# 2020 Group 1 GNSS calibration trip

## Summary

The 2020 visit to Group 1 laboratories is the fourth Group 1 trip and started in June 2020.
The trip is decomposed into several phases, each enclosed with closure at the BIPM. Some phases may be run in parallel.

- Phase 1 (June-December 2020). BIPM-NICT-TL-BIPM with the traveling receivers BP1J and BP25;
- Phase 1b (June-December 2020). BIPM-NIM-BIPM with the traveling receivers TS03 and TS04;
- Phase 2 (February-June 2021), BIPM-ROA-PTB-OP-BIPM with the traveling receivers BP1J and BP25.
- Phase 3 (October 2021-January 2022), BIPM-NIST-USNO-BIPM with the traveling receivers BP1J and BP25.

Due to the COVID situation, restrictions in shipping made it imposible to carry out Phase 1 with the three APMP laboratorios in the same trip. Taking advantage of the presence of two NIM receivers at the BIPM, a specific trip was organized, described under Phase 1b.
Since phase 3 of the 2018 Group 1 trip, results are provided for the GPS codes P1, P2 and C1 and the Galileo E1 and E5a codes.
This report provides intermediate results which are determined with respect to one BIPM receiver.
**Final results for all Group 1 receivers are determined in a separate document** BIPM Technical Memorandum 266.

### Trip 1001-2020: Report of phase 3

### 1. Description of equipment and operations

1.1 Traveling equipment

- Traveling systems:

Two systems are included in the BIPM traveling calibrator: BP1J and BP25, see Table 1 and the report of operations 1001-2020-phase3-cv.pdf.

- Other traveling equipment:

See Annex 1 of the Guidelines.

1.2 Visited equipment

See a summary in Table 1. The detailed information on the set-up and the measurements performed is in the report of operations 1001-2020-phase3-cv.pdf.

The receiver BP21 from the BIPM serves as a reference for the closure, with the receiver BP27 included as a backup system.

Table 1. Summary information on phase 3 of the calibration trip 1001-2020

| Institute | Status of equipment | Dates of measurement | BIPM code | RINEX name | Receiver type |
|---|---|---|---|---|---|
| BIPM | Traveling | | BP1J | BP1J | Septentrio PolaRx4TR |
| BIPM | Traveling | | BP25 | BP25 | Mesit GTR55 |
| | | | | | |
| BIPM | BIPM reference | 59440-59449 | BP21 | BP21 | Septentrio PolaRx5TR (AC On) (1) |
| BIPM | BIPM backup | 59440-59449 | BP27 | BP27 | |
| | | | | | |
| NIST | G1 reference | 59510-59529 | NIST | NIST | Novatel OEM4-G2 |
| NIST | G1 backup | 59510-59529 | NISG | NISG | Septentrio PolaRx5TR (AC Off) (1) |
| NIST | G1 backup | 59510-59529 | NISS | NISS | Septentrio PolaRx3TRPro |
| NIST | G1 backup | 59510-59529 | NISX | NISX | Septentrio PolaRx5TR (AC Off) (1) |
| | | | | | |
| USNO | G1 reference | 59569-59586 | US06 | USN6 | Novatel Propak3 |
| USNO | G1 backup | 59569-59586 | US09 | USN7 | |
| USNO | G1 backup | 59569-59586 | US10 | USN8 | Septentrio PolaRx5TR (AC On) (1) |
| USNO | G1 backup | 59569-59586 | US11 | USN9 | Novatel Propak6 |
| | | | | | |
| BIPM | BIPM reference | 59663-59667 | BP21 | BP21 | Septentrio PolaRx5TR (AC On) (1) |
| BIPM | BIPM backup | 59663-59667 | BP27 | BP27 | |
| | | | | | |

(1) Because it is estimated that the Auto-compensation mode of the Septentrio PolaRx5 impacts its INTDLY value at the level of 0.5 ns, the mode is indicated in Table 1.

## 2. Data used

Rinex files have been obtained from all receivers participating to this trip.

## 3. Results of raw data processing

- The raw code differences have been generated by the DCLRINEX procedure (see Guidelines Annex 3). Each run for a pair of stations generates 3 files (summary .sum, data .dif, plot .pdf). Summary files and plots are available in 1001-2020-phase3-cv.pdf. All code measurements are indicated with 2 digits numeric precision in order to minimize rounding errors in computing iono-free linear combination values.

- For each pair (traveling – visited) or (traveling – reference):
  - Plots of the data differences and of the statistical analysis (Tdev) are in the report of operations 1001-2020-phase3-cv.pdf;
  - For each code, the inferred RAWDIF(code) are taken as the median of the raw differences. The associated uncertainties are taken as the floor of the Tdev values, with a minimum of 0.1 ns.

- Summary tables.

For this report, the BIPM system BP21 is the reference. However, another system (BP27) is used as backup and is listed in Tables 2.1.
Note that the receiver BP25 could not generate data during the visit to USNO. The problem was fixed by a remote intervention of Alexander Kuna when the receiver returned to the BIPM and the receiver could be used for the closure measurements.

Table 2.1 Raw differential results for all pairs (Traveling – Reference) (ns) at the BIPM. Measurements for the local backup BP27 are also included.

| Labo | Date | Pair | RDIF(P1) | Unc | RDIF(P2) | Unc | RDIF(C1) | Unc | RDIF(E1) | Unc | RDIF(E5a) | Unc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| BIPM | 59440-59449 | BP1J-BP21 | -90.50 | 0.1 | -89.63 | 0.1 | -91.32 | 0.1 | -91.90 | 0.1 | -82.13 | 0.1 |
| BIPM | 59663-59667 | BP1J-BP21 | -90.72 | 0.1 | -89.81 | 0.1 | -91.49 | 0.1 | -92.10 | 0.1 | -82.23 | 0.1 |
| | | | | | | | | | | | | |
| BIPM | 59440-59449 | BP25-BP21 | 12.12 | 0.1 | 17.63 | 0.1 | 10.75 | 0.1 | 10.35 | 0.1 | 16.30 | 0.1 |
| BIPM | 59663-59667 | BP25-BP21 | 12.00 | 0.1 | 17.61 | 0.1 | 10.66 | 0.1 | 10.27 | 0.1 | 16.41 | 0.1 |
| | | | | | | | | | | | | |
| BIPM | 59440-59449 | BP27-BP21 | 42.59 | 0.1 | 41.59 | 0.1 | 42.82 | 0.1 | 42.63 | 0.1 | 44.17 | 0.1 |
| BIPM | 59663-59667 | BP27-BP21 | 75.54 | 0.1 | 74.48 | 0.1 | 75.80 | 0.1 | 75.63 | 0.1 | 77.13 | 0.1 |
| | | | | | | | | | | | | |

Table 2.2 Raw differential results for all pairs (Traveling – Visited) (ns)

| Labo | Date | Pair | RDIF(P1) | Unc | RDIF(P2) | Unc | RDIF(C1) | Unc | RDIF(E1) | Unc | RDIF(E5a) | Unc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| NIST | 59510-59529 | BP1J-NISG | 887.62 | 0.1 | 889.17 | 0.1 | 886.65 | 0.1 | 886.18 | 0.1 | 896.53 | 0.1 |
| NIST | 59510-59529 | BP25-NISG | 988.65 | 0.1 | 994.52 | 0.1 | 987.31 | 0.1 | 986.83 | 0.1 | 993.37 | 0.1 |
| NIST | 59510-59529 | BP1J-NIST | -512.46 | 0.1 | -513.32 | 0.1 | -511.84 | 0.1 | | | | |
| NIST | 59510-59529 | BP25-NIST | -411.42 | 0.1 | -407.99 | 0.1 | -411.15 | 0.1 | | | | |
| NIST | 59510-59529 | BP1J-NISS | -421.30 | 0.2 | -422.04 | 0.1 | -421.73 | 0.2 | | | | |
| NIST | 59510-59529 | BP25-NISS | -320.26 | 0.2 | -316.66 | 0.1 | -321.06 | 0.2 | | | | |
| NIST | 59510-59529 | BP1J-NISX | -137.45 | 0.1 | -135.69 | 0.1 | -138.33 | 0.1 | -138.91 | 0.1 | -129.49 | 0.1 |
| NIST | 59510-59529 | BP25-NISX | -36.45 | 0.1 | -30.26 | 0.1 | -37.68 | 0.1 | -38.29 | 0.1 | -32.68 | 0.1 |
| | | | | | | | | | | | | |
| USNO | 59569-59579 | BP1J-USN6 | 64.87 | 0.1 | 67.16 | 0.1 | 65.42 | 0.1 | | | | |
| USNO | 59569-59579 | BP25-USN6 | | | | | | | | | | |
| USNO | 59569-59579 | BP1J-USN7 | -94.95 | 0.1 | -91.19 | 0.1 | -95.82 | 0.1 | -96.39 | 0.1 | -87.85 | 0.1 |
| USNO | 59569-59579 | BP25-USN7 | | | | | | | | | | |
| USNO | 59569-59579 | BP1J-USN8 | -141.95 | 0.1 | -139.24 | 0.1 | -142.86 | 0.1 | -143.45 | 0.1 | -135.12 | 0.1 |
| USNO | 59569-59579 | BP25-USN8 | | | | | | | | | | |
| USNO | 59569-59579 | BP1J-USN9 | -143.95 | 0.1 | -161.51 | 0.1 | -143.36 | 0.1 | -144.92 | 0.1 | -159.77 | 0.1 |
| USNO | 59569-59579 | BP25-USN9 | | | | | | | | | | |
| | | | | | | | | | | | | |

## 4. Calibration results

In the first step, one computes **ΔSYSDLY,** the differences of SYSDLY for all pairs (Traveling-Reference) and (Traveling-Visited), from

$$\Delta SYSDLY_{A-B}(Code) = RAWDIF_{A-B}(Code) + REFDLY_{A} - REFDLY_{B} \quad (1)$$

where RAWDIF(Code) is read in Table 2 and where the values REFDLY are in the report of operations 1001-2020-phase3-cv.pdf.

The **ΔSYSDLY** values are reported in Table 3 for the pairs Traveling-Reference (section 4.1) and in Table 4 for the pairs Traveling-Visited (section 4.2).

In the second step one computes **ΔSYSDLY** (Visited-Reference) for all visited systems.

$$\Delta SYSDLY_{V-R} = \Delta SYSDLY_{T-R} - \Delta SYSDLY_{T-V.} \quad (2)$$

One can then compute **ΔINTDLY** (Visited-Reference) for all visited systems.

$$\Delta INTDLY_{V-R} = \Delta SYSDLY_{V-R} - CABDLY_{V} + CABDLY_{R} \quad (3)$$

where the values CABDLY are taken from the report of operations 1001-2020-phase3-cv.pdf;
Tables 5 reports the **$\Delta INTDLY_{V-R}$** results for the pairs Visited-Reference (section 4.3).
Using assumed **$INTDLY_{R}$** values for the Reference system, Table 6 then reports **$INTDLY_{V}$** for all visited systems (section 4.4).

### 4.1 Traveling system with respect to the reference system

REFDLY values are available from the report of operations 1001-2020-phase3-cv.pdf.

Table 3.1. Computed ΔSYSDLY values for the traveling systems with respect to BP21 used as a reference. The misclosures are also indicated. (all values in ns).

| Pair | Date | $REFDLY_T$ | $REFDLY_R$ | Note | P1 (ns) | | P2 (ns) | | C1 (ns) | | E1 (ns) | | E5a (ns) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY |
| | | | | | | | | | | | | | | |
| BP1J-BP21 | 59440-59449 | 194.5 | 43.3 | | -90.50 | 60.66 | -89.63 | 61.53 | -91.32 | 59.84 | -91.90 | 59.26 | -82.13 | 69.03 |
| BP1J-BP21 | 59663-59667 | 194.4 | 43.3 | | -90.72 | 60.37 | -89.81 | 61.28 | -91.49 | 59.60 | -92.10 | 58.99 | -82.23 | 68.86 |
| | | Misclos. | | | | 0.29 | | 0.25 | | 0.24 | | 0.27 | | 0.17 |
| BP1J-BP21 | | Mean | | | | 60.52 | | 61.41 | | 59.72 | | 59.13 | | 68.95 |
| | | | | | | | | | | | | | | |
| BP25-BP21 | 59440-59449 | 53.5 | 43.3 | | 12.12 | 22.31 | 17.63 | 27.82 | 10.75 | 20.94 | 10.35 | 20.54 | 16.30 | 26.49 |
| BP25-BP21 | 59663-59667 | 53.4 | 43.3 | | 12.00 | 22.06 | 17.61 | 27.67 | 10.66 | 20.72 | 10.27 | 20.33 | 16.41 | 26.47 |
| | | Misclos. | | | | 0.25 | | 0.15 | | 0.22 | | 0.21 | | 0.02 |
| BP25-BP21 | | Mean | | | | 22.19 | | 27.75 | | 20.83 | | 20.44 | | 26.48 |

Results for the traveling systems are reported in Table 3.1.

Results for the local backup BP27 vs. BP21 are shown in Table 3.2. The misclosure for this pair is an indicator of the relative instabilities of the two stationary receivers.

Table 3.2. Computed ΔSYSDLY values for the local backup BP1K with respect to BP21 used as a reference. All values in ns

| Pair | Date | $REFDLY_T$ | $REFDLY_R$ | Note | P1 (ns) | | P2 (ns) | | C1 (ns) | | E1 (ns) | | E5a (ns) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY |
| | | | | | | | | | | | | | | |
| BP27-BP21 | 59440-59449 | 61.3 | 43.3 | | 42.59 | 60.68 | 41.59 | 59.68 | 42.82 | 60.91 | 42.63 | 60.72 | 44.17 | 62.26 |
| BP27-BP21 | 59663-59667 | 28.2 | 43.3 | | 75.54 | 60.45 | 74.48 | 59.39 | 75.80 | 60.71 | 75.63 | 60.54 | 77.13 | 62.04 |
| | | Misclos. | | | | 0.23 | | 0.29 | | 0.20 | | 0.18 | | 0.22 |
| BP27-BP21 | | Mean | | | | 60.57 | | 59.54 | | 60.81 | | 60.63 | | 62.15 |
| | | | | | | | | | | | | | | |

### 4.2 Traveling system with respect to the visited systems

REFDLY values are available from the report of operations 1001-2020-phase3-cv.pdf.

THESE TABLES HAVE BEEN ESTABLISHED WITH REFDLY OF USNO RECEIVERS = 0.0. INFO SHEETS PROVIDE SMALL REFDLY VALUES (EXCEPT FOR USN7 WHICH SHEET IS MISSING)

Table 4. Traveling vs. Visited systems (all values in ns)

| Pair | Date | $REFDLY_T$ | $REFDLY_V$ | Note | P1 (ns) | | P2 (ns) | | C1 (ns) | | E1 (ns) | | E5a (ns) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY |
| BP1J-NISG | 59510-59529 | 606.1 | 1592.2 | | 887.62 | -98.48 | 889.17 | -96.93 | 886.65 | -99.45 | 886.18 | -99.92 | 896.53 | -89.57 |
| BP25-NISG | 59510-59529 | 467.2 | 1592.2 | | 988.65 | -136.36 | 994.52 | -130.49 | 987.31 | -137.70 | 986.83 | -138.18 | 993.37 | -131.64 |
| BP1J-NIST | 59510-59529 | 606.1 | 65.9 | | -512.46 | 27.74 | -513.32 | 26.88 | -511.84 | 28.36 | | | | |
| BP25-NIST | 59510-59529 | 467.2 | 65.9 | | -411.42 | -10.13 | -407.99 | -6.70 | -411.15 | -9.86 | | | | |
| BP1J-NISS | 59510-59529 | 606.1 | 299.4 | | -421.30 | -114.60 | -422.04 | -115.34 | -421.73 | -115.03 | | | | |
| BP25-NISS | 59510-59529 | 467.2 | 299.4 | | -320.26 | -152.47 | -316.66 | -148.87 | -321.06 | -153.27 | | | | |
| BP1J-NISX | 59510-59529 | 606.1 | 452.3 | | -137.45 | 16.35 | -135.69 | 18.11 | -138.33 | 15.47 | -138.91 | 14.89 | -129.49 | 24.31 |
| BP25-NISX | 59510-59529 | 467.2 | 452.3 | | -36.45 | -21.56 | -30.26 | -15.37 | -37.68 | -22.79 | -38.29 | -23.40 | -32.68 | -17.79 |
| | | | | | | | | | | | | | | |
| BP1J-USN6 | 59569-59579 | 171.4 | N/A | (1) | 64.87 | 236.25 | 67.16 | 238.54 | 65.42 | 236.80 | | | | |
| BP25-USN6 | 59569-59579 | | | | | | | | | | | | | |
| BP1J-USN7 | 59569-59579 | 171.4 | N/A | (1) | -94.95 | 76.43 | -91.19 | 80.19 | -95.82 | 75.56 | -96.39 | 74.99 | -87.85 | 83.53 |
| BP25-USN7 | 59569-59579 | | | | | | | | | | | | | |
| BP1J-USN8 | 59569-59579 | 171.4 | N/A | (1) | -141.95 | 29.43 | -139.24 | 32.14 | -142.86 | 28.52 | -143.45 | 27.93 | -135.12 | 36.26 |
| BP25-USN8 | 59569-59579 | | | | | | | | | | | | | |
| BP1J-USN9 | 59569-59579 | 171.4 | N/A | (1) | -143.95 | 27.43 | -161.51 | 9.87 | -143.36 | 28.02 | -144.92 | 26.46 | -159.77 | 11.61 |
| BP25-USN9 | 59569-59579 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

(1) **REFDLY**v value not available.

### 4.3 Visited systems with respect to reference system

The Table 5 provides the values obtained by differencing Table 3.1 (BP21 reference) and Table 4. CABDLY values are taken from the report of operations 1001-2020-phase3-cv.pdf and have not been measured during this calibration.

Table 5. Visited vs. BP21 Reference (all values in ns)

| Pair | Date | $CABDLY_V$ | $CABDLY_R$ | Note | P1 (ns) | | P2 (ns) | | C1 (ns) | | E1 (ns) | | E5a (ns) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ΔSYSDLY | ΔINTDLY | ΔSYSDLY | ΔINTDLY | ΔINTDLY | ΔINTDLY | ΔINTDLY | ΔINTDLY | ΔSYSDLY | ΔINTDLY |
| NISG-BP21 via BP1J | 2021.8 | 298.5 | 140.8 | | 159.00 | 1.30 | 158.34 | 0.64 | 159.17 | 1.47 | 159.05 | 1.35 | 158.52 | 0.81 |
| NISG-BP21 via BP25 | 2021.8 | 298.5 | 140.8 | | 158.55 | 0.85 | 158.24 | 0.54 | 158.53 | 0.83 | 158.62 | 0.92 | 158.12 | 0.42 |
| NIST-BP21 via BP1J | 2021.8 | 275.5 | 140.8 | | 32.78 | -101.93 | 34.53 | -100.18 | 31.36 | -103.34 | | | | |
| NIST-BP21 via BP25 | 2021.8 | 275.5 | 140.8 | | 32.32 | -102.39 | 34.45 | -100.26 | 30.69 | -104.01 | | | | |
| NISS-BP21 via BP1J | 2021.8 | 298.9 | 140.8 | | 175.12 | 17.02 | 176.75 | 18.65 | 174.75 | 16.65 | | | | |
| NISS-BP21 via BP25 | 2021.8 | 298.9 | 140.8 | | 174.66 | 16.56 | 176.62 | 18.52 | 174.10 | 16.00 | | | | |
| NISX-BP21 via BP1J | 2021.8 | 185.0 | 140.8 | | 44.17 | -0.04 | 43.30 | -0.91 | 44.25 | 0.05 | 44.24 | 0.03 | 44.64 | 0.44 |
| NISX-BP21 via BP25 | 2021.8 | 185.0 | 140.8 | | 43.75 | -0.45 | 43.12 | -1.08 | 43.62 | -0.58 | 43.84 | -0.36 | 44.27 | 0.07 |
| | | | | | | | | | | | | | | |
| USN6-BP21 via BP1J | 2022.0 | N/A | 140.8 | (1) | -175.74 | -34.94 | -177.14 | -36.34 | -177.08 | -36.28 | | | | |
| USN6-BP21 via BP25 | 2022.0 | | | | | | | | | | | | | |
| USN7-BP21 via BP1J | 2022.0 | N/A | 140.8 | (1) | -15.92 | 124.89 | -18.79 | 122.02 | -15.84 | 124.96 | -15.87 | 124.94 | -14.59 | 126.22 |
| USN7-BP21 via BP25 | 2022.0 | | | | | | | | | | | | | |
| USN8-BP21 via BP1J | 2022.0 | N/A | 140.8 | (1) | 31.09 | 171.89 | 29.27 | 170.07 | 31.20 | 172.00 | 31.20 | 172.00 | 32.69 | 173.49 |
| USN8-BP21 via BP25 | 2022.0 | | | | | | | | | | | | | |
| USN9-BP21 via BP1J | 2022.0 | N/A | 140.8 | (1) | 33.09 | 173.89 | 51.54 | 192.34 | 31.70 | 172.50 | 32.67 | 173.47 | 57.34 | 198.14 |
| USN9-BP21 via BP25 | 2022.0 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

(1) **$CABDLY_V$** value not available.

### 4.4 Provisional INTDLY values of visited systems

Table 6 lists INTDLY values of the visited systems.
These values are provisional and based on INTDLY values for BP21 (P1=28.4 ns; P2=27.3 ns; C1=30.6 ns, E1=30.7 ns, E5a=30.9 ns) from 1001-2018, as described in BIPM Technical Memorandum 266. Final INTDLY values will be based on minimizing changes between 1001-2018 and 1001-2020, as described in BIPM Technical Memorandum 266, and will be reported in the global report of the trip 1001-2020 available here. Since two results can be computed from Table 5 for the NIST receivers, using either BP1J or BP25 as traveling system, the values in Table 6 are the average of the two results, and the difference between the two is indicated. We note that the difference Δ(BP1J-BP25) is typically of order 0.2 to 0.4 ns, but 0.6 ns for C1. This is accounted for in the component $u_{b,1}$ of the uncertainty budget in Tables 7 and 8. The results for USNO receivers are based on BP1J only and the uncertainty component $u_{b,1}$ has been expanded to account for the lack of the second traveling receiver.

Table 6. Provisional INTDLY values of Visited systems using 1001-2018 reference values for the reference systems BP21 (all values in ns).

| Pair | Date | Note | P1 | P2 | C1 | E1 | E5 |
|---|---|---|---|---|---|---|---|
| | | | $INTDLY_V$ | $INTDLY_V$ | $INTDLY_V$ | $INTDLY_V$ | $INTDLY_V$ |
| NISG vs BP21 | 2021.8 | | 29.47 | 27.89 | 31.75 | 31.83 | 31.52 |
| Δ(BP1J-BP25) | | | 0.45 | 0.10 | 0.64 | 0.43 | 0.39 |
| NIST vs BP21 | 2021.8 | | -73.76 | -72.92 | -73.08 | | |
| Δ(BP1J-BP25) | | | 0.46 | 0.08 | 0.67 | | |
| NISS vs BP21 | 2021.8 | | 45.19 | 45.88 | 46.93 | | |
| Δ(BP1J-BP25) | | | 0.46 | 0.13 | 0.65 | | |
| NISX vs BP21 | 2021.8 | | 28.16 | 26.31 | 30.34 | 30.54 | 31.15 |
| Δ(BP1J-BP25) | | | 0.42 | 0.18 | 0.63 | 0.40 | 0.36 |
| | | | | | | | |
| USN6 vs BP21 | 2022.0 | (1) | -6.54 | -9.03 | -5.68 | | |
| Δ(BP1J-BP25) | | | N/A | | | | |
| USN7 vs BP21 | 2022.0 | (1) | 153.29 | 149.32 | 155.56 | 155.64 | 157.12 |
| Δ(BP1J-BP25) | | | N/A | | | | |
| USN8 vs BP21 | 2022.0 | (1) | 200.29 | 197.37 | 202.60 | 202.7 | 204.39 |
| Δ(BP1J-BP25) | | | N/A | | | | |
| USN9 vs BP21 | 2022.0 | (1) | 202.29 | 219.64 | 203.10 | 204.17 | 229.04 |
| Δ(BP1J-BP25) | | | N/A | | | | |

(1) Results ate TOTDLY values computed with the BP1J traveling receiver only.

## 5 Uncertainty estimation

In this section, we determine the uncertainty of the differential calibration process i.e. we estimate all components that can affect the accuracy. We determine a value $U_{CAL0}$ that is to be used as the accuracy of all P3/PPP links (Visited – Reference) at the epoch of calibration.

$$u_{CAL0} = \sqrt{u_a^2 + u_b^2}$$

with the statistical uncertainty $u_a$ and the systematic uncertainty $u_b$. (all are 1-sigma).
The statistical uncertainty $u_a$ originates from RAWDIF (see section 3) and is given by the statistical analysis of the raw code differences for (Traveling-Reference) and (Traveling-Visited).

The systematic uncertainty is given by $u_B = \sqrt{\sum_n u_{b,n}^2}$

where all possible terms to be considered in the sum are listed in Table 7 for GPS and Table 8 for Galileo and some detail on their estimation is provided at the end of this section. Values appear separately for each code and for the difference of the two codes (e.g. P1, P2 and P1-P2 for GPS) so as to compute a value $u_{CAL}$ applicable to P3 links.
We choose to compute $U_{CAL}$ using for $u_b$ the uncertainty $u_{bSYS}$ of $\Delta SYSDLY_{V-R}$ from equation (2)[1]
Table 7 presents all components of the uncertainty budget along with the uncertainty $u_{bSYS}$ of $\Delta SYSDLY_{V-R}$ from equation (2) and the resulting uncertainty value $U_{CAL}$.

The value $u_{CAL}$ =1.4 ns from Tables 7 and 8 is applicable to dual-frequency code or PPP links. The value $u_{CAL}$ =1.2 ns is applicable to C1/E1 links. Final values of $u_{CAL}$ are consistent with the conventional value of 1.5 ns for dual-frequency links between G1 laboratories, as used in UTC computation.

Table 7. Uncertainty contributions. For all components of $u_b$, the P3 values are computed as P1 + 1.545x(P1-P2)

| Unc. | Value C1/P1 (ns) | Value P2 (ns) | Value P1-P2 (ns) | Value P3 (ns) | Description |
|---|---|---|---|---|---|
| $u_a$ (T-V) | 0.1 | 0.1 | | | RAWDIF (traveling-visited) |
| $u_a$ (T-R) | 0.1 | 0.1 | | | RAWDIF (traveling-reference) |
| $u_a$ | 0.15 | 0.15 | | 0.4 | See text below |
| “Misclosure” | | | | | |
| $u_{b,1}$ | 0.4 | 0.4 | 0.1 | 0.5 | mis-closure NIST |
| $u_{b,1}$ | 0.6 | 0.6 | 0.1 | 0.7 | mis-closure USNO |
| Systematic components related to RAWDIF | | | | | |
| $u_{b,11}$ | 0.1 | 0.1 | 0.1 | | Position error at reference |
| $u_{b,12}$ | 0.1 | 0.1 | 0.1 | | Position error at visited |
| $u_{b,13}$ | 0.2 | 0.2 | 0.3 | | Multipaths at reference |
| $u_{b,14}$ | 0.2 | 0.2 | 0.3 | | Multipaths at visited |
| Link of the Traveling system to the local UTC(k) | | | | | |
| $u_{b,21}$ | 0.5 | 0.5 | 0 | | $REFDLY_T$ (at ref lab) |
| $u_{b,22}$ | 0.5 | 0.5 | 0 | | $REFDLY_T$ (at visited lab) |
| $u_{b,TOT}$ | 0.9/1.0 | 0.9/1.0 | 0.5 | 1.1/1.2 | Values NIST/USNO |
| Link of the Reference system to its local UTC(k) | | | | | |
| $u_{b,31}$ | 0.5 | 0.5 | 0 | | $REFDLY_R$ (at ref lab) |
| Link of the Visited system to its local UTC(k) | | | | | |
| $u_{b,32}$ | 0.5 | 0.5 | 0 | | $REFDLY_V$ (at visited lab) |
| $u_{b,SYS}$ | 1.2 | 1.2 | 0.5 | 1.4 | Components of equation (2) |
| | | | | | |
| $u_{CAL}$ | 1.2 | | | 1.4 | Composed of $u_a$ and $u_{b,SYS}$ |

[1] It is somewhat arbitrary to choose SYSDLY to estimate the link accuracy. This reflects the fact that the REFDLY is subject to change e.g. with change of reference clock and that its uncertainty should better be taken into account.

Table 8. Galileo uncertainty contributions. For all components of $u_b$, the E3 values are computed as E1 + 1.261x(E1-E5)

| Unc. | Value E1 (ns) | Value E5 (ns) | Value E1-E5 (ns) | Value E3 (ns) | Description |
|---|---|---|---|---|---|
| $u_a$ (T-V) | 0.1 | 0.1 | | | RAWDIF (traveling-visited) |
| $u_a$ (T-R) | 0.1 | 0.1 | | | RAWDIF (traveling-reference) |
| $u_a$ | 0.15 | 0.15 | | 0.4 | See text below |
| "Misclosure" | | | | | |
| $u_{b,1}$ | 0.4 | 0.4 | 0.1 | 0.5 | mis-closure NIST |
| $u_{b,1}$ | 0.6 | 0.6 | 0.1 | 0.7 | mis-closure USNO |
| Systematic components related to RAWDIF | | | | | |
| $u_{b,11}$ | 0.1 | 0.1 | 0.1 | | Position error at reference |
| $u_{b,12}$ | 0.1 | 0.1 | 0.1 | | Position error at visited |
| $u_{b,13}$ | 0.2 | 0.2 | 0.3 | | Multipaths at reference |
| $u_{b,14}$ | 0.2 | 0.2 | 0.3 | | Multipaths at visited |
| Link of the Traveling system to the local UTC(k) | | | | | |
| $u_{b,21}$ | 0.5 | 0.5 | 0 | | $REFDLY_T$ (at ref lab) |
| $u_{b,22}$ | 0.5 | 0.5 | 0 | | $REFDLY_T$ (at visited lab) |
| $u_{b,TOT}$ | 0.9/1.0 | 0.9/1.0 | 0.5 | 1.1/1.2 | Values NIST/USNO |
| Link of the Reference system to its local UTC(k) | | | | | |
| $u_{b,31}$ | 0.5 | 0.5 | 0 | | $REFDLY_R$ (at ref lab) |
| Link of the Visited system to its local UTC(k) | | | | | |
| $u_{b,32}$ | 0.5 | 0.5 | 0 | | $REFDLY_V$ (at visited lab) |
| $u_{b,SYS}$ | 1.2 | 1.2 | 0.5 | 1.4 | Components of equation (2) |
| | | | | | |
| $u_{CAL}$ | 1.2 | | | 1.4 | Composed of $u_a$ and $u_{b,SYS}$ |

The components in Tables 7 and 8 are separated in several categories:

- The $u_a$ value for P3 is conservatively estimated from the linear combination of P1 and P2 values. Lower values would be obtained from a statistical analysis of P3 RAWDIF.
- $u_{b,1}$ accounts for possible variations of the delays of the traveling systems during the trip. This is evaluated on the one hand by the observed misclosure (~ 0.2 ns average for each code, see Table 3.1), on the other hand by the observed discrepancies between the results of the two traveling receivers (~0.4 ns for each code, 0.6 ns for C1, see Table 6). For USNO receivers only one traveling receiver was available and 0.5 ns is added in quadrature to $u_{b,1}$.
- $u_{b,11}$ and $u_{b,12}$ account for errors in the differential position (Travel – Local). They are conservatively estimated to be 3 cm (100 ps) while the uncertainty in the baseline determination by the DCLRINEX software should be lower. The L5 baseline used for Galileo processing is determined from L5 data.
- $u_{b,13}$ and $u_{b,14}$ account for multipaths. This is difficult to estimate and 0.2 ns is conventionally used, following a discussion in the CCTF working group on GNSS in 2017.
- $u_{b,21}$ and $u_{b,22}$ account for the measurement between the reference point of the traveling system and the local UTC(k). They include at least one measurement with a TIC and are taken to be 0.5 ns since no specific uncertainty was reported by the participating laboratories.
- $u_{b,31}$ and $u_{b,32}$ account similarly for the measurement between the reference point of the local system and the local UTC(k). They include at least one measurement with a TIC and are taken to be 0.5 ns since no specific uncertainty was reported by the participating laboratories.

**Version history**

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