2018 Group 1 GPS calibration trip

Summary

The 2018 visit to Group 1 laboratories is the third Group 1 trip and started in March 2018.
The trip is decomposed into several phases, each enclosed with closure at the BIPM. Some phases may be run in parallel.

- Phase 1 (March-September 2018). BIPM-TL-NICT-NIM-BIPM with the traveling receivers BP1C and BP0U;
- Phase 2 (April-October 2018): BIPM-SU-BIPM with the traveling receivers BP1K;
- Phase 3 (November 2018-February 2019): BIPM-PTB-ROA-OP-BIPM with the traveling receivers BP1C and BP1X;
- Phase 4 (To Be Continued)

Since the 2016 Group 1 trip, results are provided for the GPS codes P1, P2 and C1.
Starting with this phase 3 of 1001-2018, results are also provided for Galileo E1 and E5 codes, as defined in the CGGTTS V2E format (The notation E5 corresponds to E5a).
This report provides intermediate results which are determined with respect to one BIPM receiver.
Final results for all three GPS codes for all Group 1 receivers are determined in a separate document BIPM Technical Memorandum 266.

Trip 1001-2018: 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: BP1C and BP1X, see Table 1 and the report of operations 1001-2018-phase3-cv.pdf .

The long term stability of the BIPM 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 1001-2018-phase3-cv.pdf.
The receiver BP1J from the BIPM serves as a reference for the closure, with the receiver BP0R included as a backup system.

Table 1. Summary information on phase 1 of the calibration trip 1001-2018

Institute	Status of equipment	Dates of measurement	BIPM code	RINEX name	Receiver type
BIPM	Traveling		BP1C	BP1C	Septentrio PolaRx3eTR
BIPM	Traveling		BP1X	BP1X	Dicom GTR51
BIPM	BIPM reference	58409-58415	BP1J	BP1J	Septentrio PolaRx4
BIPM	BIPM backup	58409-58415	BP0R	BP0R	Septentrio PolaRx2eTR
PTB	G1 reference	58442-58450	PT02	PTBB	Ashtech Z12T
PTB	G1 backup	58442-58450	PT03	PTBG	Ashtech Z12T
PTB	G1 backup	58442-58450	PT07	PT07	Dicom GTR50
PTB	G1 backup	58442-58450	PT09	PT09	Septentrio PolaRx4TR
PTB	G1 backup	58442-58450	PT10	PT10	Dicom GTR51
ROA	G1 reference	58466-58470	RO_5	RO_5	Dicom GTR50
ROA	G1 backup	58466-58470	RO_6	RO_6	Septentrio PolaRx3TR
ROA	G1 backup	58466-58470	RO_7	RO_7	Septentrio PolaRx4TR
ROA	G1 backup	58466-58470	RO_8	RO_8	Dicom GTR51
ROA	G1 backup	58466-58470	RO_9	RO_9	Septentrio PolaRx4TR
ROA	G1 backup	58466-58470	RO10	RO10	Septentrio PolaRx5
OP	G1 reference	58500-58511	OP02	OPMT	Ashtech Z12T
OP	G1 backup	58500-58511	OP71	OP71	Septentrio PolaRx4TR
OP	G1 backup	58500-58511	OPM9	OPM9	Dicom GTR51
BIPM	BIPM reference	58525-58535	BP1J	BP1J	Septentrio PolaRx4
BIPM	BIPM backup	58525-58535	BP0R	BP0R	Septentrio PolaRx2eTR

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 1001-2018-phase3-cv.pdf. All P1/P2 measurements are indicated with 2 digits numeric precision in order to minimize rounding errors in computing P3 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 1001-2018-phase3-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 BP1J is considered to be the reference. However another system (BP0R) is used as a backup and is listed in Table 2.1.

Table 2.1 Raw differential results for all pairs (Traveling – Reference) (ns) for three reference receivers at the BIPM. Measurements for the local backup BP0R are also included.

Labo	Date	Pair	RDIF(P1)	Unc	RDIF(P2)	Unc	RDIF(C1)	Unc	RDIF(E1)	Unc	RDIF(E5)	Unc
BIPM	58409-58415	BP1C-BP1J	45.29	0.1	51.21	0.1	45.83	0.1				
BIPM	58525-58535	BP1C-BP1J	45.44	0.1	51.45	0.1	45.99	0.1				
BIPM	58409-58415	BP1X-BP1J	39.10	0.1	38.00	0.1	39.63	0.1	41.80	0.1	26.73	0.1
BIPM	58525-58535	BP1X-BP1J	38.93	0.1	37.75	0.1	39.42	0.1	41.52	0.1	26.70	0.1
BIPM	58409-58415	BP0R-BP1J	72.02	0.1	74.03	0.1	73.84	0.1				
BIPM	58525-58535	BP0R-BP1J	72.06	0.1	74.00	0.1	73.89	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(E5)	Unc
PTB	58444-58450	BP1C-PTBB	-546.92	0.1	-556.46	0.1	-545.59	0.1				
PTB	58442-58450	BP1X-PTBB	-535.73	0.1	-552.47	0.1	-534.45	0.1				
PTB	58444-58450	BP1C-PTBG	-521.45	0.1	-538.50	0.1	-519.84	0.1				
PTB	58442-58450	BP1X-PTBG	-510.19	0.1	-534.49	0.1	-508.64	0.1				
PTB	58444-58450	BP1C-PT07	-14.43	0.1	-8.53	0.1	-12.39	0.1				
PTB	58442-58450	BP1X-PT07	-3.24	0.1	-4.48	0.1	-1.22	0.1				
PTB	58444-58450	BP1C-PT09	-86.51	0.1	-79.93	0.1	-85.98	0.1				
PTB	58442-58450	BP1X-PT09	-75.29	0.1	-75.91	0.1	-74.80	0.1	-72.76	0.1	-86.62	0.1
PTB	58444-58450	BP1C-PT10	-185.80	0.1	-173.53	0.1	-185.89	0.1				
PTB	58442-58450	BP1X-PT10	-174.57	0.1	-169.49	0.1	-174.71	0.1	-174.68	0.1	-168.41	0.1
ROA	58466-58470	BP1C-RO_5	-252.73	0.1	-248.19	0.1	-251.14	0.1				
ROA	58466-58470	BP1X-RO_5	-235.98	0.1	-238.71	0.2	-234.38	0.1				
ROA	58466-58470	BP1C-RO_6	93.31	0.1	100.19	0.1	93.59	0.1				
ROA	58466-58470	BP1X-RO_6	110.03	0.1	109.64	0.1	110.34	0.1				
ROA	58466-58470	BP1C-RO_7	52.55	0.1	59.31	0.1	53.20	0.1				
ROA	58466-58470	BP1X-RO_7	69.28	0.1	68.76	0.1	69.94	0.1	71.98	0.1	58.24	0.1
ROA	58466-58470	BP1C-RO_8	-414.41	0.1	-408.18	0.1	-414.65	0.1				
ROA	58466-58470	BP1X-RO_8	-397.64	0.1	-398.71	0.1	-397.87	0.1	-397.60	0.1	-399.69	0.1
ROA	58466-58470	BP1C-RO_9	81.74	0.1	88.45	0.1	82.25	0.1				
ROA	58466-58470	BP1X-RO_9	98.47	0.1	97.88	0.1	98.98	0.1	101.06	0.1	86.83	0.1
ROA	58466-58470	BP1C-RO10	-483.20	0.1	-476.36	0.1	-483.00	0.1				
ROA	58466-58470	BP1X-RO10	-466.50	0.1	-466.97	0.1	-466.30	0.1	-464.86	0.1	-470.93	0.1
OP	58500-58511	BP1C-OPMT	-313.83	0.2	-320.09	0.1	-312.55	0.1				
OP	58500-58511	BP1X-OPMT	-321.68	0.2	-335.12	0.1	-320.39	0.1				
OP	58506-58511	BP1C-OP71	2.83	0.2	9.89	0.1	3.29	0.1				
OP	58506-58511	BP1X-OP71	-4.97	0.2	-5.14	0.1	-4.52	0.1	-2.40	0.1	-16.36	0.1
OP	58500-58511	BP1C-OPM9	-83.58	0.2	-74.73	0.1	-83.66	0.1				
OP	58500-58511	BP1X-OPM9	-91.47	0.2	-89.76	0.1	-91.56	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

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

where RAWDIF(Code) is read in Table 2 and where the values REFDLY are in the report of operations 1001-2018-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.

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

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

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

where the values CABDLY are taken from the report of operations 1001-2018-phase3-cv.pdf;
Tables 5 reports the $\mathbf{\Delta INTDLY_{V\text{-}R}}$ results for the pairs Visited-Reference (section 4.3).
Using assumed $\mathbf{INTDLY_R}$ values for the Reference system, Table 6 then reports $\mathbf{INTDLY_V}$ 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 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)		E1 (ns)		E5 (ns)	
					RAWDIF	**ΔSYSDLY**	RAWDIF	**ΔSYSDLY**	RAWDIF	**ΔSYSDLY**	RAWDIF	**ΔSYSDLY**	RAWDIF	**ΔSYSDLY**
BP1C-BP1J	58409-58415	238.0	181.6		45.29	101.69	51.21	107.61	45.83	102.23				
BP1C-BP1J	58525-58535	238.0	181.7		45.44	101.74	51.45	107.75	45.99	102.29				
		Misclos.				0.05		0.14		0.06				
BP1C-BP1J		Mean				101.72		107.68		102.26				
BP1X-BP1J	58409-58415	52.6	181.6		39.10	-89.90	38.00	-91.00	39.63	-89.37	41.80	-87.20	26.73	-102.27
BP1X-BP1J	58525-58535	52.6	181.7		38.93	-90.17	37.75	-91.35	39.42	-89.68	41.52	-87.58	26.70	-102.40
		Misclos.				0.27		0.35		0.31		0.38		0.13
BP1X-BP1J		Mean				-90.04		-91.18		-89.53		-87.39		-102.34

Results for the local backup BP0R vs. BP1J are shown in Table 3.2. The misclosure for this pair is an indicator of the relative instabilities of two receivers.

Table 3.2. Computed **ΔSYSDLY** values for the local backup BP0R with respect to BP1J used as a reference. All values in ns

Pair	Date	$REFDLY_T$	$REFDLY_R$	Note	P1 (ns)		P2 (ns)		C1 (ns)		E1 (ns)		E5 (ns)	
					RAWDIF	**ΔSYSDLY**	RAWDIF	**ΔSYSDLY**	RAWDIF	**ΔSYSDLY**	RAWDIF	**ΔSYSDLY**	RAWDIF	**ΔSYSDLY**
BP0R-BP1J	58409-58415	283.7	181.6		72.02	174.12	74.03	176.13	73.84	175.94				
BP0R-BP1J	58525-58535	283.9	181.7		72.06	174.26	74.00	176.20	73.89	176.09				
		Misclos.				0.14		0.07		0.15				
BP0R-BP1J		Mean				174.19		176.17		176.02				

4.2 Traveling system with respect to the visited systems

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

Pair	Date	$REFDLY_T$	$REFDLY_R$	Note	P1 (ns)		P2 (ns)		C1 (ns)		E1 (ns)		E5 (ns)	
					RAWDIF	ΔSYSDLY	RAWDIF	ΔSYSDLY	RAWDIF	ΔSYSDLY	RAWDIF	ΔSYSDLY	RAWDIF	ΔSYSDLY
BP1C-PTBB	58444-58450	297.7	74.6		-546.92	-323.82	-556.46	-333.36	-545.59	-322.49				
BP1X-PTBB	58442-58450	94.8	74.6		-535.73	-515.53	-552.47	-532.27	-534.45	-514.25				
BP1C-PTBG	58444-58450	297.7	46.5		-521.45	-270.25	-538.50	-287.30	-519.84	-268.64				
BP1X-PTBG	58442-58450	94.8	46.5		-510.19	-461.89	-534.49	-486.19	-508.64	-460.34				
BP1C-PT07	58444-58450	297.7	43.4		-14.43	239.87	-8.53	245.77	-12.39	241.91				
BP1X-PT07	58442-58450	94.8	43.4		-3.24	48.16	-4.48	46.92	-1.22	50.18				
BP1C-PT09	58444-58450	297.7	183.2		-86.51	27.99	-79.93	34.57	-85.98	28.52				
BP1X-PT09	58442-58450	94.8	183.2		-75.29	-163.69	-75.91	-164.31	-74.80	-163.20	-72.76	-161.16	-86.62	-175.02
BP1C-PT10	58444-58450	297.7	52.0		-185.80	59.90	-173.53	72.17	-185.89	59.81				
BP1X-PT10	58442-58450	94.8	52.0		-174.57	-131.77	-169.49	-126.69	-174.71	-131.91	-174.68	-131.88	-168.41	-125.61
BP1C-RO_5	58466-58470	538.2	306.9	**	-252.73	-21.43	-248.19	-16.89	-251.14	-19.84				
BP1X-RO_5	58466-58470	329.9	306.9	**	-235.98	-212.98	-238.71	-215.71	-234.38	-211.38				
BP1C-RO_6	58466-58470	538.2	484.9		93.31	146.61	100.19	153.49	93.59	146.89				
BP1X-RO_6	58466-58470	329.9	484.9		110.03	-44.97	109.64	-45.36	110.34	-44.66				
BP1C-RO_7	58466-58470	538.2	452.3		52.55	138.45	59.31	145.21	53.20	139.10				
BP1X-RO_7	58466-58470	329.9	452.3		69.28	-53.12	68.76	-53.64	69.94	-52.46	71.98	-50.42	58.24	-64.16
BP1C-RO_8	58466-58470	538.2	20.4		-414.41	103.39	-408.18	109.62	-414.65	103.15				
BP1X-RO_8	58466-58470	329.9	20.4		-397.64	-88.14	-398.71	-89.21	-397.87	-88.37	-397.60	-88.10	-399.69	-90.19
BP1C-RO_9	58466-58470	538.2	451.8		81.74	168.14	88.45	174.85	82.25	168.65				
BP1X-RO_9	58466-58470	329.9	451.8		98.47	-23.43	97.88	-24.02	98.98	-22.92	101.06	-20.84	86.83	-35.07
BP1C-RO10	58466-58470	538.2	5.1		-483.20	49.90	-476.36	56.74	-483.00	50.10				
BP1X-RO10	58466-58470	329.9	5.1		-466.50	-141.70	-466.97	-142.17	-466.30	-141.50	-464.86	-140.06	-470.93	-146.13
BP1C-OPMT	58500-58511	288.2	155.9	(1)	-313.83	-181.53	-320.09	-187.79	-312.55	-180.25				
BP1X-OPMT	58500-58511	104.5	155.9	(1)	-321.68	-373.08	-335.12	-386.52	-320.39	-371.79				
BP1C-OP71	58506-58511	288.2	191.7		2.83	99.37	9.89	106.43	3.29	99.83				
BP1X-OP71	58506-58511	104.5	191.7		-4.97	-92.13	-5.14	-92.30	-4.52	-91.68	-2.40	-89.56	-16.36	-103.52
BP1C-OPM9	58500-58511	288.2	60.5		-83.58	144.10	-74.73	152.95	-83.66	144.02				
BP1X-OPM9	58500-58511	104.5	60.5		-91.47	-47.49	-89.76	-45.78	-91.56	-47.58				

(1) **REFDLY$_V$** value not measured during calibration.

4.3 Visited systems with respect to reference system

The Table 5 provides the values obtained by differencing Table 3.1 (BP1J reference) and Table 4. CABDLY values are taken from the report of operations 1001-2018-phase3-cv.pdf and have not been measured during this calibration.

Table 5. Visited vs. BP1J Reference (all values in ns)

Pair	Date	CABDLY$_V$	CABDLY$_R$	Note	P1 (ns)		P2 (ns)		C1 (ns)	
					ΔSYSDLY	ΔINTDLY	ΔSYSDLY	ΔINTDLY	ΔSYSDLY	ΔINTDLY
PTBB-BP1J via BP1C	2018.9	301.7	128.7		425.54	252.54	441.04	268.04	424.75	251.75
PTBB-BP1J via BP1X	2018.9	301.7	128.7		425.50	252.50	441.10	268.10	424.73	251.73
PTBG-BP1J via BP1C	2018.9	251.4	128.7		371.97	249.27	394.98	272.28	370.90	248.20
PTBG-BP1J via BP1X	2018.9	251.4	128.7		371.86	249.16	395.02	272.32	370.82	248.12
PT07-BP1J via BP1C	2018.9	245.8	128.7		-138.16	-255.26	-138.09	-255.19	-139.65	-256.75
PT07-BP1J via BP1X	2018.9	245.8	128.7		-138.20	-255.30	-138.10	-255.20	-139.71	-256.81
PT09-BP1J via BP1C	2018.9	198.7	128.7		73.73	3.73	73.11	3.11	73.74	3.74
PT09-BP1J via BP1X	2018.9	198.7	128.7		73.66	3.66	73.14	3.14	73.68	3.68
PT10-BP1J via BP1C	2018.9	250.0	128.7		41.82	-79.49	35.51	-85.79	42.45	-78.85
PT10-BP1J via BP1X	2018.9	250.0	128.7		41.74	-79.57	35.52	-85.79	42.39	-78.92
RO_5-BP1J via BP1C	2019.0	91.5	128.7		123.15	160.35	124.57	161.77	122.10	159.30
RO_5-BP1J via BP1X	2019.0	91.5	128.7		122.95	160.15	124.54	161.74	121.86	159.06
RO_6-BP1J via BP1C	2019.0	82.0	128.7		-44.90	1.80	-45.81	0.89	-44.63	2.07
RO_6-BP1J via BP1X	2019.0	82.0	128.7		-45.07	1.64	-45.82	0.89	-44.87	1.83
RO_7-BP1J via BP1C	2019.0	89.9	128.7		-36.74	2.07	-37.53	1.27	-36.84	1.96
RO_7-BP1J via BP1X	2019.0	89.9	128.7		-36.91	1.89	-37.54	1.27	-37.06	1.74
RO_8-BP1J via BP1C	2019.0	202.7	128.7		-1.68	-75.68	-1.94	-75.94	-0.89	-74.89
RO_8-BP1J via BP1X	2019.0	202.7	128.7		-1.89	-75.90	-1.96	-75.97	-1.15	-75.15
RO_9-BP1J via BP1C	2019.0	59.7	128.7		-66.43	2.57	-67.17	1.83	-66.39	2.61
RO_9-BP1J via BP1X	2019.0	59.7	128.7		-66.61	2.40	-67.16	1.85	-66.61	2.40
RO10-BP1J via BP1C	2019.0	204.8	128.7		51.82	-24.29	50.94	-25.16	52.16	-23.94
RO10-BP1J via BP1X	2019.0	204.8	128.7		51.67	-24.44	51.00	-25.11	51.98	-24.13
OPMT-BP1J via BP1C	2019.1	156.5	128.7		283.25	255.45	295.47	267.67	282.51	254.71
OPMT-BP1J via BP1X	2019.1	156.5	128.7		283.05	255.25	295.35	267.55	282.27	254.47
OP71-BP1J via BP1C	2019.1	128.7	128.7		2.35	2.35	1.25	1.25	2.43	2.43
OP71-BP1J via BP1X	2019.1	128.7	128.7		2.10	2.10	1.13	1.13	2.16	2.16
OPM9-BP1J via BP1C	2019.1	173.3	128.7		-42.39	-86.99	-45.27	-89.87	-41.76	-86.36
OPM9-BP1J via BP1X	2019.1	173.3	128.7		-42.55	-87.15	-45.40	-90.00	-41.95	-86.55
BP0R-BP1J	2019.0	133.4	128.7		174.19	169.49	176.17	171.47	176.02	171.32

4.4 Provisional INTDLY values of visited systems

Table 6 lists provisional INTDLY values of the visited systems based on INTDLY reference values for BP1J determined from phase 1, which are the same as the final 1001-2016 values (P1=53.0 ns; P2=52.6 ns; C1=54.4 ns), as described in BIPM Technical Memorandum 266. Results for the Galileo codes will be included when a reference value has been determined in the CCTF WG on GNSS.

Final INTDLY values will be based on minimizing changes between 1001-2016 and 1001-2018, as described in BIPM Technical Memorandum 266, and will be reported in the global report of the trip

1001-2018 available here. Since two results can be computed from Table 5, using either BP1C or BP1X 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 Δ(BP1C-BP1X), typically of order 0.2 n,s is taken into account in component $u_{b,1}$ of the uncertainty budget in Table 7.

Table 6. Provisional INTDLY values of Visited systems using 1001-2018 reference values for the reference systems BP1J (all values in ns).

Pair	Date	Note	P1	P2	C1
			$INTDLY_V$	$INTDLY_V$	$INTDLY_V$
PTBB vs. BP1J	2018.9		305.52	320.67	306.14
Δ(BP1C-BP1X)	2018.9		0.04	-0.05	0.02
PTBG vs. BP1J	2018.9		302.21	324.90	302.56
Δ(BP1C-BP1X)	2018.9		0.11	-0.03	0.09
PT07 vs. BP1J	2018.9	(1)	0.03	-0.29	-0.08
Δ(BP1C-BP1X)	2018.9		0.04	0.00	0.06
PT09 vs. BP1J	2018.9		56.69	55.72	58.11
Δ(BP1C-BP1X)	2018.9		0.07	-0.03	0.07
PT10 vs. BP1J	2018.9		-26.53	-33.19	-24.48
Δ(BP1C-BP1X)	2018.9		0.08	-0.01	0.06
RO_5 vs. BP1J	2019.0	(1)	-1.86	-0.75	-1.52
Δ(BP1C-BP1X)	2019.0		0.20	0.03	0.24
RO_6 vs. BP1J	2019.0		54.72	53.49	56.35
Δ(BP1C-BP1X)	2019.0		0.17	0.00	0.23
RO_7 vs. BP1J	2019.0		54.98	53.87	56.25
Δ(BP1C-BP1X)	2019.0		0.18	0.00	0.22
RO_8 vs. BP1J	2019.0		-22.79	-23.35	-20.62
Δ(BP1C-BP1X)	2019.0		0.22	0.02	0.26
RO_9 vs. BP1J	2019.0		55.49	54.44	56.90
Δ(BP1C-BP1X)	2019.0		0.18	-0.02	0.21
RO10 vs. BP1J	2019.0		28.64	27.47	30.37
Δ(BP1C-BP1X)	2019.0		0.15	-0.06	0.18
OPMT vs. BP1J	2019.1		308.35	320.21	308.99
Δ(BP1C-BP1X)	2019.1		0.20	0.13	0.25
OP71 vs. BP1J	2019.1		55.22	53.79	56.69
Δ(BP1C-BP1X)	2019.1		0.25	0.13	0.27
OPM9 vs. BP1J	2019.1		-34.07	-37.33	-32.05
Δ(BP1C-BP1X)	2019.1		0.16	0.13	0.18
BP1R vs. BP1J	2019		222.49	224.07	225.72

(1) Results are changes with respect to values entered in the receiver

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} =1.3 ns from Table 7 is applicable to P3/PPP links. The value u_{CAL} =1.1 ns is applicable to C1 links. Final values of u_{CAL} are consistent with the conventional value of 1.5 ns for P3/PPP 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"					
$u_{b,1}$	0.2	0.2	0.1		observed mis-closure
Systematic components related to RAWDIF					
$u_{b,11}$	0.05	0.05	0.05		Position error at reference
$u_{b,12}$	0.05	0.05	0.05		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)
$u_{b,TOT}$	0.8	0.8	0.4	1.0	
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)
$u_{b,SYS}$	1.1	1.1	0.4	1.2	Components of equation (2)
u_{CAL}	1.1			1.3	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_a(T-V) is larger (0.2 ns) for OP P1 code comparisons. The final u_a value for OP is 0.5 ns for P3. This does not affect the overall uncertainty.
- $u_{b,1}$ 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, 0.1 ns for P1-P2, see Table 3.1), on the other hand by the observed discrepancies between the results of the two traveling receivers (~ 0.2 ns average for each code, 0.1 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.
- $u_{b,13}$ 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. Note that lower uncertainties are reported by the participating laboratories: 0.2 ns at PTB, 0.1 ns at ROA, 0.2 ns at OP.
- $u_{b,31}$ 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. Note that lower uncertainties are reported by the participating laboratories: 0.1 to 0.2 ns at PTB, 0.3 ns at OP.

Version history
V1.0 2019/03/15: Draft report of phase 3.
V1.1 2020/01/06: Correction of typos in OP receiver names in Table 6.