LNE-SYRTE
GNSS station relative calibration report

G1/G2 #1018-2022

INRIM and RISE
GNSS stations relative calibration.

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Issue 1.1

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Content

1. Introduction.

This calibration report released by LNE-SYRTE is about the G1/G2 relative calibration campaign of GNSS stations located in INRIM and RISE. This campaign took place from 5 August 2022 (MJD 59796) to 28 November 2022 (MJD 59911). The measurement campaign was originally organized in the frame of the Galileo TSP and visited in the following order: INRIM (Italy), ROA (Spain), PTB (Germany) and RISE (Sweden).

The report is built according to the Annex 4 of the document "BIPM guidelines for GNSS equipment calibration", V4.0 05/08/2021 [2], and contains all the required informations, data, plots and results either required by BIPM in the frame of the CCTF Working Group on GNSS, or by BIPM and EURAMET in the frame of the Group1/Group2 calibration scheme. It also contains the uncertainty budget computation according to the Guidelines, which is showing whether the calibrated links used in the frame of the TAI computation would be in line with the conventional values.

This document contains first a summary of the results, followed by a Section devoted to the issues having happened during this campaign. After the list of the acronyms used in the document and of the reference documents, Section 5 describes the equipment and operations during the calibration campaign. Section 6 provides all informations about data handling and calibration processing. Section 7 is about the calibration results between stations, and Section 8 is devoted to the uncertainty budgets computation. After an assessment of the stability of the GNSS reference station and of the traveling ones during this campaign in Section 9, the resulting delays and related uncertainties of the calibrated stations are provided in Section 10.

Annex A is about the implementation of OP traveling stations in each visited site alongside local GNSS stations, Annex B shows the plots of the raw data together with the related TDEV. Annex C describes all the terms appearing in the uncertainty budgets.

This is Issue 1.1 of this calibration report, approved by visited laboratories and by BIPM.

This report is consistent with the capabilities that are included in Appendix C of the CIPM MRA drawn up by the CIPM. Under the CIPM MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in the KCDB (for details see https://www.bipm.org/kcdb/).

2. Summary of the results.

This Section is a summary of the INRIM and RISE GNSS stations relative calibration results. Table 1 provides the GPS P1-code and P2-code calibrated delays for all stations, from where P3 delays are computed, and Table 2 provides the Galileo E1-code and E5a-code calibrated delays for all stations, from where E3 delays are computed, together with their related uncertainties. These results are fully valid for the period of the calibration campaign.

Despite a deviation from closure of the traveling equipment larger than expected for GPS P1-code, the combined uncertainties of the GPS P3 delays remain below the 2.5 ns conventional value. As a consequence, Table 1 shows the conventional value from a G1/G2 relative calibration to be considered for all GPS P3 data when using any of the listed stations in the TAI network.

Table 1. Summary of the UTC(k) stations GPS delays (all values in ns).

Station	Measurement period	P1-code Delays	Combined uncertainty	P2-code Delays	Combined uncertainty	P3 Delays	Combined uncertainty [*]
IT08 (INR5)	59817-59825	309.0	1.1	308.5	0.7	309.8	2.5
IT09 (INR6)	59817-59825	55.0	1.1	55.5	0.7	54.2	2.5
IT10 (IENG))	59817-59825	54.3	1.1	55.0	0.7	53.2	2.5
IT11 (GR01)	59817-59825	56.0	1.1	54.4	0.7	58.5	2.5
IT12 (GR02))	59817-59825	352.8	1.1	352.7	0.7	353.0	2.5
IT14 (GR04)	59817-59825	279.8	1.1	277.5	0.7	283.4	2.5
IT15 (GR05)	59817-59825	27.5	1.1	24.4	0.7	32.3	2.5
IT16 (GR06)	59817-59825	27.6	1.1	25.5	0.7	30.8	2.5
IT2_ (GTRB)	59817-59825	- 37.1	1.1	- 23.0	0.7	- 58.9	2.5
SP03	59880-59888	268.1	1.1	265.0	0.7	272.9	2.5
SP05	59880-59888	200.7	1.1	195.7	0.7	208.4	2.5
SP06 (RIT1)	59880-59888	273.7	1.1	269.7	0.7	279.9	2.5
SP07 (RIT2)	59880-59888	231.7	1.1	228.2	0.7	237.1	2.5

[*] *Conventional combined uncertainty value for G1/G2 calibration.*

On the other hand however, as can be seen in Sections 8 and 10 of this report, the unexpected large deviation from closure of the traveling equipment in Galileo E1-code data hampers the combined uncertainties of Galileo E3 delays to remain below the conventional value. When using the combined uncertainties $u_{CAL}(E3)$ of Table 40 (Section 10.2), we obtain a combined uncertainty below 2.67 ns. As a consequence, the combined uncertainty in Table 2 is 2.7 ns, which has to be considered for all listed stations here for Galileo E3 delays in the TAI network as a result of the G1/G2 relative calibration described in this report.

Table 2. Summary of the UTC(k) stations Galileo delays (all values in ns).

Station	Measurement period	E1-code Delays	Combined uncertainty	E5a-code Delays	Combined uncertainty	E3 delays	Combined uncertainty [**]
IT08 (INR5)	59817-59825	309.9	1.1	320.3	0.7	296.8	2.7
IT09 (INR6)	59817-59825	55.8	1.1	65.1	0.7	44.1	2.7
IT10 (IENG)	59817-59825	55.1	1.1	64.5	0.7	43.2	2.7
IT11 (GR01)	59817-59825	56.9	1.1	63.9	0.7	48.1	2.7
IT12 (GR02)	59817-59825	353.7	1.1	362.4	0.7	345.0	2.7
IT14 (GR04)	59817-59825	282.1	1.1	281.9	0.7	282.4	2.7
IT15 (GR05)	59817-59825	29.7	1.1	28.4	0.7	31.3	2.7
IT16 (GR06)	59817-59825	29.9	1.1	28.3	0.7	31.9	2.7
SP03	59880-59888	270.5	1.1	282.9	0.7	254.9	2.7
SP05	59880-59888	203.3	1.1	202.1	0.7	204.8	2.7
SP06 (RIT1)	59880-59888	276.1	1.1	273.5	0.7	279.4	2.7
SP07 (RIT2)	59880-59888	234.6	1.1	238.1	0.7	230.2	2.7

[**] *Combined uncertainty <u>above</u> the conventional value for G1/G2 calibration.*

3. Acknowledgements and major issues during the calibration campaign.

The LNE-SYRTE acknowledges the support of Colleagues in all visited UTC(k) laboratories. In particular, we are thankful for the flexibility of Colleagues about the ever changing planning of the calibration campaign. There were nevertheless some technical and administrative issues during the campaign we wish to remind here.

3.1. Technical issues.

a) We saw an unexpected effect appearing between GPS CV and Galileo CV between both traveling receivers when implemented in different sites. What was expected was a 0 mean for CV between OP72 and OP74, either for GPS or Galileo data, thanks to the initial calibration against a given reference station, which was OP73 (See Section 5 for more details). Any effect generating a change in the hardware of the traveling equipment would modify these offsets, but when considering that both main units were always implemented in common-clock and common-antenna set-up, any potential differences in the CV would normally come from main units only. We were expecting potential hardware changes to affect equally GPS and Galileo data, but it proved not to be the case, and we have no clear explanation for that today. Section 9 provides a detailed analysis of this effect.

b) We note significant diurnals in many TDEV (see Annex B). But this is not the case everywhere. It is for example not the case for all stations in RISE. The most peculiar aspect here is the diurnal of traveling equipment when implemented in OP. At the start of the campaign, the diurnals are pretty high, and we assume this to be related to the unprecedented heatwave in Paris. But during the closure, a diurnal can hardly be seen in the TDEV plots. In other words, the level of average temperature seems to have a direct effect on diurnal appearance with the traveling equipment as it is today.

c) The misclosure values are much higher than usual. We obtain about 1.6 ns for GPS P3 data and about 2.0 ns for Galileo E3 data, leading to final combined uncertainties largely away from the state of the art in the matter. It is mostly due to unexplained P1/E1 misclosure. One assumption is that this misclosure is directly issued from the large temperature difference between the start and the end of the campaign in OP. The start took place in August during an unprecedented heatwave, with temperatures above 40 °C during the day, and the closure took place at the end of November, with temperatures below 12 °C during the day. Heatwaves being planned to become typical, this kind of issue cannot be foreseen easy to solve.

3.2. Administrative issues.

As expected, transport issues hampered severely the campaign planning. LNE-SYRTE is committed to use a French Research service and cannot address to any private transport company directly. It was not possible to get any equipment transport from one site to the other in less than two weeks. This also resulted in a very significant increase of the transport cost, even before the current inflation rate inside EU.

4. Acronym list and Reference Document.

4.1. Acronym list:

ADEV :	Allan deviation, square root of AVAR.
AVAR :	Allan variance or two-sample variance.
BIPM:	Bureau International des Poids et Mesures, Sèvres, France.
BRDC :	IGS harmonized GNSS broadcast ephemeris.
CCTF:	Consultative Committee on Time and Frequency.
CGGTTS:	CCTF Global GNSS Time Transfer Standard format.
CIPM:	Comité International des Poids et Mesures.
CV :	Common-View.
DI :	Designated Institute.
EURAMET :	European association of metrology laboratories.
G1:	Group 1 laboratory in the frame of the TAI network.
G2:	Group 2 laboratory in any given Regional Metrology Area.
GLONASS:	Russian GNSS.
GNSS:	Global Navigation Satellite System.
GPS:	United States of America GNSS.
GST:	Galileo System Time.
IGS:	International GNSS Service.
INRIM:	Istituto Nazionale di Ricerca Metrologica, Italian NMI.
LNE:	Laboratoire National de Métrologie et d'Essais, French NMI.
LNE-SYRTE:	French designated laboratory in charge of Time and Frequency units.
MDEV:	Modified Allan deviation, square root of MVAR.
MVAR:	Modified Allan variance.
na:	Not available.
nc:	Not computed.
NMI:	National Metrology Institute.
NRCan :	National Ressources Canada, Canadian NMI.
OP:	Observatoire de Paris, France.
ORB :	Observatoire Royal de Belgique, Brussels, Belgium DI.
PPP :	Precise Point Positioning.
PPS:	Pulse per second.
PTB:	Physikalisch Technische Bundesanstalt, German NMI.
PTF:	Precise Time Facility.
RINEX:	GNSS Receiver International Exchange format for Geodesy.
RISE:	Reasearch Institute of Sweden, Swedish NMI.
ROA:	Real Instituto y Observatorio de la Armada, Spanish DI.
SYRTE:	Systèmes de Référence Temps-Espace, OP laboratory where LNE-SYRTE is located.
TAI:	Temps Atomique International.
TDEV:	Time Allan deviation, square root of TVAR.
TIC:	Time Interval Counter.
TSP:	Time Service Provider.
TVAR:	Time Allan variance, derived from AVAR and MVAR.
UTC:	Coordinated Universal Time.

4.2. References.

[1] Pierre Uhrich and David Valat, "*GPS receiver relative calibration campaign preparation for Galileo In-Orbit Validation*", Proc. of the 24th European Frequency and Time Forum (EFTF), Noordwijk, The Netherlands, April 2010 (CD-Rom).

[2] BIPM Guidelines for GNSS equipment calibration, v4.0, 05/08/2021.

[3] G.D. Rovera, J-M. Torre, R. Sherwood, M. Abgrall, C. Courde, M. Laas-Bourez and P. Uhrich, "*Link calibration against receiver calibration: an assessment of GPS time transfer uncertainties*", Metrologia 51 (2014) 476-490.

[4] Daniele Rovera, Michel Abgrall, Pierre Uhrich and Marco Siccardi, "*Techniques of antenna cable delay measurement for GPS time transfer*", Proc. of the 5th International Colloquium on Scientific and Fundamental Aspects of the Galileo Programme, 27-29 October 2015, Braunschweig, Germany.

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5. Description of equipment and operations.

5.1. OP GNSS equipment.

The OP GNSS reference station for this campaign is made of one multi-GNSS Septentrio PolaRx5TR main unit called OP73, connected by a 30 m long antenna cable to a SepChoke B3/E6 multi-GNSS antenna. This station was part of the last G1 calibration campaign (#1001-2020), its delays having been computed by BIPM.

The OP GNSS traveling equipment is made of two multi-GNSS Septentrio PolaRx5TR main units called OP72 and OP74, connected to one single 50 m long antenna cable thanks to a power splitter, and to one single multi-GNSS NovAtel GPS-703-GGG antenna.

The firmware of all PolaRx5TR was 5.4.0. Septentrio released a firmware upgrade 5.5.0 for PolaRx5TR units after the start of the campaign, but we decided to wait until the end of the campaign for this upgrade, in order to avoid any potential effect on the delays during the data collection.

5.2. UTC(k) GNSS equipment.

The UTC(k) GNSS equipment to calibrate was depending on the visited site. The receiver main units were either Septentrio PolaRx4TR and PolaRx5TR, or Dicom (company name today is Mesit) GTR50, or Javad TRE_G3T Delta 3. There were also different antennas, and the reference signal distribution was not such a single common one in each visited laboratory. Annex A contains the details about the local implementations in the visited stations.

All these stations were calibrated as G2 GNSS stations according to the BIPM Guidelines for the delays computations including the related combined uncertainties. But the resulting uncertainties are also provided below within the 95 % uncertainty level as recommended by EURAMET. PTB and ROA were also part of the original Galileo TSP campaign, but as G1 laboratories their station delays are computed and provided by BIPM, and we do not provide any calibration result for these two laboratories in this report. Note however that we used some data collected in PTB and ROA for validation purpose.

5.3. Summary of the involved equipment and planning.

Table 3 summarizes the equipment involved in the GNSS relative calibration campaign of UTC(k) laboratories with highlighted traveling station measurement periods on each site.

Table 3. Summary of equipment and planning.

Institute	Equipment status	MJD of measurement	Receiver type	BIPM code	RINEX name
OP	Traveling	59796 - 59911	Septentrio PolaRx5TR	OP72	OP72
OP	Traveling	59796 - 59911	Septentrio PolaRx5TR	OP74	OP74
OP	G1 reference	59796 - 59911	Septentrio PolaRx5TR	OP73	OP73
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT11	IT11
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT12	IT12
INRIM	G2	59817 - 59825	Septentrio PolaRx5TR	IT14	IT14
INRIM	G2	59817 - 59825	Septentrio PolaRx5TR	IT15	IT15
INRIM	G2	59817 - 59825	Septentrio PolaRx5TR	IT16	IT16
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT08	IT08
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT09	IT09
INRIM	G2	59817 - 59825	Dicom GTR50	IT2_	IT2_
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT10	IT10
RISE	G2	59880 - 59888	Javad TRE_G3T Delta 3	SP03	SP03
RISE	G2	59880 - 59888	Septentrio PolaRx5TR	SP05	SP05
RISE	G2	59880 - 59888	Septentrio PolaRx5TR	SP06	RIT1
RISE	G2	59880 - 59888	Septentrio PolaRx5TR	SP07	RIT2

6. Data and processing.

All OP collected raw Septentrio binary files (SBF) data are transformed into GNSS RINEX 3 format by using the Septentrio proprietary SBF2RIN software. Local receivers SBF and/or RINEX 3 and/or RINEX 2 data, together with CGGTTS files when they exist, are provided by the visited institution/laboratory. The calibration is consisting in building differential 30 s sampled CGGTTS data for each P1- and P2-codes for GPS and for each E1- and E5a-codes for Galileo between pairs of receivers, for which we partly use the R2CGGTTS software developed by P. Defraigne (ORB). Another part of the calibration software is an original development by LNE-SYRTE. These CGGTTS differences are corrected by the known reference delay (REFDLY) and antenna cable delay (CABDLY) when available. In this case, the calibrated delays are for the ensemble receiver main unit plus antenna.

For each location, the coordinates of the antenna phase centers are especially computed for the calibration period from RINEX files by using the NRCan PPP software. Unfortunately, this computation is limited to GPS phase center for L1 and L2 carrier frequencies. Galileo E1 carrier being equal to L1, we assume the phase center is identical. But it is not the case for Galileo E5a compared to L2, and we can only approximate the Galileo E5a phase center by using L2 one. The geometric correction between pairs of antenna phase centers for receivers in common-clock set-up is computed by using Rapid BRDC files provided by IGS.

Reference delays are measured against either the local UTC(k) physical reference point or the local time scale reference point at the trigger level currently used in the involved laboratories. The trigger level in LNE-SYRTE is 1.0 V. Antenna cable delay is either obtained from dedicated measurements or included in the P1 and P2 delays and in the E1 and E5a delays when no value is available for this parameter. In this latter case, the CABDLY value is set to 0 in the parameter file, and the calibrated delays are for the ensemble receiver main unit plus antenna cable plus antenna.

For validation purposes, ionosphere-free linear combinations P3 and E3 CGGTTS files are computed by using the R2CGGTTS software provided by P. Defraigne (ORB), and CV are built between pairs of receivers. This is more especially the case when we are using two traveling receivers in a visited location, in order to better assess the stability of this traveling ensemble all over the calibration campaign. But this usual validation process cannot be applied when both traveling receivers are not connected to the same local time scale. The conservative estimated value for the traveling equipment stability during such a campaign is typically chosen for each code as the maximum between the misclosure between the start and the end of the campaign and the average offset between both traveling receivers as measured in each location.

As conservative estimate, the noise of the P1 and P2 differences and of the E1 and E5a differences is obtained from the highest value of the one-sigma statistical uncertainty of the TDEV at 1 d, issued from a linear interpolation between consecutive TDEV points when required. In the case there is not enough data to compute a TDEV at 1 d, the upper limit of the last error bar available is considered as noise of the raw differences. The noise of P3 and E3 data is issued from a similar analysis on TDEV data.

Note finally that there is a specific computation to be applied to obtain updated GPS delays when dealing with a DICOM GTR50 in a calibration process. The new delays computation is as follows:

$$INTDLY(Px)_{New} = INTDLY(Px)_{Old} + CABDLY - REFDLY + INTDLY(Px)_{Cal} \quad (1)$$

where Px is either P1 or P2-code, $INTDLY(Px)_{Old}$ are the INTDLY which are currently implemented in the main unit and $INTDLY(Px)_{Cal}$ are the results of the calibration processing carried out by LNE-SYRTE during this campaign. The $INTDLY(Px)_{Old}$, CABDLY and REFDLY are taken from the Information sheet provided by the visited laboratory. This computation was applied for the station IT2_ in INRIM.

7. Results of data processing.

7.1. GPS delays calibration.

The plots of the GPS codes raw data processing and the related TDEV can be found in Annex B. Table 4 to 6 provide a summary of all the delays involved in the GPS code calibrations for all stations. First, the calibration of the traveling stations OP72 and OP74 against the reference station OP73, leading to the OP72 and OP74 delay mean values between the start and the end of the campaign. Second, the calibration of the visited stations against these mean values. As typically expected, the noise estimates from the TDEVs are around or below 100 ps, and are hence remaining low enough in the uncertainty budgets (see Section 8).

*Table 4. Summary of **GPS** delays for traveling stations **OP72 and OP74** (all values in ns).*

Receiver	Reference	MJD of Measurement	REFDLY	CABDLY	P1 DLY	TDEV	P2 DLY	TDEV
OP73	*1001-2020*	*59796 – 59807*	*85.2*	*129.6*	*29.500*	*NC*	*26.300*	*NC*
OP72	OP73	59796 – 59807	93.4	0.0	231.830	0.061	230.621	0.040
OP74	OP73	59796 – 59807	111.4	0.0	232.262	0.059	231.337	0.041
OP73	*1001-2020*	*59902 – 59911*	*85.2*	*129.6*	*29.500*	*NC*	*26.300*	*NC*
OP72	OP73	59902 – 59911	93.3	0.0	230.950	0.045	230.290	0.025
OP74	OP73	59902 – 59911	111.3	0.0	231.468	0.041	230.987	0.025

*Table 5. Summary of **GPS** delays for all visited stations against **OP72 mean delays** (all values in ns).*

Receiver	Reference	MJD of Measurement	REFDLY	CABDLY	P1 DLY	TDEV	P2 DLY	TDEV
OP72	*OP73*	*59817 – 59825*	*166.3*	*0.0*	*231.390*	*0.061*	*230.455*	*0.040*
IT11	OP72	59817 – 59825	483.6	298.6	56.013	0.085	54.434	0.106
IT12	OP72	59817 – 59825	483.5	0.0	352.838	0.078	352.775	0.080
IT14	OP72	59817 – 59825	376.2	0.0	279.773	0.076	277.537	0.062
IT15	OP72	59817 – 59825	432.9	306.4	27.498	0.122	24.439	0.095
IT16	OP72	59817 – 59825	161.1	355.5	27.634	0.099	25.567	0.094
IT10	OP72	59817 – 59825	483.6	130.5	54.269	0.074	55.042	0.050
IT08	OP72	59817 – 59825	483.9	0.0	308.992	0.096	308.554	0.075
IT09	OP72	59817 – 59825	484.0	130.5	55.007	0.072	55.513	0.050
IT2_ [*]	OP72	59817 – 59825	107.3	131.0	- 26.096	0.111	- 25.956	0.077
OP72	*OP73*	*59880 – 59888*	*65.6*	*0.0*	*231.390*	*0.061*	*230.455*	*0.040*
RIT1	OP72	59880 – 59888	0.0	0.0	273.667	0.058	269.699	0.032
RIT2	OP72	59880 – 59888	0.0	0.0	231.657	0.055	228.167	0.028
SP03	OP72	59880 – 59888	0.0	0.0	2668.122	0.089	264.956	0.032
SP05	OP72	59880 – 59888	0.0	0.0	200.652	0.091	195.642	0.030

[*] According to equation (1), the IT2_ delays here are INTDLY(Px)Cal

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*Table 6. Summary of **GPS** delays for all visited stations against **OP74 mean delays** (all values in ns).*

Receiver	Reference	MJD of Measurement	REFDLY	CABDLY	P1 DLY	TDEV	P2 DLY	TDEV
OP74	*OP73*	*59817 – 59825*	*151.1*	*0.0*	*231.865*	*N0.059*	*231.162*	*0.041*
IT11	OP74	59817 – 59825	483.6	298.6	55.996	0.083	54.353	0.106
IT12	OP74	59817 – 59825	483.5	0.0	352.821	0.076	352.694	0.080
IT14	OP74	59817 – 59825	376.2	0.0	279.754	0.073	277.456	0.061
IT15	OP74	59817 – 59825	432.9	306.4	27.481	0.119	24.358	0.095
IT16	OP74	59817 – 59825	161.1	355.5	27.616	0.097	25.485	0.094
IT10	OP74	59817 – 59825	483.6	130.5	54.251	0.071	54.961	0.049
IT08	OP74	59817 – 59825	483.9	0.0	308.975	0.093	308.473	0.074
IT09	OP74	59817 – 59825	484.0	130.5	54.990	0.069	55.432	0.049
IT2_ [*]	OP74	59817 – 59825	107.3	131.0	- 26.112	0.110	- 26.037	0.075
OP74	*OP73*	*59880 – 59888*	*83.5*	*0.0*	*231.865*	*0.059*	*231.162*	*0.041*
RIT1	OP74	59880 – 59888	0.0	0.0	273.682	0.059	269.760	0.032
RIT2	OP74	59880 – 59888	0.0	0.0	231.673	0.054	228.228	0.029
SP03	OP74	59880 – 59888	0.0	0.0	268.137	0.089	265.017	0.033
SP05	OP74	59880 – 59888	0.0	0.0	200.667	0.089	195.703	0.031

[*] According to equation (1), the IT2_ delays here are INTDLY(Px)$_{Cal}$

Table 7 provides the differential GPS delays of the visited systems with respect to the traveling system, according to BIPM Guidelines [2]. We note here that the offsets of the differences between either OP72 or OP74 and OP73 at the start and at the end of the campaign are about – 0.880 ns (P1) and – 0.331 ns (P2) for OP72 and – 0.794 ns (P1) and – 0.350 ns (P2) for OP74 respectively, which is higher than expected for P1: the campaign having started in August and ended in November, there is most probably a temperature effect affecting these offsets. Meanwhile, there is an excellent consistency of the remote station delays obtained either from OP72 or from OP74 in each visited location, the maximum offset between both staying below 82 ps.

Table 7. Visited systems with respect to reference system via traveling systems (all values in ns).

Pair	MJD of Measurement	INTDLY P1	INTDLY P2	P1 – P2
OP72 – OP73	59796 – 59807	231.830	230.621	1.209
OP74 – OP73	59796 – 59807	232.262	231.337	0.925
OP72 – OP73	59902 – 59911	230.950	230.290	0.660
OP74 – OP73	59902 – 59911	231.468	230.987	0.481
IT11– OP72	59817 – 59825	56.013	54.434	1.579
IT11– OP74	59817 – 59825	55.996	54.353	1.643
IT12 – OP72	59817 – 59825	352.838	352.775	0.063
IT12 – OP74	59817 – 59825	352.821	352.694	0.127
IT14 – OP72	59817 – 59825	279.773	277.537	2.236

IT14 – OP74	59817 – 59825	279.754	277.456	2.298
IT15 – OP72	59817 – 59825	27.498	24.439	3.059
IT15 – OP74	59817 – 59825	27.481	24.358	3.123
IT16 – OP72	59817 – 59825	27.634	25.567	2.067
IT16 – OP74	59817 – 59825	27.616	25.485	2.131
IT10 – OP72	59817 – 59825	54.269	55.042	- 0.773
IT10 – OP74	59817 – 59825	54.251	54.961	- 0.710
IT08 – OP72	59817 – 59825	308.992	308.554	0.438
IT08 – OP74	59817 – 59825	308.975	308.473	0.502
IT09 – OP72	59817 – 59825	55.007	55.513	- 0.506
IT09 – OP74	59817 – 59825	54.990	55.432	- 0.442
IT2_ – OP72 [*]	59817 – 59825	- 26.096	- 25.956	- 0.140
IT2_ – OP74 [*]	59817 – 59825	- 26.112	- 26.037	- 0.075
RIT1 – OP72	59880 – 59888	273.667	269.699	3.968
RIT1 – OP74	59880 – 59888	273.682	269.760	3.922
RIT2 – OP72	59880 – 59888	231.657	228.167	3.490
RIT2 – OP74	59880 – 59888	231.673	228.228	3.445
SP03 – OP72	59880 – 59888	268.122	264.956	3.166
SP03 – OP74	59880 – 59888	268.137	265.017	3.120
SP05 – OP72	59880 – 59888	200.652	195.642	5.010
SP05 – OP74	59880 – 59888	200.667	195.703	4.964

[*] *According to equation (1), the IT2_ delays here are INTDLY(Px)$_{Cal}$*

7.2. Galileo delays calibration.

The plots of the Galileo codes raw data processing and related TDEV can be found in Annex B. Table 8 to 10 provide a summary of all the delays involved in the Galileo code calibrations for all stations. First, the calibration of the traveling stations OP72 and OP74 against the reference station OP73, leading to the OP72 and OP74 delay mean values between the start and the end of the campaign. Second, the calibration of the visited stations against these mean values. As typically expected, the noise estimates from the TDEVs are largely below 200 ps, and are hence remaining low enough in the uncertainty budgets (see Section 8).

*Table 8. Summary of **Galileo** delays for traveling stations **OP72 and OP74** (all values in ns).*

Receiver	Reference	MJD of Measurement	REFDLY	CABDLY	E1 DLY	TDEV	E5a DLY	TDEV
OP73	*1001-2020*	*59796 – 59807*	*85.2*	*129.6*	*31.700*	*NC*	*31.300*	*NC*
OP72	OP73	59796 – 59807	93.4	0.0	234.349	0.083	233.836	0.050
OP74	OP73	59796 – 59807	111.4	0.0	234.926	0.084	234.504	0.050
OP73	*1001-2020*	*59902 – 59911*	*85.2*	*129.6*	*31.700*	*NC*	*31.300*	*NC*
OP72	OP73	59902 – 59911	93.3	0.0	233.451	0.058	233.880	0.035
OP74	OP73	59902 – 59911	111.3	0.0	234.101	0.059	234.598	0.036

*Table 9. Summary of **Galileo** delays for all visited stations against **OP72 mean delays** (all values in ns).*

Receiver	Reference	MJD of Measurement	REFDLY	CABDLY	E1 DLY	TDEV	E5a DLY	TDEV
OP72	*OP73*	*59817 – 59825*	*166.3*	*0.0*	*233.900*	*0.084*	*233.858*	*0.050*
IT11	OP72	59817 – 59825	483.6	298.6	56.919	0.109	63.949	0.040
IT12	OP72	59817 – 59825	483.5	0.0	353.742	0.105	362.399	0.046
IT14	OP72	59817 – 59825	376.2	0.0	282.070	0.120	281.947	0.070
IT15	OP72	59817 – 59825	432.9	306.4	29.692	0.149	28.393	0.056
IT16	OP72	59817 – 59825	161.1	355.5	29.921	0.122	28.293	0.029
IT10	OP72	59817 – 59825	483.6	130.5	55.119	0.103	64.483	0.099
IT08	OP72	59817 – 59825	483.9	0.0	309.880	0.131	320.325	0.046
IT09	OP72	59817 – 59825	484.0	130.5	55.861	0.102	65.171	0.101
OP72	*OP73*	*59880 – 59888*	*65.6*	*0.0*	*233.900*	*0.084*	*233.858*	*0.050*
RIT1	OP72	59880 – 59888	0.0	0.0	276.040	0.064	273.440	0.040
RIT2	OP72	59880 – 59888	0.0	0.0	234.545	0.061	238.071	0.030
SP03	OP72	59880 – 59888	0.0	0.0	270.537	0.090	282.855	0.050
SP05	OP72	59880 – 59888	0.0	0.0	203.286	0.079	202.094	0.039

*Table 10. Summary of **Galileo** delays for all visited stations against **OP74 mean delays** (all values in ns).*

Receiver	Reference	MJD of Measurement	REFDLY	CABDLY	E1 DLY	TDEV	E5a DLY	TDEV
OP74	*OP73*	*59817 – 59825*	*151.1*	*0.0*	*234.514*	*0.059*	*234.551*	*0.036*
IT11	OP74	59817 – 59825	483.6	298.6	56.896	0.108	63.901	0.041
IT12	OP74	59817 – 59825	483.5	0.0	353.719	0.105	362.350	0.046
IT14	OP74	59817 – 59825	376.2	0.0	282.047	0.119	281.899	0.070
IT15	OP74	59817 – 59825	432.9	306.4	29.669	0.148	28.345	0.057
IT16	OP74	59817 – 59825	161.1	355.5	29.898	0.121	28.245	0.029
IT10	OP74	59817 – 59825	483.6	130.5	55.096	0.102	64.435	0.100
IT08	OP74	59817 – 59825	483.9	0.0	309.857	0.131	320.276	0.047
IT09	OP74	59817 – 59825	484.0	130.5	55.838	0.101	65.122	0.102
OP74	*OP73*	*59880 – 59888*	*83.5*	*0.0*	*234.514*	*0.059*	*234.551*	*0.036*
RIT1	OP74	59880 – 59888	0.0	0.0	276.064	0.064	273.465	0.040
RIT2	OP74	59880 – 59888	0.0	0.0	234.568	0.061	238.096	0.029
SP03	OP74	59880 – 59888	0.0	0.0	270.561	0.092	282.880	0.050
SP05	OP74	59880 – 59888	0.0	0.0	203.309	0.080	202.120	0.040

Table 11 provides the differential Galileo delays of the visited systems with respect to the traveling system, according to BIPM Guidelines [2]. We note here that the offsets of the differences between either OP72 or OP74 and OP73 at the start and at the end of the campaign are about – 0,898 ns (E1) and 0,044 ns (E5a) for OP72 or – 0,825 ns (E1) and 0,094 ns (E5a) for OP74, which is higher than expected for E1. Again, the campaign having started in August and ended in November, it is highly probable that there is a temperature effect

leading to these results. What remains however unexplained is the large difference between E1 and E5a offsets for each receiver. On the other hand, the consistency of the results in visited stations is even better here compared to GPS delays, thanks to offsets staying within a maximum of 49 ns.

Table 11. Visited systems with respect to reference system via traveling system (all values in ns).

Pair	MJD of Measurement	INTDLY E1	INTDLY E5a	E1 – E5a
OP72 – OP73	59796 – 59807	234.349	233.836	0.513
OP74 – OP73	59796 – 59807	234.926	234.504	0.422
OP72 – OP73	59902 – 59911	233.451	233.880	- 0.429
OP74 – OP73	59902 – 59911	234.101	234.598	- 0.497
IT11 – OP72	59817 – 59825	56.919	63.949	- 7.030
IT11 – OP74	59817 – 59825	56.896	63.901	- 7.005
IT12 – OP72	59817 – 59825	353.742	362.399	- 8.657
IT12 – OP74	59817 – 59825	353.719	362.350	- 8.631
IT14 – OP72	59817 – 59825	282.070	281.947	0.123
IT14 – OP74	59817 – 59825	282.047	281.899	0.148
IT15 – OP72	59817 – 59825	29.692	28.393	1.299
IT15 – OP74	59817 – 59825	29.669	28.345	1.324
IT16 – OP72	59817 – 59825	29.921	28.293	1.628
IT16 – OP74	59817 – 59825	29.898	28.245	1.653
IT10 – OP72	59817 – 59825	55.119	64.483	- 9.364
IT10 – OP74	59817 – 59825	55.096	64.435	- 9.339
IT08 – OP72	59817 – 59825	309.880	320.325	- 10.445
IT08 – OP74	59817 – 59825	309.857	320.276	- 10.419
IT09 – OP72	59817 – 59825	55.861	65.171	- 9.310
IT09 – OP74	59817 – 59825	55.838	65.122	- 9.284
RIT1 – OP72	59880 – 59888	276.040	273.440	2.600
RIT1 – OP74	59880 – 59888	276.064	273.465	2.599
RIT2 – OP72	59880 – 59888	234.545	238.071	- 3.526
RIT2 – OP74	59880 – 59888	234.568	238.096	- 3.528
SP03 – OP72	59880 – 59888	270.537	282.855	- 12.318
SP03 – OP74	59880 – 59888	270.561	282.880	- 12.319
SP05 – OP72	59880 – 59888	203.286	202.094	1.192
SP05 – OP74	59880 – 59888	203.309	202.120	1.189

8. Uncertainty budgets.

We provide in this section an estimation of the combined uncertainty of the differential calibration for the receivers located in visited laboratories. All the uncertainty budgets have been built according to the reference [2] in order to provide the required u_{CAL0} values. More details on the uncertainty estimations are provided in Annex C.

The Type A uncertainty on measured codes is estimated from the high value of the 1 sigma statistical uncertainty of the TDEV(1 d). The Type A uncertainty of the difference between codes is the quadratic sum between both estimations. But the P3 and E3 Type A uncertainties are estimated from the high value of the 1 sigma statistical uncertainty of the related TDEV(1 d). All TDEV plots are in Annex B. Table 12 shows the P3 and E3 TDEV(1 d) computed values for all receiver pairs during the campaign. Note how OP72 and OP74 P3 and E3 noises are staying close to each other at the start and at the end of the campaign at OP. This is mostly because they are connected to the same antenna cable and antenna. The conservative values eventually chosen for the uncertainty budget computation are highlighted in **bold purple**.

Table 12. One sigma statistical uncertainty of TDEV(1 d) computed values for P3 and E3 for all station pairs (all values in ns).

Linear combination	P3	E3
OP72 – OP73 Start	**0.124**	**0.234**
OP72 – OP73 End	0.091	0.148
OP74 – OP73 Start	**0.121**	**0.233**
OP74 – OP73 End	0.084	0.145
IT11 (GR01) – OP72	**0.093**	**0.266**
IT11 (GR01) – OP74	0.083	0.266
IT12 (GR02) – OP72	**0.092**	**0.269**
IT12 (GR02) – OP74	0.085	0.269
IT14 (GR04) – OP72	**0.110**	**0.330**
IT14 (GR04) – OP74	0.102	0.330
IT15 (GR05) – OP72	**0.174**	**0.373**
IT15 (GR05) – OP74	0.168	0.373
IT16 (GR06) – OP72	**0.114**	0.285
IT16 (GR06) – OP74	0.109	**0.286**
IT10 (IENG) – OP72	**0.138**	**0.335**
IT10 (IENG) – OP74	0.132	0.334
IT08 (INR5) – OP72	**0.156**	**0.296**
IT08 (INR5) – OP74	0.150	0.296
IT09 (INR6) – OP72	**0.136**	**0.333**
IT09 (INR6) – OP74	0.129	0.332
IT2_ – OP72	**0.183**	na/nc
IT2_ – OP74	0.180	na/nc
SP03 – OP72	0.213	0.191
SP03 – OP74	**0.217**	**0.192**
SP05 – OP72	**0.221**	0.182

SP05 – OP74	0.216	**0.189**
SP06 – OP72	**0.161**	0.150
SP06 – OP74	0.160	**0.153**
SP07 – OP72	0.159	0.149
SP07 – OP74	**0.162**	**0.153**

In the calibration process only P1 and P2 delays for GPS and E1 and E5a delays for Galileo are estimated, therefore the misclosure for P3 delay (GPS) or E3 delay (Galileo) is not directly available from the calibration computation. The GPS P3 misclosure is estimated by applying to the misclosure values computed for P1- and P2-code the ionosphere-free linear combination formula:

$$P3 = P1 + 1.546 \times (P1 - P2)$$

The Galileo E3 misclosure is estimated by applying to the misclosure values computed for E1- and E5a-code the ionosphere-free linear combination formula:

$$E3 = E1 + 1.261 \times (E1 - E5a)$$

Table 13 shows the values of the considered misclosures, which are actually much higher than expected. This might be linked to the large temperature difference of about 30 °C between the start and the end of the campaign. Note that only positive offsets will be used as u_b values in the uncertainty budget computation.

Table 13. Mean misclosure values between traveling stations and reference station OP73 (all values in ns).

Misclosure	ΔP1	ΔP2	Δ(P1 - P2)	ΔP3	ΔE1	ΔE5a	Δ(E1 - E5a)	ΔE3
OP72	- 0.880	- 0.331	- 0.549	- 1.728	- 0.898	0.044	- 0.942	- 2.086
OP74	- 0.794	- 0.350	- 0.444	- 1.480	- 0.825	0.094	- 0.919	- 1.984
Mean value	**- 0.837**	**- 0.341**	**- 0.497**	**- 1.604**	**- 0.862**	**0.069**	**- 0.931**	**- 2.035**

The offsets between OP72 and OP74 when implemented in each location are to be compared to the misclosure values above. Table 14 provides the computed offsets by including the equipment stay in PTB and ROA.

Table 14. Mean offset between OP72 and OP74 measured in all locations for all GNSS codes (all values in ns).

OP72 - OP74	OP (start)	INRIM	ROA	PTB	RISE	OP (end)
ΔP1	- 0.042	- 0.027	- 0.134	- 0.005	- 0.131	0 .073
ΔP2	0.009	0.037	- 0.214	- 0.046	- 0.179	0.020
ΔP3	- 0.121	- 0.125	- 0.011	0.059	- 0.058	0.155
ΔE1	- 0.037	- 0.021	- 0.129	- 0.001	- 0.141	0.067
ΔE5a	- 0.025	0.005	**- 0.136**	- 0.005	**- 0.142**	0.055
ΔE3	- 0.051	- 0.053	- 0.120	0.004	- 0.139	0.081

But as already mentioned above, we also detected an unexpected offset between GPS CV and Galileo CV between OP72 and OP74 depending on the locations. Figure 1 shows the issue, something having happened with the traveling equipment between INRIM and ROA. The computation is achieved by using the average delays of OP72 and OP74 against OP73 between the start and the end of the campaign. Table 15 provides the offsets between GPS P3

CV and Galileo E3 CV mean values observed during the campaign. We see there that the mean offset between the start of the campaign and the closure in OP on the difference E3 CV – P3 CV is about 143 ps.
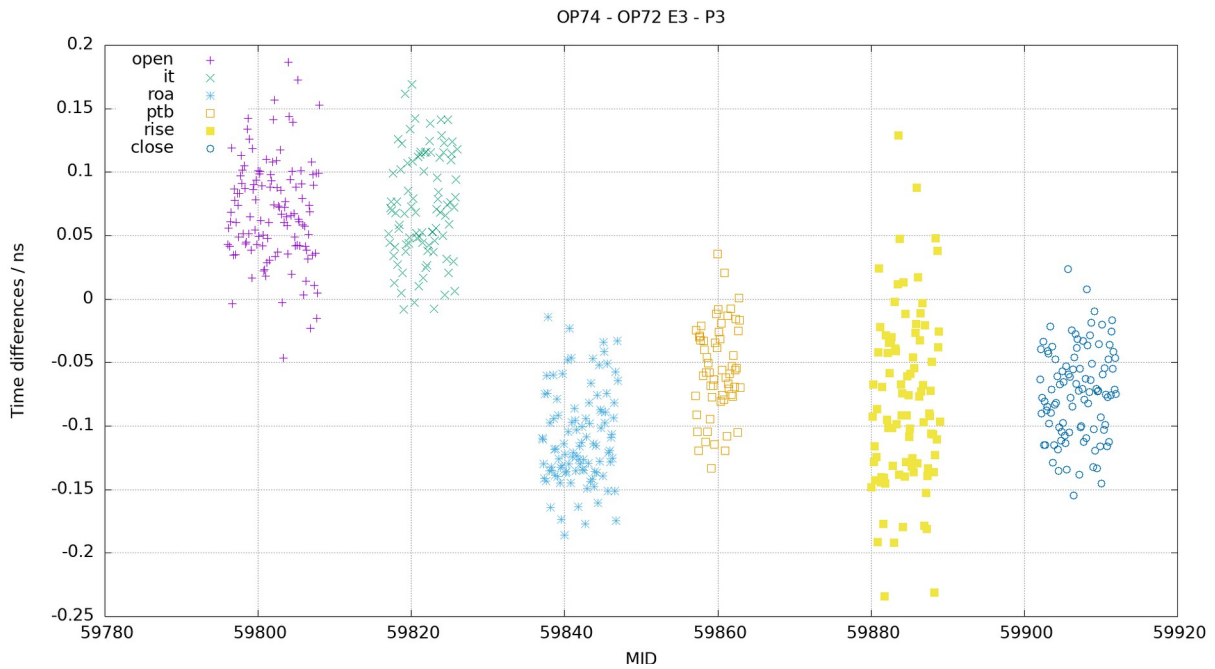
Figure 1. Offsets between Galileo E3 CV and GPS P3 CV between OP72 and OP74 in all the different locations of the calibration campaign as follows: opening at OP, INRIM, ROA, PTB, RISE, and close at OP. Each point is an average value sampled every 0.1 d for clarity. There is a visible offset between the INRIM period and the ROA one, of mean amplitude about 180 ps, leading to two apparent steady positions of the traveling equipment during this campaign.

Table 15. Mean offset between Galileo P3 CV and GPS E3CV between OP72 and OP74 depending on the locations (all values in ns).

OP72 - OP74	OP (Start)	INRIM	ROA	PTB	RISE	OP (End)
Galileo E3 CV – GPS P3 CV	0.069	0.072	- 0.109	- 0.055	- 0.081	- 0.074
Standard deviation	0.698	0.698	0.668	0.669	0.808	0.683

When considering all these effects, and in a conservative way, we have decided to choose the maximum value between all offset types given in Table 13, 14 and 15 for the "misclosure" uncertainty in the budget computation for each code in each visited station (highlighted in **bold purple**).

Table 16 to 28 are providing the uncertainty budgets for GPS delays of all visited stations. Table 29 to 40 are providing similar uncertainty budgets for Galileo delays of all visited stations tracking Galileo signal.

*Table 16. **IT11** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT11**)	0.085	0.106	0.136	0.093	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.105	0.114	0.154	0.155	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.032	0.695		**1.718**	Composed of u_a and $u_{b,SYS}$

*Table 17. **IT12** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT12**)	0.078	0.080	0.112	0.092	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.099	0.090	0.133	0.154	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.031	0.692		**1.718**	Composed of u_a and $u_{b,SYS}$

Table 18. **IT14** *uncertainty budget for* **GPS** *calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT14**)	0.076	0.062	0.098	0.110	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.097	0.074	0.122	0.166	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.031	0.690		**1.719**	Composed of u_a and $u_{b,SYS}$

Table 19. **IT15** *uncertainty budget for* **GPS** *calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT15**)	0.122	0.095	0.155	0.174	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.136	0.103	0.171	0.214	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.035	0.694		**1.724**	Composed of u_a and $u_{b,SYS}$

*Table 20. **IT16** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT16**)	0.099	0.094	0.137	0.114	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.116	0.103	0.155	0.168	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.033	0.694		**1.719**	Composed of u_a and $u_{b,SYS}$

*Table 21. **IT10** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT10**)	0.074	0.050	0.089	0.138	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.096	0.065	0.115	0.186	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.030	0.689		**1.721**	Composed of u_a and $u_{b,SYS}$

Table 22. **IT08** *uncertainty budget for* **GPS** *calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT08**)	0.096	0.075	0.122	0.156	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.114	0.085	0.142	0.199	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.032	0.691		**1.723**	Composed of u_a and $u_{b,SYS}$

*Table 23. **IT09** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT09**)	0.072	0.050	0.088	0.136	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.094	0.065	0.114	0.184	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.030	0.689		**1.721**	Composed of u_a and $u_{b,SYS}$

*Table 24. **IT2_** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT2_**)	0.111	0.077	0.135	0.183	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.127	0.087	0.154	0.221	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.034	0.691		**1.725**	Composed of u_a and $u_{b,SYS}$

*Table 25. **SP03** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**SP03**)	0.089	0.033	0.095	0.217	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.108	0.053	0.120	0.250	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.032	0.688		**1.729**	Composed of u_a and $u_{b,SYS}$

*Table 26. **SP05** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**SP05**)	0.091	0.031	0.096	0.221	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.110	0.051	0.121	0.253	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.032	0.687		**1.730**	Composed of u_a and $u_{b,SYS}$

*Table 27. **SP06/RIT1** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**SP06/RIT1**)	0.059	0.032	0.067	0.161	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.085	0.052	0.099	0.203	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.030	0.687		**1.723**	Composed of u_a and $u_{b,SYS}$

*Table 28. **SP07/RIT2** uncertainty budget for **GPS** calibrated delays (all values in ns).*

Uncertainty type	P1	P2	P1 – P2	P3	Description
u_a(reference)	0.061	0.041	0.073	0.124	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**SP07/RIT2**)	0.055	0.029	0.062	0.162	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.082	0.050	0.096	0.204	Visited against reference
Misclosure					
$u_{b,1}$	0.837	0.341	0.497	1.604	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	0.978	0.611	0.638	1.682	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.026	0.686		1.711	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.029	0.688		**1.723**	Composed of u_a and $u_{b,SYS}$

*Table 29. **IT11** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT11**)	0.109	0.041	0.116	0.266	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.138	0.065	0.152	0.354	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.069	0.931	2.035	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.511	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.599		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.056	0.603		**2.149**	Composed of u_a and $u_{b,SYS}$

*Table 30. **IT12** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT12**)	0.105	0.046	0.115	0.269	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.134	0.068	0.151	0.357	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.069	0.931	2.035	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.511	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.599		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.056	0.603		**2.150**	Composed of u_a and $u_{b,SYS}$

Table 31. **IT14** *uncertainty budget for* **Galileo** *calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT14**)	0.120	0.070	0.139	0.330	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.146	0.086	0.170	0.405	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.069	0.931	2.035	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.511	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.599		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.057	0.605		**2.158**	Composed of u_a and $u_{b,SYS}$

*Table 32. **IT15** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT15**)	0.149	0.056	0.159	0.373	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.171	0.075	0.187	0.440	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.069	0.931	2.035	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.511	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.599		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.061	0.604		**2.165**	Composed of u_a and $u_{b,SYS}$

*Table 33. **IT16** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT16**)	0.122	0.029	0.125	0.286	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.148	0.058	0.159	0.370	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.069	0.931	2.035	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.511	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.599		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.057	0.602		**2.152**	Composed of u_a and $u_{b,SYS}$

*Table 34. **IT10** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT10**)	0.103	0.100	0.144	0.335	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.133	0.112	0.174	0.409	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.069	0.931	2.035	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.511	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.599		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.055	0.609		**2.159**	Composed of u_a and $u_{b,SYS}$

*Table 35. **IT08** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT08**)	0.131	0.047	0.139	0.296	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.156	0.069	0.170	0.377	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.069	0.931	2.035	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.511	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.599		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.059	0.603		**2.153**	Composed of u_a and $u_{b,SYS}$

*Table 36. **IT09** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**IT09**)	0.102	0.102	0.144	0.333	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.132	0.114	0.174	0.407	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.069	0.931	2.035	Actual misclosure offset
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.511	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.599		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.055	0.610		**2.159**	Composed of u_a and $u_{b,SYS}$

*Table 37. **SP03** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**SP03**)	0.092	0.050	0.105	0.192	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.125	0.071	0.143	0.303	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.142	0.931	2.035	Actual misclosure offset except for E5a
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.526	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.611		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.054	0.615		**2.141**	Composed of u_a and $u_{b,SYS}$

*Table 38. **SP05** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**SP05**)	0.080	0.040	0.089	0.189	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.116	0.064	0.133	0.301	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.142	0.931	2.035	Actual misclosure offset except for E5a
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.526	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.611		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.053	0.627		**2.141**	Composed of u_a and $u_{b,SYS}$

*Table 39. **SP06/RIT1** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**SP06/RIT1**)	0.064	0.040	0.075	0.153	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.106	0.064	0.124	0.280	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.142	0.931	2.035	Actual misclosure offset except for E5a
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.526	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.611		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.052	0.614		**2.138**	Composed of u_a and $u_{b,SYS}$

*Table 40. **SP07/RIT2** uncertainty budget for **Galileo** calibrated delays (all values in ns).*

Uncertainty type	E1	E5a	E1 – E5a	E3	Description
u_a(Reference)	0.084	0.050	0.098	0.234	Largest TDEV(1 d) sigma between the start and the end of OP72 or OP74 against OP73
u_a(**SP07/RIT2**)	0.061	0.030	0.068	0.153	Largest TDEV(1 d) sigma of offset between visited station and OP72 or OP74
Type A uncertainties					
u_a	0.104	0.058	0.119	0.280	Visited against reference
Misclosure					
$u_{b,1}$	0.862	0.142	0.931	2.035	Actual misclosure offset except for E5a
Systematic components related to RAWDIF					
$u_{b,11}$	0.200	0.200	0.200	0.200	Position error at OP
$u_{b,12}$	0.200	0.200	0.200	0.200	Position error at visited site
$u_{b,13}$	0.200	0.200	0.200	0.200	Multipaths at OP
$u_{b,14}$	0.200	0.200	0.200	0.200	Multipaths at visited site
Link of the traveling system to local time scales					
$u_{b,21}$	0.220	0.220		0.220	REFDLY at OP
$u_{b,22}$	0.220	0.220		0.220	REFDLY at visited site
$u_{b,TOT}$	1.000	0.526	1.013	2.097	
Link of the reference system to UTC(OP)					
$u_{b,31}$	0.220	0.220		0.220	REFDLY at OP
Link of the visited system to its local time scale					
$u_{b,32}$	0.220	0.220		0.220	REFDLY at visited site
Antenna cable delays					
$u_{b,41}$	0.0	0.0		0.0	CABDLY at OP
$u_{b,42}$	0.0	0.0		0.0	CABDLY at visited site
Type B uncertainties					
$u_{b,SYS}$	1.047	0.611		2.120	Quadratic sum of u_b
Combined uncertainties					
u_{CAL0}	1.052	0.614		**2.138**	Composed of u_a and $u_{b,SYS}$

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9. Validation of the results.

9.1. Stability of the reference station.

The reference station in OP was based on a Septentrio PolaRx5TR receiver called OP73. Figure 2 is showing a plot which demonstrate the stability of this GNSS station during the calibration campaign. The plot is the daily averaged offset between the Two-Way Satellite Time and Frequency Transfer (TWSTFT) between OP and PTB, based on the Software-Defined Radio (SDR) technique, and the GNSS Common View (CV) time transfer using P3 GPS data between OP and PTB, based on OP73 in OP side and PTBB in PTB side. In both laboratories, the signal source is a UTC(k) time scale: UTC(PTB) and UTC(OP). In this computation, the time scales being cancelled, what remains is only the offset between the two time transfer techniques.
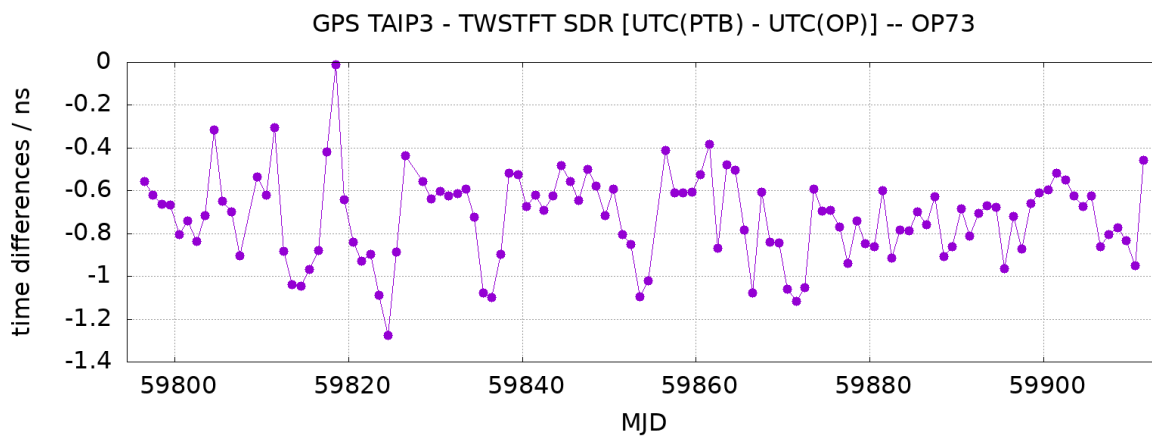
Figure 2. Daily averaged offset between TWSTFT and GPS P3 CV on the link OP-PTB during the calibration campaign.

The mean offset over that period of time is about - 0.72 ns, with a standard deviation of about 0.20 ns. This mean offset is mostly coming from the last G1 calibration of GNSS stations achieved by BIPM for OP and PTB stations (#1001-2020) and from the last TWSTFT relative calibration (#0546-2021). We remind here that the conventional combined uncertainty of GNSS stations located in G1 laboratories is 1.5 ns, as decided by the CCTF Working Group (WG) on GNSS time transfer. The offset seen here is in full agreement with the claimed uncertainties.

What can be seen on Figure 2 is the excellent sub-ns stability of this ensemble of four systems, two inside each laboratory, among which OP73 in OP. We consider that any potential effect of OP73 on this calibration campaign can be disregarded with respect to the final uncertainty of the calibration (see Section 10).

9.2. Offset between the two traveling receivers.

Figure 3 is showing the offset between the two traveling receivers during the whole calibration campaign, based on CV between CGGTTS P3 (GPS) and E3 (Galileo) data, by

using for OP72 and OP74 the average delays computed against OP73 between the start and the closure of the campaign.
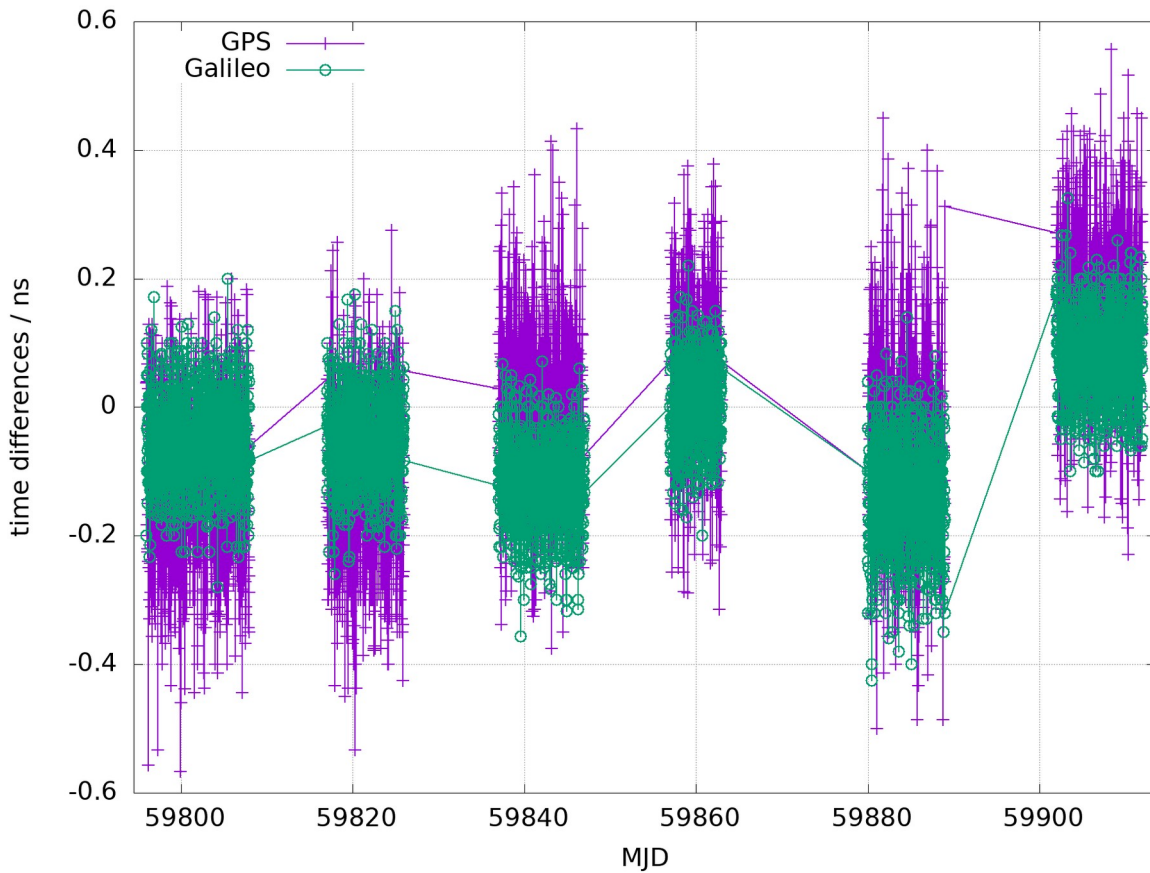
Figure 3. Offset between OP72 and OP74 during the UTC(k) calibration campaign, based on either CGGTTS P3 CV data (purple) or on CGGTTS E3 CV data (green). From left to right, the sequence of data sets is: start at OP, INRIM, ROA, PTB, RISE and closure at OP.

What can be seen here is a clear sub-ns consistency between both traveling receivers all over the campaign. The issue about Galileo CV minus GPS CV offset change was already addressed in Section 8 above.

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10. Final results for the systems to calibrate.

In this Section, we provide the final results of the calibration campaign, based on the uncertainty budgets of Section 8, and according to the BIPM guidelines [2]. In addition, we also provide a conservative k = 2 computation of the uncertainties (95 % confidence interval), according to the EURAMET recommendations. All visited stations are calibrated for P3 (GPS) time transfer and all but IT2_ for E3 (Galileo) time transfer within the given combined uncertainties.

10.1. GPS delays.

Table 38 provides the final results of the calibration campaign for GPS delays for all involved stations. Table 39 provides the conservative k = 2 expanded uncertainties for all GPS codes in line with EURAMET requirements.

Table 38. Summary GPS calibrations on the calibration trip (all values in ns).

BIPM code	RINEX name	Cal Id	Date	u_{CAL}(P3)	INTDLY P1	INTDLY P2
Reference system						
OP73	OP73	1001-2020	2021	1.5 [*]	29.5	26.3
Visited systems						
IT11	IT11	1018-2022	2022	1.8	56.0	54.4
IT12	IT12	1018-2022	2022	1.8	352.8	352.7
IT14	IT14	1018-2022	2022	1.8	279.8	277.5
IT15	IT15	1018-2022	2022	1.8	27.5	24.4
IT16	IT16	1018-2022	2022	1.8	27.6	25.5
IT10	IT10	1018-2022	2022	1.8	54.3	55.0
IT08	IT08	1018-2022	2022	1.8	309.0	308.5
IT09	IT09	1018-2022	2022	1.8	55.0	55.5
IT2_	IT2_	1018-2022	2022	1.8	- 37.1 [**]	- 23.0 [**]
SP03	SP03	1018-2022	2022	1.8	268.1	265.0
SP05	SP05	1018-2022	2022	1.8	200.7	195.7
SP06/RIT1	SP06/RIT1	1018-2022	2022	1.8	273.7	269.7
SP07/RIT2	SP07/RIT2	1018-2022	2022	1.8	231.7	228.2

[*] Conventional combined uncertainty value for G1 laboratories.
[**] The IT2_ delays here are computed according to equation (1).

Table 39. Conservative k = 2 expanded GPS code uncertainties following EURAMET standard (all values in ns).

BIPM code	RINEX name	u(P1)	u(P2)	u(P3)
IT11	IT11	2.1	1.4	3.5
IT12	IT12	2.1	1.4	3.5

IT14	IT14	2.1	1.4	3.5
IT15	IT15	2.1	1.4	3.5
IT16	IT16	2.1	1.4	3.5
IT10	IT10	2.1	1.4	3.5
IT08	IT08	2.1	1.4	3.5
IT09	IT09	2.1	1.4	3.5
IT2_	IT2_	2.1	1.4	3.5
SP03	SP03	2.1	1.4	3.5
SP05	SP05	2.1	1.4	3.5
SP06/RIT1	SP06/RIT1	2.1	1.4	3.5
SP07/RIT2	SP07/RIT2	2.1	1.4	3.5

10.2. Galileo delays.

Table 40 provides the final results of the calibration campaign for Galileo delays for all involved stations. Table 41 provides the conservative k = 2 expanded uncertainties for all Galileo codes in line with EURAMET requirements.

Table 40. Summary Galileo calibrations on the calibration trip (all values in ns).

BIPM code	RINEX name	Cal Id	Date	u_{CAL}(E3)	INTDLY E1	INTDLY E5a
Reference system						
OP73	OP73	1001-2020	2021	1.5 [*]	31.7	31.3
Visited systems						
IT11	IT11	1018-2022	2022	2.2	56.9	63.9
IT12	IT12	1018-2022	2022	2.2	353.7	362.4
IT14	IT14	1018-2022	2022	2.2	282.1	281.9
IT15	IT15	1018-2022	2022	2.2	29.7	28.4
IT16	IT16	1018-2022	2022	2.2	29.9	28.3
IT10	IT10	1018-2022	2022	2.2	55.1	64.5
IT08	IT08	1018-2022	2022	2.2	309.9	320.3
IT09	IT09	1018-2022	2022	2.2	55.8	65.1
SP03	SP03	1018-2022	2022	2.2	270.5	282.9
SP05	SP05	1018-2022	2022	2.2	203.3	202.1
SP06/RIT1	SP06/RIT1	1018-2022	2022	2.2	276.1	273.5
SP07/RIT2	SP07/RIT2	1018-2022	2022	2.2	234.6	238.1

[*] *Conventional combined uncertainty value for G1 laboratories.*

Table 41. Conservative k = 2 expanded Galileo code uncertainties following EURAMET standard (all values in ns).

BIPM code	RINEX name	u(E1)	u(E5a)	u(E3)
IT11	IT11	2.2	1.3	4.3
IT12	IT12	2.2	1.3	4.4
IT14	IT14	2.2	1.3	4.4
IT15	IT15	2.2	1.3	4.4
IT16	IT16	2.2	1.3	4.4
IT10	IT10	2.2	1.3	4.4
IT08	IT08	2.2	1.3	4.4
IT09	IT09	2.2	1.3	4.4
SP03	SP03	2.2	1.3	4.3
SP05	SP05	2.2	1.3	4.3
SP06/RIT1	SP06/RIT1	2.2	1.3	4.3
SP07/RIT2	SP07/RIT2	2.2	1.3	4.3

10.3. Comparison with former PTBB GPS delays.

Figure 4 shows the CV between GPS P3 data from PTBB as obtained during the campaign period, the station PTBB having been calibrated G1 by BIPM, and GPS P3 data from PTBB after application of the LNE-SYRTE calibrated delays. The mean offset is about − 1.02 ns with a standard deviation of about 0.05 ns. This offset is clearly within the combined uncertainty of the GPS P3 data calibration. Moreover, assuming a perfect calibration where all the effects due to the traveling equipment are negligible, the calibration result should lead to the direct difference between PTBB G1 calibrated and the reference station of the campaign, OP73. This should be close to the plot on Figure 2 above, where the difference between GPS CV, based on PTBB - OP73, and TWSTFT is mostly due to GPS CV thanks to the performance of the SDR technique on TWSTFT. This is what we observe, with a mean value at about − 0.6 ns in Figure 2 over the same period of time as in Figure 4 below. This is bringing confidence on the calibration results of this campaign, despite the large combined uncertainty due to the P1/E1 misclosure.

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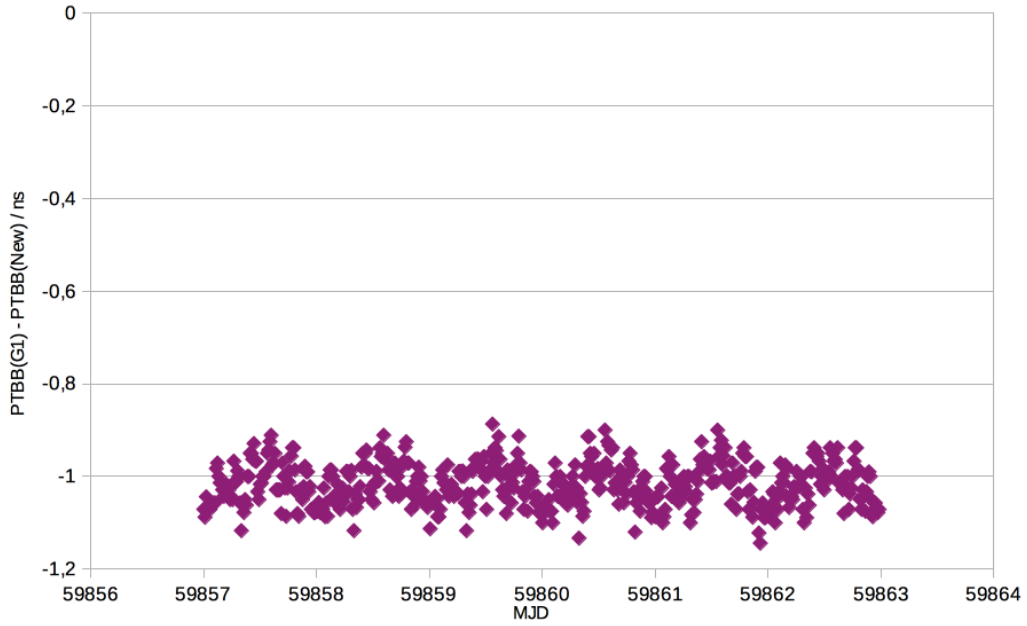
Figure 4. CV between GPS P3 data collected by PTBB as calibrated G1 by BIPM and similar GPS P3 data obtained after application of the newly calibrated delays during the data collection period at PTB.

11. Appendix.

ANNEX A

Implementation of OP traveling stations in visited sites.

A1. Implementation in OP.

Figure A1 is showing the implementation of OP traveling equipment, namely OP72 and OP74 connected to the same antenna cable and antenna, alongside OP73 reference station in LNE-SYRTE in OP at the start and at the end of the campaign.
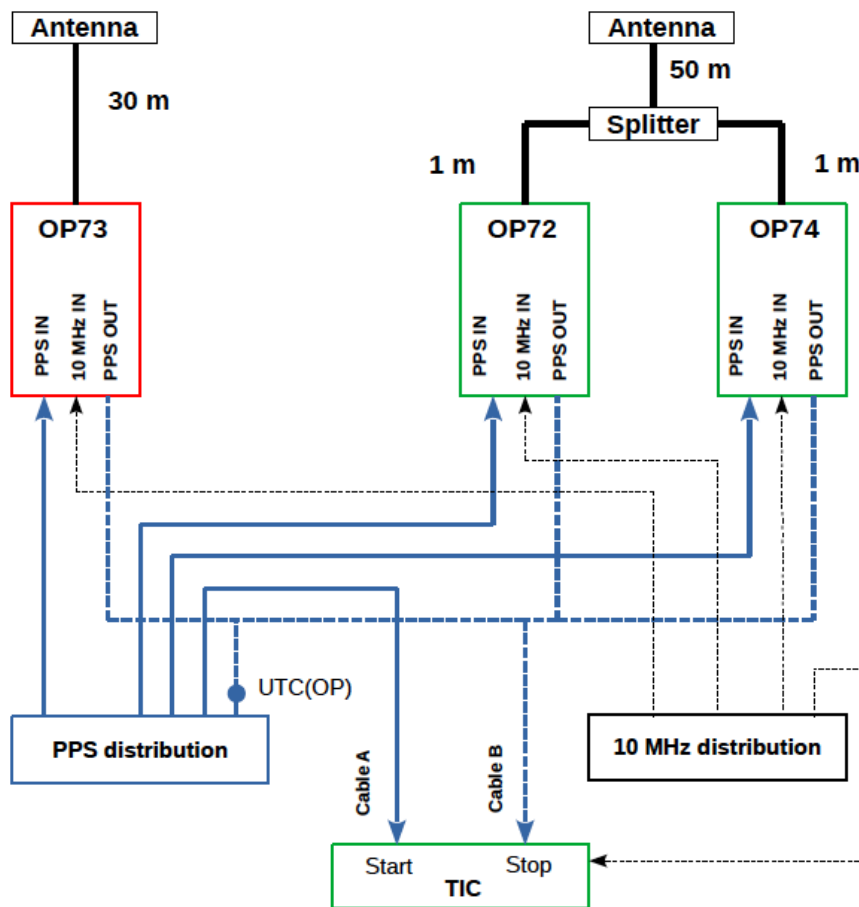
Figure A1. Implementation of OP traveling equipment in OP.

The next pages are providing the BIPM information sheets for OP72 and OP74.

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Cal Id: 1018-2022   Version / Date: 1 / 17-01-2023

BIPM Information sheet

Laboratory	OP opening
Date and hour beginning of measurements	05-08-2022 00:00
Date and hour end measurements	17-08-2022 00:00

Information on the system			
	Local	**Traveling**	
4-Character BIPM code	OP73	OP72	OP74
Receiver maker and type	Septentrio PolarXTr5	Septentrio PolarXTr5	Septentrio PolarXTr5
Receiver serial number	4701467	4701463	4701497
1 PPS triger level / V	1 V	1 V	1 V
Antenna cable marker and type		HY 400 UF	HY 400 UF
Phase stabilized cable (Y/N)			
Cable length outside building / m	20 m	20 m	20 m
Antenna maker and type	SEPCHOKE_B3E6	Novatel GPS-703-GGG	Novatel GPS-703-GGG
Antenna serial number	5759	01018146	01018146
Temperature if stabilized / °C			

Mesured delays / ns			
	Local	**Traveling**	
Delay from local UTC(k) to receiver 1 PPS_IN			
Delay from 1 PPS_IN to internal reference (see Annex 1)			
Antenna cable delay			
Splitter delay			
Additional cable delay			

Data used for the generation of CGGTTS files						
	Local		**Traveling**			
INT DLY (GPS) / ns	P1: 29.5	P2: 26.3	P1: 0.0	P2: 0.0	P1: 0.0	P2: 0.0
INT DLY (Galileo) / ns	E1: 31.7	E5a: 31.3	E1: 0.0	E5a: 0.0	E1: 0.0	E5a: 0.0
CAB DLY / ns	129.6		0.0		0.0	
REF DLY / ns	85.2		93.4		111.4	
Coordinate reference frame	ITRF		ITRF		ITRF	
Latitude or X / m	4202777.071		4202783.316		4202783.316	
Longitude or Y / m	171367.028		171368.064		171368.064	
Height or Z / m	4778661.392		4778657.798		4778657.798	

General Information	
Rise time of local UTC pulse	< 1 ns
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	22¡C / 1¡C
Set humidity value and uncertainty	22¡C / 1¡C

Cal Id: | 1018-2022 |

Version / Date: | 1 / 17-01-2023 |

BIPM Information sheet

Laboratory	OP closure
Date and hour beginning of measurements	19-11-2022 00:00
Date and hour end measurements	29-11-2022 00:00

Information on the system			
	Local	**Traveling**	
4-Character BIPM code	OP73	OP72	OP74
Receiver maker and type	Septentrio PolarXTr5	Septentrio PolarXTr5	Septentrio PolarXTr5
Receiver serial number	4701467	4701463	4701497
1 PPS triger level / V	1 V	1 V	1 V
Antenna cable marker and type		HY 400 UF	HY 400 UF
Phase stabilized cable (Y/N)			
Cable length outside building / m	20 m	20 m	20 m
Antenna maker and type	SEPCHOKE_B3E6	Novatel GPS-703-GGG	Novatel GPS-703-GGG
Antenna serial number	5759	01018146	01018146
Temperature if stabilized / °C			

Mesured delays / ns			
	Local	**Traveling**	
Delay from local UTC(k) to receiver 1 PPS_IN			
Delay from 1 PPS_IN to internal reference (see Annex 1)			
Antenna cable delay			
Splitter delay			
Additional cable delay			

Data used for the generation of CGGTTS files			
	Local	**Traveling**	
INT DLY (GPS) / ns	P1: 29.5 P2: 26.3	P1: 0.0 P2: 0.0	P1: 0.0 P2: 0.0
INT DLY (Galileo) / ns	E1: 31.7 E5a: 31.3	E1: 0.0 E5a: 0.0	E1: 0.0 E5a: 0.0
CAB DLY / ns	129.6	0.0	0.0
REF DLY / ns	85.2	93.3	111.3
Coordinate reference frame	ITRF	ITRF	ITRF
Latitude or X / m	4202777.071	4202783.314	4202783.314
Longitude or Y / m	171367.028	171368.096	171368.096
Height or Z / m	4778661.392	4778657.801	4778657.801

General Information	
Rise time of local UTC pulse	< 1 ns
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	22¡C / 1¡C
Set humidity value and uncertainty	22¡C / 1¡C

A2. Implementation in INRIM.

Figure A2 is showing the implementation of OP traveling equipment, namely OP72 and OP74 connected to the same antenna cable and antenna, alongside all visited stations in INRIM.
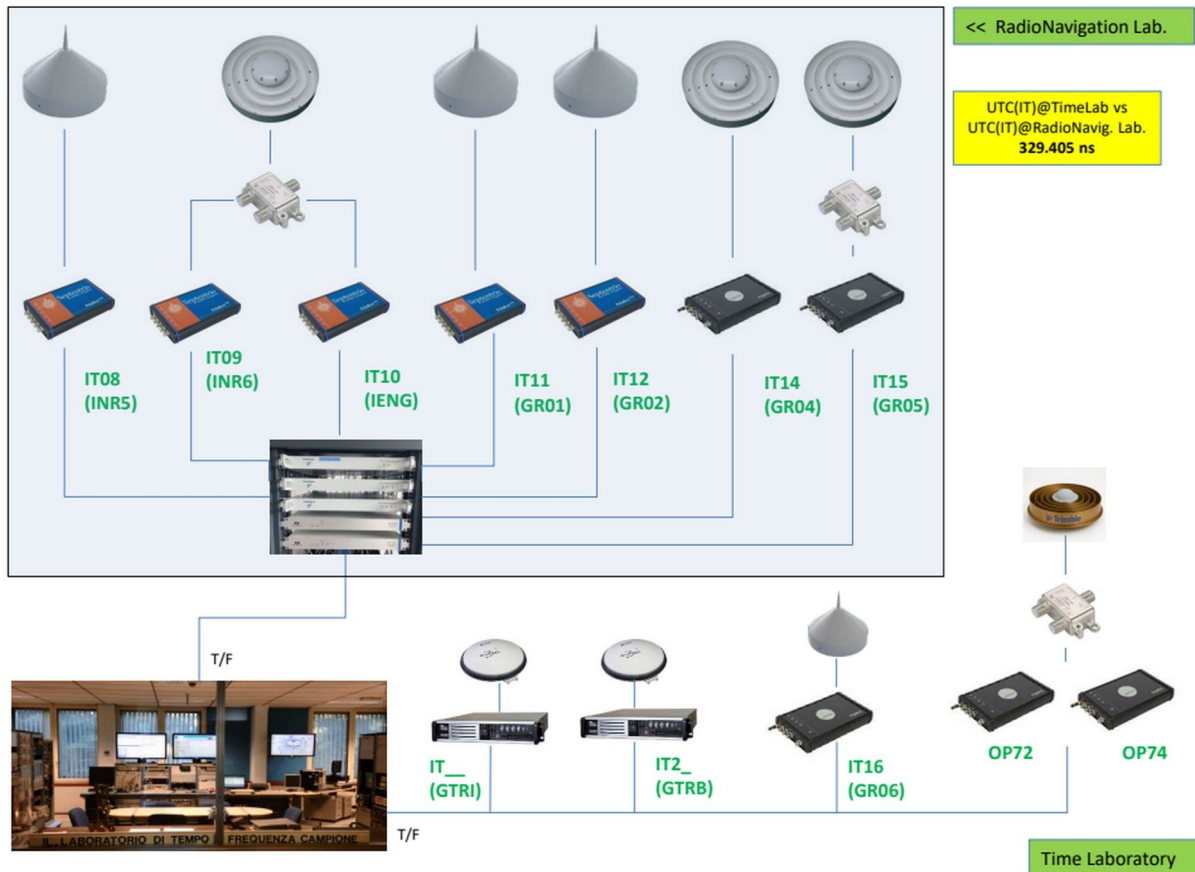
Figure A2. Implementation of OP traveling equipment in INRIM.

The next pages are providing the BIPM information sheets for each INRIM station.

[**Readme.txt** file mentioned in the following pages is as follows:
IT__, IT2_, GR06 are hosted at INRIM Time Laboratory: T= (23 ± 2) °C / H= (30 ÷ 85) %.
INR5(IT08), INR6(IT09), IENG(IT10), GR01(IT11), GR02(IT12), GR04*(IT14), GR05*(IT15) are hosted at INRIM RadioNavigation Laboratory: T= (23 ± 2) °C / H= (30 ÷ 85) % .
The time difference between UTC(IT) reference plane 1PPS signal as generated Time Laboratory, and UTC(IT) 1PPS signal as defined at RadioNavigation Laboratory, is 329.405 ns. This value is included in the REF DLY measurements for the GNSS stations located at the RadioNavigation Laboratory.]

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Cal Id: [   ]   Version / Date: [   ]

BIPM Infortion sheet

Laboratory	IT
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC

Information on the system		
	Local	**Traveling**
4-Character BIPM code	IT11 (GR01)	OP72	OP74
Receiver maker and type	Septentrio PolaRx4-TR		
Receiver serial number	3008032		
1 PPS triger level / V	1 V		
Antenna cable marker and type	RG214		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	5 m		
Antenna maker and type	SEPCHOKE_B3E6		
Antenna serial number	5025		
Temperature if stabilized / °C	NA		

Mesured delays / ns		
	Local	**Traveling**
Delay from local UTC(k) to receiver 1 PPS_IN	483.574 (REF DLY)	166.318 (REF DLY)	151.069 (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	298.6		
Splitter delay	NA		
Additional cable delay	NA		

Data used for the generation of CGGTTS files		
	Local	**Traveling**
INT DLY (GPS) / ns	P1: 55.9 ns P2: 53.9 ns	P1: [ ] P2: [ ]	P1: [ ] P2: [ ]
INT DLY (Galileo) / ns	E1: 57.2 ns E5a: 63.6 ns	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]
CAB DLY / ns	298.6 ns		
REF DLY / ns	483.8 ns		
Coordinate reference frame	ITRF		
Latitude or X / m	4476537.727		
Longitude or Y / m	600441.720		
Height or Z / m	4488754.845		

General Information	
Rise time of local UTC pulse	< 500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

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Cal Id: [   ]   Version / Date: [   ]

BIPM Infortion sheet

Laboratory	IT
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC

Information on the system			
	Local	**Traveling**	
4-Character BIPM code	IT12 (GR02)	OP72	OP74
Receiver maker and type	Septentrio PolaRx4-TR		
Receiver serial number	3008058		
1 PPS triger level / V	1 V		
Antenna cable marker and type	RG214		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	5 m		
Antenna maker and type	SEPCHOKE_B3E6		
Antenna serial number	5004		
Temperature if stabilized / °C	NA		

Mesured delays / ns			
	Local	**Traveling**	
Delay from local UTC(k) to receiver 1 PPS_IN	483.490 (REF DLY)	166.318 (REF DLY)	151.069 (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	NA		
Splitter delay	NA		
Additional cable delay	NA		

Data used for the generation of CGGTTS files			
	Local	**Traveling**	
INT DLY (GPS) / ns	P1: 353.6 ns P2: 353.1 ns	P1: [ ] P2: [ ]	P1: [ ] P2: [ ]
INT DLY (Galileo) / ns	E1: 354.9 ns E5a: 362.7 ns	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]
CAB DLY / ns	NA		
REF DLY / ns	483.6 ns		
Coordinate reference frame	ITRF		
Latitude or X / m	4476534.535		
Longitude or Y / m	600442.576		
Height or Z / m	4488757.911		

General Information	
Rise time of local UTC pulse	< 500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

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BIPM Infortion sheet

Laboratory	IT
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC

Information on the system			
	Local	**Traveling**	
4-Character BIPM code	IT14 (GR04)	OP72	OP74
Receiver maker and type	Septentrio PolaRx5-TR		
Receiver serial number	3074186		
1 PPS triger level / V	1 V		
Antenna cable marker and type	RG213		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	5 m		
Antenna maker and type	SEPCHOKE_B3E6 NO		
Antenna serial number	5788		
Temperature if stabilized / °C	NA		

Mesured delays / ns			
	Local	**Traveling**	
Delay from local UTC(k) to receiver 1 PPS_IN	376.242 (REF DLY)	166.318 (REF DLY)	151.069 (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	NA		
Splitter delay	NA		
Additional cable delay	NA		

Data used for the generation of CGGTTS files			
	Local	**Traveling**	
INT DLY (GPS) / ns	P1: [ ] P2: [ ]	P1: [ ] P2: [ ]	P1: [ ] P2: [ ]
INT DLY (Galileo) / ns	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]
CAB DLY / ns			
REF DLY / ns			
Coordinate reference frame			
Latitude or X / m			
Longitude or Y / m			
Height or Z / m			

General Information	
Rise time of local UTC pulse	< 500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

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Cal Id: [   ]   Version / Date: [   ]

BIPM Infortion sheet

Laboratory	IT
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC

Information on the system			
	Local	**Traveling**	
4-Character BIPM code	IT15 (GR05)	OP72	OP74
Receiver maker and type	Septentrio PolaRx5-TR		
Receiver serial number	3080203		
1 PPS triger level / V	1 V		
Antenna cable marker and type	RG213		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	5 m		
Antenna maker and type	SEPCHOKE_B3E6 NO		
Antenna serial number	5901		
Temperature if stabilized / ℃	NA		

Mesured delays / ns			
	Local	**Traveling**	
Delay from local UTC(k) to receiver 1 PPS_IN	432.885 ns (REF DLY)	166.318 ns (REF DLY)	151.069 ns (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	304.2 ns		
Splitter delay	0.7 ns		
Additional cable delay	1.5 ns		

Data used for the generation of CGGTTS files						
	Local		**Traveling**			
INT DLY (GPS) / ns	P1: [ ] P2: [ ]		P1: [ ] P2: [ ]		P1: [ ] P2: [ ]	
INT DLY (Galileo) / ns	E1: [ ] E5a: [ ]		E1: [ ] E5a: [ ]		E1: [ ] E5a: [ ]	
CAB DLY / ns						
REF DLY / ns						
Coordinate reference frame						
Latitude or X / m						
Longitude or Y / m						
Height or Z / m						

General Information	
Rise time of local UTC pulse	< 500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

G1/G2 #1018-2022

Cal Id: [   ]

Version / Date: [   ]

BIPM Infortion sheet

Laboratory	IT
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC

Information on the system		
	Local	**Traveling**
4-Character BIPM code	IT16 (GR06)	OP72	OP74
Receiver maker and type	Septentrio PolaRx5-TR		
Receiver serial number	3083484		
1 PPS triger level / V	1 V		
Antenna cable marker and type	RG213		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	10 m		
Antenna maker and type	SEPCHOKE_B3E6		
Antenna serial number	5987		
Temperature if stabilized / °C	NA		

Mesured delays / ns		
	Local	**Traveling**
Delay from local UTC(k) to receiver 1 PPS_IN	161.089 (REF DLY)	166.318 (REF DLY)	151.069 (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	355.5 ns		
Splitter delay	NA		
Additional cable delay	NA		

Data used for the generation of CGGTTS files		
	Local	**Traveling**
INT DLY (GPS) / ns	P1: [ ] P2: [ ]	P1: [ ] P2: [ ]	P1: [ ] P2: [ ]
INT DLY (Galileo) / ns	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]
CAB DLY / ns			
REF DLY / ns			
Coordinate reference frame			
Latitude or X / m			
Longitude or Y / m			
Height or Z / m			

General Information	
Rise time of local UTC pulse	< 500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

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Cal Id: [   ]

Version / Date: [   ]

BIPM Infortion sheet

Laboratory	IT
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC

Information on the system			
	Local	**Traveling**	
4-Character BIPM code	IT2_ (GTRB)	OP72	OP74
Receiver maker and type	MESIT GTR50		
Receiver serial number	1012124		
1 PPS triger level / V	1 V		
Antenna cable marker and type	Belden Venlo Holland 2		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	10 m		
Antenna maker and type	Novatel NOV702		
Antenna serial number	00455		
Temperature if stabilized / °C	NA		

Mesured delays / ns			
	Local	**Traveling**	
Delay from local UTC(k) to receiver 1 PPS_IN	107.346 (REF DLY)	166.318 (REF DLY)	151.069 (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	131.0 ns		
Splitter delay	NA		
Additional cable delay	NA		

Data used for the generation of CGGTTS files						
	Local		**Traveling**			
INT DLY (GPS) / ns	P1: -34.8 ns P2: -20.8 ns	P1: [ ] P2: [ ]		P1: [ ] P2: [ ]		
INT DLY (Galileo) / ns	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]		E1: [ ] E5a: [ ]		
CAB DLY / ns	131.0 ns					
REF DLY / ns	107.2 ns					
Coordinate reference frame	ITRF					
Latitude or X / m	476545.08					
Longitude or Y / m	600407.32					
Height or Z / m	4488741.16					

General Information	
Rise time of local UTC pulse	500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

G1/G2 #1018-2022

Cal Id: [　　　　　]　　　　　　　　　　　　　　　　　Version / Date: [　　　　　]

BIPM Infortion sheet

Laboratory	IT
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC

Information on the system			
	Local	**Traveling**	
4-Character BIPM code	IT08 (INR5)	OP72	OP74
Receiver maker and type	Septentrio PolaRx4-TR		
Receiver serial number	3002130		
1 PPS triger level / V	1 V		
Antenna cable marker and type	RG214		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	5 m		
Antenna maker and type	SEPCHOKE_B3E6		
Antenna serial number	5410		
Temperature if stabilized / °C	NA		

Mesured delays / ns			
	Local	**Traveling**	
Delay from local UTC(k) to receiver 1 PPS_IN	483.942 (REF DLY)	166.318 (REF DLY)	151.069 (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	NA		
Splitter delay	NA		
Additional cable delay	NA		

Data used for the generation of CGGTTS files			
	Local	**Traveling**	
INT DLY (GPS) / ns	P1: 310.1 ns P2: 309.0 ns	P1: [　] P2: [　]	P1: [　] P2: [　]
INT DLY (Galileo) / ns	E1: 311.3 ns E5a: 321.0 ns	E1: [　] E5a: [　]	E1: [　] E5a: [　]
CAB DLY / ns	NA		
REF DLY / ns	484.1 ns		
Coordinate reference frame	ITRF		
Latitude or X / m	4476532.120		
Longitude or Y / m	600443.149		
Height or Z / m	4488760.246		

General Information	
Rise time of local UTC pulse	< 500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

G1/G2 #1018-2022

Cal Id: [   ]   Version / Date: [   ]

BIPM Infortion sheet

Laboratory	IT	
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC	
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC	

Information on the system		
	Local	**Traveling**
4-Character BIPM code	IT09 (INR6)	OP72	OP74
Receiver maker and type	Septentrio PolaRx4-TR		
Receiver serial number	3102240		
1 PPS triger level / V	1 V		
Antenna cable marker and type	RG214		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	5 m		
Antenna maker and type	SEPCHOKE_MC NON		
Antenna serial number	5261		
Temperature if stabilized / °C	NA		

Mesured delays / ns		
	Local	**Traveling**
Delay from local UTC(k) to receiver 1 PPS_IN	483.951 (REF DLY)	166.318 (REF DLY)	151.069 (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	128.8 ns		
Splitter delay	0.7 ns (shared IT10)		
Additional cable delay	1.0 ns		

Data used for the generation of CGGTTS files		
	Local	**Traveling**
INT DLY (GPS) / ns	P1: 55.8 ns P2: 55.5 ns	P1: [ ] P2: [ ]	P1: [ ] P2: [ ]
INT DLY (Galileo) / ns	E1: 57.1 ns E5a: 65.3 ns	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]
CAB DLY / ns	130.5 ns		
REF DLY / ns	484.1 ns		
Coordinate reference frame	ITRF		
Latitude or X / m	4476537.275		
Longitude or Y / m	600431.705		
Height or Z / m	4488761.547		

General Information	
Rise time of local UTC pulse	< 500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

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Cal Id: [   ]   Version / Date: [   ]

BIPM Infortion sheet

Laboratory	IT
Date and hour beginning of measurements	2022 August 25th (MJD 59816), 13 UTC
Date and hour end measurements	2022 September 9th (MJD 59831), 09 UTC

Information on the system			
	Local	**Traveling**	
4-Character BIPM code	IT10 (IENG)	OP72	OP74
Receiver maker and type	Septentrio PolaRx4-TR		
Receiver serial number	3102220		
1 PPS triger level / V	1 V		
Antenna cable marker and type	RG214		
Phase stabilized cable (Y/N)	N		
Cable length outside building / m	5 m		
Antenna maker and type	SEPCHOKE_MC NON		
Antenna serial number	5261		
Temperature if stabilized / °C	NA		

Mesured delays / ns			
	Local	**Traveling**	
Delay from local UTC(k) to receiver 1 PPS_IN	483.555 (REF DLY)	166.318 (REF DLY)	151.069 (REF DLY)
Delay from 1 PPS_IN to internal reference (see Annex 1)	NA		
Antenna cable delay	128.8 ns		
Splitter delay	0.7 ns (shared w. IT09)		
Additional cable delay	1.0 ns		

Data used for the generation of CGGTTS files			
	Local	**Traveling**	
INT DLY (GPS) / ns	P1: 55.0 ns P2: 55.3 ns	P1: [ ] P2: [ ]	P1: [ ] P2: [ ]
INT DLY (Galileo) / ns	E1: 56.2 ns E5a: 64.8 ns	E1: [ ] E5a: [ ]	E1: [ ] E5a: [ ]
CAB DLY / ns	130.5 ns		
REF DLY / ns	483.7 ns		
Coordinate reference frame	ITRF		
Latitude or X / m	4476537.275		
Longitude or Y / m	600431.705		
Height or Z / m	4488761.547		

General Information	
Rise time of local UTC pulse	< 500 ps
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	See readme.txt file
Set humidity value and uncertainty	See readme.txt file

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A3. Implementation in RISE.

Figure A6 is showing the implementation of OP traveling equipment, namely OP72 and OP74 connected to the same antenna cable and antenna, alongside all visited stations in RISE.
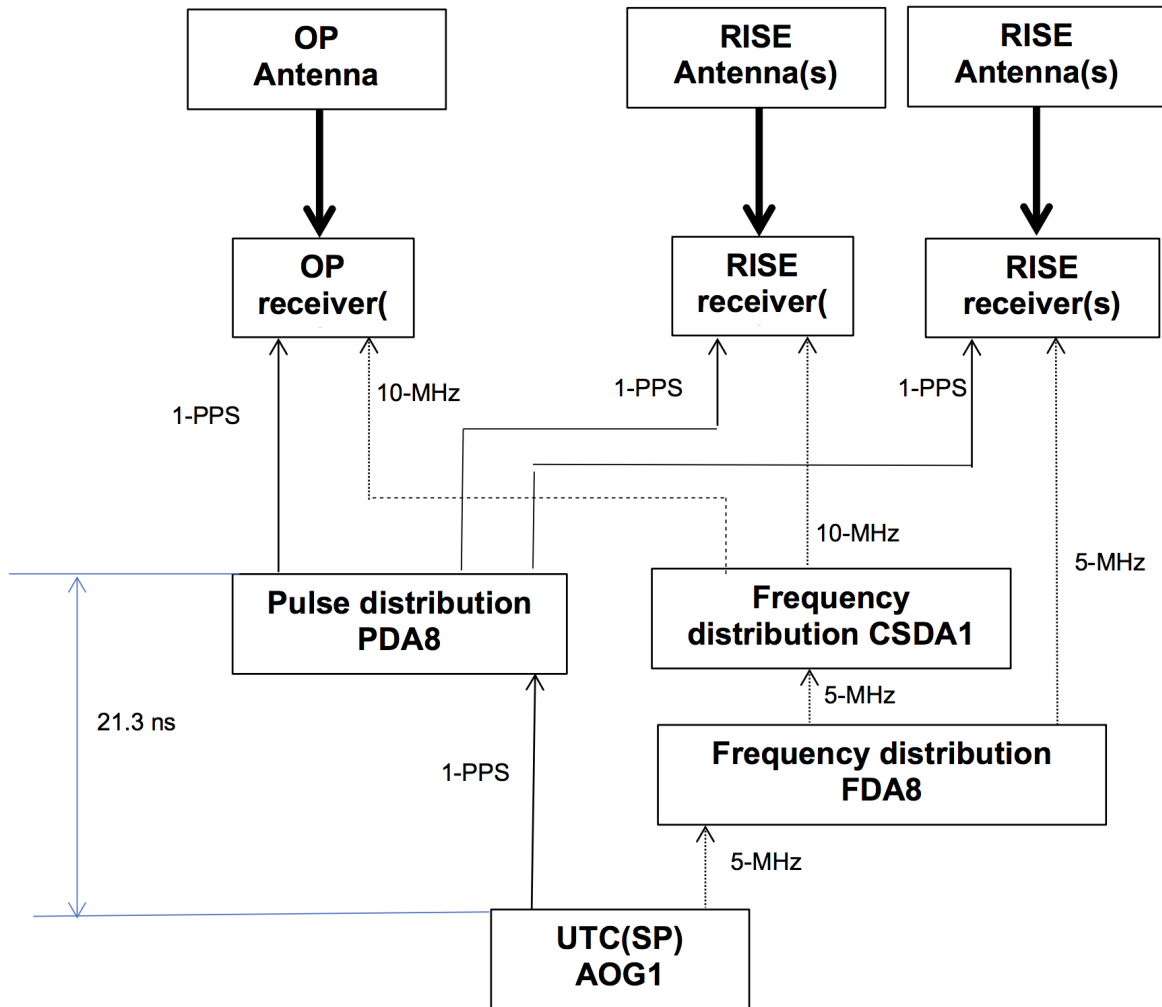
Figure A6. Implementation of OP traveling equipment in RISE.

The next pages are providing the BIPM information sheets for each RISE station.

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Cal_Id

Version/date: 2022-11-09

BIPM Information Sheet

Laboratory	RISE
Date and hour beginning of measurements	2022-10-27 12:00
Date and hour end of measurements	2022-11-07 12:00

Information on the system		
	Local	**Traveling**
4-character BIPM code	SP03	OP72 and OP74
Receiver maker and type	JAVAD TRE_G3T DELTA	
Receiver serial number	00L8XRYF355HZ2WVKRHE	
1 PPS trigger level /V	1.0 V	
Antenna cable maker and type	Andrew Heliax FSJ1-50A	
Phase stabilized cable (Y/N)	Y	
Cable length outside building /m	0.2 m	
Antenna maker and type	JAVRINGANT_DM JVDM	
Antenna serial number	758	
Temperature if stabilized /°C	N/A	

Measured delays / ns		
	Local	**Traveling**
Delay from local UTC(k) to receiver 1 PPS_IN	N/A	
Delay from 1 PPS_IN to internal reference (see Annex 1)	N/A	
Antenna cable delay	N/A	
Splitter delay	N/A	
Additional cable delay	N/A	

Data used for the generation of CGGTTS files		
	Local	**Traveling**
INT DLY (GPS) /ns	P1: 270.7 P2: 267.4	
INT DLY (Galileo) /ns	E1: 268.7 E5a: 280.5	
CAB DLY /ns	N/A	
REF DLY /ns	N/A	
Coordinate reference frame	ITRF	
Latitude or X /m	3328961.86	
Longitude or Y /m	761868.28	
Height or Z /m	5369060.13	

General information	
Rise time of local UTC pulse	< 1 ns
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	23.0 ± 0.3 °C
Set humidity value and uncertainty	45 ± 10 %

Version/date: 2022-11-09

BIPM Information Sheet

Laboratory	RISE
Date and hour beginning of measurements	2022-10-27 12:00
Date and hour end of measurements	2022-11-07 12:00

Information on the system		
	Local	**Traveling**
4-character BIPM code	SP05	OP72 and OP74
Receiver maker and type Receiver serial number	SEPT POLARX5TR 3014102	
1 PPS trigger level /V	1.0 V	
Antenna cable maker and type Phase stabilized cable (Y/N)	Andrew Heliax FSJ1-50A Y	
Cable length outside building /m	0.2 m	
Antenna maker and type Antenna serial number	JAVRINGANT_DM JVDM 758	
Temperature if stabilized /°C	N/A	

Measured delays / ns		
	Local	**Traveling**
Delay from local UTC(k) to receiver 1 PPS_IN	N/A	
Delay from 1 PPS_IN to internal reference (see Annex 1)	N/A	
Antenna cable delay	N/A	
Splitter delay	N/A	
Additional cable delay	N/A	

Data used for the generation of CGGTTS files		
	Local	**Traveling**
INT DLY (GPS) /ns	P1: 201.4 P2: 195.6	
INT DLY (Galileo) /ns	E1: 201.4 E5a: 199.7	
CAB DLY /ns	N/A	
REF DLY /ns	N/A	
Coordinate reference frame	ITRF	
Latitude or X /m	3328961.86	
Longitude or Y /m	761868.28	
Height or Z /m	5369060.13	

General information	
Rise time of local UTC pulse	< 1 ns
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	23.0 ± 0.3 °C
Set humidity value and uncertainty	45 ± 10 %

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BIPM Information Sheet

Laboratory	RISE
Date and hour beginning of measurements	2022-10-27 12:00
Date and hour end of measurements	2022-11-07 12:00

Information on the system		
	Local	**Traveling**
4-character BIPM code	RIT1	OP72 and OP74
Receiver maker and type	SEPT POLARX5TR	
Receiver serial number	3018492	
1 PPS trigger level /V	1.0 V	
Antenna cable maker and type	Andrew Heliax FSJ1-50A	
Phase stabilized cable (Y/N)	Y	
Cable length outside building /m	About 70 m but all below ground or inside antenna pillar	
Antenna maker and type	LEIAR25.R4 NONE	
Antenna serial number	???	
Temperature if stabilized /°C	N/A	

Measured delays / ns		
	Local	**Traveling**
Delay from local UTC(k) to receiver 1 PPS_IN	N/A	
Delay from 1 PPS_IN to internal reference (see Annex 1)	N/A	
Antenna cable delay	N/A	
Splitter delay	N/A	
Additional cable delay	N/A	

Data used for the generation of CGGTTS files		
	Local	**Traveling**
INT DLY (GPS) /ns	P1: 273.5 P2: 269.7	
INT DLY (Galileo) /ns	E1: 273.8 E5a: 270.9	
CAB DLY /ns	N/A	
REF DLY /ns	N/A	
Coordinate reference frame	ITRF	
Latitude or X /m	3328988.29	
Longitude or Y /m	761918.19	
Height or Z /m	5369032.01	

General information	
Rise time of local UTC pulse	< 1 ns
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	23.0 ± 0.3 °C
Set humidity value and uncertainty	45 ± 10 %

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Cal_Id

BIPM Information Sheet

Laboratory	RISE
Date and hour beginning of measurements	2022-10-27 12:00
Date and hour end of measurements	2022-11-07 12:00

Information on the system		
	Local	**Traveling**
4-character BIPM code	RIT2	OP72 and OP74
Receiver maker and type Receiver serial number	SEPT POLARX5TR 3024912	
1 PPS trigger level /V	1.0 V	
Antenna cable maker and type Phase stabilized cable (Y/N)	Andrew Heliax FSJ1-50A Y	
Cable length outside building /m	About 70 m but all below ground or inside antenna pillar	
Antenna maker and type Antenna serial number	TRM159800.00 NONE 5025353801	
Temperature if stabilized /°C	N/A	

Measured delays / ns		
	Local	**Traveling**
Delay from local UTC(k) to receiver 1 PPS_IN	N/A	
Delay from 1 PPS_IN to internal reference (see Annex 1)	N/A	
Antenna cable delay	N/A	
Splitter delay	N/A	
Additional cable delay	N/A	

Data used for the generation of CGGTTS files		
	Local	**Traveling**
INT DLY (GPS) /ns	P1: 231.6 P2: 228.0	
INT DLY (Galileo) /ns	E1: 232.2 E5a: 235.5	
CAB DLY /ns	N/A	
REF DLY /ns	N/A	
Coordinate reference frame	ITRF	
Latitude or X /m	3328984.40	
Longitude or Y /m	761910.47	
Height or Z /m	5369033.95	

General information	
Rise time of local UTC pulse	< 1 ns
Air conditioning (Y/N)	Y
Set temperature value and uncertainty	23.0 ± 0.3 °C
Set humidity value and uncertainty	45 ± 10 %

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ANNEX B

Raw data and TDEV.

1. Reminder of equipment and planning.

Institute	Equipment status	MJD of measurement	Receiver type	BIPM code	RINEX name
OP	Traveling	59796 - 59911	Septentrio PolaRx5TR	OP72	OP72
OP	Traveling	59796 - 59911	Septentrio PolaRx5TR	OP74	OP74
OP	G1 reference	59796 - 59911	Septentrio PolaRx5TR	OP73	OP73
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT11 (GR01)	IT11 (GR01)
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT12 (GR02)	IT12 (GR02)
INRIM	G2	59817 - 59825	Septentrio PolaRx5TR	IT14 (GR04)	IT14 (GR04)
INRIM	G2	59817 - 59825	Septentrio PolaRx5TR	IT15 (GR05)	IT15 (GR05)
INRIM	G2	59817 - 59825	Septentrio PolaRx5TR	IT16 (GR06)	IT16 (GR06)
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT08 (INR5)	IT08 (INR5)
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT09 (INR6)	IT09 (INR6)
INRIM	G2	59817 - 59825	Dicom GTR50	IT2_	IT2_
INRIM	G2	59817 - 59825	Septentrio PolaRx4TR	IT10 (IENG)	IT10 (IENG)
RISE	G2	59880 - 59888	Javad TRE_G3T Delta 3	SP03	SP03
RISE	G2	59880 - 59888	Septentrio PolaRx5TR	SP05	SP05
RISE	G2	59880 - 59888	Septentrio PolaRx5TR	SP06	RIT1
RISE	G2	59880 - 59888	Septentrio PolaRx5TR	SP07	RIT2

2. GPS calibration of OP72 and OP74 against OP73.

2.1. Results of raw data processing.

Pair	MJD of measurement	RawDiff P1	TDEV	RawDiff P2	TDEV
OP72 - OP73	59796-59807	- 64.560	0.061	- 66.551	0.040
OP74 - OP73	59796-59807	- 46.992	0.059	- 49.267	0.041
OP72 - OP73	59902-59911	- 63.731	0.045	- 66.271	0.025
OP74 - OP73	59902-59911	- 46.219	0.041	- 48.938	0.025

2.2. Plots of raw data and TDEV.
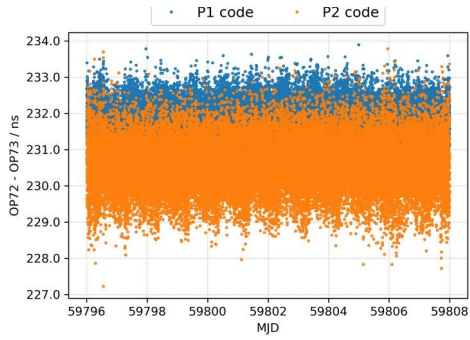
(a) P-code phase differences
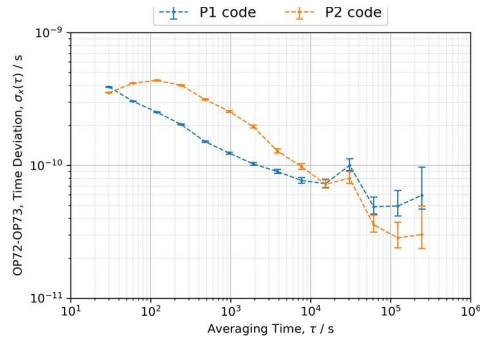
(b) TDEV of P-code delays

Figure B1: GPS relative calibration of OP72 with respect to OP73 (start).
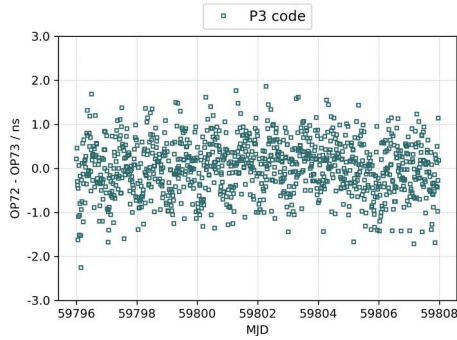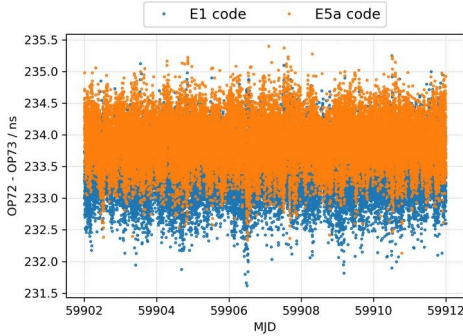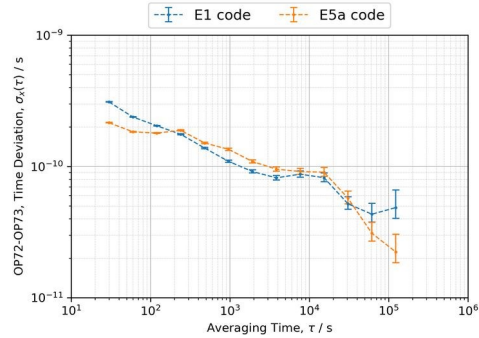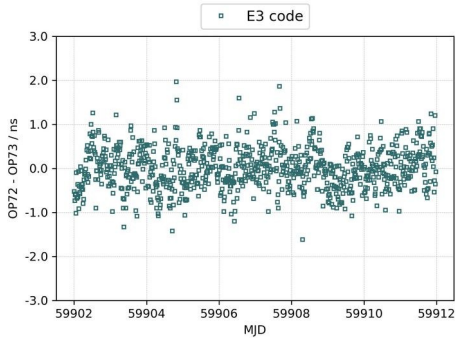
(a) P3 CV after calibration
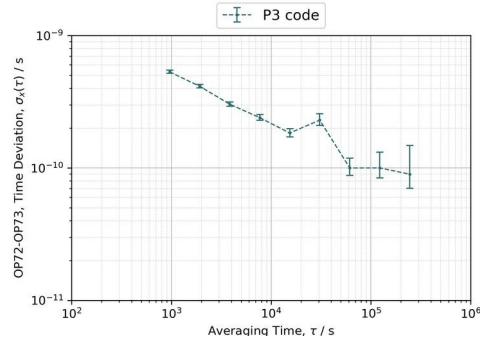
(b) TDEV of P3 CV

Figure B2: P3 CV time difference of OP72 with respect to OP73 (start).
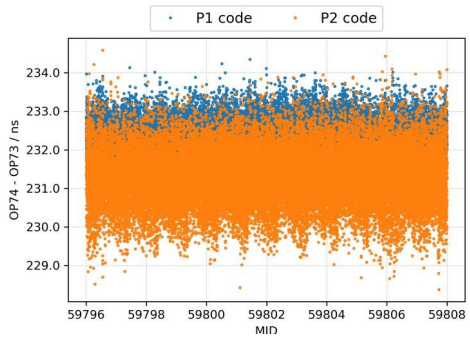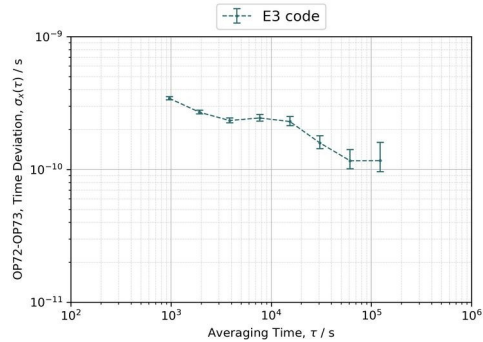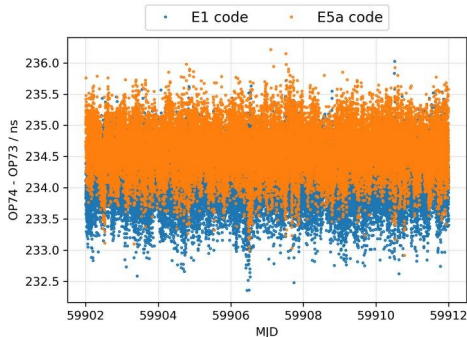
(a) P-code phase differences
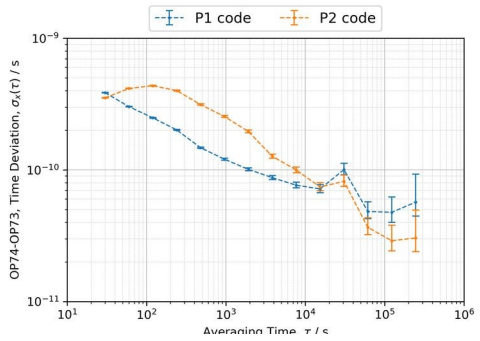
(b) TDEV of P-code delays

Figure B3: GPS relative calibration of OP74 with respect to OP73 (start).
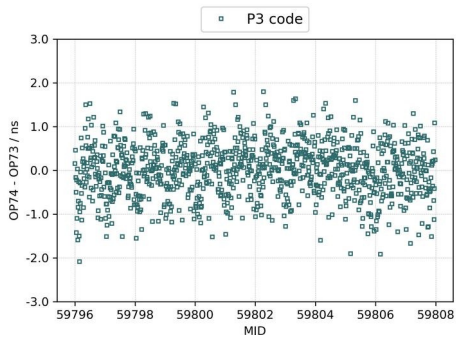
(a) P3 CV after calibration
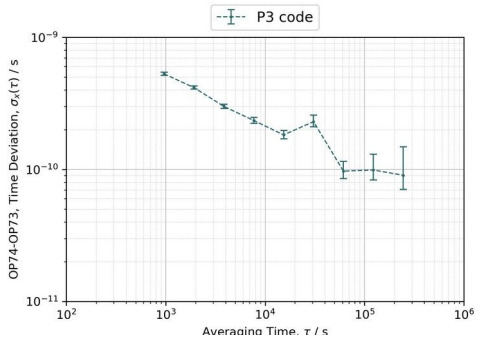
(b) TDEV of P3 CV

Figure B4: P3 CV time difference of OP74 with respect to OP73 (start).

B3

(a) P-code phase differences

(b) TDEV of P-code delays
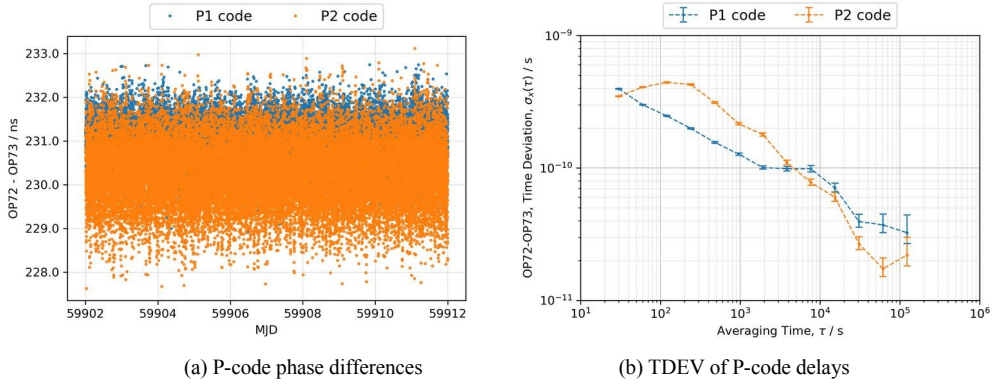
Figure B5: GPS relative calibration of OP72 with respect to OP73 (closure).

(a) P3 CV after calibration

(b) TDEV of P3 CV
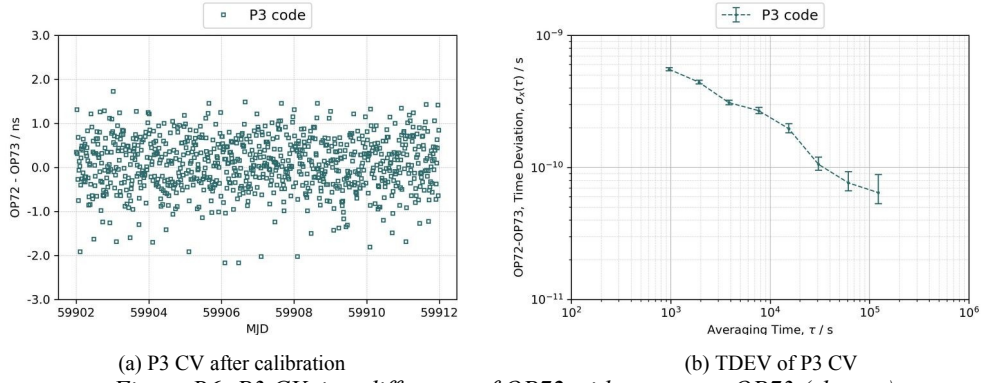
Figure B6: P3 CV time difference of OP72 with respect to OP73 (closure).

(a) P-code phase differences

(b) TDEV of P-code delays
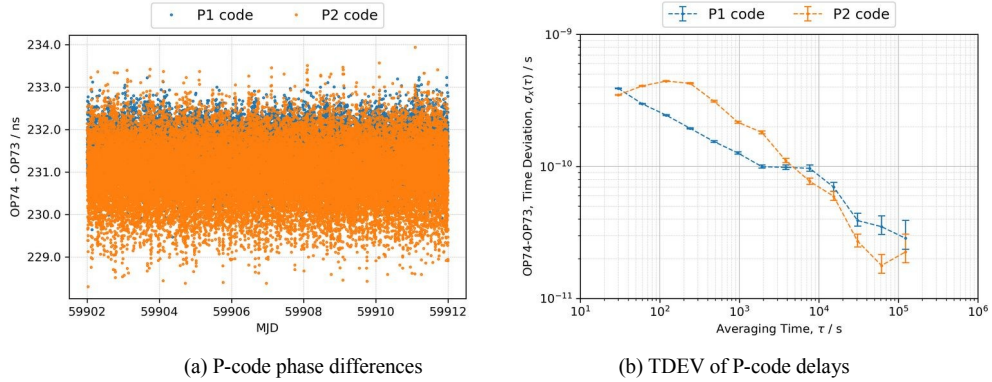
Figure B7: GPS relative calibration of OP74 with respect to OP73 (closure).

(a) P3 CV after calibration

(b) TDEV of P3 CV
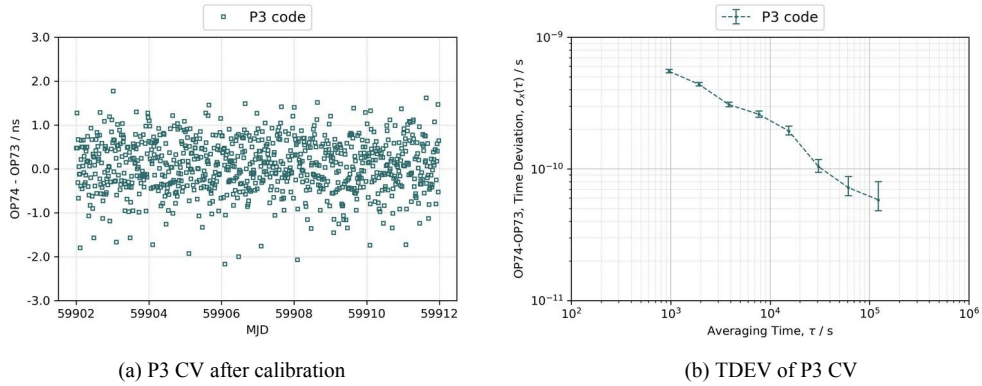
Figure B8: P3 CV time difference of OP74 with respect to OP73 (closure).

B4

3. GPS calibration of visited stations against OP72 and OP74.

3.1. Results of raw data processing.

| Pair	MJD of measurement	RawDiff P1	TDEV	RawDiff P2	TDEV
IT11 (GR01) - OP72	59817-59825	194.043	0.085	194.687	0.106
IT11 (GR01) - OP74	59817-59825	209.779	0.083	210.719	0.106
IT12 (GR02) - OP72	59817-59825	195.734	0.078	194.862	0.080
IT12 (GR02) - OP74	59817-59825	211.470	0.076	210.894	0.080
IT14 (GR04) - OP72	59817-59825	161.551	0.076	162.852	0.062
IT14 (GR04) - OP74	59817-59825	177.289	0.073	178.884	0.061
IT15 (GR05) - OP72	59817-59825	164.069	0.122	166.193	0.095
IT15 (GR05) - OP74	59817-59825	179.805	0.119	182.225	0.095
IT16 (GR06) - OP72	59817-59825	- 156.963	0.099	- 155.831	0.094
IT16 (GR06) - OP74	59817-59825	- 141.226	0.097	- 139.798	0.094
IT10 (IENG) - OP72	59817-59825	363.868	0.074	362.160	0.050
IT10 (IENG) - OP74	59817-59825	379.605	0.071	378.192	0.049
IT08 (INR5) - OP72	59817-59825	240.032	0.096	239.535	0.075
IT08 (INR5) - OP74	59817-59825	255.768	0.093	255.567	0.074
IT09 (INR6) - OP72	59817-59825	363.526	0.072	362.085	0.050
IT09 (INR6) - OP74	59817-59825	379.262	0.069	378.117	0.049
IT2_ - OP72	59817-59825	67.524	0.111	66.449	0.077
IT2_ - OP74	59817-59825	83.259	0.110	82.481	0.075
RIT1 - OP72	59880-59888	- 107.870	0.058	- 104.837	0.032
RIT1 - OP74	59880-59888	- 125.339	0.059	- 122.120	0.032
RIT2 - OP72	59880-59888	- 65.680	0.055	- 63.305	0.028
RIT2 - OP74	59880-59888	- 83.330	0.054	- 80.588	0.029
SP03 - OP72	59880-59888	- 102.325	0.089	- 100.094	0.032
SP03 - OP74	59880-59888	- 119.794	0.089	- 117.377	0.033
SP05 - OP72	59880-59888	- 34.855	0.091	- 30.780	0.030
SP05 - OP74	59880-59888	- 52.324	0.089	- 48.063	0.031

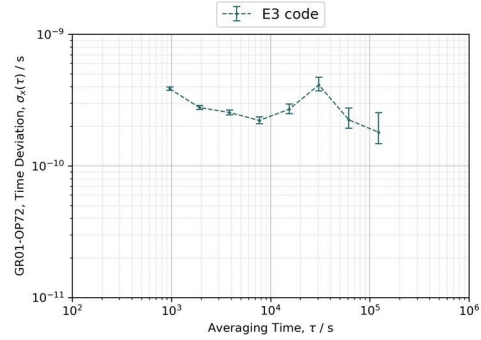### 3.2. Plots of raw data and TDEV.
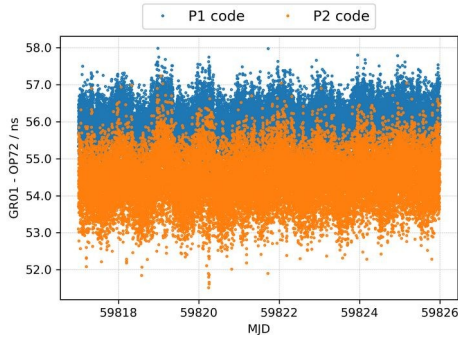
(a) P-code phase differences
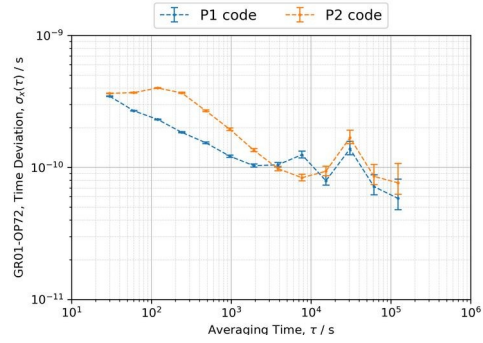
(b) TDEV of P-code delays

Figure B9: GPS relative calibration of IT11 (GR01) with respect to OP72.
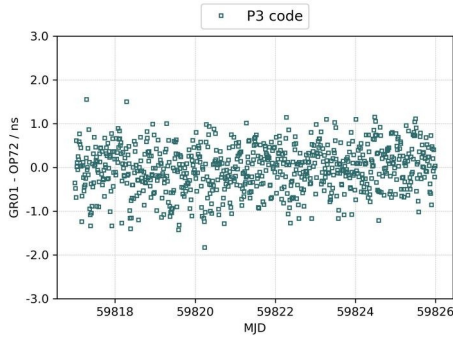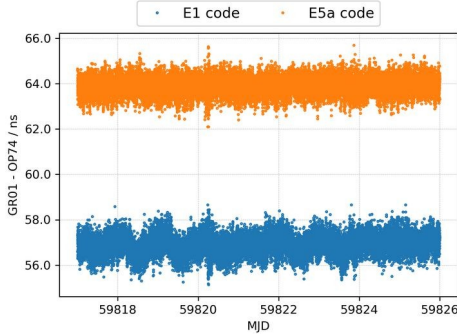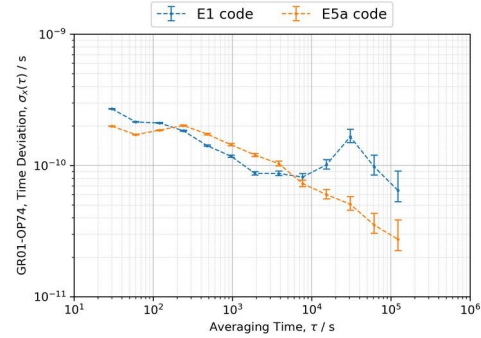

(a) P3 CV after calibration
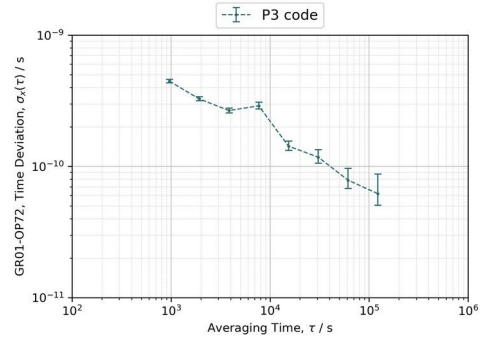
(b) TDEV of P3 CV

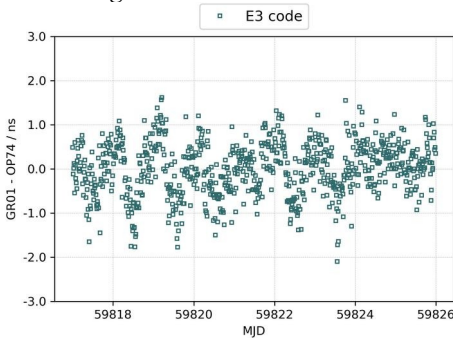*Figure B10: P3 CV time difference of IT11 (GR01) with respect to OP72.*
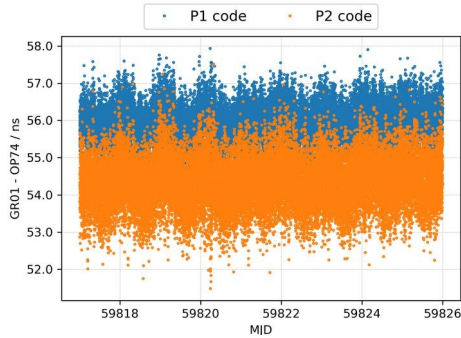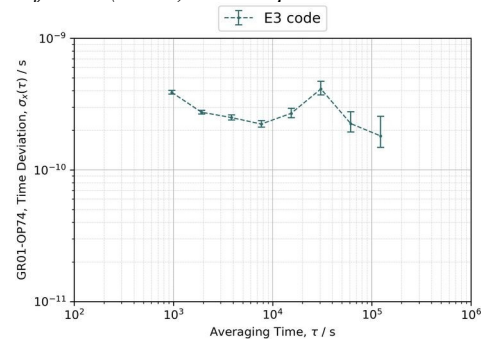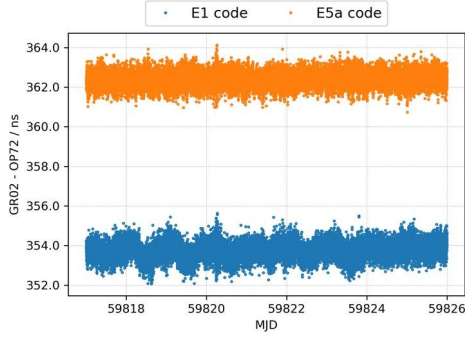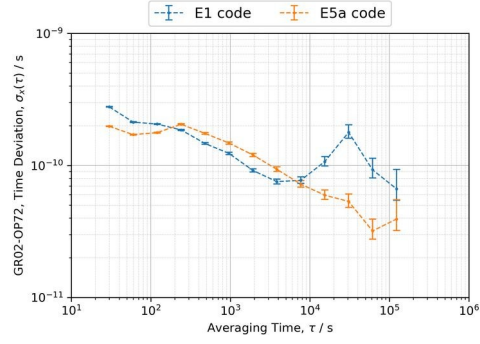
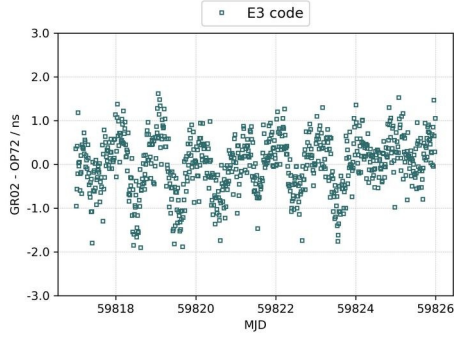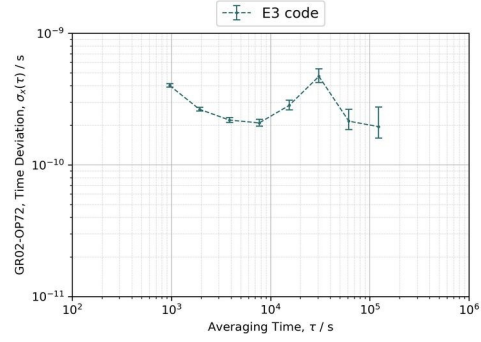

(a) P-code phase differences
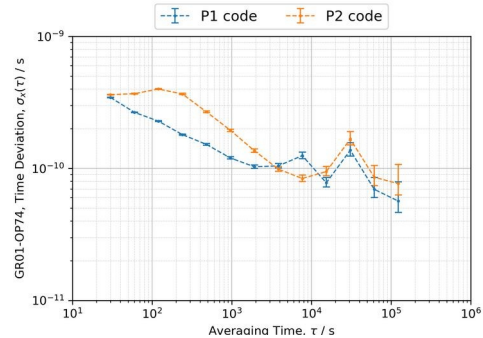
(b) TDEV of P-code delays

Figure B11: GPS relative calibration of IT11 (GR01) with respect to OP74.
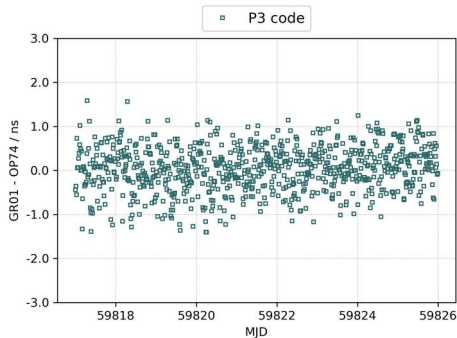
(a) P3 CV after calibration
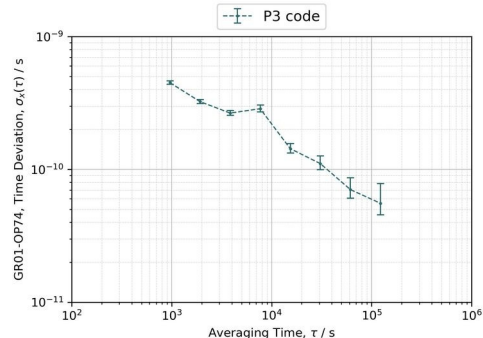
(b) TDEV of P3 CV

Figure B12: P3 CV time difference of IT11 (GR01) with respect to OP74.

B6
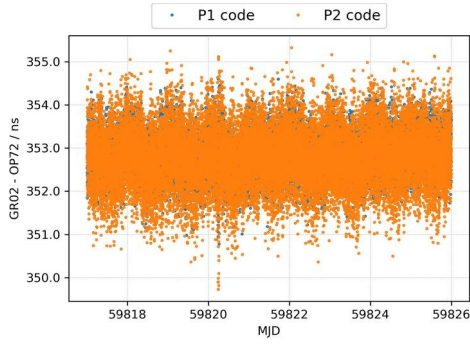
(a) P-code phase differences
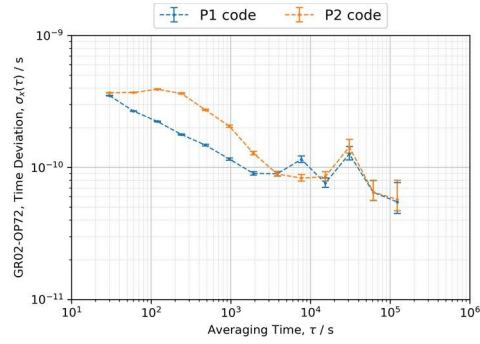
(b) TDEV of P-code delays

Figure B13: GPS relative calibration of IT12 (GR02) with respect to OP72.
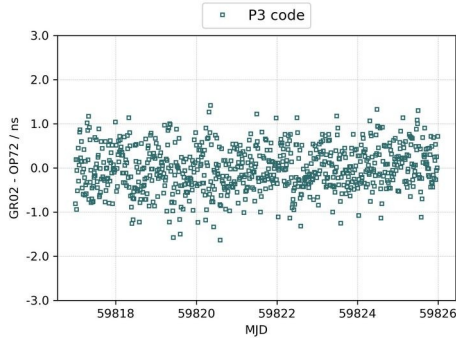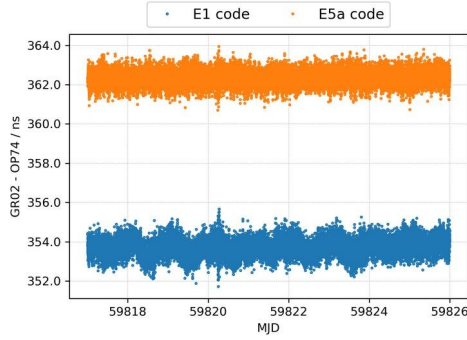

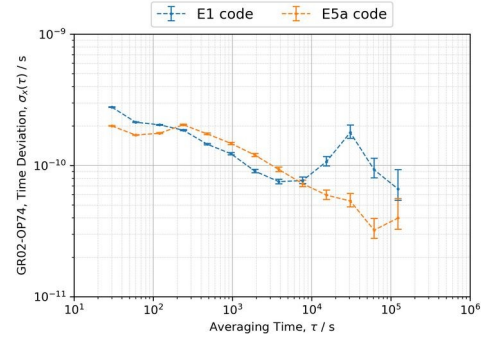(a) P3 CV after calibration
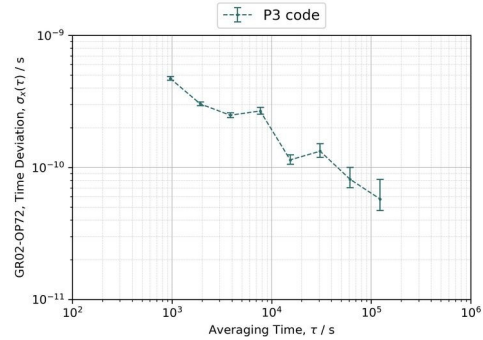
(b) TDEV of P3 CV

Figure B14: P3 CV time difference of IT12 (GR02) with respect to OP72.
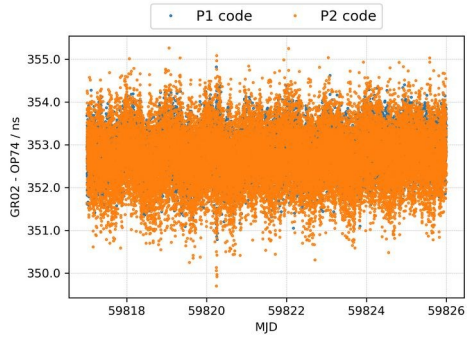
(a) P-code phase differences
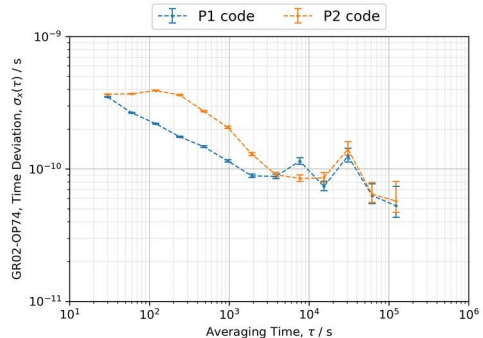
(b) TDEV of P-code delays

Figure B15: GPS relative calibration of IT12 (GR02) with respect to OP74.
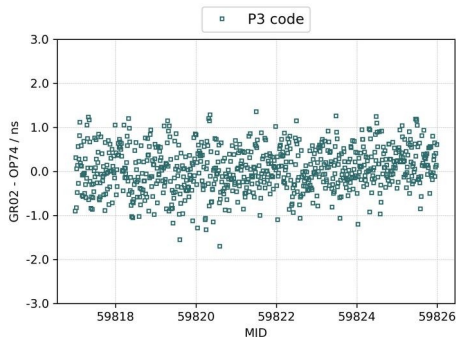
(a) P3 CV after calibration
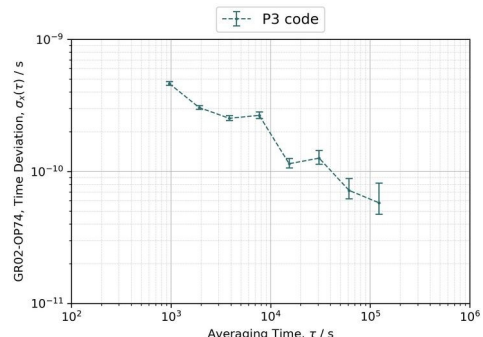
(b) TDEV of P3 CV

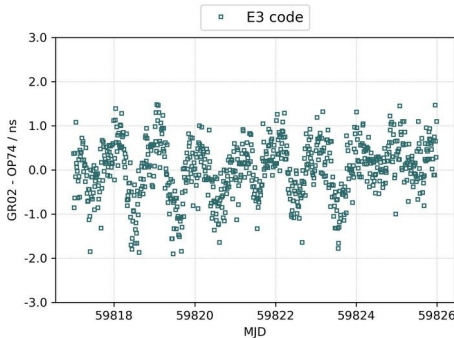*Figure B16: P3 CV time difference of IT12 (GR02) with respect to OP74.*

B7
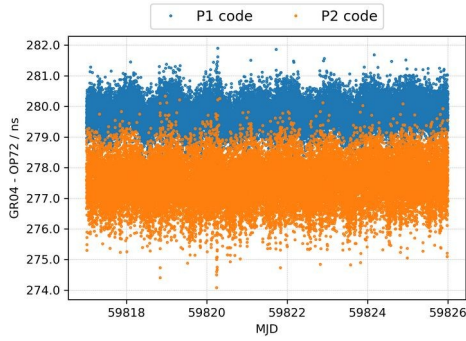
(a) P-code phase differences
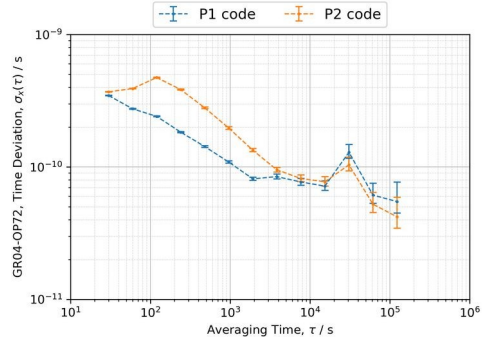
(b) TDEV of P-code delays

Figure B17: GPS relative calibration of IT14 (GR04) with respect to OP72.
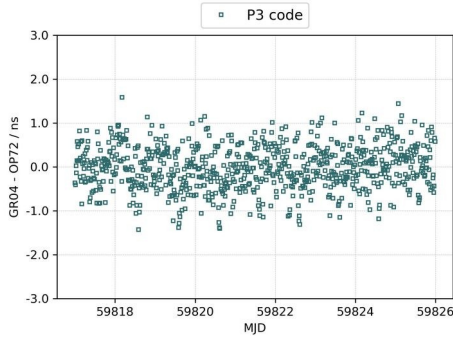
(a) P3 CV after calibration
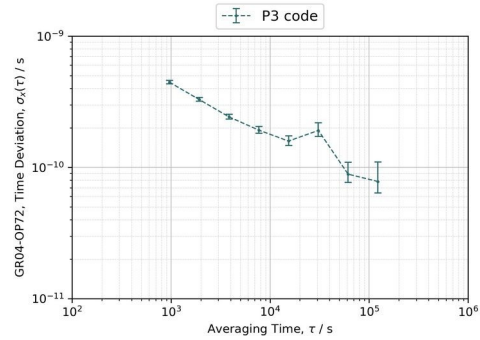
(b) TDEV of P3 CV

Figure B18: P3 CV time difference of IT14 (GR04) with respect to OP72.
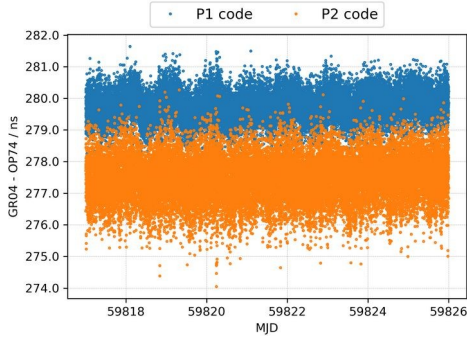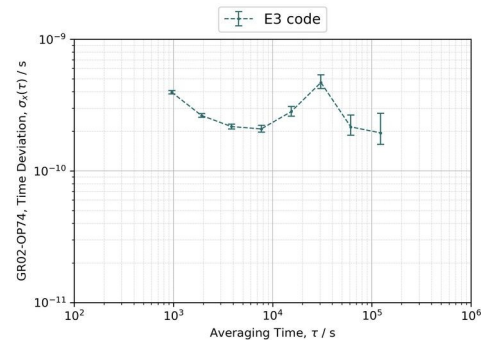

(a) P-code phase differences
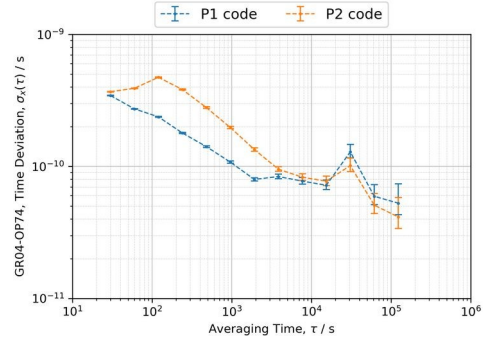
(b) TDEV of P-code delays

Figure B19: GPS relative calibration of IT14 (GR04) with respect to OP74.
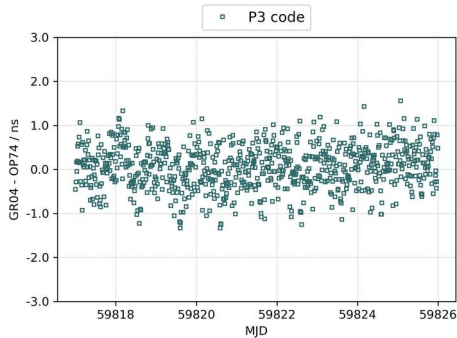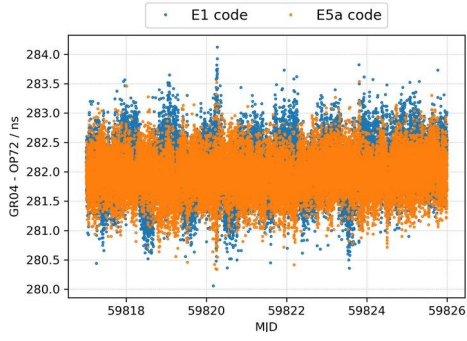

(a) P3 CV after calibration
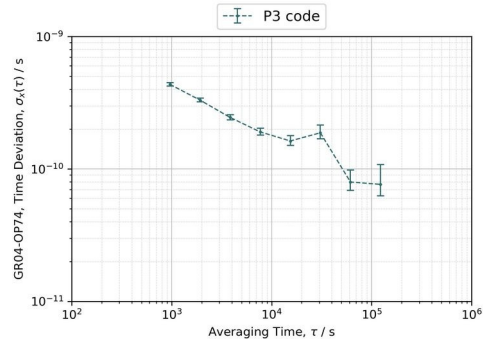
(b) TDEV of P3 CV

Figure B20: P3 CV time difference of IT14 (GR04) with respect to OP74.

B8
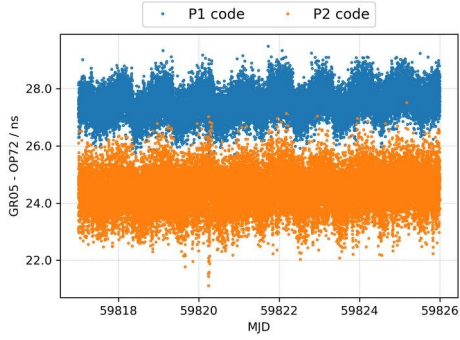
(a) P-code phase differences
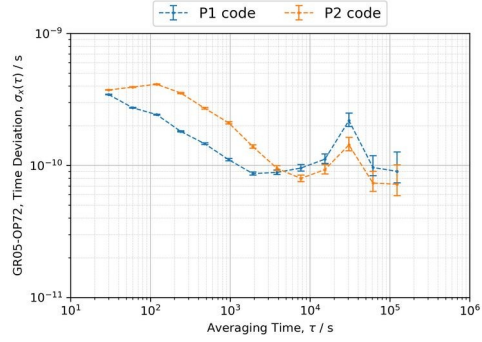
(b) TDEV of P-code delays

Figure B21: GPS relative calibration of IT15 (GR05) with respect to OP72.
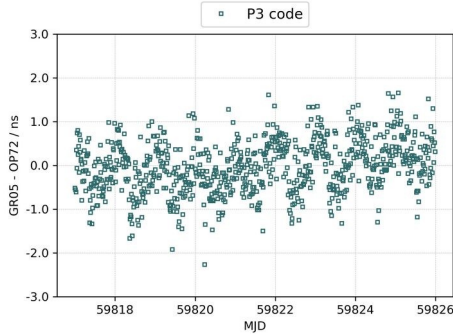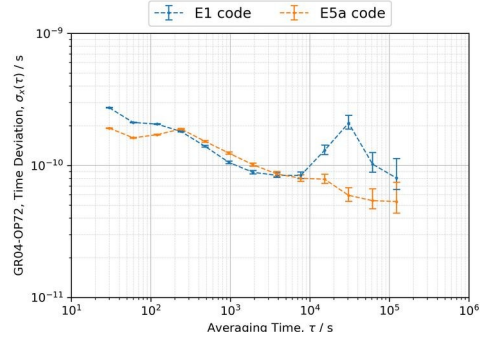

(a) P3 CV after calibration
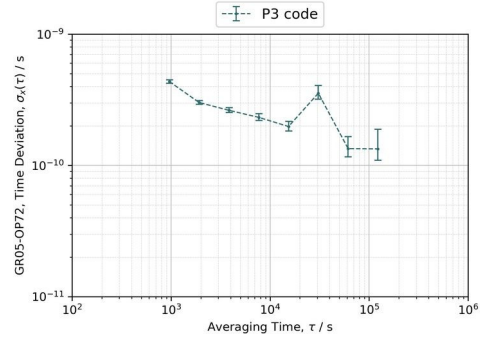
(b) TDEV of P3 CV

Figure B22: P3 CV time difference of IT15 (GR05) with respect to OP72.
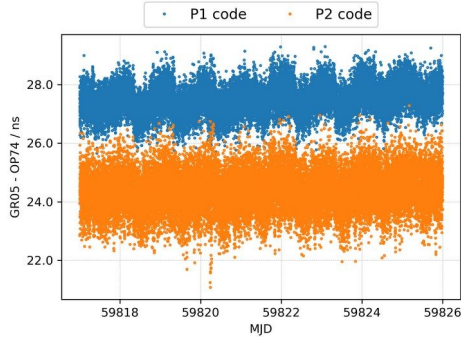
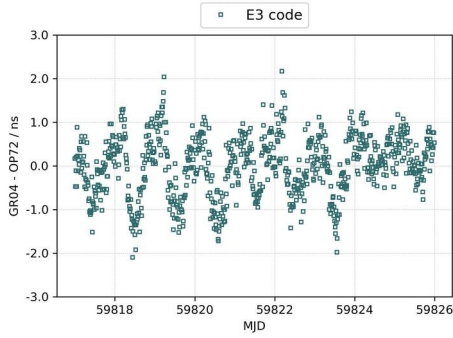(a) P-code phase differences
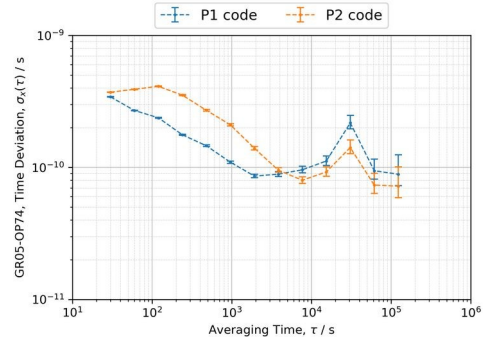
(b) TDEV of P-code delays

Figure B23: GPS relative calibration of IT15 (GR05) with respect to OP74.
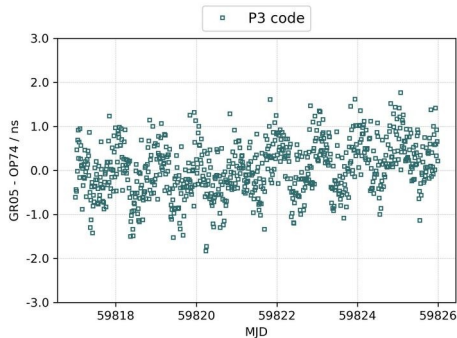
(a) P3 CV after calibration
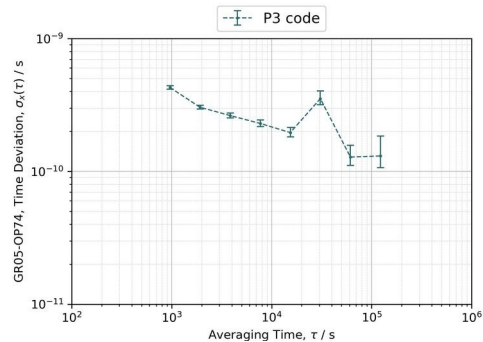
(b) TDEV of P3 CV

Figure B24: P3 CV time difference of IT15 (GR05) with respect to OP74.
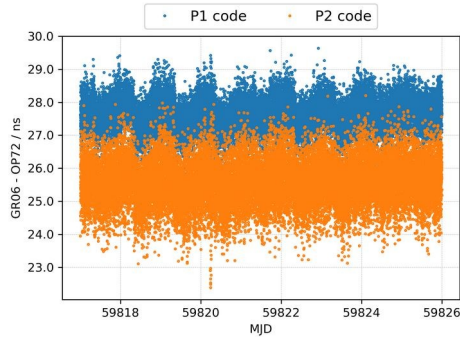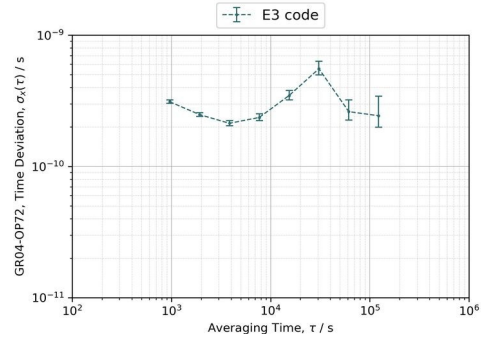
(a) P-code phase differences

(b) TDEV of P-code delays

Figure B25: GPS relative calibration of IT16 (GR06) with respect to OP72.
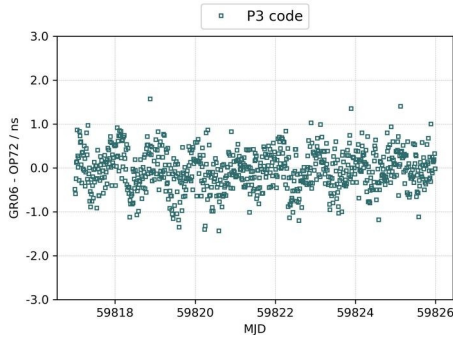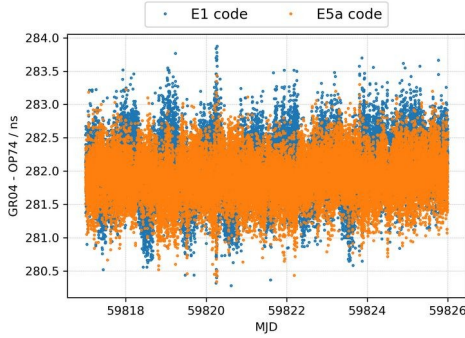

(a) P3 CV after calibration
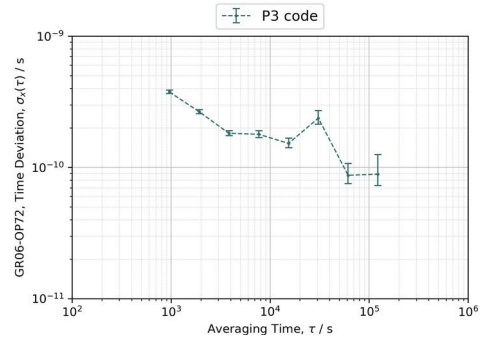
(b) TDEV of P3 CV

Figure B26: P3 CV time difference of IT16 (GR06) with respect to OP72.
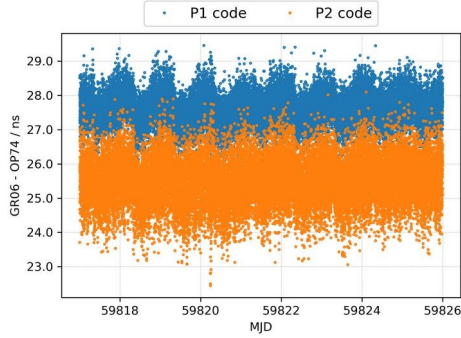
(a) P-code phase differences
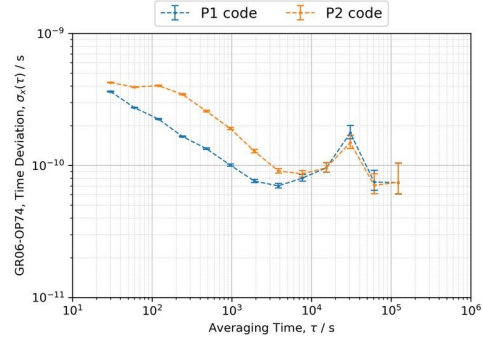
(b) TDEV of P-code delays

Figure B27: GPS relative calibration of IT16 (GR06) with respect to OP74.
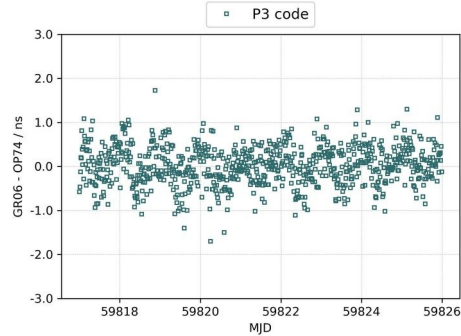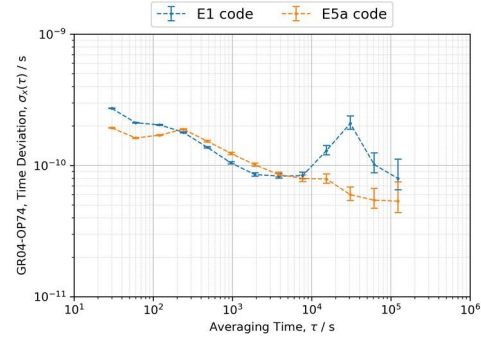

(a) P3 CV after calibration
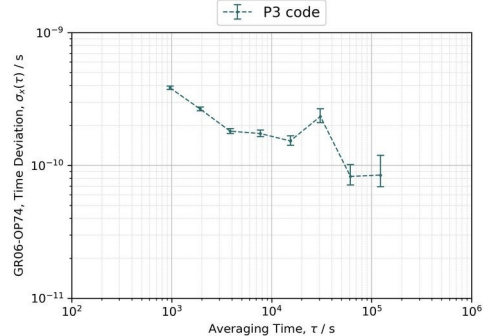
(b) TDEV of P3 CV

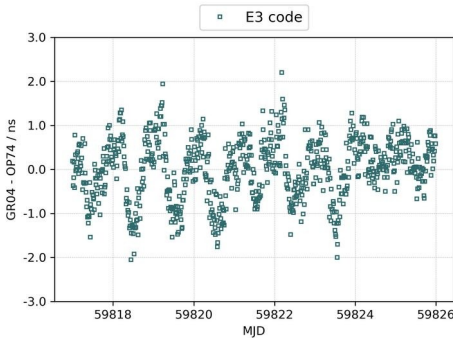*Figure B28: P3 CV time difference of IT16 (GR06) with respect to OP74.*
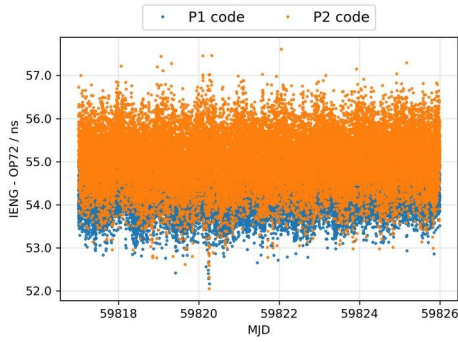
(a) P-code phase differences

(b) TDEV of P-code delays

Figure B29: GPS relative calibration of IT10 (IENG) with respect to OP72.
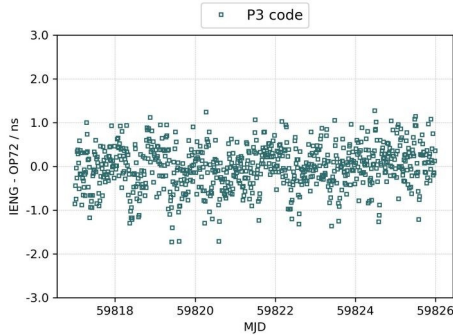
(a) P3 CV after calibration
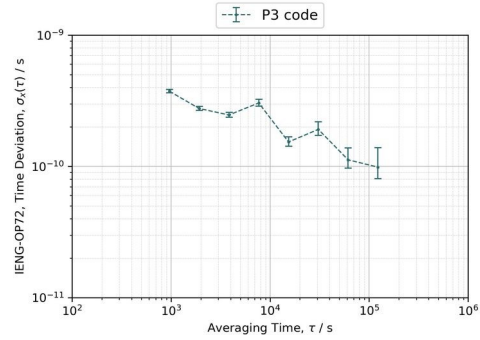
(b) TDEV of P3 CV

Figure B30: P3 CV time difference of IT10 (IENG) with respect to OP72.
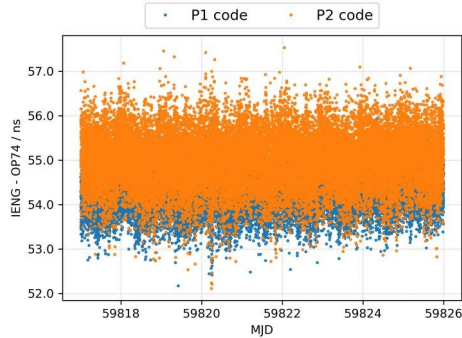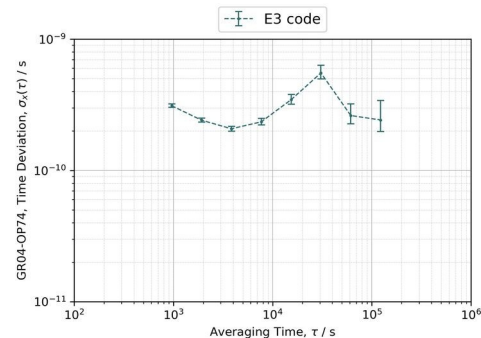

(a) P-code phase differences
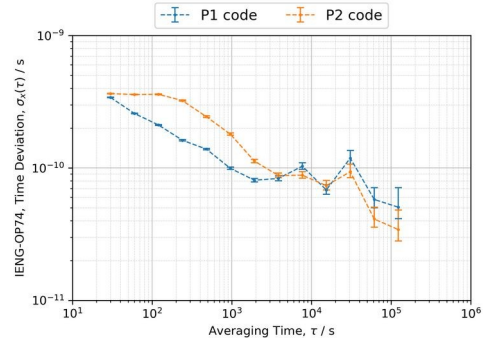
(b) TDEV of P-code delays

Figure B31: GPS relative calibration of IT10 (IENG) with respect to OP74.
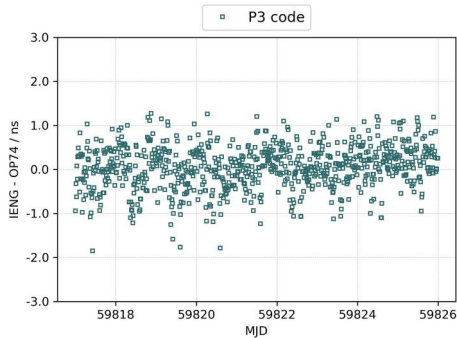
(a) P3 CV after calibration
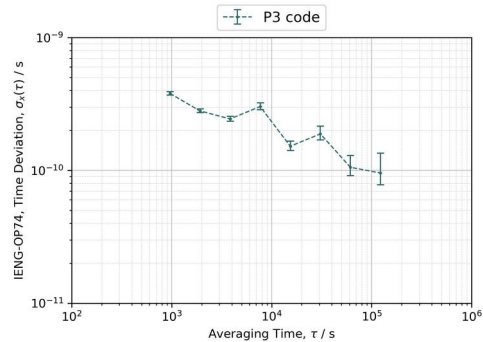
(b) TDEV of P3 CV

Figure B32: P3 CV time difference of IT10 (IENG) with respect to OP74.

B11
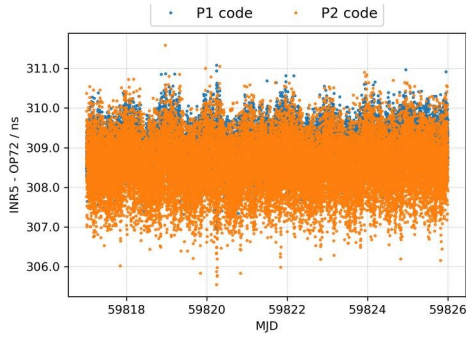
(a) P-code phase differences

(b) TDEV of P-code delays

Figure B33: GPS relative calibration of IT08 (INR5) with respect to OP72.
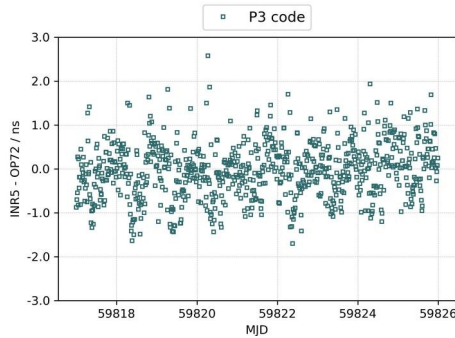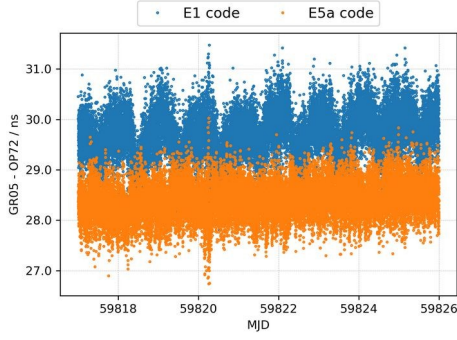

(a) P3 CV after calibration
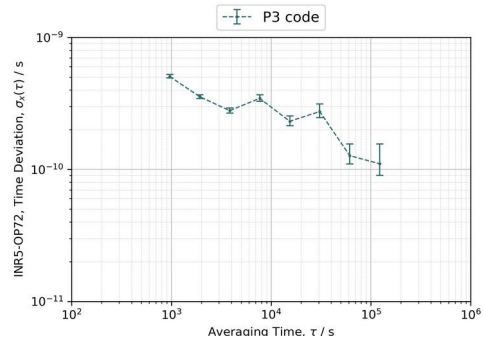
(b) TDEV of P3 CV

Figure B34: P3 CV time difference of IT08 (INR5) with respect to OP72.
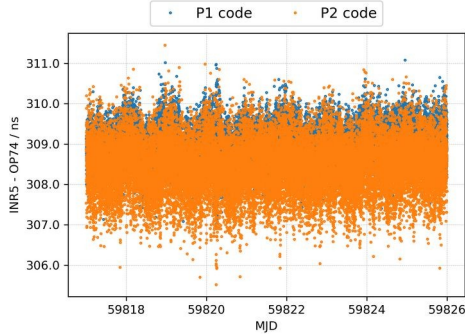
(a) P-code phase differences
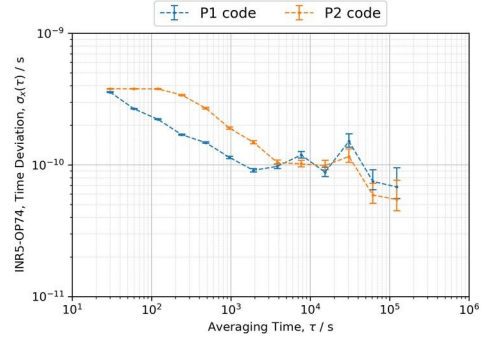
(b) TDEV of P-code delays

Figure B35: GPS relative calibration of IT08 (INR5) with respect to OP74.
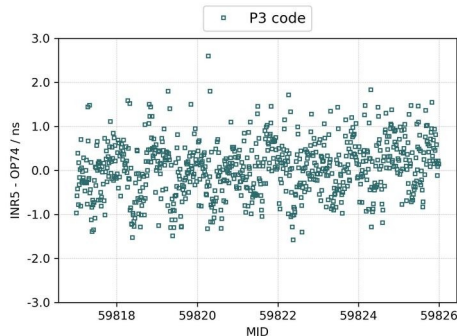
(a) P3 CV after calibration
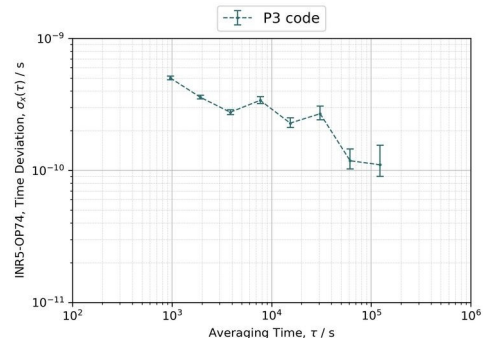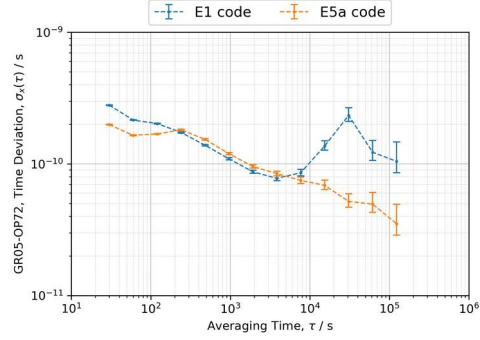
(b) TDEV of P3 CV

Figure B36: P3 CV time difference of IT08 (INR5) with respect to OP74.
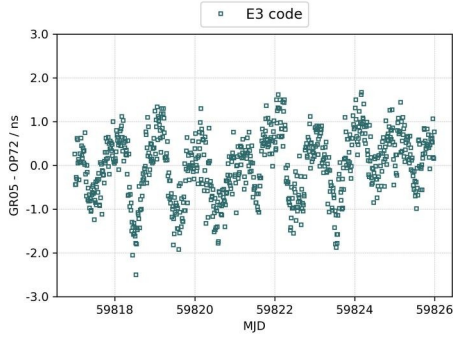
B12

G1/G2 #1018-2022
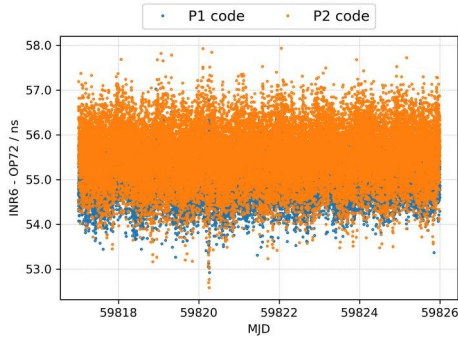
(a) P-code phase differences
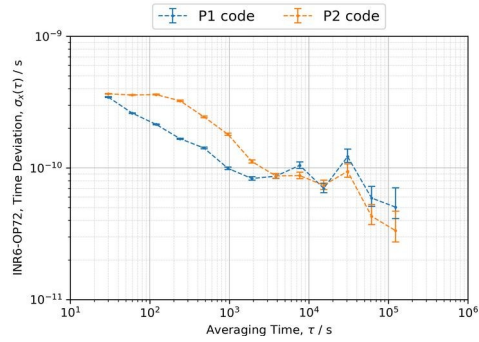
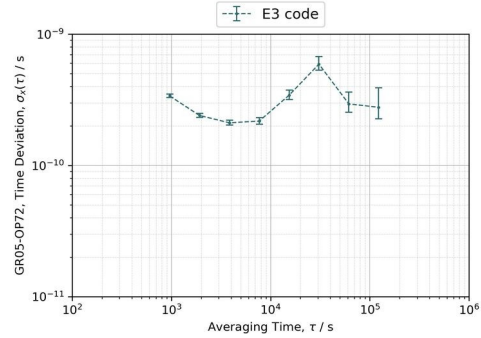(b) TDEV of P-code delays

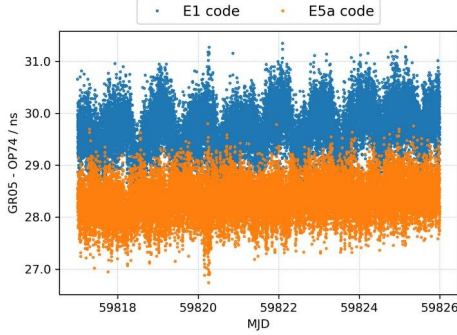*Figure B37: GPS relative calibration of IT09 (INR6) with respect to OP72.*
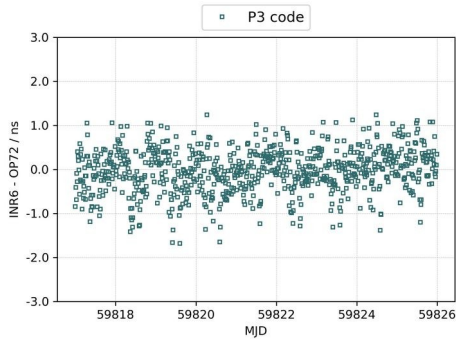
(a) P3 CV after calibration
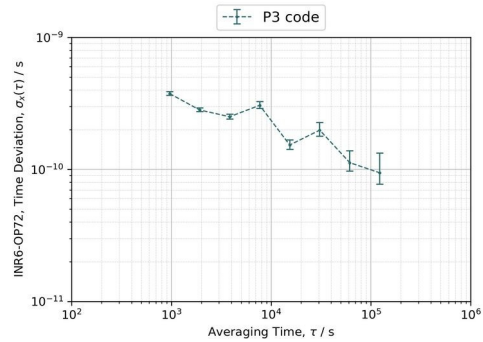
(b) TDEV of P3 CV

Figure B38: P3 CV time difference of IT09 (INR6) with respect to OP72.

(a) P-code phase differences
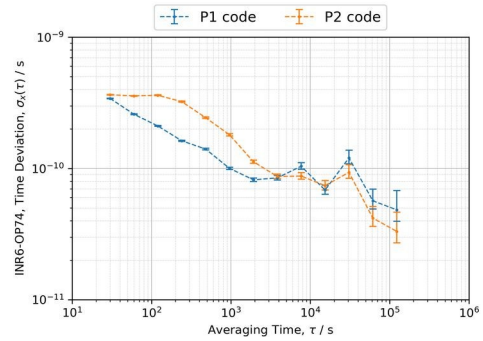
(b) TDEV of P-code delays

Figure B39: GPS relative calibration of IT09 (INR6) with respect to OP74.
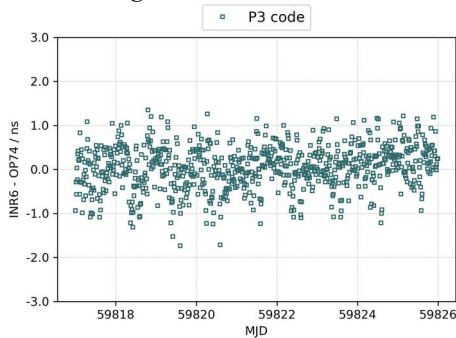
(a) P3 CV after calibration
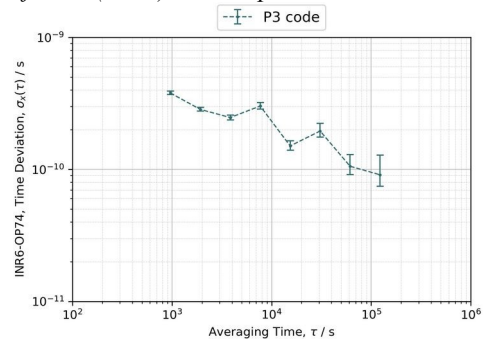
(b) TDEV of P3 CV

Figure B40: P3 CV time difference of IT09 (INR6) with respect to OP74.

B13
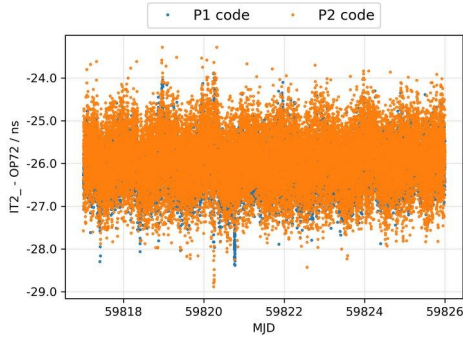
(a) P-code phase differences

(b) TDEV of P-code delays

Figure B41: GPS relative calibration of IT2_ with respect to OP72.
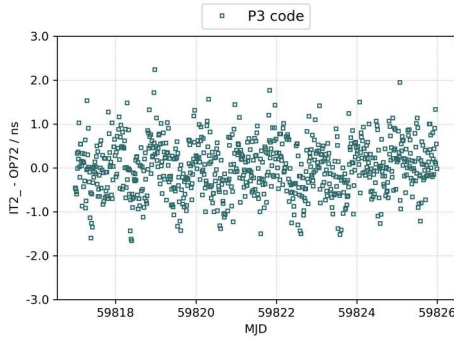
(a) P3 CV after calibration
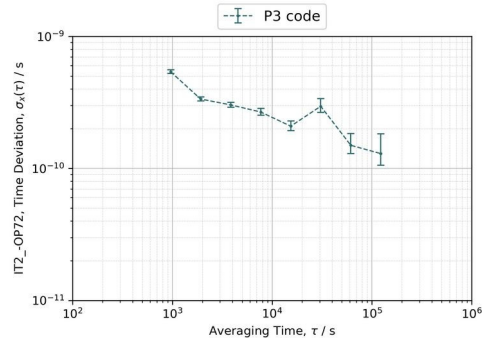
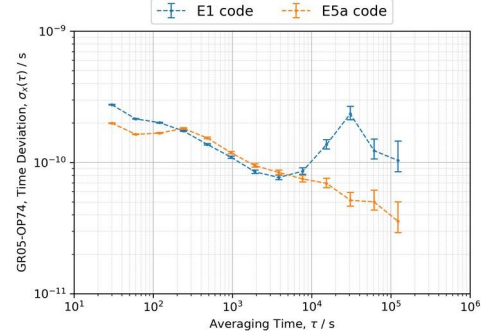(b) TDEV of P3 CV

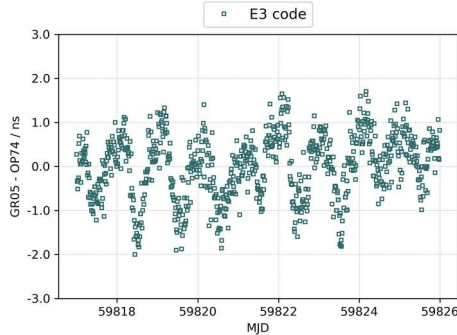*Figure B42: P3 CV time difference of IT2_ with respect to OP72.*
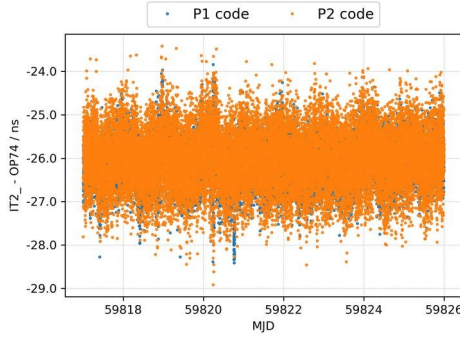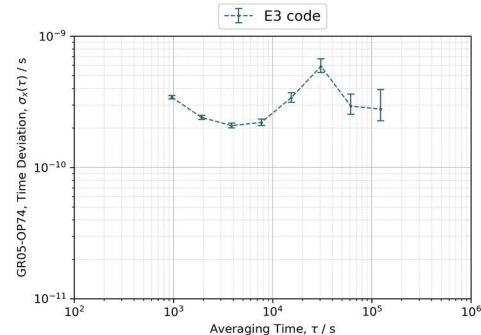

(a) P-code phase differences
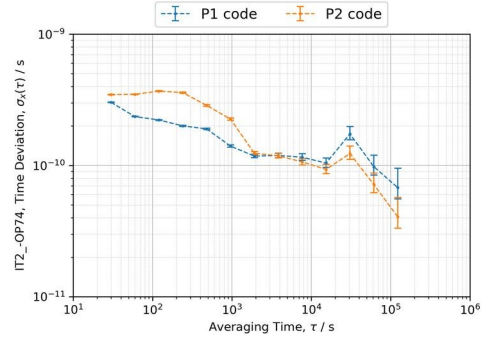
(b) TDEV of P-code delays

Figure B43: GPS relative calibration of IT2_ with respect to OP74.
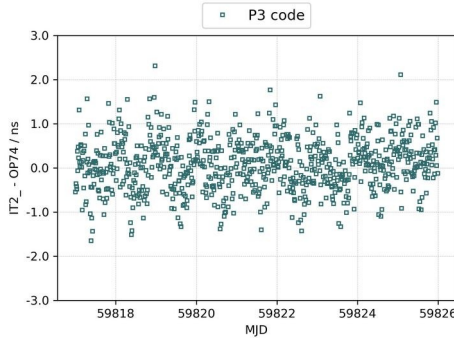
(a) P3 CV after calibration
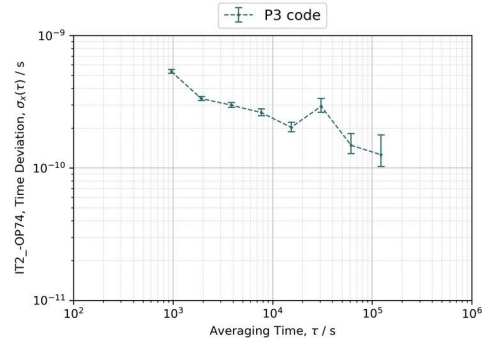
(b) TDEV of P3 CV

Figure B44: P3 CV time difference of IT2_ with respect to OP74.

B14
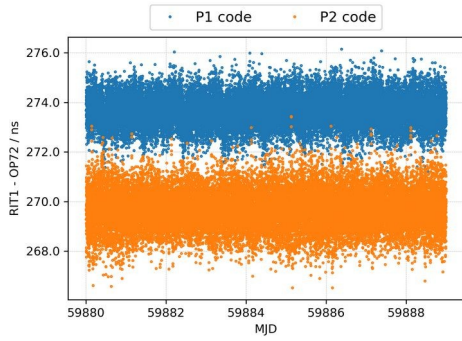
(a) P-code phase differences

(b) TDEV of P-code delays

Figure B45: GPS relative calibration of RIT1 with respect to OP72.
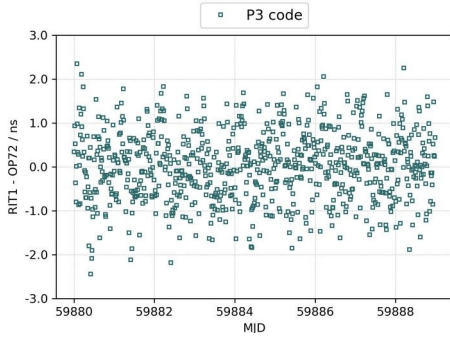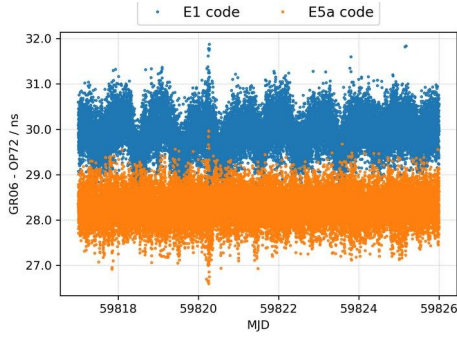

(a) P3 CV after calibration
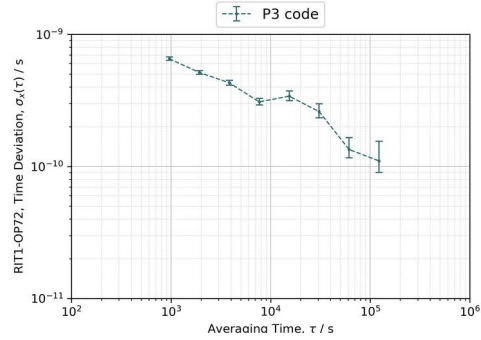
(b) TDEV of P3 CV

Figure B46: P3 CV time difference of RIT1 with respect to OP72.
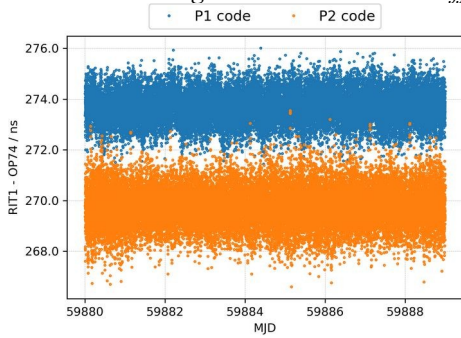
(a) P-code phase differences
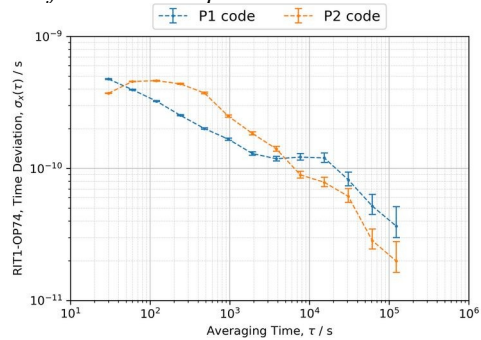
(b) TDEV of P-code delays

Figure B47: GPS relative calibration of RIT1 with respect to OP74.
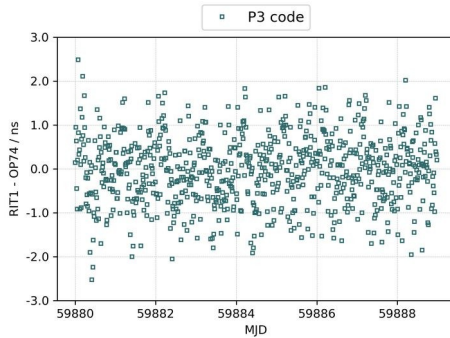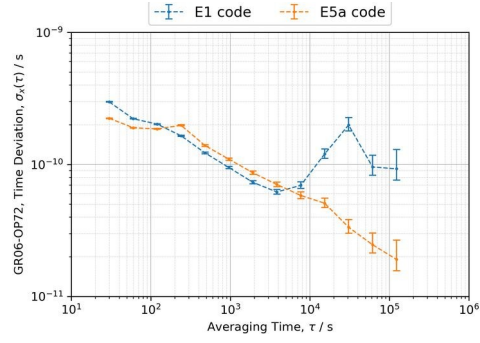

(a) P3 CV after calibration
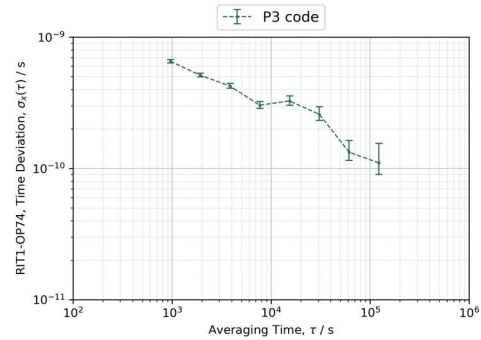
(b) TDEV of P3 CV

Figure B48: P3 CV time difference of RIT1 with respect to OP74.

B15
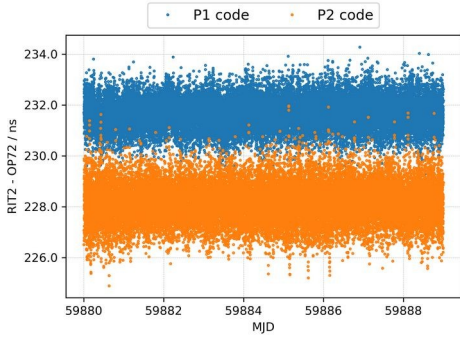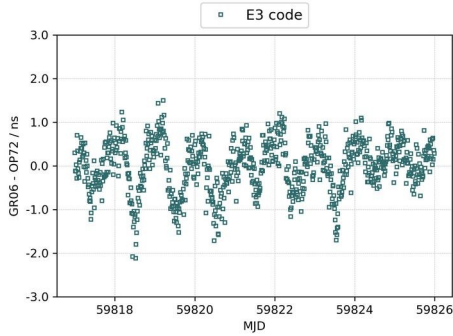
(a) P-code phase differences

(b) TDEV of P-code delays

Figure B49: GPS relative calibration of RIT2 with respect to OP72.
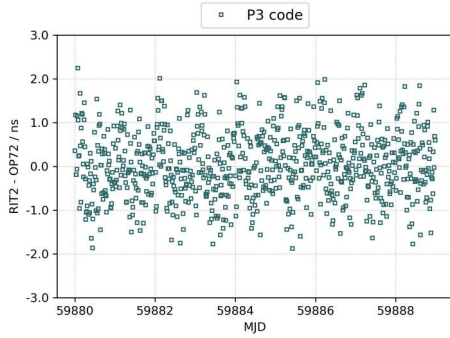
(a) P3 CV after calibration
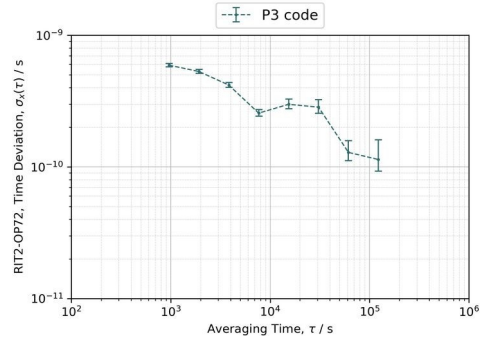
(b) TDEV of P3 CV

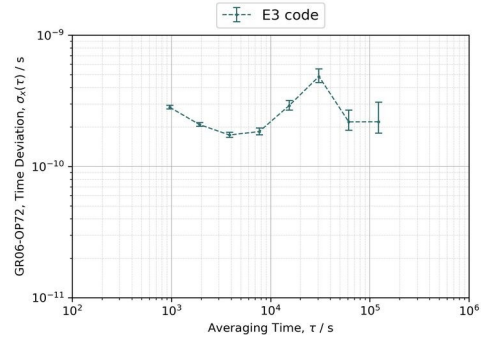*Figure B50: P3 CV time difference of RIT2 with respect to OP72.*
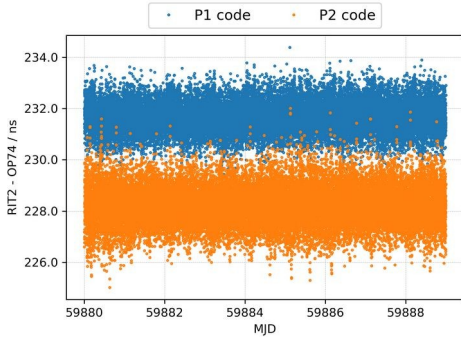
(a) P-code phase differences
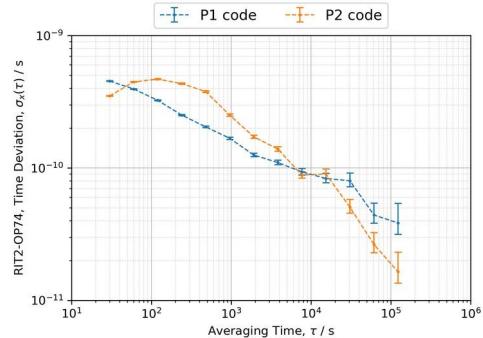
(b) TDEV of P-code delays

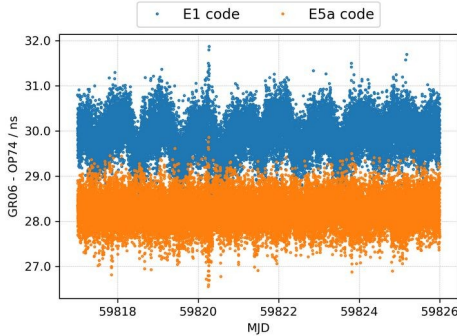*Figure B51: GPS relative calibration of RIT2 with respect to OP74.*
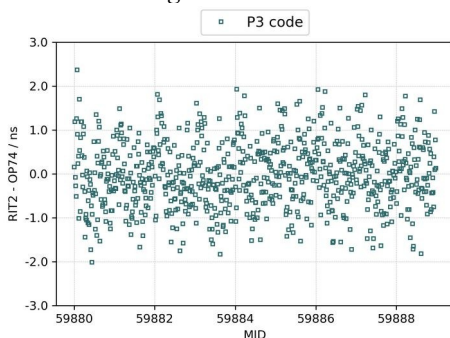
(a) P3 CV after calibration
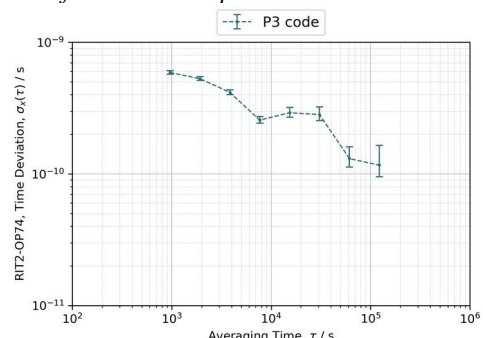
(b) TDEV of P3 CV

Figure B52: P3 CV time difference of RIT2 with respect to OP74.

B16
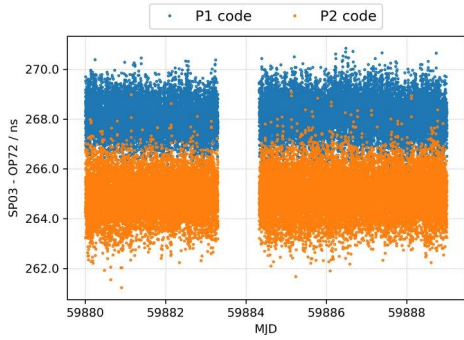
(a) P-code phase differences
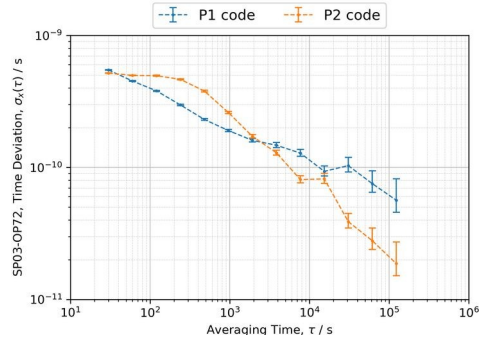
(b) TDEV of P-code delays

Figure B53: GPS relative calibration of SP03 with respect to OP72.
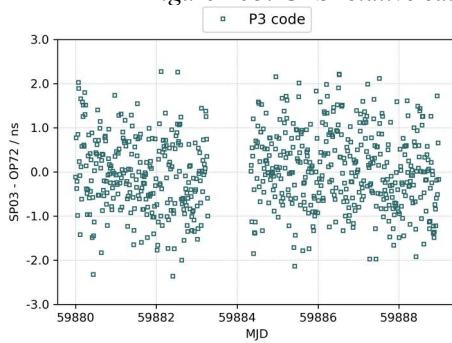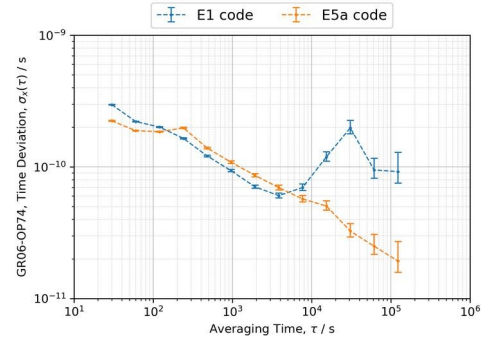
(a) P3 CV after calibration
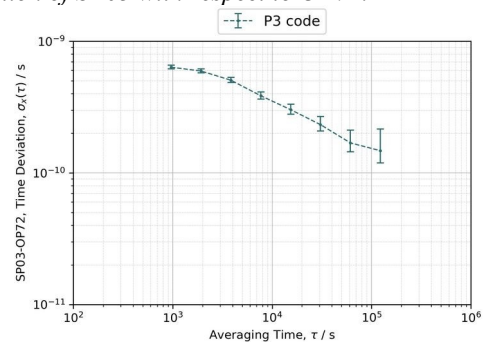
(b) TDEV of P3 CV

Figure B54: P3 CV time difference of SP03 with respect to OP72.
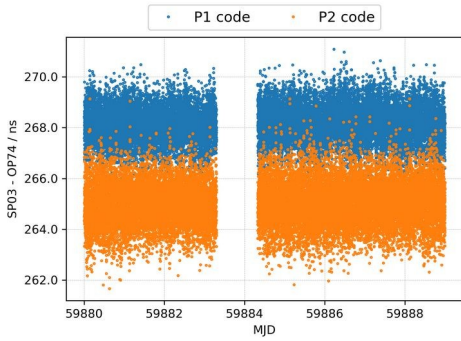
(a) P-code phase differences
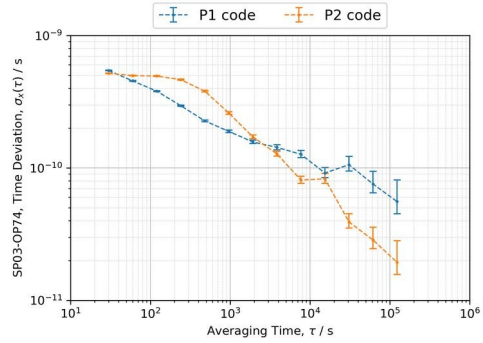
(b) TDEV of P-code delays

Figure B55: GPS relative calibration of SP03 with respect to OP74.
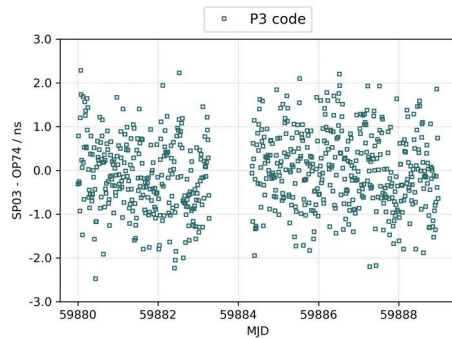
(a) P3 CV after calibration
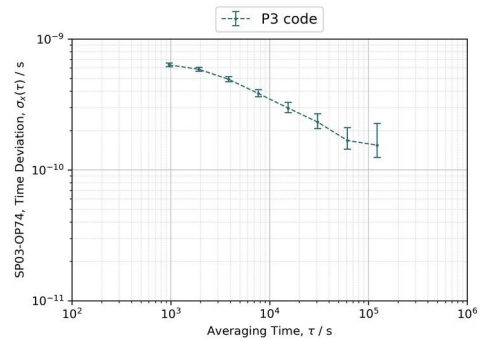
(b) TDEV of P3 CV

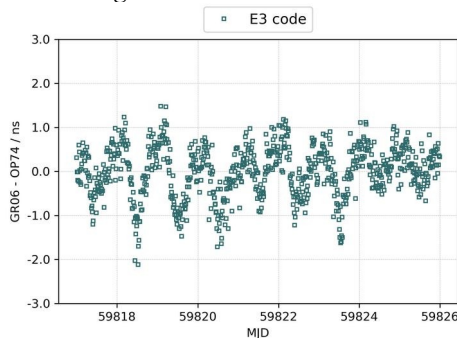*Figure B56: P3 CV time difference of SP03 with respect to OP74.*

B17
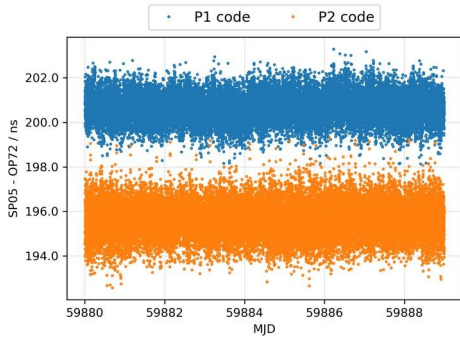
(a) P-code phase differences
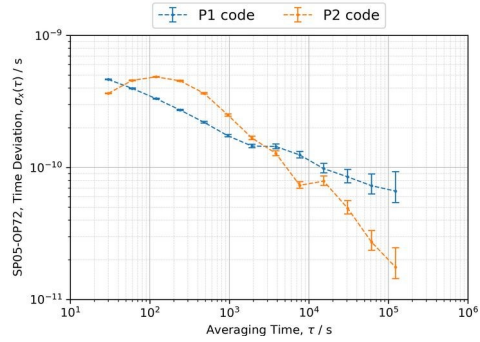
(b) TDEV of P-code delays

Figure B57: GPS relative calibration of SP05 with respect to OP72.
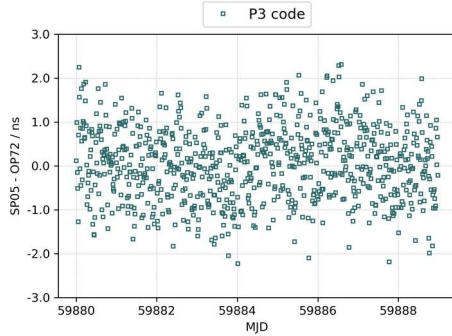
(a) P3 CV after calibration
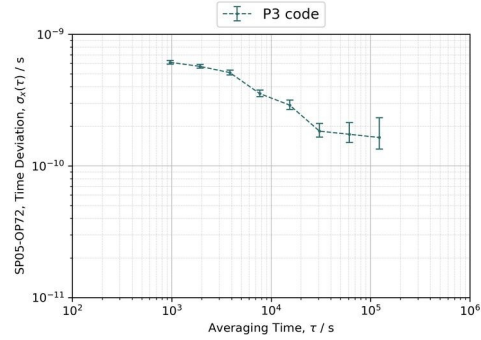
(b) TDEV of P3 CV

Figure B58: P3 CV time difference of SP05 with respect to OP72.
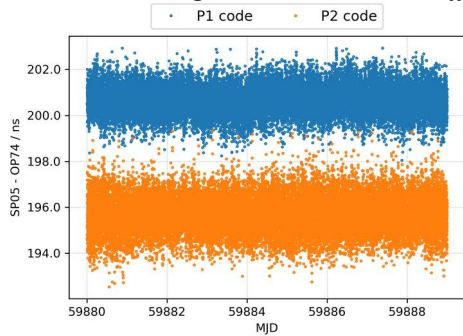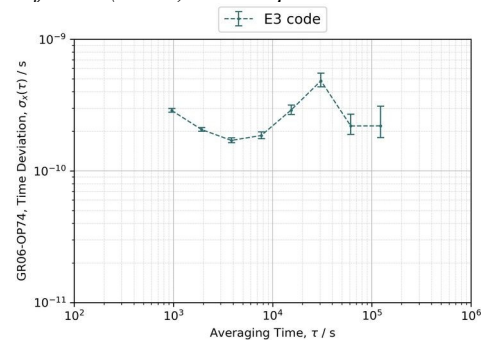

(a) P-code phase differences
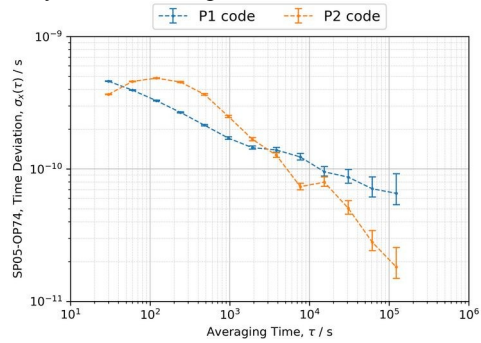
(b) TDEV of P-code delays

Figure B59: GPS relative calibration of SP05 with respect to OP74.
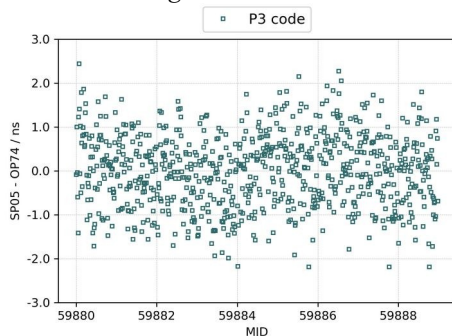
(a) P3 CV after calibration
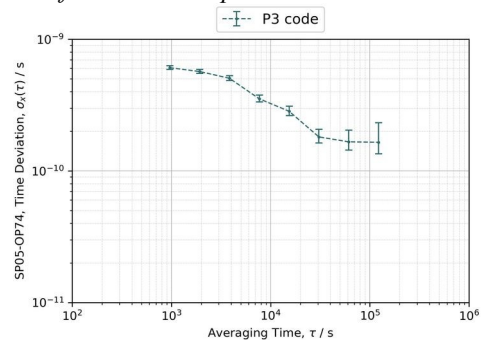
(b) TDEV of P3 CV

Figure B60: P3 CV time difference of SP05 with respect to OP74.

B18

4. Galileo calibration of OP72 and OP74 with respect to OP73.

4.1. Results of raw data processing.

Pair	MJD of measurement	RawDiff E1	TDEV	RawDiff E5a	TDEV
OP72 − OP73	59796-59807	- 64.879	0.083	- 64.766	0.050
OP74 − OP73	59796-59807	- 47.456	0.084	- 47.434	0.050
OP72 − OP73	59902-59911	- 64.032	0.058	- 64.861	0.035
OP74 − OP73	59902-59911	- 46.652	0.059	- 47.549	0.036

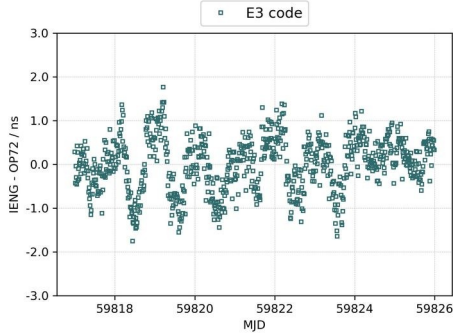### 4.2 Plots of raw data and TDEV.
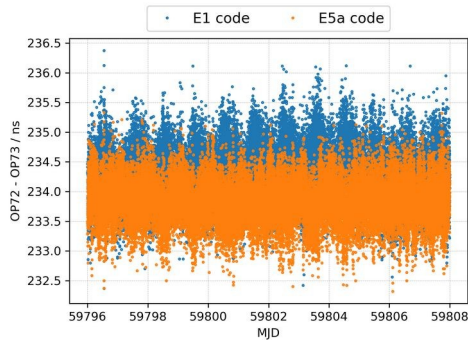
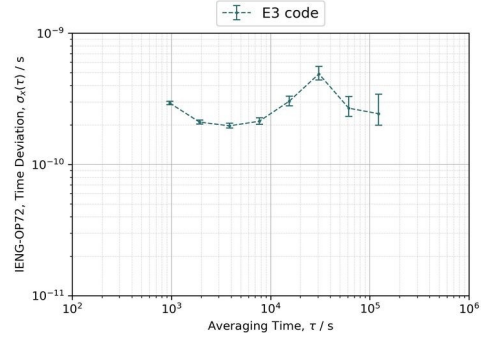(a) E-code phase differences
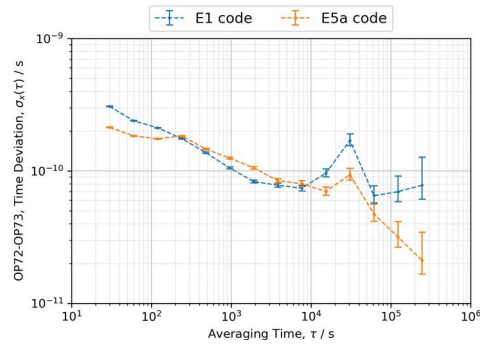
(b) TDEV of E-code delays

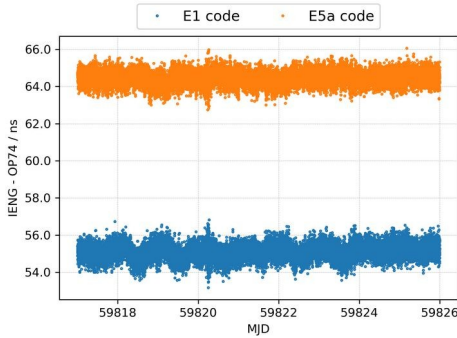*Figure B61: Galileo relative calibration of OP72 with respect to OP73 (start).*
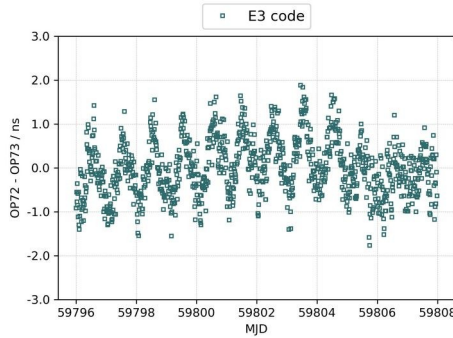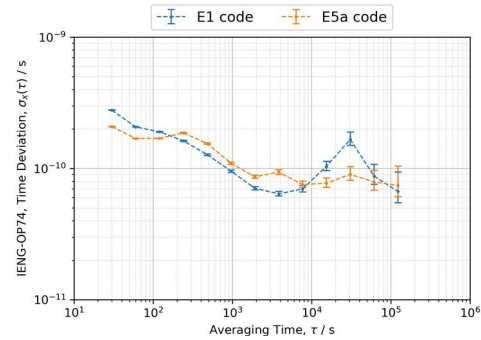

(a) E3 CV after calibration
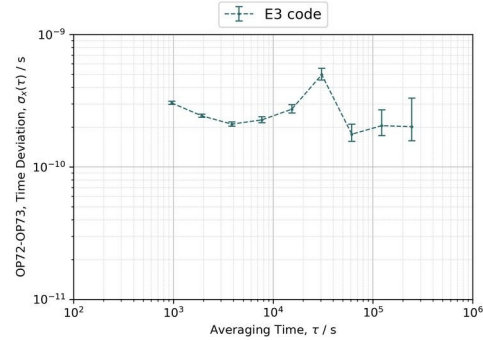
(b) TDEV of E3 CV

Figure B62: E3 CV time difference of OP72 with respect to OP73 (start).
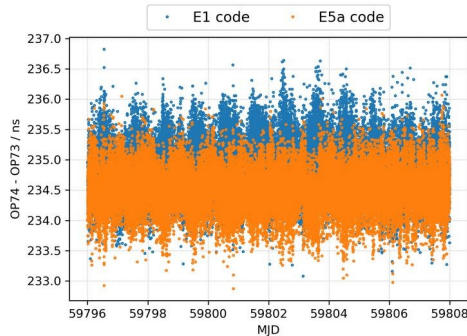
(a) E-code phase differences
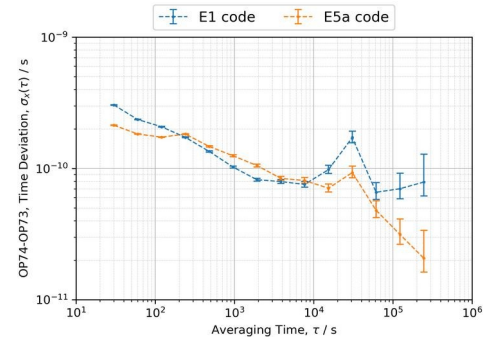
(b) TDEV of E-code delays

Figure B63: Galileo relative calibration of OP74 with respect to OP73 (start).

B19
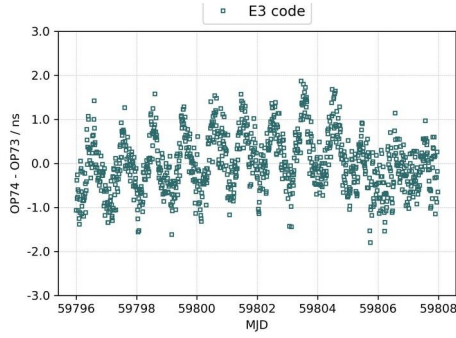
(a) E3 CV after calibration

(b) TDEV of E3 CV

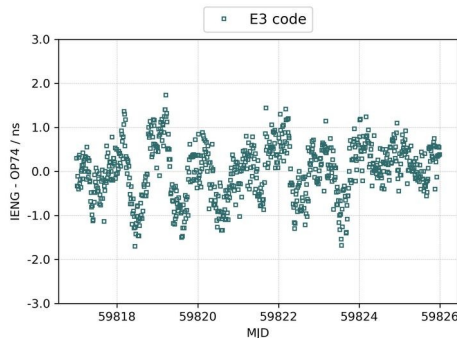*Figure B64: E3 CV time difference of OP74 with respect to OP73 (start).*

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B65: Galileo relative calibration of OP72 with respect to OP73 (closure).

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B66: E3 CV time difference of OP72 with respect to OP73 (closure).
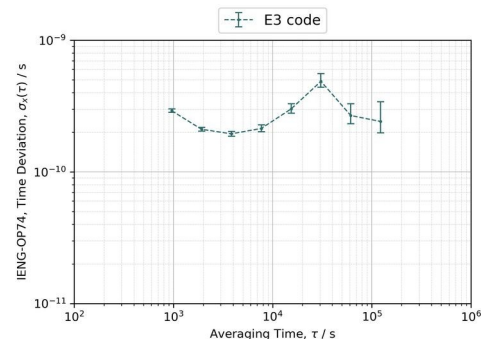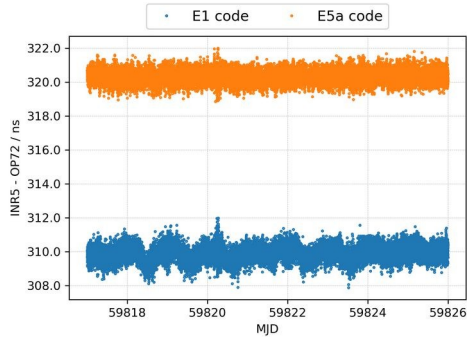

(a) E-code phase differences
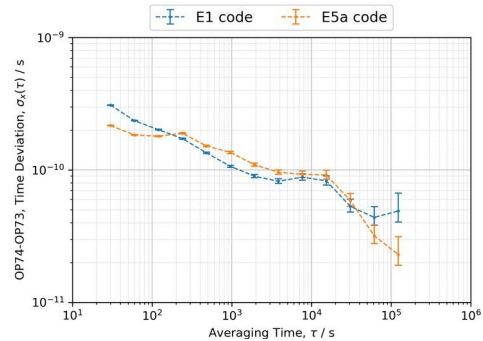
(b) TDEV of E-code delays

Figure B67: Galileo relative calibration of OP74 with respect to OP73 (closure).

B20

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<div align="center">

(a) E3 CV after calibration   (b) TDEV of E3 CV
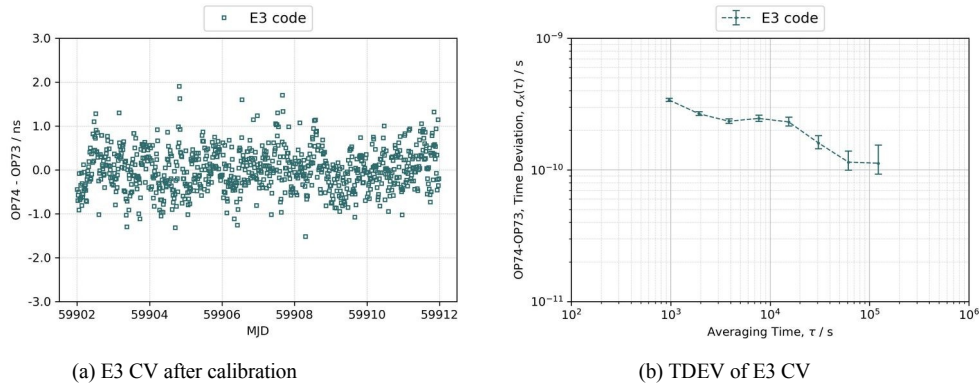
Figure B68: E3 CV time difference of OP74 with respect to OP73 (closure).

</div>

5. Galileo calibration of visited stations against OP72 and OP74.

5.1. Results of raw data processing.

Pair	MJD of measurement	RawDiff E1	TDEV	RawDiff E5a	TDEV
IT11 (GR01) - OP72	59817-59825	195.647	0.109	188.575	0.040
IT11 (GR01) - OP74	59817-59825	211.528	0.108	204.560	0.041
IT12 (GR02) - OP72	59817-59825	197.340	0.105	188.641	0.046
IT12 (GR02) - OP74	59817-59825	213.221	0.105	204.627	0.046
IT14 (GR04) - OP72	59817-59825	161.764	0.120	161.845	0.070
IT14 (GR04) - OP74	59817-59825	177.645	0.119	177.830	0.070
IT15 (GR05) - OP72	59817-59825	164.385	0.149	165.642	0.056
IT15 (GR05) - OP74	59817-59825	180.266	0.148	181.627	0.057
IT16 (GR06) - OP72	59817-59825	- 156.740	0.122	- 155.154	0.029
IT16 (GR06) - OP74	59817-59825	- 140.859	0.121	- 139.169	0.029
IT10 (IENG) - OP72	59817-59825	365.528	0.103	356.122	0.099
IT10 (IENG) - OP74	59817-59825	381.409	0.102	372.107	0.100
IT08 (INR5) - OP72	59817-59825	241.654	0.131	231.167	0.046
IT08 (INR5) - OP74	59817-59825	257.535	0.131	247.153	0.047
IT09 (INR6) - OP72	59817-59825	365.182	0.102	355.830	0.101
IT09 (INR6) - OP74	59817-59825	381.063	0.101	371.816	0.102
RIT1 - OP72	59880-59888	- 107.733	0.064	- 105.175	0.040
RIT1 - OP74	59880-59888	- 125.072	0.064	- 122.436	0.040
RIT2 - OP72	59880-59888	- 66.238	0.061	- 69.806	0.030
RIT2 - OP74	59880-59888	- 83.576	0.061	- 87.067	0.029
SP03 - OP72	59880-59888	- 102.230	0.090	- 114.590	0.050
SP03 - OP74	59880-59888	- 119.569	0.092	- 131.851	0.050
SP05 - OP72	59880-59888	- 34.979	0.079	- 33.829	0.039
SP05 - OP74	59880-59888	- 52.317	0.080	- 51.091	0.040

5.2. Plots of raw data and TDEV.
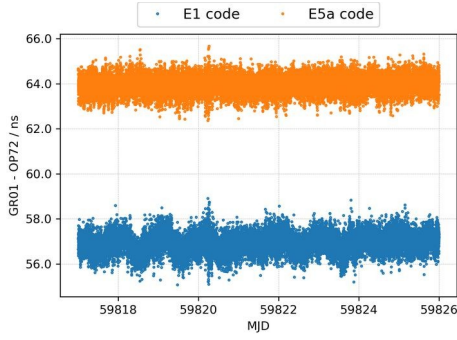
(a) E-code phase differences
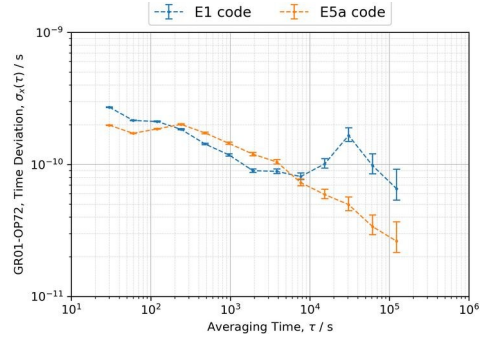
(b) TDEV of E-code delays

Figure B69: Galileo relative calibration of IT11 (GR01) with respect to OP72.
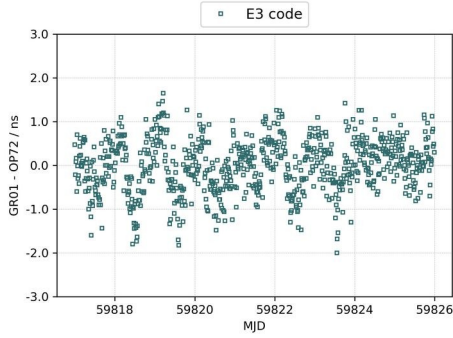
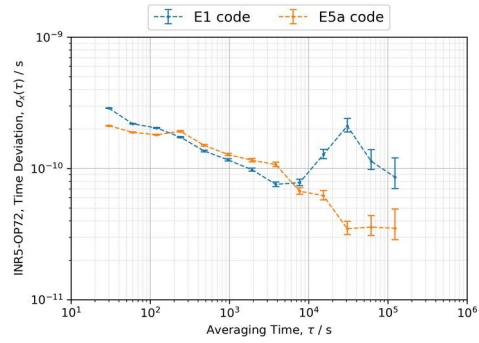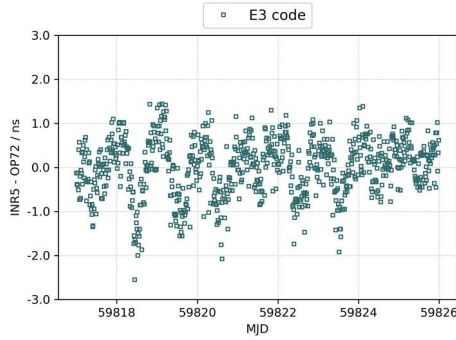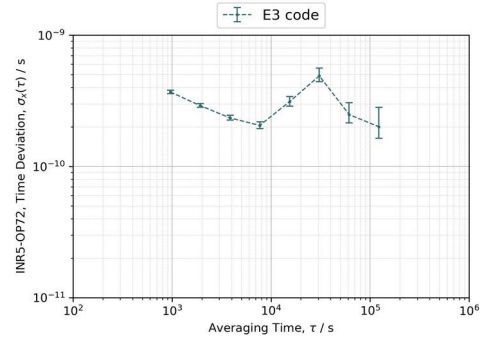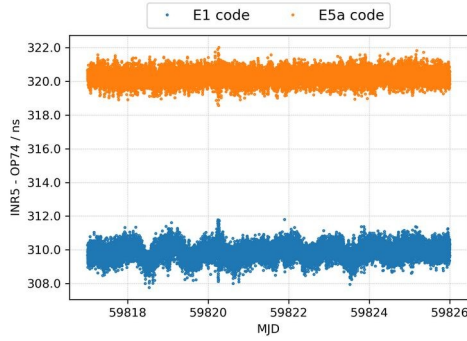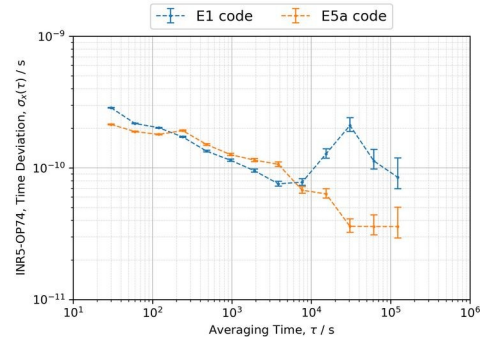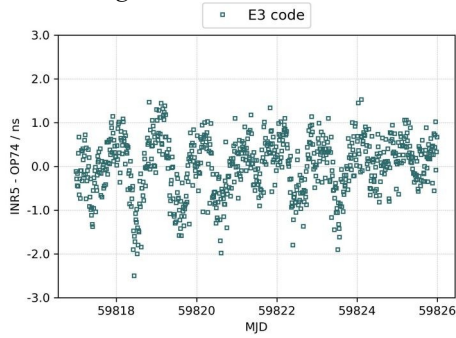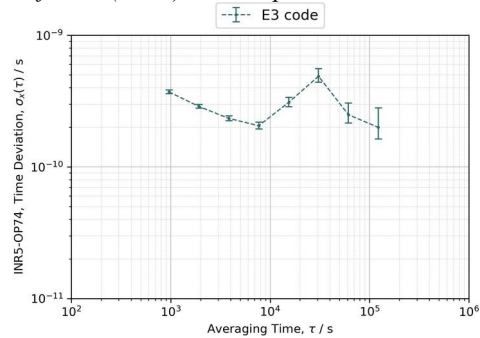(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B70: E3 CV time difference of IT11 (GR01) with respect to OP72.

(a) E-code phase differences

(b) TDEV of E-code delays

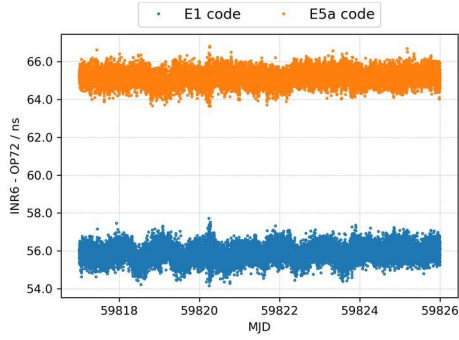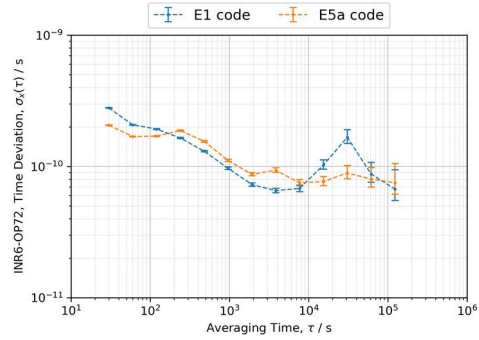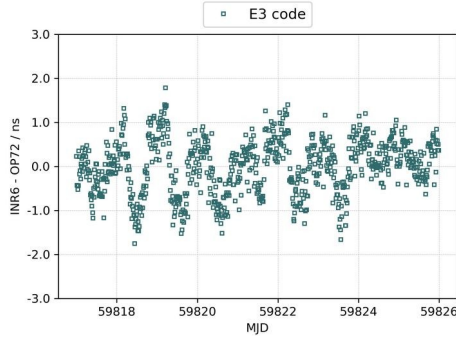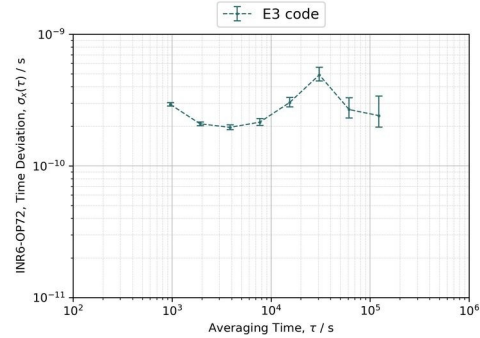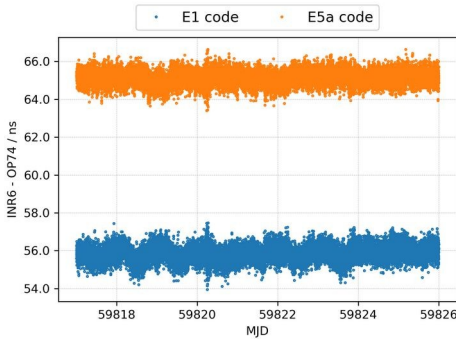*Figure B71: Galileo relative calibration of IT11 (GR01) with respect to OP74.*

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B72: E3 CV time difference of IT11 (GR01) with respect to OP74.

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B73: Galileo relative calibration of IT12 (GR02) with respect to OP72.
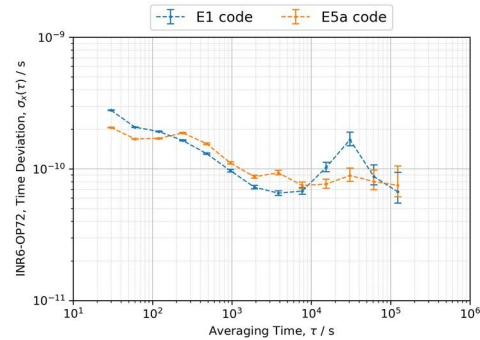

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B74: E3 CV time difference of IT12 (GR02) with respect to OP72.
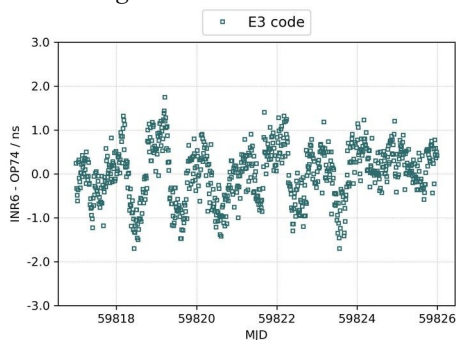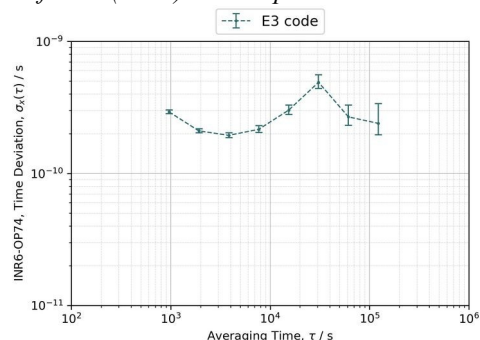

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B75: Galileo relative calibration of IT12 (GR02) with respect to OP74.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B76: E3 CV time difference of IT12 (GR02) with respect to OP74.

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(a) E-code phase differences

(b) TDEV of E-code delays

Figure B77: Galileo relative calibration of IT14 (GR04) with respect to OP72.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B78: E3 CV time difference of IT14 (GR04) with respect to OP72.

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B79: Galileo relative calibration of IT14 (GR04) with respect to OP74.

(a) E3 CV after calibration

(b) TDEV of E3 CV

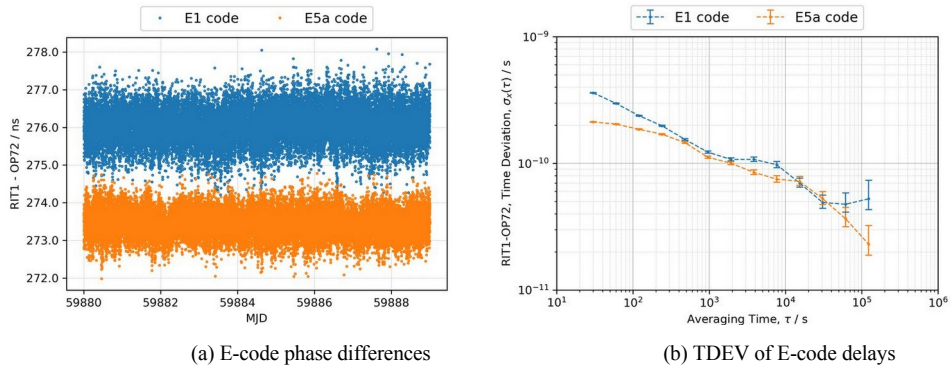*Figure B80: E3 CV time difference of IT14 (GR04) with respect to OP74.*

B24

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B81: Galileo relative calibration of IT15 (GR05) with respect to OP72.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B82: E3 CV time difference of IT15 (GR05) with respect to OP72.

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B83: Galileo relative calibration of IT15 (GR05) with respect to OP74.
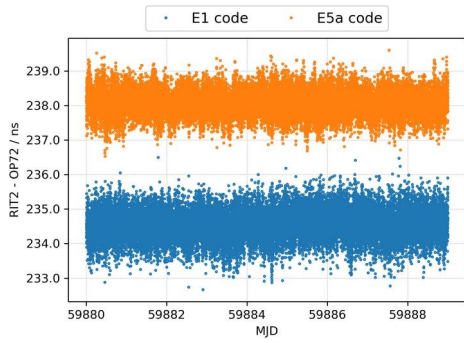

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B84: E3 CV time difference of IT15 (GR05) with respect to OP74.

B25

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B85: Galileo relative calibration of IT16 (GR06) with respect to OP72.
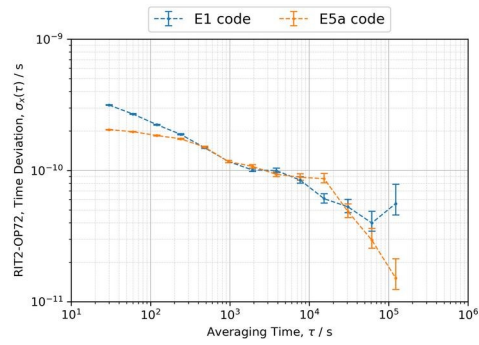

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B86: E3 CV time difference of IT16 (GR06) with respect to OP72.
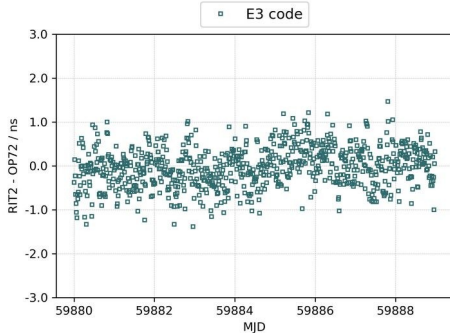

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B87: Galileo relative calibration of IT16 (GR06) with respect to OP74.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B88: E3 CV time difference of IT16 (GR06) with respect to OP74.

B26
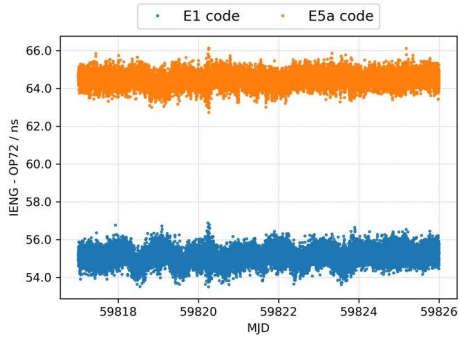
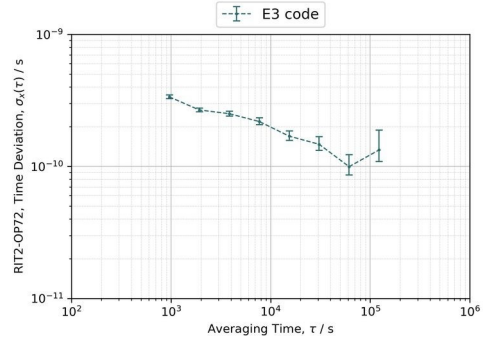(a) E-code phase differences
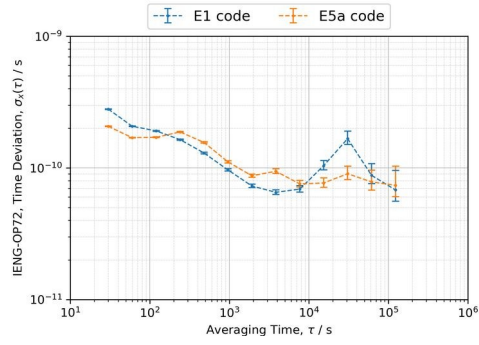
(b) TDEV of E-code delays

Figure B89: Galileo relative calibration of IT10 (IENG) with respect to OP72.
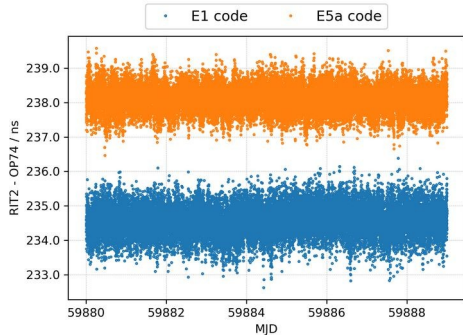

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B90: E3 CV time difference of IT10 (IENG) with respect to OP72.

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B91: Galileo relative calibration of IT10 (IENG) with respect to OP74.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B92: E3 CV time difference of IT10 (IENG) with respect to OP74.

B27

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B93: Galileo relative calibration of IT08 (INR5) with respect to OP72.
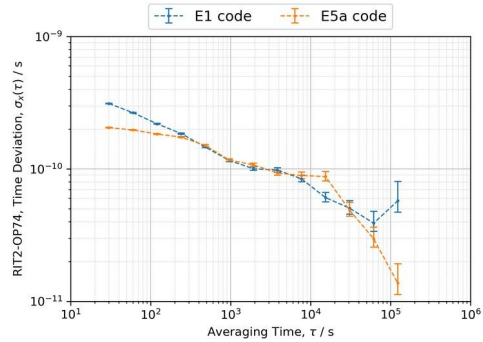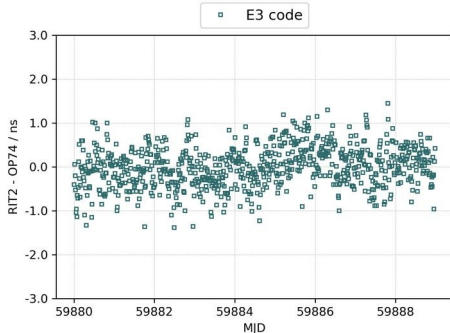

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B94: E3 CV time difference of IT08 (INR5) with respect to OP72.
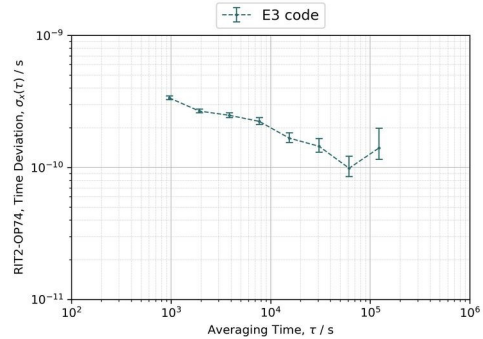

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B95: Galileo relative calibration of IT08 (INR5) with respect to OP74.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B96: E3 CV time difference of IT08 (INR5) with respect to OP74.

(a) E-code phase differences

(b) TDEV of E-code delays

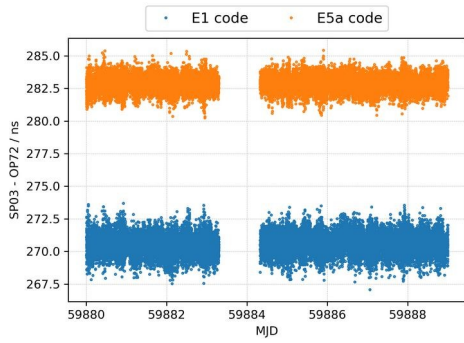*Figure B97: Galileo relative calibration of IT09 (INR6) with respect to OP72.*

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B98: E3 CV time difference of IT09 (INR6) with respect to OP72.

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B99: Galileo relative calibration of IT09 (INR6) with respect to OP74.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B100: E3 CV time difference of IT09 (INR6) with respect to OP74.

B29

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B101: Galileo relative calibration of RIT1 with respect to OP72.
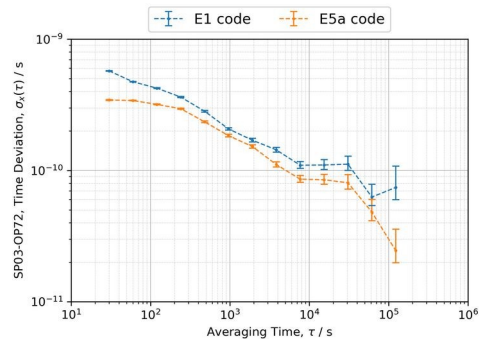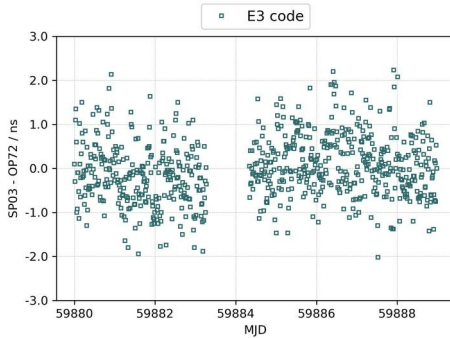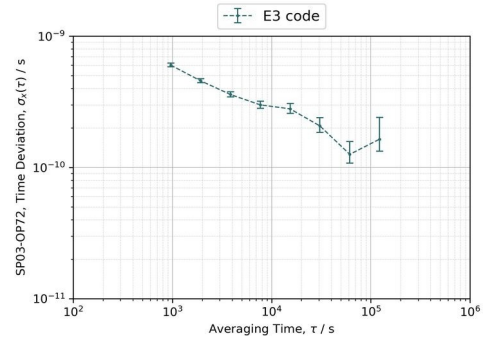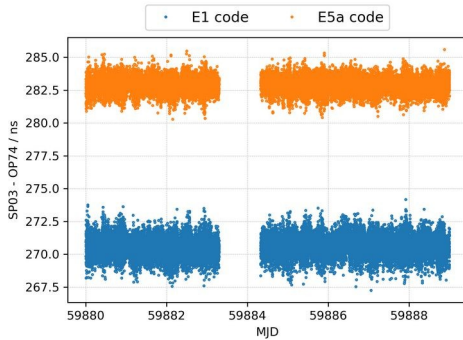

(a) E3 CV after calibration

(b) TDEV of E3 CV
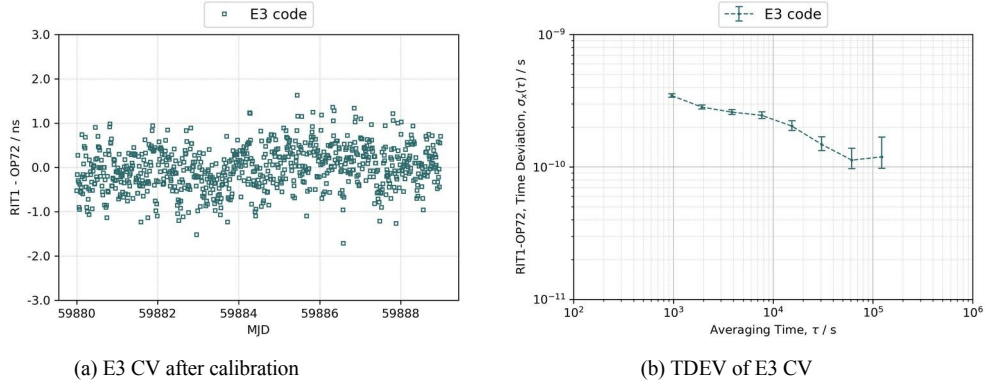
Figure B102: E3 CV time difference of RIT1 with respect to OP72.

(a) E-code phase differences

(b) TDEV of E-code delays
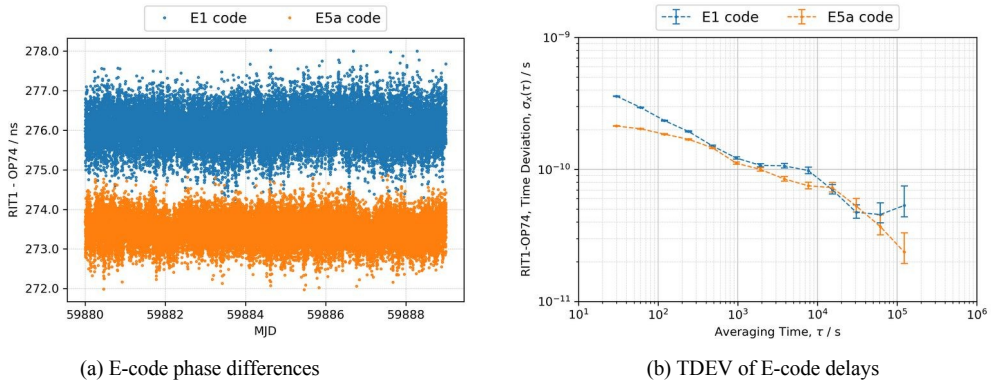
Figure B103: Galileo relative calibration of RIT1 with respect to OP74.

(a) E3 CV after calibration
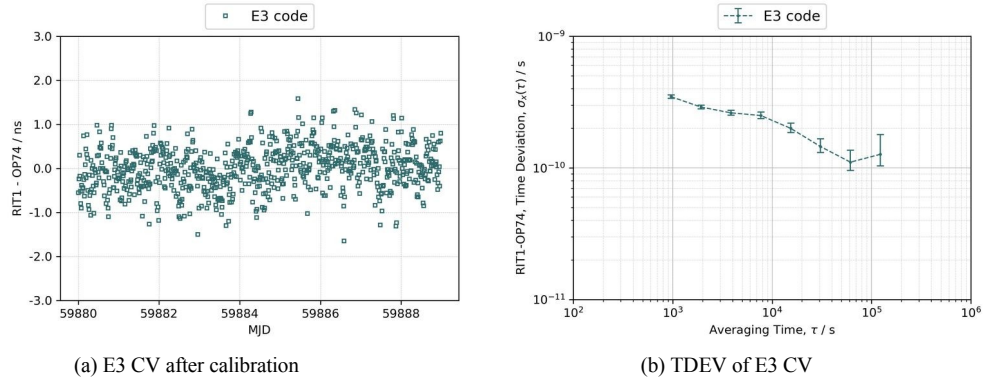
(b) TDEV of E3 CV

Figure B104: E3 CV time difference of RIT1 with respect to OP74.

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(a) E-code phase differences

(b) TDEV of E-code delays

Figure B105: Galileo relative calibration of RIT2 with respect to OP72.
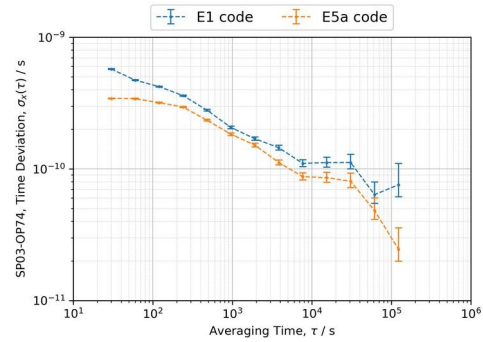

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B106: E3 CV time difference of RIT2 with respect to OP72.

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B107: Galileo relative calibration of RIT2 with respect to OP74.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B108: E3 CV time difference of RIT2 with respect to OP74.

B31

(a) E-code phase differences

(b) TDEV of E-code delays

Figure B109: Galileo relative calibration of SP03 with respect to OP72.

(a) E3 CV after calibration

(b) TDEV of E3 CV

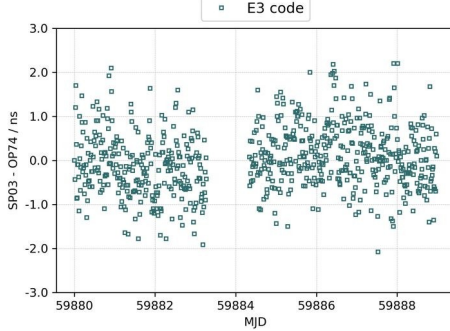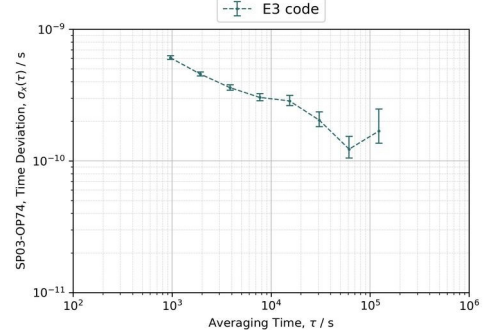*Figure B110: E3 CV time difference of SP03 with respect to OP72.*

(a) E-code phase differences

(b) TDEV of E-code delays

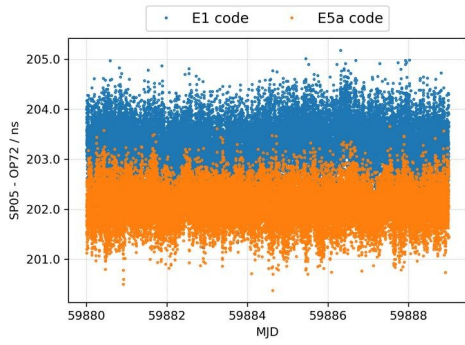*Figure B111: Galileo relative calibration of SP03 with respect to OP74.*
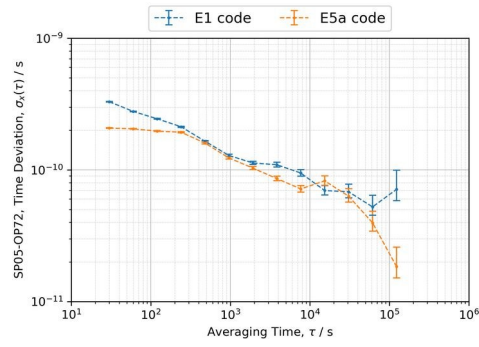

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B112: E3 CV time difference of SP03 with respect to OP74.
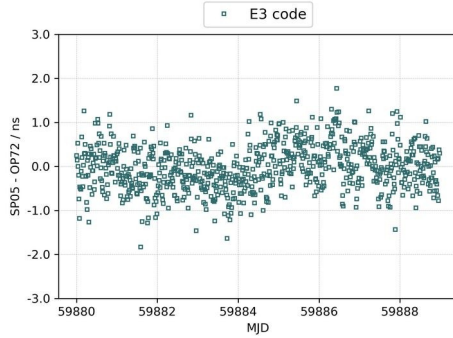
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(a) E-code phase differences

(b) TDEV of E-code delays

Figure B113: Galileo relative calibration of SP05 with respect to OP72.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B114: E3 CV time difference of SP05 with respect to OP72.
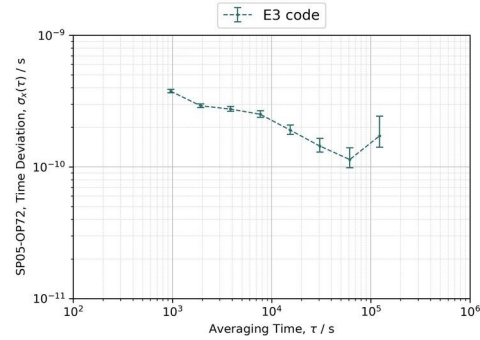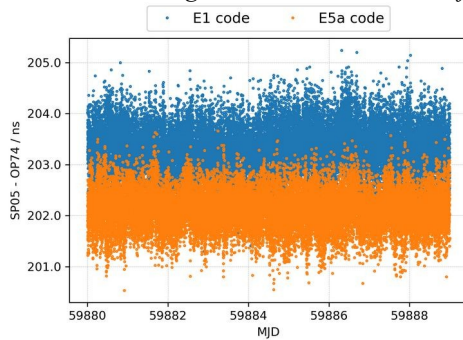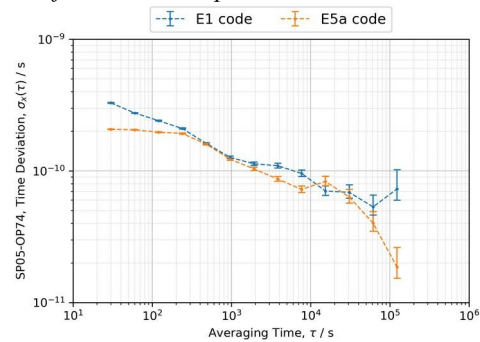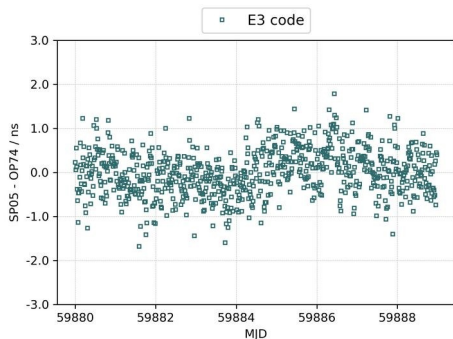

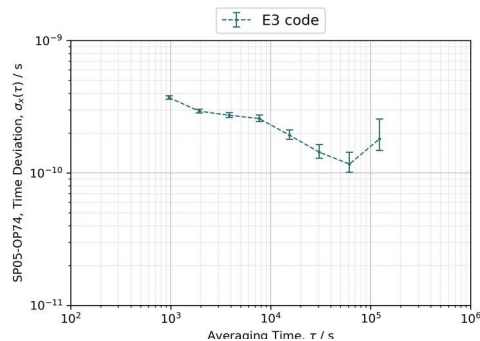(a) E-code phase differences

(b) TDEV of E-code delays

Figure B115: Galileo relative calibration of SP05 with respect to OP74.

(a) E3 CV after calibration

(b) TDEV of E3 CV

Figure B116: E3 CV time difference of SP05 with respect to OP74.

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ANNEX C

Uncertainty budget terms.

1. Type A uncertainty.

The statistical uncertainty u_a(A-B) for the comparison between two GNSS stations A and B and for each GNSS code is evaluated by computing the upper limit of the error bar of the TDEV at 1 d when possible, or otherwise the upper limit of the last error bar available. The sampling periods of computed calibrated offset usually lead to TDEV data available for 61 440 s and 122 880 s averaging periods. The computed u_a is obtained by a linear interpolation between consecutive TDEV data at an 86 400 s averaging period. When required, a simple quadratic sum leads to the Type A uncertainty required for an uncertainty budget computation.

2. Type B uncertainty.

Here are the u_b uncertainties taken into account in the uncertainty budget computations, together with the way they are estimated when necessary.

- $u_{b,1}$ observed maximum misclosure. This uncertainty component is an estimation of the stability of the traveling equipment during the campaign. The misclosure $u_{b,1}$ we used here is the actual misclosure between the start and the end of the campaign. There are two exceptions for ROA and RISE with E5a uncertainties, where the offsets between both traveling receivers are used instead, being higher than the actual misclosure.

- $u_{b,11}$ position error at reference site. The position of the center of phase of traveling antenna is estimated at opening and closure by using the NRCan PPP software, while for the OP reference station antenna the coordinates of the last G1 calibration are used. Note that this computation is achieved by using GPS data only. This might lead to a small bias on the phase center of the antenna for Galileo signals. We safely choose a conventional value of 200 ps ($\approx$ 6 cm) for the position error at the reference site.

- $u_{b,12}$ position error at visited site. At visited sites the position of the center of phase of all antennas is estimated by using the NRCan PPP software. Note that this computation is achieved by using GPS data only. This might lead to a small bias on the phase center of the antenna for Galileo signals. We safely choose a conventional value of 200 ps ($\approx$ 6 cm) for the position error at all visited sites.

- $u_{b,13}$ multipath at reference site. We assume in all cases a conventional value of 200 ps, which is in line with some experiment achieved at OP and ORB, especially when using the calibration software developed at OP, where outliers are properly averaged out. (see: G.D. Rovera, M. Abgrall, P. Uhrich, P. Defraigne and B. Bertrand, "*GNSS antenna multipath effects*", Proc. of the 31st European Frequency and Time Forum (EFTF), Torino, 2018).

- $u_{b,14}$ multipath at visited site. Same as above.

- $u_{b,21}$ REFDLY (traveling receiver at reference lab). Uncertainty of the measure of the time difference between the reference point of the traveling receiver and the local UTC(k). The used value is the quadratic sum of an uncertainty value attributed to the Time Interval Counter (TIC) with the standard deviation of the actual measurement. When the REFDLY is obtained by summing several individual measurement the uncertainty is increased by quadratic sum as required. We use 220 ps as conservative conventional value.

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- $u_{b,22}$ REFDLY (traveling receiver at visited lab). Same as above. This is possible because the TIC we are using for all REFDLY measurements is traveling along with the OP GNSS stations.

- $u_{b,TOT}$: Quadratic sum of all previous u_b.

- $u_{b,31}$ REFDLY uncertainty of the GNSS reference station to its local UTC(k). Computed similarly as $u_{b,21}$. This term can be set to 0 when the GNSS reference station has been recently calibrated, the uncertainty of REFDLY being already included in the conventional uncertainty decided by the CCTF WG on GNSS.

- $u_{b,32}$ REFDLY uncertainty (at visited lab) of the link of the visited station to its local UTC(k). Computed similarly as $u_{b,21}$. When this delay is measured and the $u_{b,32}$ is taken into account, the local distribution system can be modified afterwards without loosing the calibration of the local GNSS station, provided the new REFDLY is taken into account afterwards

- $u_{b,41}$ uncertainty of the antenna cable delay at reference station. The chosen value here is based on a comprehensive study which is available in reference [4].

- $u_{b,42}$ uncertainty of antenna cable delay at visited station. Same as just above. When for some reason the antenna cable of the traveling system is changed during the campaign, $u_{b,42}$ is typically obtained from the quadratic sum of the uncertainty of the antenna cable delay actually used at the visited station and the uncertainty of the antenna cable delay of the traveling equipment.

- $u_{b,SYS}$: Quadratic sum of all type B uncertainties above.

3. Combined uncertainty.

- u_{CAL0}: Quadratic sum of u_a and $u_{b,SYS}$. This uncertainty is for the link between the calibrated station and the reference station, without taking into account the uncertainty of this reference station.

Note finally that, in our computation, P3 uncertainty values are not based on a linear combination of P1 and P2 uncertainty values but estimated in a similar way as for P1 and P2. And this is also the case for E3 uncertainty values, which are computed in a similar way as E1 and E5a uncertainty values.

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