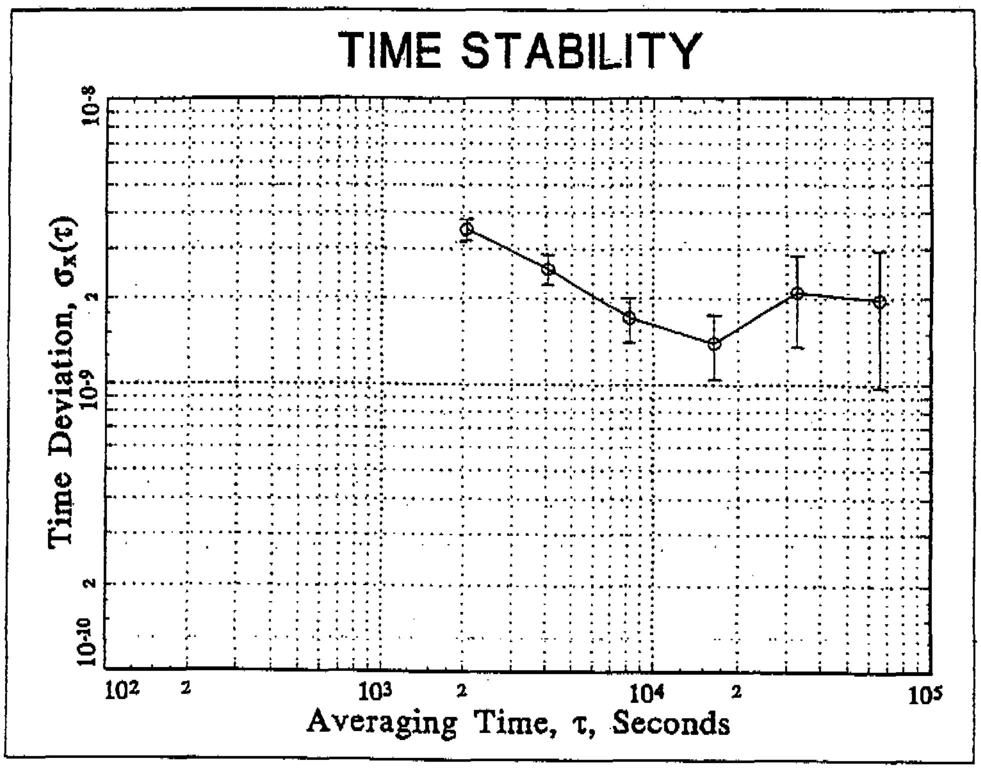

Fig. 10. Time deviation of the [BIPM clock - AOS clock] differences from Motorola one-channel observations.

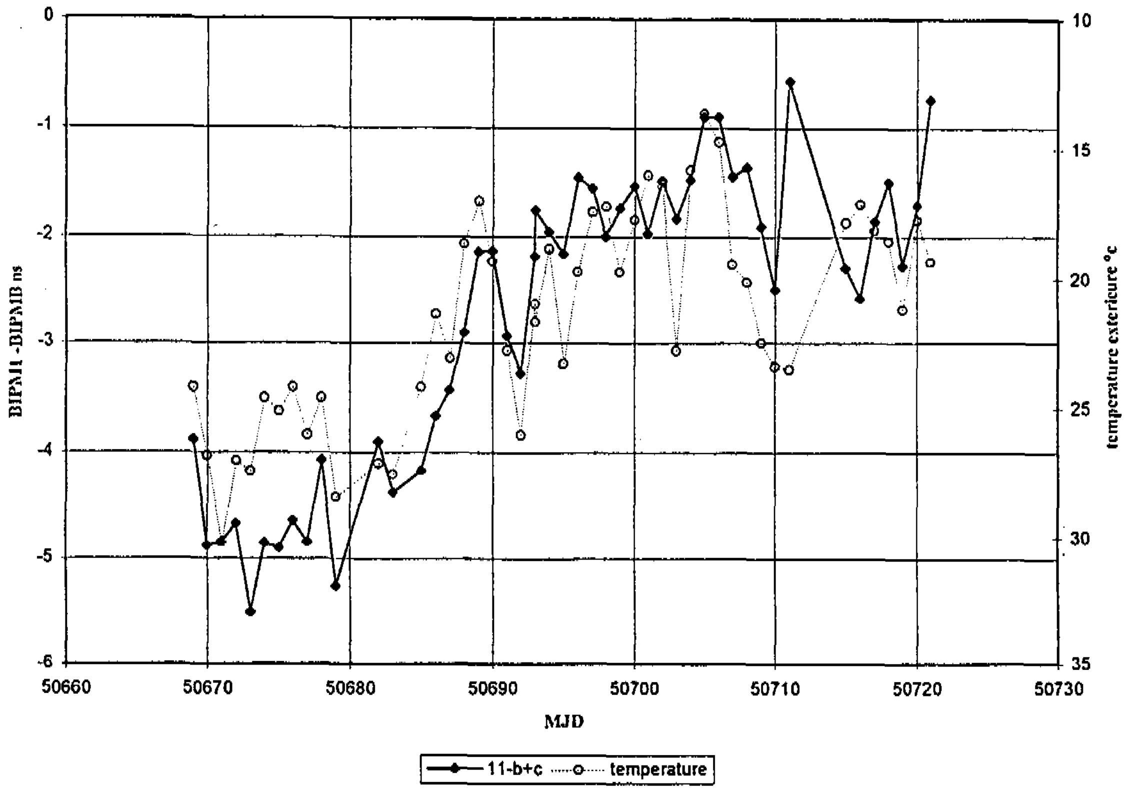

Fig. 11. Zero-baseline comparison between Sercel receiver (BIPM1) and Motorola receiver (BIPMB), and corresponding external temperature.