COMMON-VIEW TIME TRANSFER WITH COMMERCIAL GPS RECEIVERS AND NIST/NBS-TYPE RECEIVERS*

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Abstract

We report comparisons among three different types of commercial GPS receivers and NBS-type receivers. All comparisons are local common-clock, common-view short baseline comparisons. All systems use separate antennas located on the roof at NIST, Boulder, Colorado. Long-term stabilities vary from 100-700 ps, from integration times of 1 day to 30 days.

INTRODUCTION

Common-view GPS time transfer is one of the main means of comparing clocks for the generation of International Atomic Time (TAI) [1]. Whereas improvements have been demonstrated using two-way satellite time and frequency transfer (TWSTFT), this latter being more expensive and time-intensive leaves many labs still relying on common-view transfer [2]. Though there have been efforts to supplement the use of GLONASS signals for time transfer, GPS still appears most used [3]. There is some evidence that the short-term stability of TAI from 5 d to 30 d is limited by common-view GPS time transfer, rather than by the clocks in the time scale [3].

The NBS-type GPS receiver was developed around 1980 at the National Bureau of Standards, now the National Institute of Standards and Technology. For years this device was the main instrument available for common-view time transfer. There are now several different brands of commercial receivers available. We contribute to the development of commercial receivers by studying three brands of them here and characterizing their stabilities from 1 d to 10 d. We look at six different receivers in this study. NBS10 is the primary reference receivers at NIST, and NBS08 is one of the two backups. All are NBS-type receivers. N02 and N03 are both multi-channel, single-frequency receivers purchased as GPS boards and integrated into systems at NIST. NO is a multi-channel, two-frequency receiver. It can track the WAAS satellite as well as GPS satellites. The NO's use of the L2 frequency mainly affects common-view with codeless measurements of ionospheric delay. The R receiver is a multi-channel GPS/GLONASS receiver.

See Table 1, below.

Table 1

Receiver Name	Single/Multi Channel	Frequencies Received	Satellite Systems Tracked	Ionospheric delay Measured/Modeled
NBS10	Single	L1	GPS	modeled
NBS08	Single	L1	GPS	modeled
N02	Multi	L1	GPS	modeled
N03	Multi	L1	GPS	modeled
NO	Multi	L1 & L2	GPS, WAAS	modeled, measured
R	Multi	L1 & GLONASS	GPS, GLONASS	modeled

RESULTS

We summarize results in Table 2 below in the form of the Time Deviation, TDEV [4]. We previously reported an annual term in NBS10 [5]. Hence, we use NBS08 as a general reference for these comparisons. However, NBS08 is a single-channel L1-only receiver. For multi-channel comparisons we use other receivers.

The best results are comparisons among N02, N03, and R100. N02 and N03 are identical systems with regard to manufacture and model of equipment. Hence, there may be common-mode variations. The R100 is a significantly different receiver, which gives some credence to the reported flicker-floor stabilities between 100 to 200 ps after 1 d. With the N01, N02, and N03 receivers, we carefully controlled reflected signals in the antenna cable. We previously reported improved long-term stabilities following the effort to minimize reflected signals [6].

Table 2. All TDEV values are in ns, rounded to 1 significant digit. Confidences are for 95% certainty.

Receiver	1 d TDEV	Upper conf	Lower conf	10 d TDEV	Upper conf	Lower conf
NBS10-NBS08	0.3	0.27	0.30	0.2	0.20	0.31
N01-NBS08	0.4	0.34	0.54			
N02-NBS08	0.4	0.36	0.44	0.2	0.14	0.3
N03-NBS08	0.4	0.39	0.46	0.3	0.24	0.38
NO-NBS08	0.5	0.46	0.56	0.3	0.21	0.5
R100-NBS08	0.5	0.4	0.5	0.3	0.24	0.4
NO-N03	0.3	0.24	0.3	0.3	0.22	0.22
R100-NO	0.7	0.66	0.81	0.3	0.26	0.5
R100-N02	0.4	0.4	0.5	0.2	0.16	0.28
R100-N03	0.2	*	*	0.1	*	*
N03-N02	0.2	*	*	0.1	*	*

* We were unable to compute confidences for these data because the data sets were larger than our tables allowed for. However, since they were so large we can assume that the digit reported for TDEV is significant.

CONCLUSIONS

We conclude that there appear to be a number of commercial receivers available now which can replace the NBS-type receivers for common-view GPS time transfer. These commercial receivers compare favorably to the NBS-type for stabilites needed for laboratories that contribute to TAI. Whereas these results are from local common-clock studies only, the implication is that stabilities of these commercial receivers should be at least as good as the NBS-type over long baselines, if the ionospheric and tropospheric models are used correctly. There may be further improvements with some of these commercial receivers that have features not available in the NBS-type receivers. Measured ionospheric delays may be significant, especially during periods of maximum solar sunspot activity. The ability to track other satellites, such as GLONASS or WAAS, may add stability due to the increase in data.

REFERENCES

[1] C. Thomas, 1997, *"The accuracy of International Atomic Time TAI,"* in Proceedings of the 11th European Frequency and Time Forum (EFTF), 4-6 March 1997, Neuchâtel, Switzerland, pp. 283-289.

[2] T. Parker, P. Hetzel, S. Jefferts, L. Nelson, A. Bauch, and J. Levine, 2001, *"First Comparison of Remote Cesium Fountains,"* in Proceedings of the 15th European Frequency and Time Forum (EFTF), 6-8 March 2001, Neuchâtel, Switzerland (FSRM, Neuchâtel), pp. 57-61.

[3] W. Lewandowski and J. Azoubib, 2000, *"Time Transfer and TAI,"* in Proceedings of the 2000 IEEE/EIA International Frequency Control Symposium and Exhibition, 7-9 June 2000, Kansas City, Missouri, USA (IEEE Publication 00CH37052), pp. 586-597.

[4] ANSI (Telecommunications) Standard T1.101-1994, available from American National Standards Institute, 11 West 42nd Street, New York, New York 10036 USA, or on the World Wide Web at *http://web.ansi.org*

[5] M. A. Weiss, V. Zhang, L. Nelson, V. Hanns, and M.G.L. Regalado, 1997, *"Delay Variations in Some Timing Receivers,"* in Proceedings of the 1997 IEEE International Frequency Symposium, 28-31 May 1997, Orlando, Florida, USA (IEEE Publication 97CH36016), pp. 304-312.

[6] M. A. Weiss, 2000, *"Long Term Effects of Antenna Cables on GPS Timing Receivers,"* in Proceedings of the 2000 IEEE International Frequency Control Symposium and Exhibition, 7-9 June 2000, Kansas City, Missouri, USA (IEEE Publication 00CH37052), pp. 637-641.

QUESTIONS AND ANSWERS

DEMETRIOS MATSAKIS (U.S. Naval Observatory): Marc, you seemed to have gone out of your way to avoid an N-cornered-hat analysis. Is there any reason why?

MARC WEISS: I didn't think of it.

MATSAKIS: Well, it would have the same answer.

WEISS: It is not clear to me that you would get more information from N-cornered-hat because there are so many correlations that we do at three-cornered hat between the four-cornered hat. You get negative variances for some of them, and you end up saying, well, these are better, maybe, but I don't know how to do an uncertainty on an N-cornered-hat.

MATSAKIS: There is a poster paper by Ekstrom and Koppang on that question.

WEISS: I would like to see that.

MATSAKIS: But also, you are right: you can get negative variances, and particularly you get them for a long τ.

WEISS: Yes.

MATSAKIS: They come up because the degrees of freedom go away, and we have some papers about how to deal with it, to account for it all. Of course, there are Patrizia Tavella's landmark papers.

WEISS: Oh, yes.