ANALYSIS OF GLONASS AND GPS TIME TRANSFER USING MULTI-CHANNEL RECEIVERS

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ABSTRACT

The use of the multi-channel GPS/GLONASS receivers for comparisons of the remote clocks began in 1996, when R-100 type receivers manufacturing by 3S Navigation were installed at some time laboratories. However their application did not lead to increase of time transfer accuracy in comparison with one-channel one-system receivers. This paper describes possible reasons of this situation and the ways of their elimination, which were realized in the new Time Transfer Unit designed in the Russian Institute of Radionavigation and Time (RIRT).

1. INTRODUCTION

At present the most popular and precise method for international remote clock comparisons remains the common-view mode using the signals of the navigation satellite systems GPS and GLONASS. The estimated uncertainty of operational GPS time transfer using one-channel C/A-code GPS receivers is a few nanoseconds for a daily average. The use of the multi-channel GPS/GLONASS receivers should be led to the increase in the stability of this time transfer in comparison with using of the one-channel one-system receivers. However, the results of time comparisons between USNO, NIST, VSL, NPL, CRL, used multi-channel GPS/GLONASS receivers R-100 type, did not confirm this supposition.

Analysis of the obtained results shown that the improvement in the time transfer stability was limited by a difference between GPS and GLONASS links in consequence of an uncorrected account of the internal delays between GPS and GLONASS parts of the receivers.

Obviously this problem can be solved by means of the absolute calibration of the GPS and GLONASS parts of the receiver, including calibration for each GLONASS frequency, or by differential calibration by one of two methods: using a portable GPS/GLONASS receiver, or using existing calibrated GPS links.
The determination of the GPS and GLONASS signals delays in the receiver was made during manufacturing of the new Time Transfer Unit in RIRT. Therefore an increase in the stability of time transfer has been achieved in comparison with one-channel one-system receivers.

2. GPS AND GLONASS COMMON-VIEW OBSERVATIONS

For the past twenty years international time transfer using GPS and GLONASS signals is the most popular and precise method for comparisons of the remote clocks. It presupposes execution of the simultaneous measurements via signals of the same satellites and subsequent exchange of the results [1].

The measurements and their processing are executed according to the Technical Directives of the CCDS Sub-group on GPS and GLONASS Time Transfer Standards [2]. The BIPM international common-view schedules stipulate executing of a maximum of 48 tracks per day for classical one-channel GPS receivers and 89 tracks per day for two-channel GLONASS receivers. The multi-channel GPS/GLONASS time receivers observe all GPS and GLONASS satellites in view and use standard 13 minute tracks at the standard hours for forming results.

Possible increase of time comparison accuracy with use the multi-channel receivers is explained by the following [3]. For using of one-channel one-system receivers about 30-35 tracks per day are usually available in practice for regional time comparisons and about 10 – for intercontinental distances. Although in theory up to 12 GPS and GLONASS satellites can be observe simultaneously, there are only 5 satellites above 15^{o} (and thus of interest for time transfer) observed for each system at each time. Using all available observations we may therefore observe 445 tracks per day for each system and 890 - for two systems for regional common-view links and 160-200 tracks for intercontinental distances. The increase by a factor of twenty in the number of tracks in the GPS+GLONASS multi-channel approach compared with the one-channel one-system mode, leads one to expect a consequent improvement in the quality of time transfer.

3. RESULTS OF TIME COMPARISONS USING MULTI-CHANNEL RECEIVERS R-100 TYPE

The one-channel C/A-code GPS receivers TTR-6 built especially for timing purposes by Allen Osborne Associates or similar receivers are used as the main equipment for common view observations in the time laboratories. The delays in this receivers are determined by their calibration.

The use of multi-channel GPS/GLONASS receivers R 100/30 and R-100/40 manufactured by 3S Navigation began in some laboratories since 1996. R-100/30 and R 100/40 receivers contain 12 measurements channels of GPS and GLONASS one-frequency C/A-code signals and one or more channels of GLONASS two-frequency P-code signals. The receivers are controlled by a PC and use a standard format developed for the GPS common-view technique by the CCDS Sub-group on GPS and GLONASS Time Transfer Standards, adapted to suit two-system two-code multi channel observation. For the GLONASS part the receivers use the standards formulas and parameters adopted for GPS.

The results of clocks comparisons between several laboratories used the one-channel GPS and the multi-channel GPS/GLONASS receivers on an interval from August 1 till August 15, 2001 are given in Table 1. The results are presented as the offset between clocks at the middle of the interval and comparison accuracy, as well as the average number of the tracks per day. The results were got on the basis of the method of the least squares interpolation and linear model for time differences.

The received data was absolutely surprising both in part of the clocks' mutual offset and in the comparison accuracy. Therefore the additional estimations were calculated for R-100 receivers via GPS and GLONASS signals separately. These estimations are given in Table 1 also.

The given data shows the following:

- for most laboratories there are a differences in the results of comparisons for one-channel GPS receivers and multi-channel GPS/GLONASS receivers;
- the use of multi-channel receivers during operation only via GPS signals does not result in obvious gain in clocks comparisons accuracy despite of essential increase of a number of the tracks;
- the comparisons accuracy via GLONASS signals only is slightly higher than the accuracy via GPS signals only.

Table 1. Results of clocks comparisons using GPS/GLONASS receivers R-100 type

Labora-tories	Clocks' offset/uncertainty (rms), ns (average number of the tracks per day)			
	TTR-6	R-100 (GPS/GLONASS)	R-100 (GPS)	R-100 (GLONASS)
USNO-NIST	-25,1/3,4 (30)	-26,0/4,3 (520)	-24,7/3,2 (430)	-32,2/2,7 (100)
USNO-VSL	-36,3/3,6 (10)	-100,0/4,3 (200)	-43,8/6,8 (130)	-178,6/2,4 (85)
USNO-NPL	-19,9/4,6 (9)	-19,8/8,8 (340)	-13,4/6,8 (250)	-37,5/3,2 (90)
USNO-CRL	-28<0/9,3 (8)	96,6/23,2 (10)	116,4/6,3 (10)	22,0/2,2 (4)
VSL-NPL	16,5/4,1 (35)	74,0/35,8 9485)	31,2/4,7 (320)	141,5/2,7 (190)

4. ANALYSIS OF THE RECEIVED DATA

Analysis of the received data shown that absence of the gain in the clocks comparisons accuracy when using multi-channel GPS/GLONASS receivers R-100 type was caused by the uncorrected account of GPS and GLONASS signals delays. This can be stipulated by the fact that the receivers are not calibrated or wrong values of signals delays in the antenna channels and directly in the receivers are used.

Absence of the gain in the comparisons accuracy via GPS signals only for use of R-100 receivers can be explained by their lower parameters as compared with TTR-6 receivers. In its turn higher comparisons accuracy via GLONASS signals only can be connected with execution of measurements using P-code signals.

Its obvious that the first problem can be solved by means of the absolute calibration of the GPS and GLONASS parts of the receivers, including calibration for each GLONASS frequency, or by differential calibration by one of two methods: using a portable GPS/GLONASS receiver, or using existing calibrated GPS links.

The absolute calibration of the receivers is important from the point of view of the clocks synchronization relative to UTC (SU) and UTC (USNO). From the point of view of the mutual clocks comparisons the relative calibration of the receivers using existing calibrated links is sufficient.

5. TIME TRANSFER UNIT ON THE BASE OF 16 CHANNEL GPS/GLONASS RECEIVER

The Time Transfer Unit designed in RIRT is intended for determination of the offset between the local clock and GPS time and GLONASS time to subsequent determining of the mutual offset between the remote clocks, as well as for forming the output 1 pps pulse signal synchronized relative to the national Universal Time Coordinated of Russia UTC(SU) [4].

The Time Transfer Unit consists of the antenna box, the main amplifier, the comparison device including 16 channel GPS/GLONASS receiver and PC with special software.

The active type of the antenna with the built-in amplifier is used as the antenna box. The main amplifier is intended for additional amplification of the received signals if the damping in the antenna cable is more than 11,5 dB. The input of the main amplifier is connected to the output of the antenna box, and the output of the main amplifier is connected to the antenna cable.

Used GPS/GLONASS receiver K-161B type has 16 independent measurement channels of C/A-code signals in L1 range with an arbitrary distribution between GPS and GLONASS. The measurements are executed out relative to the internal time scale of the receiver. Therefore, the time interval counter is used for measurement of the offset between the internal time scale of the receiver and the local clock for subsequent accounting while determining of the offset between the local clock and GPS-time and GLONASS time.
PC is intended to form and give out the control signals to the comparison device, to receive the measurements and other information from the comparison device, to process, store, display and record the information on FD. All parameters and constants, necessary for measurements processing, correspond to those given in the GPS and GLONASS Interface Control Documents.

The determination of the GPS and GLONASS signals delays in the antenna box, in the main amplifier and in the receiver for subsequent accounting are made during their manufacturing. The special test bench equipment including the GPS/GLONASS signals simulator is used for calibration of the devices. The summary error of the absolute signal delay determination is about 10 ns. The additional measurement of the delay correction for each GLONASS frequency is made with an error no more than 1 ns.

The estimations of the accuracy characteristics of the Time Transfer Unit was made during 10 days interval. The estimation of time comparisons accuracy of the RIRT's Secondary Time/Frequency Reference (STFR) with GLONASS-time and GPS-time are given in Table 2. The estimation of instrumental accuracy of the mutual clocks comparisons using the Time Transfer Units are given in Table 3.

Table 2. The estimations of time comparisons accuracy of the RIRT's STFR with GLONASS-time and GPS-time.

Receiver type	Uncertainty (rms), ns		
	GLONASS		GPS
	one satellite	all satellites	
TTU(1)	23–37	15–21	6–10
TTU(2)	25–33	14–17	5–9
TTU(3)	28–34	8–14	5–10

Table 3. The estimations of instrumental accuracy of the mutual clocks comparisons

Receiver type	Uncertainty (rms), ns			
	GLONASS		GPS	GLONASS +GPS
	one satellite	all satellites		
TTU(1) – TTU(2)	2,4–3,5	2,2–3,7	2,7-3.1	3,5–4.1
TTU(1) – TTU(3)	2,7–3,4	2,4–3,7	2,6-3,3	3,2–3,8
TTU(2) – TTU(3)	2,3–3,7	2,7–3,4	2,5-3.0	3,0–3,5

The presented results confirm realization of the given requirements to the Time Transfer Unit and the possibility of time comparison with error no more than 5 ns (rms) if the distance between clocks is up to 100 km and no more than 10 ns at large distances.

6. CONCLUSION

Analysis of the clocks comparisons results using multi-channel GPS/GLONASS receivers R-100 type shown that absence of the gain in time transfer accuracy was caused by the uncorrected account of GPS and GLONASS signals delays in the receivers.

The determination of the GPS and GLONASS signals delays in the receiver was made in RIRT during manufacturing of the new Time Transfer Unit on the base of the 16-channel GPS/GLONASS receiver. Therefore an increase in the stability of time transfer has been achieved in comparison with one-channel one-system receivers.

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