PROGRESS ON A NEW GPS COMMON-VIEW RECEIVER*

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Abstract

We are developing a new GPS common-view time transfer receiver to support both International Atomic Time (TAI) and comparison of frequency standards. Our goal is to realize a time-transfer accuracy of one ns or below, and time-transfer stabilities of 0.5 ns out to 1 year. Having obtained consistent stabilities at 100 ps or below with common-clock experiments out to 1 month with three laboratory prototype systems, we are now building a unit that can be moved among different timing labs. We show studies of three different time-interval counter cards considered for this project, revealing stabilities as a function of temperature and supplied voltage.

INTRODUCTION

We have developed a common-view time transfer receiver using a commercial GPS engine [1]. We have stabilized the time delay through the receiver by controlling receiver temperature, and supply voltage, and by minimizing reflected power through the downlink antenna cable [2]. Three prototype units have obtained pair-wise common-clock Time Deviation (TDEV) stabilities below 100 ps for periods from 1 d to 10 d and longer. This can be seen in Figures 1 and 2. Figure 1 shows data from MJD 51600 (January 7, 2000) to MJD 51835 (October 8, 2000) for the common-clock common-view difference between two units, N3 and N2, whose antennas are separated about 10 m. Figure 2 shows the TDEV of the data from Figure 1. Figure 3 shows the outdoor temperature for this period. While there are large changes in temperature, the data do not visibly exhibit a correlation. Nor do the TDEV data show evidence of a +1 slope in long term. This would occur if parabolic behavior appeared due to a measurable annual variation. We are now interested in building a portable system which can be moved to different sites, to determine its capabilities for common-view time transfer over longer baselines.

Common-view time transfer is one of the two main systems for measuring clock differences as input for the generation of International Atomic Time (TAI) [3]. A receiver was developed in 1980 at NIST (then NBS) that has been used since then as the most popular receiver for this purpose. There is a need to replace it with newer technology. While there has been significant research in developing new common-view systems, the goal of receiver stability below 1 ns for time periods of 1 year still remains a challenge. The prototype systems we have built may be able to achieve this.

We are packaging the system in a design which can be moved to other labs. This includes a rack mounted PC, a temperature-controlled receiver, and a choke-ring mounted antenna, with electronics underneath it. The PC will contain a time-interval counter on a card that plugs into the PC bus. We discuss the design of this system here, and report tests of some of the components. In particular, we studied the stability and accuracy of various counter cards with variations in temperature and voltage. We also have stability measurements using the antenna system for the new unit. Here we have duplicated the design that terminates the antenna cable with 50 ohms at both the antenna and the receiver.

A STUDY OF THREE COUNTERS

The receiver needs a counter that plugs into the PC bus. Our three existing systems use counter cards that were built at NIST by D. Davis [4] some years ago in support of a project to build a two-way time transfer modem. These have been shown to be accurate to better than 100 ps. Since we don't have any more of these, we needed to find an alternative counter that is accurate to 100 ps or better. We studied three time-interval counters for this purpose: two made under contract especially for NIST, and one manufactured commercially. We refer to the two counters built for NIST as DD and BD, and the commercial counter as GT. The BD counter has been studied in [5].

We studied the variations of the three counters' time-interval measurements with voltage and with temperature. We did this by placing a PC in a temperature-controlled chamber. We then altered a PC bus extension card so we could supply the +/- 5 V and the +/- 12 V from an external power supply. This allowed us to control the counters and collect the data using the PC, while independently controlling and monitoring the power supply voltages.

When counters showed a dependence of the measurement on voltage, it was only on the +5 volts. The results are summarized in Table 1 below.

Table 1

	+5 Volt Dependence ps/V	Temperature Dependence ps/°C
DD Counter	negligible	15.6
BD Counter	800.7	3.2
GT Counter	-2704.4	21.2

We decided to use the DD counter both because of availability and because of the above results. The various counters can be calibrated against a more accurate counter, and the result of this calibration used in the receiver software. This will change with the instability of the counter and its internal calibration. It appears that all the counters studied can be calibrated to an internal consistency of 100 ps.

STABILITY OF ANTENNA AND CABLING SYSTEM

We have shown that the long-term stability of a common-view GPS receiver can be significantly improved by reducing coherently reflected signals in the antenna cable [2]. We have duplicated the systems we used previously for this purpose. We provide a temperature-stable 25 dB amplifier after the antenna, followed by a DC-pass 10 dB attenuator, then a temperature-stable antenna cable down to the lab, then another 10 dB DC-pass attenuator. The stability of this system has reproduced previous results. Figure 4 shows common-clock common-view difference between the N01 receiver with the new antenna system, and another, N03, from MJD 51803 to 51862, September 15-November 13, 2000. Figure 5 shows the TDEV of these data. We obtain TDEV stabilities of under 100 ps from 1 d on, independent of temperature or rain. Snow, on the other hand, causes delay shifts, presumably because of effects from covering the antenna.

FUTURE WORK

We are planning to build a temperature controller around the GPS engine, and a precise power supply. We also plan to package the counter in a rack-mountable PC that will control both the counter and the GPS receiver. This is functionally equivalent to what we have done in our three prototype systems, but this operational system will use more compact than the prototype.

REFERENCES

[1] We used a Motorola VP ONCORE receiver for our commercial engine. We mention the trade name for completeness. No endorsement by NIST is implied. We are aware that these receivers are discontinued, yet we have a number of them available which we can use.

[2] M. A. Weiss 2001, *"Long-term effects of antenna cables on GPS timing receivers,"* Proceedings of the 2001 IEEE International Frequency Control Symposium, 6-8 June 2001, Seattle, Washington, USA (in press).

[3] C. Thomas 1997, *"The accuracy of International Atomic Time TAI,"* Proceedings of the 11th European Forum on Time and Frequency, 1997, pp. 283-289.

[4] V. S. Zhang, D. D. Davis, and M. A. Lombardi 1995, *"High resolution time interval counter,"* Proceedings of the 26th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, 6-8 December 1994, Reston, Virginia, USA, pp. 191-200.

[5] A. N. Novick, M. A. Lombardi, V. S. Zhang, and A. Carpentier 2000, *"A high performance multi-channel time-interval counter with an integrated GPS receiver,"* Proceedings of the 31st Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, 7-9 December 1999, Dana Point, California, USA, pp. 561-567.

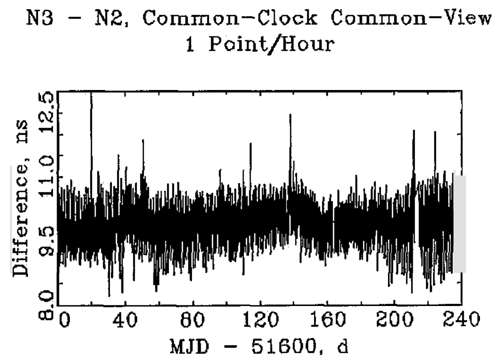

Figure 1 235 days of common-view common-clock differences between two prototype receivers. The data are 1-hour averages.

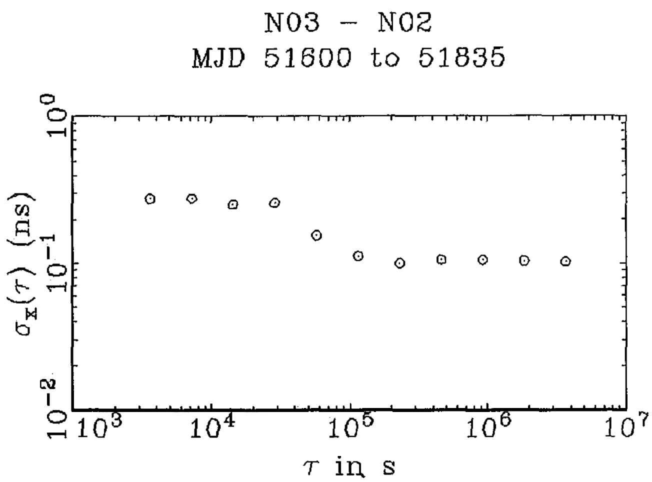

Figure 2 TDEV of the data in Figure 1, showing a flicker PM floor of about 100 ps.

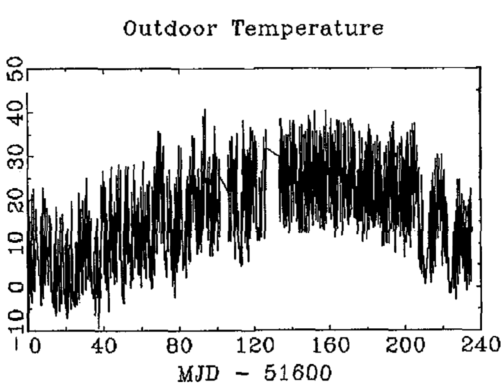

Figure 3 Outdoor temperature for the antennas during the periods shown in Figures 1 and 2.

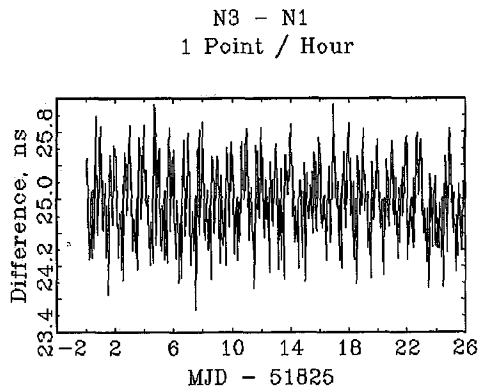

Figure 4 N3-N1 common-view common-clock difference with 1-hour averages, for the antenna system of the new receiver.

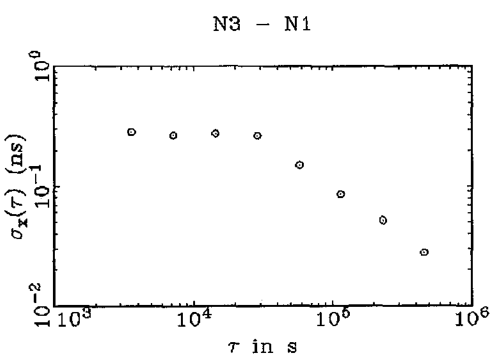

Figure 5 TDEV of data of Figure 4.