

2016 Group 1 GPS calibration trip

Summary

The 2016 visit to Group 1 laboratories started in March 2016.

The trip is decomposed into several phases, each separated with closures at the BIPM.

- Phase 1 (March-September 2016). BIPM-TL-NICT-NIM-BIPM with the traveling receivers BP1C and BP0U; In addition, a visit to NTSC was organized to check results of a previous Group 2 trip by NIM.
- Phase 2 (October-December 2016): BIPM-PTB-ROA-OP-BIPM with the traveling receivers BP1C and BP0U;
- Phase 3 (To Be Continued)

Following work described in [BIPM Technical Memorandum 243](#), calibration results for code C1 (L1C) have been added to the original Group 1 P1/P2 calibration. Starting with this report for the second Group 1 trip, results are provided for the GPS codes P1, P2 and C1.

This report provides intermediate results which are determined with respect to one BIPM receiver.

Final results for all three codes for all Group 1 receivers are determined in a separate document [BIPM Technical Memorandum 266](#).

Trip 1001-2016: Report of phase 1

1. Description of equipment and operations

1.1 Traveling equipment

- Traveling systems:

Two systems are included in the BIPM traveling calibrator: BP1C and BP0U, see Table 1 and the report of operations [1001-2016-phase1-cv.pdf](#).

The long term stability of the two systems is described in the [BIPM Technical Memorandum 204](#).

- 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 [1001-2016-phase1-cv.pdf](#).

For reasons mentioned in section 3, two receivers (BP1J and BP1X) from the BIPM have been included as backup systems to check the closure.

Table 1. Summary information on phase 1 of the calibration trip 1001-2016

| Institute | Status of equipment | Dates of measurement | BIPM code | RINEX name | Receiver type |
|-----------|---------------------|----------------------|-----------|------------|---------------------------|
| BIPM | Traveling | | BP1C | BP1C | Septentrio PolaRx3eTR |
| BIPM | Traveling | | BP0U | BP0U | Dicom GTR50 |
| | | | | | |
| BIPM | BIPM reference | 57435-57439 | BP0R | BP0R | Septentrio PolaRx2eTR |
| BIPM | BIPM backup | 57435-57439 | BP1J | BP1J | Septentrio PolaRx4 |
| BIPM | BIPM backup | 57435-57439 | BP1X | BP1X | Dicom GTR51 |
| | | | | | |
| TL | G1 reference | 57468-57489 | TLT1 | TLT1 | Ashtech Z12T (1) |
| TL | G1 backup | 57468-57489 | TLT2 | TLT2 | Piktime TTS4 |
| TL | G1 backup | 57468-57489 | TLT3 | TLT3 | Dicom GTR50 |
| | | | | | |
| NICT | G1 reference | 57498-57523 | NC01 | NC01 | Septentrio PolaRx2eTR |
| NICT | G1 backup | 57498-57523 | NC5G | NC5G | Dicom GTR50 |
| NICT | G1 backup | 57498-57523 | NC4C | NC4C | Septentrio PolaRx4 TR Pro |
| NICT | G1 backup | 57498-57523 | NC4S | NC4S | Septentrio PolaRx4 |
| | | | | | |
| NIM | G1 reference | 57576-57582 | IMEJ | IMEJ | Dicom GTR50 |
| NIM | G1 backup | 57576-57582 | IMEU | IMEU | Javad E_GGD |
| NIM | G1 backup | 57576-57582 | BJNM | BJNM | Septentrio PolaRx3eTR |
| | | | | | |
| NTSC | G2 reference | 57589-57600 | NTP1 | NTP1 | Septentrio PolaRx4 TR |
| NTSC | G2 backup | 57589-57600 | NTP2 | NTP2 | Septentrio PolaRx4 TR |
| NTSC | G2 backup | 57589-57600 | NTP4 | NTP4 | Septentrio PolaRx4 TR |
| | | | | | |
| BIPM | BIPM reference | 57646-57657 | BP0R | BP0R | Septentrio PolaRx2eTR |
| BIPM | BIPM backup | 57646-57657 | BP1J | BP1J | Septentrio PolaRx4 |
| BIPM | BIPM backup | 57646-57657 | BP1X | BP1X | Dicom GTR51 |
| | | | | | |

(1) TLT1 is a modified Z12T which internal reference is the 1PPS-in, see 1001-2016-phase1-cv.pdf

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 1001-2016-phase1-cv.pdf. All P1/P2 measurements are indicated with 2 digits numeric precision in order to minimize rounding errors in computing P3 values.
- During this processing, we noted that the phase measurements of BP0R are sometimes corrupted and could not be fully trusted to compute the baseline that is needed to compute the code differences. To overcome this, we used two other receivers (BP1J and BP1X), which have previously been compared to BP0R, as additional references to check the baselines and the results obtained from BP0R;

- 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 [1001-2016-phase1-cv.pdf](#);
 - The inferred RAWDIF(P1), RAWDIF(P2) and RAWDIF(C1) 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 BP0R is considered to be the reference. However two other systems (BP1J and BP1X) are used as backups to check the behavior of BP0R and are listed in Table 2.1.

Table 2.1 Raw differential results for all pairs (Traveling – Reference) (ns) for three reference receivers at the BIPM.

| Labo | Date | Pair | RAWDIF(P1) | Unc | RAWDIF(P2) | Unc | RAWDIF(C1) | Unc |
|------|-------------|-----------|------------|-----|------------|-----|------------|-----|
| BIPM | 57435-57439 | BP1C-BP0R | -59.37 | 0.1 | -55.84 | 0.1 | -60.63 | 0.1 |
| BIPM | 57646-57657 | BP1C-BP0R | -59.44 | 0.1 | -55.61 | 0.1 | -60.83 | 0.1 |
| | | | | | | | | |
| BIPM | 57435-57439 | BP0U-BP0R | -94.83 | 0.1 | -91.01 | 0.1 | -97.99 | 0.1 |
| BIPM | 57650-57657 | BP0U-BP0R | -95.19 | 0.1 | -91.09 | 0.1 | -98.12 | 0.1 |
| | | | | | | | | |
| BIPM | 57435-57439 | BP1C-BP1J | 25.71 | 0.1 | 31.74 | 0.1 | 26.14 | 0.1 |
| BIPM | 57646-57657 | BP1C-BP1J | 25.52 | 0.1 | 31.44 | 0.1 | 25.98 | 0.1 |
| | | | | | | | | |
| BIPM | 57435-57439 | BP0U-BP1J | -9.71 | 0.1 | -3.38 | 0.1 | -11.18 | 0.1 |
| BIPM | 57650-57657 | BP0U-BP1J | -10.07 | 0.1 | -3.74 | 0.1 | -11.21 | 0.1 |
| | | | | | | | | |
| BIPM | 57435-57439 | BP1C-BP1X | 31.89 | 0.1 | 35.14 | 0.1 | 37.56 | 0.1 |
| BIPM | 57646-57657 | BP1C-BP1X | 31.38 | 0.1 | 34.65 | 0.1 | 37.26 | 0.1 |
| | | | | | | | | |
| BIPM | 57435-57439 | BP0U-BP1X | -3.61 | 0.1 | -0.12 | 0.1 | 0.11 | 0.1 |
| BIPM | 57650-57657 | BP0U-BP1X | -4.36 | 0.1 | -0.68 | 0.1 | -0.08 | 0.1 |
| | | | | | | | | |

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

| Labo | Date | Pair | RAWDIF(P1) | Unc | RAWDIF(P2) | Unc | RAWDIF(C1) | Unc |
|------|-------------|-----------|------------|-----|------------|-----|------------|-----|
| | | | | | | | | |
| TL | 57468-57489 | BP1C-TLT1 | -389.78 | 0.1 | -393.25 | 0.1 | -387.81 | 0.1 |
| TL | 57468-57489 | BPOU-TLT1 | -422.74 | 0.1 | -426.09 | 0.1 | -422.49 | 0.2 |
| TL | 57468-57489 | BP1C-TLT2 | -55.46 | 0.1 | -48.85 | 0.1 | -55.42 | 0.1 |
| TL | 57468-57489 | BPOU-TLT2 | -88.36 | 0.1 | -81.60 | 0.1 | -90.03 | 0.1 |
| TL | 57468-57489 | BP1C-TLT3 | 30.81 | 0.1 | 40.40 | 0.1 | 33.95 | 0.1 |
| TL | 57468-57489 | BPOU-TLT3 | -2.10 | 0.1 | 7.62 | 0.1 | -0.67 | 0.1 |
| | | | | | | | | |
| NICT | 57498-57523 | BP1C-NC01 | -427.98 | 0.1 | -426.36 | 0.1 | -429.13 | 0.1 |
| NICT | 57506-57523 | BPOU-NC01 | -480.86 | 0.1 | -479.09 | 0.1 | -483.80 | 0.1 |
| NICT | 57498-57523 | BP1C-NC5G | -412.90 | 0.1 | -413.96 | 0.1 | -403.53 | 0.1 |
| NICT | 57506-57523 | BPOU-NC5G | -465.81 | 0.1 | -466.77 | 0.1 | -458.22 | 0.1 |
| NICT | 57498-57523 | BP1C-NC4C | -16.30 | 0.1 | -9.11 | 0.1 | -15.91 | 0.1 |
| NICT | 57506-57523 | BPOU-NC4C | -69.23 | 0.1 | -61.83 | 0.1 | -70.62 | 0.1 |
| NICT | 57498-57523 | BP1C-NC4S | -366.32 | 0.1 | -360.22 | 0.1 | -365.80 | 0.1 |
| NICT | 57506-57523 | BPOU-NC4S | -419.24 | 0.1 | -412.99 | 0.1 | -420.51 | 0.1 |
| | | | | | | | | |
| NIM | 57576-57582 | BP1C-IMEJ | -58.54 | 0.1 | -53.05 | 0.1 | -55.32 | 0.1 |
| NIM | 57576-57582 | BPOU-IMEJ | -118.50 | 0.1 | -113.08 | 0.1 | -117.15 | 0.1 |
| NIM | 57576-57582 | BP1C-IMEU | -167.92 | 0.1 | -175.14 | 0.1 | -167.59 | 0.1 |
| NIM | 57576-57582 | BPOU-IMEU | -227.89 | 0.1 | -235.14 | 0.1 | -229.43 | 0.1 |
| NIM | 57576-57582 | BP1C-BJNM | 61.58 | 0.1 | 59.69 | 0.1 | 61.67 | 0.1 |
| NIM | 57576-57582 | BPOU-BJNM | 1.60 | 0.1 | -0.33 | 0.1 | -0.19 | 0.1 |
| | | | | | | | | |
| NTSC | 57589-57600 | BP1C-NTP1 | 89.12 | 0.1 | 95.69 | 0.1 | 89.37 | 0.1 |
| NTSC | 57589-57600 | BPOU-NTP1 | 57.95 | 0.2 | 63.94 | 0.1 | 56.25 | 0.1 |
| NTSC | 57589-57600 | BP1C-NTP2 | 81.46 | 0.1 | 88.80 | 0.1 | 81.70 | 0.1 |
| NTSC | 57589-57600 | BPOU-NTP2 | 50.29 | 0.2 | 57.04 | 0.1 | 48.59 | 0.1 |
| NTSC | 57589-57600 | BP1C-NTP3 | -78.50 | 0.1 | -71.58 | 0.1 | -77.99 | 0.1 |
| NTSC | 57589-57600 | BPOU-NTP3 | -109.70 | 0.2 | -103.37 | 0.2 | -111.12 | 0.1 |
| | | | | | | | | |

4. Calibration results

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

$$\Delta\text{SYSDLY}_{A-B}(\text{Code}) = \text{RAWDIF}_{A-B}(\text{Code}) + \text{REFDLY}_A - \text{REFDLY}_B \quad (1)$$

where RAWDF(Code) is read in Table 2 and where the values REFDLY are in the report of operations [1001-2016-phase1-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.

$$\Delta\text{SYSDLY}_{V-R} = \Delta\text{SYSDLY}_{T-R} - \Delta\text{SYSDLY}_{T-V} \quad (2)$$

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

$$\Delta\text{INTDLY}_{V-R} = \Delta\text{SYSDLY}_{V-R} - \text{CABDLY}_V + \text{CABDLY}_R \quad (3)$$

where the values CABDLY are taken from the report of operations [1001-2016-phase1-cv.pdf](#); Tables 5 reports the $\Delta\text{INTDLY}_{V-R}$ 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

Table 3.1. Computed ΔSYSDLY values for the traveling systems with respect to BP0R 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) | |
|-----------|-------------|---------------------|---------------------|------|---------|-----------------------|---------|-----------------------|---------|-----------------------|
| | | | | | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY |
| BP1C-BP0R | 57435-57439 | 256.0 | 268.8 | | -59.37 | -72.18 | -55.84 | -68.65 | -60.63 | -73.44 |
| BP1C-BP0R | 57646-57657 | 256.4 | 268.9 | | -59.44 | -71.94 | -55.61 | -68.11 | -60.83 | -73.33 |
| | | Misclos. | | | | 0.24 | | 0.54 | | 0.11 |
| | | Mean | | | | -72.06 | | -68.38 | | -73.39 |
| BPOU-BP0R | 57435-57439 | 52.6 | 268.8 | | -94.83 | -311.04 | -91.01 | -307.22 | -97.99 | -314.20 |
| BPOU-BP0R | 57650-57657 | 52.6 | 268.9 | | -95.19 | -311.49 | -91.09 | -307.39 | -98.12 | -314.42 |
| | | Misclos. | | | | 0.45 | | 0.17 | | 0.22 |
| | | Mean | | | | -311.27 | | -307.31 | | -314.31 |

Results for BP0R have been checked using BP1J and BP1X. Misclosures for BP1J and BP1X can be directly interpreted from the data in Table 3.2 and 3.3. However, the mean values of ΔSYSDLY obtained for (Traveling – BP1J) and (Traveling – BP1X) in Table 3.2 and 3.3 cannot be directly compared to those obtained for (Traveling – BP0R).

Table 3.2. Computed ΔSYSDLY values for the traveling systems with respect to BP1J 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) | |
|-----------|-------------|---------------------|---------------------|------|---------|-----------------------|---------|-----------------------|---------|-----------------------|
| | | | | | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY |
| BP1C-BP1J | 57435-57439 | 256.0 | 180.1 | | 25.71 | 101.61 | 31.74 | 107.64 | 26.14 | 102.04 |
| BP1C-BP1J | 57646-57657 | 256.4 | 180.0 | | 25.52 | 101.92 | 31.44 | 107.84 | 25.98 | 102.38 |
| | | Misclos. | | | | 0.31 | | 0.20 | | 0.34 |
| | | Mean | | | | 101.77 | | 107.74 | | 102.21 |
| BPOU-BP1J | 57435-57439 | 52.6 | 180.1 | | -9.71 | -137.21 | -3.38 | -130.88 | -11.18 | -138.68 |
| BPOU-BP1J | 57650-57657 | 52.6 | 180.0 | | -10.07 | -137.47 | -3.74 | -131.14 | -11.21 | -138.61 |
| | | Misclos. | | | | 0.26 | | 0.26 | | 0.07 |
| | | Mean | | | | -137.34 | | -131.01 | | -138.65 |

Table 3.3. Computed ΔSYSDLY values for the traveling systems with respect to BP1X 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) | |
|-----------|-------------|---------------------|---------------------|------|---------|-----------------------|---------|-----------------------|---------|-----------------------|
| | | | | | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY |
| BP1C-BP1X | 57435-57439 | 256.0 | 42.6 | | 31.89 | 245.29 | 35.14 | 248.54 | 37.56 | 250.96 |
| BP1C-BP1X | 57646-57657 | 256.4 | 42.6 | | 31.38 | 245.18 | 34.65 | 248.45 | 37.26 | 251.06 |
| | | Misclos. | | | | 0.11 | | 0.09 | | 0.10 |
| | | Mean | | | | 245.24 | | 248.50 | | 251.01 |
| BPOU-BP1X | 57435-57439 | 52.6 | 42.6 | | -3.61 | 6.39 | -0.12 | 9.88 | 0.11 | 10.11 |
| BPOU-BP1X | 57650-57657 | 52.6 | 42.6 | | -4.36 | 5.64 | -0.68 | 9.32 | -0.08 | 9.92 |
| | | Misclos. | | | | 0.75 | | 0.56 | | 0.19 |
| | | Mean | | | | 6.02 | | 9.60 | | 10.02 |

This is done in Table 3.4 using comparisons (BP1J-BP0R) and (BP1X-BP0R) obtained in December 2015. As can be seen from Table 3.4, the various evaluations of ΔSYSDLY for (BP1C-BP0R) vary by no more than about 0.3 ns. They are considered close enough so that, in the following, the directly measured values (BP1C-BP0R) and (BPOU-BP0R) will be used to compute the results of the Group 1 trip.

Table 3.4. Computed ΔSYSDLY mean values for the traveling systems with respect to BP0R computed directly (Table 3.1) or through BP1J (Table 3.2) or BP1X (Table 3.3). Numerical discrepancies of 0.01 ns are due to rounding (all values in ns).

| | | $\Delta\text{SYSDLY P1}$ | $\Delta\text{SYSDLY P2}$ | $\Delta\text{SYSDLY C1}$ |
|-----------|--------------|--------------------------|--------------------------|--------------------------|
| BP1C-BP0R | Mean value | -72.06 | -68.38 | -73.39 |
| | | | | |
| BP1C-BP1J | Mean value | 101.77 | 107.74 | 102.21 |
| BP1J-BP0R | Dec 2015 | -174.1 | -176.4 | -175.9 |
| BP1C-BP0R | Sum of above | -72.34 | -68.66 | -73.69 |
| | | | | |
| BP1C-BP1X | Mean value | 245.24 | 248.50 | 251.01 |
| BP1X-BP0R | Dec 2015 | -317.5 | -317.1 | -324.7 |
| BP1C-BP0R | Sum of above | -72.27 | -68.61 | -73.69 |
| | | | | |
| BPOU-BP0R | Mean value | -311.27 | -307.31 | -314.31 |
| | | | | |
| BPOU-BP1J | Mean value | -137.34 | -131.01 | -138.65 |
| BP1J-BP0R | Dec 2015 | -174.1 | -176.4 | -175.9 |
| BPOU-BP0R | Sum of above | -311.44 | -307.41 | -314.55 |
| | | | | |
| BPOU-BP1X | Mean value | 6.02 | 9.60 | 10.02 |
| BP1X-BP0R | Dec 2015 | -317.5 | -317.1 | -324.7 |
| BPOU-BP0R | Sum of above | -311.49 | -307.50 | -314.69 |
| | | | | |

4.2 Traveling system with respect to the visited systems

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

| Pair | Date | REFDLY _T | REFDLY _V | Note | P1 (ns) | | P2 (ns) | | C1 (ns) | |
|-----------|-------------|---------------------|---------------------|------|---------|---------|---------|---------|---------|---------|
| | | | | | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY | RAWDIF | ΔSYSDLY |
| BP1C-TLT1 | 57468-57489 | 258.5 | 0.0 | (1) | -389.78 | -131.28 | -393.25 | -134.75 | -387.81 | -129.31 |
| BPOU-TLT1 | 57468-57489 | 52.6 | 0.0 | (1) | -422.74 | -370.14 | -426.09 | -373.49 | -422.49 | -369.89 |
| BP1C-TLT2 | 57468-57489 | 258.5 | 24.5 | (2) | -55.46 | 178.54 | -48.85 | 185.15 | -55.42 | 178.58 |
| BPOU-TLT2 | 57468-57489 | 52.6 | 24.5 | (2) | -88.36 | -60.26 | -81.60 | -53.50 | -90.03 | -61.93 |
| BP1C-TLT3 | 57468-57489 | 258.5 | 25.5 | * | 30.81 | 263.81 | 40.40 | 273.40 | 33.95 | 266.95 |
| BPOU-TLT3 | 57468-57489 | 52.6 | 25.5 | * | -2.10 | 25.00 | 7.62 | 34.72 | -0.67 | 26.43 |
| | | | | | | | | | | |
| BP1C-NC01 | 57498-57523 | 687.4 | 407.6 | | -427.98 | -148.18 | -426.36 | -146.56 | -429.13 | -149.33 |
| BPOU-NC01 | 57506-57523 | 501.7 | 407.6 | | -480.86 | -386.76 | -479.09 | -384.99 | -483.80 | -389.70 |
| BP1C-NC5G | 57498-57523 | 687.4 | 169.7 | * | -412.90 | 104.80 | -413.96 | 103.74 | -403.53 | 114.17 |
| BPOU-NC5G | 57506-57523 | 501.7 | 169.7 | * | -465.81 | -133.81 | -466.77 | -134.77 | -458.22 | -126.22 |
| BP1C-NC4C | 57498-57523 | 687.4 | 599.9 | | -16.30 | 71.20 | -9.11 | 78.39 | -15.91 | 71.59 |
| BPOU-NC4C | 57506-57523 | 501.7 | 599.9 | | -69.23 | -167.43 | -61.83 | -160.03 | -70.62 | -168.82 |
| BP1C-NC4S | 57498-57523 | 687.4 | 314.3 | | -366.32 | 6.78 | -360.22 | 12.88 | -365.80 | 7.30 |
| BPOU-NC4S | 57506-57523 | 501.7 | 314.3 | | -419.24 | -231.84 | -412.99 | -225.59 | -420.51 | -233.11 |
| | | | | | | | | | | |
| BP1C-IMEJ | 57576-57582 | 341.4 | 122.2 | * | -58.54 | 160.66 | -53.05 | 166.15 | -55.32 | 163.88 |
| BPOU-IMEJ | 57576-57582 | 162.8 | 122.2 | * | -118.50 | -77.90 | -113.08 | -72.48 | -117.15 | -76.55 |
| BP1C-IMEU | 57576-57582 | 341.4 | 112.8 | | -167.92 | 60.68 | -175.14 | 53.46 | -167.59 | 61.01 |
| BPOU-IMEU | 57576-57582 | 162.8 | 112.8 | | -227.89 | -177.89 | -235.14 | -185.14 | -229.43 | -179.43 |
| BP1C-BJNM | 57576-57582 | 341.4 | 319.7 | | 61.58 | 83.28 | 59.69 | 81.39 | 61.67 | 83.37 |
| BPOU-BJNM | 57576-57582 | 162.8 | 319.7 | | 1.60 | -155.30 | -0.33 | -157.23 | -0.19 | -157.09 |
| | | | | | | | | | | |
| BP1C-NTP1 | 57589-57600 | 303.2 | 373.8 | | 89.12 | 18.52 | 95.69 | 25.09 | 89.37 | 18.77 |
| BPOU-NTP1 | 57589-57600 | 96.5 | 373.8 | | 57.95 | -219.35 | 63.94 | -213.36 | 56.25 | -221.05 |
| BP1C-NTP2 | 57589-57600 | 303.2 | 378.0 | | 81.46 | 6.66 | 88.80 | 14.00 | 81.70 | 6.90 |
| BPOU-NTP2 | 57589-57600 | 96.5 | 378.0 | | 50.29 | -231.21 | 57.04 | -224.46 | 48.59 | -232.91 |
| BP1C-NTP3 | 57589-57600 | 303.2 | 192.6 | | -78.50 | 32.10 | -71.58 | 39.02 | -77.99 | 32.61 |
| BPOU-NTP3 | 57589-57600 | 96.5 | 192.6 | | -109.70 | -205.80 | -103.37 | -199.47 | -111.12 | -207.22 |
| | | | | | | | | | | |

* GTR50/51 with REFDLY_V value introduced a priori.

(1) No REFDLY_V information

(2) REFDLY_V not measured according to the specifications in Annex 1 of the [Guidelines](#)

4.3 Visited systems with respect to reference system

The Table 5 provides the values obtained by differencing Table 3.1 (BPOR reference) and Table 4. CABDLY values are taken from the report of operations [1001-2016-phase1-cv.pdf](#).

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

| Pair | Date | CABDLY _V | CABDLY _R | Note | P1 (ns) | | P2 (ns) | | C1 (ns) | |
|--------------------|--------|---------------------|---------------------|------|---------|---------|---------|---------|---------|---------|
| | | | | | ΔSYSDLY | ΔINTDLY | ΔSYSDLY | ΔINTDLY | ΔSYSDLY | ΔINTDLY |
| TLT1-BPOR via BP1C | 2016.2 | 0.0 | 133.4 | (1) | 59.22 | 192.62 | 66.37 | 199.77 | 55.93 | 189.33 |
| TLT1-BPOR via BPOU | 2016.2 | 0.0 | 133.4 | (1) | 58.88 | 192.28 | 66.18 | 199.59 | 55.58 | 188.98 |
| TLT2-BPOR via BP1C | 2016.2 | 140.3 | 133.4 | | -250.60 | -257.50 | -253.53 | -260.43 | -251.97 | -258.87 |
| TLT2-BPOR via BPOU | 2016.2 | 140.3 | 133.4 | | -251.01 | -257.91 | -253.81 | -260.71 | -252.38 | -259.28 |
| TLT3-BPOR via BP1C | 2016.2 | 143.6 | 133.4 | * | -335.87 | -346.07 | -341.78 | -351.98 | -340.34 | -350.54 |
| TLT3-BPOR via BPOU | 2016.2 | 143.6 | 133.4 | * | -336.27 | -346.47 | -342.03 | -352.23 | -340.74 | -350.94 |
| NC01-BPOR via BP1C | 2016.3 | 213.4 | 133.4 | | 76.12 | -3.88 | 78.18 | -1.82 | 75.95 | -4.05 |
| NC01-BPOR via BPOU | 2016.3 | 213.4 | 133.4 | | 75.50 | -4.50 | 77.69 | -2.32 | 75.39 | -4.61 |
| NC5G-BPOR via BP1C | 2016.3 | 268.7 | 133.4 | * | -176.86 | -312.16 | -172.12 | -307.42 | -187.56 | -322.86 |
| NC5G-BPOR via BPOU | 2016.3 | 268.7 | 133.4 | * | -177.46 | -312.76 | -172.54 | -307.84 | -188.09 | -323.39 |
| NC4C-BPOR via BP1C | 2016.3 | 157.5 | 133.4 | | -143.26 | -167.36 | -146.77 | -170.87 | -144.98 | -169.08 |
| NC4C-BPOR via BPOU | 2016.3 | 157.5 | 133.4 | | -143.84 | -167.94 | -147.28 | -171.38 | -145.49 | -169.59 |
| NC4S-BPOR via BP1C | 2016.3 | 0.0 | 133.4 | ** | -78.84 | 54.56 | -81.26 | 52.14 | -80.68 | 52.72 |
| NC4S-BPOR via BPOU | 2016.3 | 0.0 | 133.4 | ** | -79.43 | 53.98 | -81.72 | 51.69 | -81.20 | 52.20 |
| IMEJ-BPOR via BP1C | 2016.5 | 248.7 | 133.4 | * | -232.72 | -348.02 | -234.53 | -349.83 | -237.27 | -352.57 |
| IMEJ-BPOR via BPOU | 2016.5 | 248.7 | 133.4 | * | -233.37 | -348.67 | -234.83 | -350.13 | -237.76 | -353.06 |
| IMEU-BPOR via BP1C | 2016.5 | 250.3 | 133.4 | | -132.74 | -249.64 | -121.84 | -238.74 | -134.40 | -251.30 |
| IMEU-BPOR via BPOU | 2016.5 | 250.3 | 133.4 | | -133.38 | -250.28 | -122.17 | -239.07 | -134.88 | -251.78 |
| BJNM-BPOR via BP1C | 2016.5 | 125.0 | 133.4 | | -155.34 | -146.94 | -149.77 | -141.37 | -156.76 | -148.36 |
| BJNM-BPOR via BPOU | 2016.5 | 125.0 | 133.4 | | -155.97 | -147.57 | -150.08 | -141.68 | -157.22 | -148.82 |
| NTP1-BPOR via BP1C | 2016.6 | 209.0 | 133.4 | | -90.58 | -166.18 | -93.47 | -169.07 | -92.16 | -167.76 |
| NTP1-BPOR via BPOU | 2016.6 | 209.0 | 133.4 | | -91.92 | -167.52 | -93.95 | -169.55 | -93.26 | -168.86 |
| NTP2-BPOR via BP1C | 2016.6 | 221.0 | 133.4 | | -78.72 | -166.32 | -82.38 | -169.98 | -80.29 | -167.89 |
| NTP2-BPOR via BPOU | 2016.6 | 221.0 | 133.4 | | -80.06 | -167.66 | -82.85 | -170.45 | -81.40 | -169.00 |
| NTP3-BPOR via BP1C | 2016.6 | 198.0 | 133.4 | | -104.16 | -168.76 | -107.40 | -172.00 | -106.00 | -170.60 |
| NTP3-BPOR via BPOU | 2016.6 | 198.0 | 133.4 | | -105.47 | -170.07 | -107.84 | -172.44 | -107.09 | -171.69 |

* GTR50/51 with CABDLY_V value introduced a priori.

** Rough CABDLY_V value available, not used in the solution

(1) No CABDLY_V information

4.4 Provisional INTDLY values of visited systems

Table 6 lists provisional INTDLY values of the visited systems using 1001-2014 Group 1 values for BPOR (P1=222.6 ns; P2=224.8 ns; C1=225.8 ns), see in [TM243 Group1-reference-values V7.pdf](#).

Final INTDLY values will be based on minimizing changes between 1001-2014 and 1001-2016, as described in [BIPM Technical Memorandum 266](#), and will be reported in the global report of the trip 1001-2016 available [here](#). Since two results can be computed from Table 5, using either BP1C or BPOU as traveling system, the values in Table 6 are the simple mean of the two results, and the

difference between the two is indicated. We note that the difference $\Delta(\text{BP1C-BPOU})$ presents a systematic trend of order 0.45 ns (not considering NTSC receivers as they are not formally part of the Group 1 trip), which is still considered reasonable and covered in the uncertainty budget. For the NTSC visit, the discrepancy between the two traveling receivers is significantly larger and an additional uncertainty $\Delta U_{\text{CAL}} = 0.8$ ns will be introduced to account for this fact.

Table 6. Provisional INTDLY values of Visited systems using 1001-2014 reference values for the reference systems BP0R (all values in ns).

| Pair | Date | Note | P1 | P2 | C1 |
|----------------------------|--------|------|---------------------|---------------------|---------------------|
| | | | INTDLY _v | INTDLY _v | INTDLY _v |
| TLT1 vs. BP0R | 2016.2 | (1) | 415.05 | 424.48 | 414.95 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.34 | 0.19 | 0.34 |
| TLT2 vs. BP0R | 2016.2 | (2) | -35.10 | -35.77 | -33.27 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.40 | 0.27 | 0.41 |
| TLT3 vs. BP0R | 2016.2 | (3) | -5.57 | -9.20 | -6.84 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.39 | 0.25 | 0.40 |
| | | | | | |
| NC01 vs. BP0RC | 2016.3 | | 218.41 | 222.73 | 221.47 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.63 | 0.50 | 0.55 |
| NC5G vs. BP0R | 2016.3 | (3) | 6.04 | 13.07 | -1.42 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.60 | 0.42 | 0.53 |
| NC4C vs. BP0R | 2016.3 | | 54.95 | 53.68 | 56.47 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.57 | 0.51 | 0.51 |
| NC4S vs. BP0R | 2016.3 | (4) | 276.87 | 276.71 | 278.26 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.58 | 0.46 | 0.51 |
| | | | | | |
| IMEJ vs. BP0R | 2016.5 | (3) | 0.76 | 1.32 | -0.51 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.64 | 0.30 | 0.50 |
| IMEU vs. BP0R | 2016.5 | | -27.36 | -14.10 | -25.74 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.63 | 0.33 | 0.48 |
| BJNM vs. BP0R | 2016.5 | | 75.35 | 83.28 | 77.21 |
| $\Delta(\text{BP1C-BPOU})$ | | | 0.63 | 0.31 | 0.46 |
| | | | | | |
| NTP1 vs. BP0R | 2016.6 | | 55.75 | 55.49 | 57.49 |
| $\Delta(\text{BP1C-BPOU})$ | | | 1.33 | 0.48 | 1.10 |
| NTP2 vs. BP0R | 2016.6 | | 55.61 | 54.59 | 57.36 |
| $\Delta(\text{BP1C-BPOU})$ | | | 1.33 | 0.47 | 1.12 |
| NTP3 vs. BP0R | 2016.6 | | 53.19 | 52.58 | 54.66 |
| $\Delta(\text{BP1C-BPOU})$ | | | 1.31 | 0.44 | 1.09 |

(1) Results for TLT1 are Total Delay values (TOTDLY).

(2) The REF DLY value of TLT2 (TTS4) has not been measured in full accordance with the [guidelines](#)

(3) For GTR50/51, results are changes with respect to values entered in the receiver

(4) Results for NC4S are System Delay values (SYSDLY).

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 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 (P1, P2 and P1-P2) 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 $u_{CAL} = 1.5$ ns from Table 7 is applicable to all P3/PPP links, except for NICT receivers for which an additional uncertainty $\Delta U_{CAL} = 0.8$ ns will be introduced (see note 1 at the end of this section), and for NTSC receivers for which an additional uncertainty $\Delta U_{CAL} = 0.8$ ns will be introduced (see section 4.4).

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

| 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 | |
| “Misclosure” | | | | | |
| $u_{b,1}$ | 0.4 | 0.4 | 0.2 | | observed mis-closure |
| Systematic components related to RAWDIF | | | | | |
| $u_{b,11}$ | 0.1 | 0.1 | 0.1 | | Position error at reference |
| $u_{b,12}$ | 0.05 | 0.05 | 0.05 | | Position error at visited |
| $u_{b,13}$ | 0.3 | 0.3 | 0.4 | | Multipaths at reference |
| $u_{b,14}$ | 0.3 | 0.3 | 0.4 | | 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) (1) |
| $u_{b,TOT}$ | 0.9 | 0.9 | 0.6 | 1.3 | |
| 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 | 0.6 | 1.5 | Components of equation (2) |
| u_{CAL} | 1.2 | | | 1.5 | 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 or distribution and that its uncertainty should better be taken into account.

The components in Table 7 are separated in several categories:

- $u_{b,1}$ 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 (~ 0.3 ns average for each code, 0.3 ns for P1-P2, see Table 3.1), on the other hand by the observed discrepancies between the results of the two traveling receivers (~ 0.5 ns average for each code, 0.2 ns for P1-P2, see Table 6). The chosen values represent an average of both evaluations.
 - $u_{b,11}$ and $u_{b,12}$ account for errors in the differential position (Travel – Local). In general they are estimated to be 1.5 cm (50 ps) because the standard uncertainty of the differential positioning obtained with the data used for calibration is typically at or below this level. Due to the possible problem with BP0R (see section 3), $u_{b,11}$ has been estimated more conservatively at 0.1 ns.
 - $u_{b,13}$ and $u_{b,14}$ account for multipaths. This is difficult to estimate and a conservative estimate of 0.3 ns is conventionally used.
 - $u_{b,21}$ 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.
- (1)Note that the uncertainty $u_{b,22}$ is larger at NICT because the traveling system was positioned in a room distant from UTC(NICT). No direct connection to UTC(NICT) could be established and clock transport was used. In the final results, an additional uncertainty $\Delta U_{CAL} = 0.8$ ns will be introduced for NICT receivers to account for a larger uncertainty $u_{b,22}$.
- $u_{b,31}$ 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.

Version history

V1.0 2016/12/15:

V1.1 2017/01/18: Cosmetic changes. No change to numerical results. P3 u_a uncertainty component computed as RSS from the independent P1 and P2 values. Additional uncertainty $\Delta U_{CAL} = 0.8$ ns for NTSC.

V1.2 2017/02/10: Results for NC5G and NC4C changed to account for measured CABDLY values. NC5G INTDLY values change by +37.0 ns. NC4C INTDLY values change by -157.5 ns.