# GNSS System Time Scales and Time Transfer Accuracy

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## Abstract

The paper provides the assessment of GNSS System Time offsets from their reference time scales for the period of January-November 2021. The influence of the offset deviations on the accuracy of time transfer by GNSS has been analyzed.

## 1. Introduction

Global Navigation Satellite Systems (GNSS) provide navigation and timing services to different kinds of users. To provide the services, time scales of GNSS space vehicles (SV) are referenced to GNSS Time Scales and GNSS Time Scales are referenced and steered to their Reference Time.

GNSS Reference time scales are, as a rule, realizations of Universal Coordinated Time, namely UTC(k), which are steered to UTC with specified accuracy: UTC(USNO) for GPS, UTC(SU) for GLONASS, UTC(NTSC) for BeiDou. Galileo Reference Time is UTC prediction as provided by the Galileo Time Service Provider based on contributions from European UTC laboratories, and is denoted as "UTC(EU)".

## 2. Specified Time Transfer Accuracy

Corrections to convert from SV time scales to GNSS Time and corrections to convert from GNSS Time to Reference Time are broadcast in GNSS navigation messages. The broadcast corrections are the parameters of time offset prediction models and are calculated on the basis of the offset assessments for the previous period of time (observation interval).

Users calculate GNSS Time using the corrections to SV Time and convert GNSS Time to reference realization UTC(k) using the corrections to GNSS Time.

The accuracy of UTC(k) provided by GNSS is characterized by the parameter Signal-In-Space (SIS) Time Transfer Accuracy which is the statistical value of the difference between the estimated receiver time scale offset from reference realization UTC(k) and true offset value. The values of Time Transfer Accuracy for different GNSS are maintained within the limits that are specified in GNSS Performance Standards documents [1-4].

The specified values of SIS Time Transfer Accuracy (TTA) are presented in Table 1.

**Table 1.** Specified SIS Time Transfer Accuracy.

| | GPS | GLONASS | Galileo | BeiDou |
|---|---|---|---|---|
| SIS TTA (95%), ns | 30 | 40 | 30 | 20 |

## 3. Assessment of GNSS Time and Time Transfer Accuracy

GNSS Time Scales broadcast by GNSS [UTC(k)-GNSS Time] for GPS, GLONASS and BeiDou have been assessed on the basis of measurements at Reference Time Generating Facilities. Galileo Time broadcast by Galileo has been assessed on the basis of measurements at the measuring site of Russian metrological institute VNIIFTRI.

The accuracy of UTC(k) broadcast by GNSS has been assessed as [UTC(k)-UTC(k)_GNSS] on the basis of the measurements mentioned above and corrections to convert from GNSS Time to Reference Time.

The results of the assessment for GPS, GLONASS, Galileo and BeiDou for the period of January – November 2021 are presented in Figures 1-4.

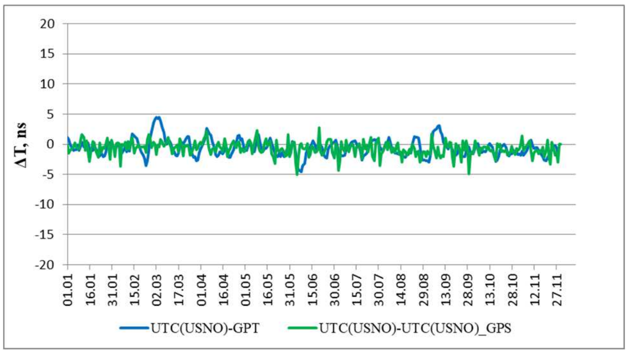


**Figure 1.** UTC(USNO) – GPS Time and the accuracy of UTC(USNO) broadcast by GPS.

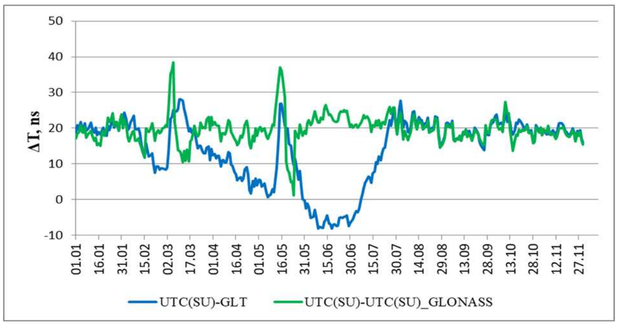


**Figure 2.** UTC(SU) – GLONASS Time and the accuracy of UTC(SU) broadcast by GLONASS.

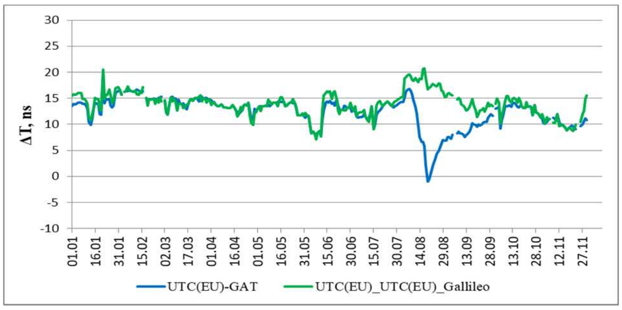


**Figure 3.** UTC(EU) – Galileo Time and the accuracy of UTC(EU) broadcast by Galileo.

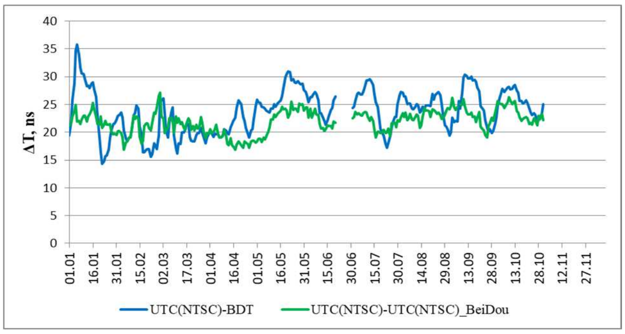


**Figure 4.** UTC(NTSC) – BeiDou Time and the accuracy of UTC(NTSC) broadcast by BeiDou.

## 3. Analysis of the Assessment Results

The results show that in January-November 2021 the values of [UTC(k)-GNSS Time] offsets and the accuracy of UTC(k) broadcast by GNSS were as follows.

The offset of GPS Time from UTC(USNO) was maintained within ±4 ns. The error of UTC(USNO) broadcast by GPS was also within ±4 ns.

The offset of GLONASS Time from UTC(SU) was maintained within ±5 ns, except for the interval March-June, when there were several deviations of GLONASS Time – UTC(SU) offset because of control operations at GLONASS Time Generating Facility. In this interval the offset was from (–30) ns up to (+10) ns. At the same time, the systematic error of GLONASS Time and UTC(SU) broadcast by GLONASS were about 20 ns. The error of UTC(SU) broadcast by GLONASS was mainly within ±5 ns, except for two intervals: 3-6 March (with maximum value of 18,5 ns) and 13-24 May (with maximum value of 16 ns). These intervals correlate with the beginnings of GLONASS Time disturbances. At the same time, the error of UTC(SU) broadcast by GLONASS remained within specified limits.

The offset of Galileo Time from UTC(EU) was maintained within ±3 ns, the error of UTC(SU) broadcast by Galileo was within ±5 ns, except for the interval August 4 – September 16, when Galileo Time – UTC(EU) offset was to up to (-17) ns and the error of UTC(EU) broadcast by Galileo increased by up to 5 ns. The systematic error of Galileo Time and UTC(SU) broadcast by Galileo in Figure 3 must have been caused by the lack of receiver calibration at VNIIFTRI measuring site.

The offset of BeiDou Time from UTC(NTSC) was within (15-30) ns. The error of UTC(NTSC) broadcast by BeiDou was within (17-27) ns. The systematic error of BeiDou Time and UTC(NTSC) broadcast by BeiDou was about (20-25) ns.

## 5. Conclusion

The deviations of GLONASS Time and Galileo Time had limited influence on the accuracy of reference time broadcast to users.

In January-November 2021 the values of Time Transfer Accuracy were maintained within specified limits for all GNSS.

## 6. Acknowledgements

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## References

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