2022 Group 1 GNSS Calibration Trip

Revision History

Revision	Date	Author(s)	Description
1.0	26.02.2024	GT	Created
1.1	15.04.2024	GT	Typos fixed, ionofree values corrected

Summary

The 2022 visit to Group 1 laboratories is the fifth Group 1 trip and started in July 2022. The trip is decomposed into several phases, each enclosed with closure at the BIPM.

- Phase 1 (July 2022-February 2023). BIPM-NIM-NICT-TL-BIPM with the traveling receivers BP2G and BP25;
- Phase 2 (March-June 2023), BIPM-ROA-PTB-OP-BIPM with the traveling receivers BP2G and BP2D.
- Phase 3 (June 2023 - January 2024), BIPM-USNO-NIST-BIPM with the traveling receivers BP2G and BP2D.

Due to the current situation a trip to COMMET G1 lab SU has been not possible. Since phase 1 of the 2022 Group 1 trip, results are provided for the GPS codes P1, P2 and C1, the Galileo E1 and E5a codes, and the BDS B1C B5 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 1001-2022: Report of Phase 3

1 Description of Equipment and Operations

1.1 Traveling Equipment

Two systems were included in the BIPM traveling claibrator: BP2G and BP2D. See Table 2 and the report of operations 1001-2022-phase3-cv.pdf. The rest of the traveling equipment is described in Annex 1 of the Guidelines.

1.2 Visited Equipment

See a summary in Table 2. The detailed information on the set-up and the measurements performed is in the report of operations 1001-2022-phase3-cv.pdf.

The receiver BP21from the BIPM serves as a reference for the closure.

2 Data Used

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

Table 2: Summary information on the calibration trip

Institute	Status of Equipment	Dates of measurement	BIPM code	RINEX name	Receiver Type
BIPM	Traveling		BP2G	BP2G	Septentrio PolaRx5TR (AC On)
BIPM	Traveling		BP2D	BP2D	Dicom GTR55
BIPM	Reference	60119-60128	BP21	BP21	Septentrio PolaRx5TR (AC On)
USNO	G1	60152-60170	US06	usn6	ProPak-V3
USNO	G1	60152-60170	US10	USN8	Septentrio PolaRx5TR
USNO	G1	60152-60169	US09	USN7	Septentrio PolaRx5TR
NIST	G1	60237-60256	NISG	NISG	Septentrio PolaRx5TR
NIST	G1	60237-60256	NISX	NIST	Septentrio PolaRx5TR
NIST	G1	60237-60246	NISQ	NISQ	Septentrio PolaRx5TR
NIST	G1	60251-60256	NISK	NISK	Septentrio PolaRx5TR
NIST	G1	60251-60256	NISP	NISP	Septentrio PolaRx5TR
BIPM	Reference	60314-60320	BP21	BP21	Septentrio PolaRx5TR (AC On)

3 Results of Raw Data Processing

- The raw code differences have been generated by the DCLRINEX procedure (see GuidelinesAnnex 3). Each run for a pair of stations generates 3 files (summary .sum, data .dif, plot .pdf). Summary files and plots are available in 1001-2022-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 1001-2022-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 BP21is considered to be the reference. The raw code differences between the reference receiver and the traveling ones are presented in Tables 3 4 5.

Table 3: GPS raw differential results for all pairs (Traveling – Reference) (ns)

Labo	Date	Pair	RDIF(C1)	Unc	RDIF(P1)	Unc	RDIF(P2)	Unc
BIPM	60119-60128	BP2D-BP21	8.14	0.1	9.48	0.1	14.12	0.1
BIPM	60119-60128	BP2G-BP21	25.28	0.1	25.11	0.1	23.66	0.1
USNO	60152-60170	US06-BP2G	-151.06	0.1	-149.56	0.1	-149.16	0.1
USNO	60152-60170	US06-BP2D	-134.39	0.1	-134.31	0.1	-139.76	0.1
USNO	60152-60169	US09-BP2G	62.79	0.1	62.88	0.1	61.59	0.1
USNO	60152-60169	US09-BP2D	79.40	0.1	78.14	0.1	70.97	0.1
USNO	60152-60170	US10-BP2G	57.41	0.1	57.45	0.1	57.24	0.1
USNO	60152-60170	US10-BP2D	74.01	0.1	72.71	0.1	66.62	0.1
NIST	60237-60246	NISG-BP2D	-1013.50	0.1	-1014.94	0.1	-1019.67	0.1
NIST	60251-60256	NISG-BP2G	-1030.27	0.1	-1030.36	0.1	-1029.37	0.1
NIST	60251-60256	NISX-BP2D	461.88	0.1	460.65	0.1	455.22	0.1
NIST	60237-60246	NISX-BP2G	445.08	0.1	445.20	0.1	445.47	0.1
NIST	60237-60246	NISQ-BP2D	44.12	0.1	42.80	0.1	30.98	0.1
NIST	60237-60246	NISQ-BP2G	27.25	0.1	27.23	0.1	21.10	0.1
NIST	60251-60256	NISK-BP2D	-932.57	0.1	-934.26	0.1	-937.69	0.1
NIST	60251-60256	NISK-BP2G	-949.38	0.1	-949.72	0.1	-947.30	0.1
NIST	60251-60256	NISP-BP2D	45.67	0.1	44.23	0.1	33.66	0.1
NIST	60251-60256	NISP-BP2G	28.90	0.1	28.82	0.1	23.99	0.1
BIPM	60314-60320	BP2D-BP21	8.44	0.1	9.81	0.1	13.91	0.1
BIPM	60314-60320	BP2G-BP21	25.08	0.1	24.94	0.1	23.64	0.1

Table 4: Galileo raw differential results for all pairs (Traveling – Reference) (ns)

Labo	Date	Pair	RDIF(E1)	Unc	RDIF(E5)	Unc
BIPM	60119-60128	BP2D-BP21	7.93	0.1	11.86	0.1
BIPM	60119-60128	BP2G-BP21	25.23	0.1	24.38	0.1
USNO	60152-60169	US09-BP2G	62.78	0.1	64.85	0.1
USNO	60152-60169	US09-BP2D	79.79	0.1	77.13	0.1
USNO	60152-60170	US10-BP2G	57.41	0.1	59.76	0.1
USNO	60152-60170	US10-BP2D	74.42	0.1	72.05	0.1
NIST	60237-60246	NISG-BP2D	-1013.26	0.1	-1017.70	0.1
NIST	60251-60256	NISG-BP2G	-1030.38	0.1	-1029.55	0.1
NIST	60251-60256	NISX-BP2D	462.16	0.1	458.76	0.1
NIST	60237-60246	NISX-BP2G	445.04	0.1	446.66	0.1
NIST	60237-60246	NISQ-BP2D	44.41	0.1	34.34	0.1
NIST	60237-60246	NISQ-BP2G	27.17	0.1	22.27	0.1
NIST	60251-60256	NISK-BP2D	-932.28	0.1	-937.55	0.1
NIST	60251-60256	NISK-BP2G	-949.42	0.1	-949.54	0.1
NIST	60251-60256	NISP-BP2D	45.92	0.1	37.51	0.1
NIST	60251-60256	NISP-BP2G	28.82	0.1	25.61	0.1
BIPM	60314-60320	BP2D-BP21	8.21	0.1	12.45	0.1
BIPM	60314-60320	BP2G-BP21	25.06	0.1	24.14	0.1

Table 5: Beidou raw differential results for all pairs (Traveling – Reference) (ns)

Labo	Date	Pair	RDIF(BC)	Unc	RDIF(B5)	Unc
BIPM	60119-60128	BP2D-BP21	7.36	0.1	11.48	0.1
BIPM	60119-60128	BP2G-BP21	25.19	0.1	24.36	0.1
USNO	60152-60169	US09-BP2G	62.87	0.1	64.86	0.1
USNO	60152-60169	US09-BP2D	80.44	0.1	77.54	0.1
NIST	60237-60246	NISG-BP2D	-1012.82	0.1	-1017.62	0.1
NIST	60251-60256	NISG-BP2G	-1030.37	0.1	-1029.87	0.1
NIST	60251-60256	NISX-BP2D	462.78	0.1	459.13	0.1
NIST	60237-60246	NISX-BP2G	445.11	0.1	446.60	0.1
NIST	60237-60246	NISQ-BP2D	45.28	0.1	34.76	0.1
NIST	60237-60246	NISQ-BP2G	27.50	0.1	22.28	0.1
NIST	60251-60256	NISK-BP2D	-932.08	0.1	-937.44	0.1
NIST	60251-60256	NISK-BP2G	-949.70	0.1	-949.83	0.1
NIST	60251-60256	NISP-BP2D	46.87	0.1	37.94	0.1
NIST	60251-60256	NISP-BP2G	29.22	0.1	25.62	0.1
BIPM	60314-60320	BP2D-BP21	7.64	0.1	12.05	0.1
BIPM	60314-60320	BP2G-BP21	25.05	0.1	24.12	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

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

where RAWDIF(Code) is read in Tables 3 4 5 and where the values REFDLY are in the report of operations 1001-2022-phase3-cv.pdf. The ΔSYSDLY values are reported in Tables 6 7 8 for the pairs Traveling-Reference (section 4.3) and in Table 9 10 11 for the pairs Visited-Traveling (section 4.3). In the second step one computes ΔSYSDLY (Visited-Reference) for all visited systems.

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

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 1001-2022-phase3-cv.pdf; Tables 12 13 14 reports the $\Delta INTDLY_{V-R}$ results for the pairs Visited-Reference (section 4.3). Using assumed $INTDLY_R$ values for the Reference system, Tables 15 16 17 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 1001-2022-phase3-cv.pdf.

Results for the traveling systems are reported in Tables 6 7 8.

4.2 Traveling System with Respect to the Visited Systems

REFDLY values are available from the report of operations 1001-2022-phase3-cv.pdf.

4.3 Visited Systems with Respect to Reference System

The Tables 12 13 14 provide the values obtained by differencing Tables in sub-section (BP21reference) and Tables in sub-section . CABDLY values are taken from the report of operations 1001-2022-phase3-cv.pdfand have not been measured during this calibration.

Table 6: Computed GPS ΔSYSDLY values for the traveling systems with respect to reference receiver. The misclosures are also indicated. (all values in ns).

Pair	**Date**	**REFDLY$_T$**	**REFDLY$_R$**	**Note**	**C1 (ns)**		**P1 (ns)**		**P2 (ns)**		**P3 (ns)**	
					RAWDIF	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**
BP2G-BP21	60119-60128	53.51	43.39		25.28	35.44	25.11	35.27	23.66	33.82	27.36	37.52
BP2G-BP21	60314-60320	53.51	43.39		25.08	35.24	24.94	35.10	23.64	33.80	26.96	37.12
		Miscl.				0.20		0.17		0.01		0.41
BP2G-BP21		Mean				35.34		35.19		33.81		37.32
BP2D-BP21	60119-60128	53.41	43.39		8.14	18.20	9.48	19.54	14.12	24.17	2.31	12.37
BP2D-BP21	60314-60320	53.45	43.39		8.44	18.50	9.81	19.87	13.91	23.97	3.46	13.52
		Miscl.				-0.30		-0.33		0.20		-1.15
BP2D-BP21		Mean				18.35		19.70		24.07		12.95

Table 7: Computed Galileo ΔSYSDLY values for the traveling systems with respect to reference receiver. The misclosures are also indicated. (all values in ns).

Pair	**Date**	**REFDLY$_T$**	**REFDLY$_R$**	**Note**	**E1 (ns)**		**E5 (ns)**		**E3 (ns)**	
					RAWDIF	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**
BP2G-BP21	60119-60128	53.51	43.39		25.23	35.39	24.38	34.54	26.31	36.47
BP2G-BP21	60314-60320	53.51	43.39		25.06	35.22	24.14	34.30	26.22	36.38
		Miscl.				0.17		0.24		0.09
BP2G-BP21		Mean				35.31		34.42		36.43
BP2D-BP21	60119-60128	53.41	43.39		7.93	17.99	11.86	21.92	2.98	13.04
BP2D-BP21	60314-60320	53.45	43.39		8.21	18.28	12.45	22.51	2.87	12.93
		Miscl.				-0.28		-0.59		0.11
BP2D-BP21		Mean				18.13		22.22		12.98

Table 8: Computed Beidou ΔSYSDLY values for the traveling systems with respect to reference receiver. The misclosures are also indicated. (all values in ns).

Pair	**Date**	**REFDLY$_T$**	**REFDLY$_R$**	**Note**	**BC (ns)**		**B5 (ns)**		**B3 (ns)**	
					RAWDIF	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**
BP2G-BP21	60119-60128	53.51	43.39		25.19	35.35	24.36	34.52	26.23	36.39
BP2G-BP21	60314-60320	53.51	43.39		25.05	35.21	24.12	34.28	26.22	36.38
		Miscl.				0.13		0.24		0.00
BP2G-BP21		Mean				35.28		34.40		36.38
BP2D-BP21	60119-60128	53.41	43.39		7.36	17.42	11.48	21.54	2.17	12.23
BP2D-BP21	60314-60320	53.45	43.39		7.64	17.70	12.05	22.11	2.07	12.13
		Miscl.				-0.28		-0.58		0.10
BP2D-BP21		Mean				17.56		21.83		12.18

Table 9: Computed GPS ΔSYSDLY values for the traveling systems with respect to visited receiver. (all values in ns).

Pair	**Date**	**REFDLY$_V$**	**REFDLY$_T$**	**Note**	**C1 (ns)**		**P1 (ns)**		**P2 (ns)**	
					RAWDIF	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**
US06-BP2G	60152-60170	0.00	62.57		-151.06	-213.63	-149.56	-212.13	-149.16	-211.72
US10-BP2G	60152-60170	0.00	62.57		57.41	-5.16	57.45	-5.12	57.24	-5.33
US09-BP2G	60152-60169	0.00	62.57		62.79	0.22	62.88	0.31	61.59	-0.98
NISG-BP2G	60251-60256	1622.32	467.11		-1030.27	124.94	-1030.36	124.85	-1029.37	125.84
NISX-BP2G	60237-60246	121.80	467.11		445.08	99.77	445.20	99.89	445.47	100.16
NISQ-BP2G	60237-60246	466.20	467.11		27.25	26.33	27.23	26.32	21.10	20.19
NISK-BP2G	60251-60256	1535.60	467.11		-949.38	119.11	-949.72	118.77	-947.30	121.19
NISP-BP2G	60251-60256	466.20	467.11		28.90	27.99	28.82	27.91	23.99	23.08
US06-BP2D	60152-60170	0.00	62.47		-134.39	-196.86	-134.31	-196.78	-139.76	-202.23
US10-BP2D	60152-60170	0.00	62.47		74.01	11.54	72.71	10.24	66.62	4.15
US09-BP2D	60152-60169	0.00	62.47		79.40	16.93	78.14	15.67	70.97	8.50
NISG-BP2D	60237-60246	1622.32	467.01		-1013.50	141.81	-1014.94	140.37	-1019.67	135.64
NISX-BP2D	60251-60256	121.80	467.01		461.88	116.67	460.65	115.44	455.22	110.01
NISQ-BP2D	60237-60246	466.20	467.01		44.12	43.31	42.80	41.99	30.98	30.17
NISK-BP2D	60251-60256	1535.60	467.01		-932.57	136.02	-934.26	134.33	-937.69	130.90
NISP-BP2D	60251-60256	466.20	467.01		45.67	44.86	44.23	43.42	33.66	32.85

Table 10: Computed Galileo ΔSYSDLY values for the traveling systems with respect to visited receiver. (all values in ns).

Pair	**Date**	**REFDLY$_V$**	**REFDLY$_T$**	**Note**	**E1 (ns)**		**E5 (ns)**	
					RAWDIF	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**
US10-BP2G	60152-60170	0.00	62.57		57.41	-5.16	59.76	-2.81
US09-BP2G	60152-60169	0.00	62.57		62.78	0.21	64.85	2.28
NISG-BP2G	60251-60256	1622.32	467.11		-1030.38	124.83	-1029.55	125.66
NISX-BP2G	60237-60246	121.80	467.11		445.04	99.73	446.66	101.35
NISQ-BP2G	60237-60246	466.20	467.11		27.17	26.26	22.27	21.36
NISK-BP2G	60251-60256	1535.60	467.11		-949.42	119.07	-949.54	118.95
NISP-BP2G	60251-60256	466.20	467.11		28.82	27.91	25.61	24.69
US10-BP2D	60152-60170	0.00	62.47		74.42	11.95	72.05	9.58
US09-BP2D	60152-60169	0.00	62.47		79.79	17.32	77.13	14.66
NISG-BP2D	60237-60246	1622.32	467.01		-1013.26	142.05	-1017.70	137.61
NISX-BP2D	60251-60256	121.80	467.01		462.16	116.95	458.76	113.55
NISQ-BP2D	60237-60246	466.20	467.01		44.41	43.60	34.34	33.53
NISK-BP2D	60251-60256	1535.60	467.01		-932.28	136.31	-937.55	131.04
NISP-BP2D	60251-60256	466.20	467.01		45.92	45.11	37.51	36.70

Table 11: Computed Beidou ΔSYSDLY values for the traveling systems with respect to visited receiver. (all values in ns).

Pair	**Date**	**REFDLY$_V$**	**REFDLY$_T$**	**Note**	**BC (ns)**		**B5 (ns)**	
					RAWDIF	**ΔSYSDLY**	**RAWDIF**	**ΔSYSDLY**
US09-BP2G	60152-60169	0.00	62.57		62.87	0.30	64.86	2.29
NISG-BP2G	60251-60256	1622.32	467.11		-1030.37	124.84	-1029.87	125.34
NISX-BP2G	60237-60246	121.80	467.11		445.11	99.80	446.60	101.29
NISQ-BP2G	60237-60246	466.20	467.11		27.50	26.59	22.28	21.37
NISK-BP2G	60251-60256	1535.60	467.11		-949.70	118.79	-949.83	118.66
NISP-BP2G	60251-60256	466.20	467.11		29.22	28.31	25.62	24.71
US09-BP2D	60152-60169	0.00	62.47		80.44	17.97	77.54	15.07
NISG-BP2D	60237-60246	1622.32	467.01		-1012.82	142.49	-1017.62	137.69
NISX-BP2D	60251-60256	121.80	467.01		462.78	117.57	459.13	113.92
NISQ-BP2D	60237-60246	466.20	467.01		45.28	44.47	34.76	33.95
NISK-BP2D	60251-60256	1535.60	467.01		-932.08	136.51	-937.44	131.15
NISP-BP2D	60251-60256	466.20	467.01		46.87	46.06	37.94	37.13

Table 12: Computed GPS ΔINTDLY values for the visited systems with respect to reference receiver. (all values in ns).

Pair	**Date**	**CABDLY$_V$**	**CABDLY$_R$**	**Note**	**C1 (ns)**		**P1 (ns)**		**P2 (ns)**	
					ΔSYSDLY	**ΔINTDLY**	**ΔSYSDLY**	**ΔINTDLY**	**ΔSYSDLY**	**ΔINTDLY**
NISQ-BP21 via BP2G	2023.8	199.60	140.80		61.68	2.88	61.51	2.71	54.00	-4.80
NISQ-BP21 via BP2D	2023.8	199.60	140.80		61.66	2.86	61.70	2.90	54.24	-4.56
NISX-BP21 via BP2G	2023.8	275.50	140.80		135.11	0.41	135.08	0.38	133.97	-0.73
NISX-BP21 via BP2D	2023.8	275.50	140.80		135.02	0.32	135.15	0.45	134.09	-0.61
NISP-BP21 via BP2G	2023.8	199.60	140.80		63.33	4.53	63.09	4.29	56.89	-1.91
NISP-BP21 via BP2D	2023.8	199.60	140.80		63.21	4.41	63.13	4.33	56.92	-1.88
NISG-BP21 via BP2G	2023.8	298.50	140.80		160.29	2.59	160.04	2.34	159.65	1.95
NISG-BP21 via BP2D	2023.8	298.50	140.80		160.15	2.45	160.07	2.37	159.71	2.01
NISK-BP21 via BP2G	2023.8	298.90	140.80		154.46	-3.64	153.96	-4.14	155.00	-3.10
NISK-BP21 via BP2D	2023.8	298.90	140.80		154.37	-3.73	154.04	-4.06	154.97	-3.13
US06-BP21 via BP2G	2023.6	0.00	140.80		-178.29	-37.49	-176.95	-36.15	-177.92	-37.12
US06-BP21 via BP2D	2023.6	0.00	140.80		-178.51	-37.71	-177.08	-36.28	-178.16	-37.36
US10-BP21 via BP2G	2023.6	0.00	140.80		30.18	170.98	30.07	170.87	28.48	169.28
US10-BP21 via BP2D	2023.6	0.00	140.80		29.89	170.69	29.94	170.74	28.22	169.02
US09-BP21 via BP2G	2023.6	0.00	140.80		35.57	176.37	35.50	176.30	32.83	173.63
US09-BP21 via BP2D	2023.6	0.00	140.80		35.28	176.08	35.37	176.17	32.57	173.37

Table 13: Computed Galileo ΔINTDLY values for the visited systems with respect to reference receiver. (all values in ns).

Pair	**Date**	**CABDLY$_V$**	**CABDLY$_R$**	**Note**	**E1 (ns)**		**E5 (ns)**	
					ΔSYSDLY	**ΔINTDLY**	**ΔSYSDLY**	**ΔINTDLY**
NISQ-BP21 via BP2G	2023.8	199.60	140.80		61.57	2.77	55.78	-3.02
NISQ-BP21 via BP2D	2023.8	199.60	140.80		61.74	2.94	55.75	-3.05
NISX-BP21 via BP2G	2023.8	275.50	140.80		135.03	0.33	135.77	1.07
NISX-BP21 via BP2D	2023.8	275.50	140.80		135.09	0.39	135.77	1.07
NISP-BP21 via BP2G	2023.8	199.60	140.80		63.22	4.42	59.11	0.31
NISP-BP21 via BP2D	2023.8	199.60	140.80		63.24	4.44	58.92	0.12
NISG-BP21 via BP2G	2023.8	298.50	140.80		160.14	2.44	160.08	2.38
NISG-BP21 via BP2D	2023.8	298.50	140.80		160.18	2.48	159.83	2.13
NISK-BP21 via BP2G	2023.8	298.90	140.80		154.37	-3.73	153.37	-4.73
NISK-BP21 via BP2D	2023.8	298.90	140.80		154.44	-3.66	153.26	-4.84
US10-BP21 via BP2G	2023.6	0.00	140.80		30.15	170.95	31.61	172.41
US10-BP21 via BP2D	2023.6	0.00	140.80		30.09	170.89	31.80	172.60
US09-BP21 via BP2G	2023.6	0.00	140.80		35.52	176.32	36.70	177.50
US09-BP21 via BP2D	2023.6	0.00	140.80		35.45	176.25	36.88	177.68

Table 14: Computed Beidou ΔINTDLY values for the visited systems with respect to reference receiver. (all values in ns).

Pair	**Date**	**CABDLY$_V$**	**CABDLY$_R$**	**Note**	**BC (ns)**		**B5 (ns)**	
					ΔSYSDLY	**ΔINTDLY**	**ΔSYSDLY**	**ΔINTDLY**
NISQ-BP21 via BP2G	2023.8	199.60	140.80		61.87	3.07	55.78	-3.02
NISQ-BP21 via BP2D	2023.8	199.60	140.80		62.02	3.22	55.77	-3.03
NISX-BP21 via BP2G	2023.8	275.50	140.80		135.08	0.38	135.69	0.99
NISX-BP21 via BP2D	2023.8	275.50	140.80		135.13	0.43	135.74	1.04
NISP-BP21 via BP2G	2023.8	199.60	140.80		63.59	4.79	59.11	0.31
NISP-BP21 via BP2D	2023.8	199.60	140.80		63.62	4.82	58.95	0.15
NISG-BP21 via BP2G	2023.8	298.50	140.80		160.12	2.42	159.74	2.04
NISG-BP21 via BP2D	2023.8	298.50	140.80		160.05	2.35	159.52	1.82
NISK-BP21 via BP2G	2023.8	298.90	140.80		154.07	-4.03	153.06	-5.04
NISK-BP21 via BP2D	2023.8	298.90	140.80		154.07	-4.03	152.98	-5.12
US09-BP21 via BP2G	2023.6	0.00	140.80		35.58	176.38	36.69	177.49
US09-BP21 via BP2D	2023.6	0.00	140.80		35.53	176.33	36.89	177.69

Table 15: Provisional GPS INTDLY values of Visited systems (all values in ns).

Pair	Date	Note	C1 $INTDLY_v$	P1 $INTDLY_v$	P2 $INTDLY_v$	P3 $INTDLY_v$
NISQ vs BP21	2023.8		33.47	31.20	22.62	44.47
Δ(BP2G-BP2D)			0.02	-0.18	-0.25	-0.09
NISP vs BP21	2023.8		35.07	32.71	25.41	44.00
Δ(BP2G-BP2D)			0.13	-0.03	-0.03	-0.03
NISX vs BP21	2023.8		30.97	28.81	26.63	32.19
Δ(BP2G-BP2D)			0.09	-0.07	-0.12	0.01
NISG vs BP21	2023.8		33.12	30.76	29.28	33.04
Δ(BP2G-BP2D)			0.13	-0.03	-0.06	0.00
NISK vs BP21	2023.8		26.91	24.30	24.18	24.47
Δ(BP2G-BP2D)			0.09	-0.08	0.03	-0.25
US06 vs BP21	2023.6	1	-7.00	-7.81	-9.94	-4.53
Δ(BP2G-BP2D)			0.22	0.14	0.24	-0.03
US09 vs BP21	2023.6	1	206.82	204.63	200.80	210.55
Δ(BP2G-BP2D)			0.29	0.13	0.25	-0.07
US10 vs BP21	2023.6	1	201.43	199.20	196.45	203.46
Δ(BP2G-BP2D)			0.29	0.12	0.25	-0.08

1: CABDLY of the receiver was not reported, values are SYSDLYs.

4.4 Provisional INTDLY Values of Visited Systems

Tables 15 16 17 list INTDLY values of the visited systems. These values are provisional and based on INTDLY values for BP21(C1=30.6 ns; P1=28.4 ns; P2=27.3 ns; E1=30.7 ns; E5=30.9 ns; BC=30.4 ns; B5=30.3 ns) from 1001-2020, as described in BIPM Technical Memorandum 266. Final INTDLY values will be based on minimizing changes between 1001-2020 and 1001-2022, as described in BIPM Technical Memorandum 266, and will be reported in the global report of the trip 1001-2022 available here.

Since two results can be computed from Tables 12 13 14, using either BP2G or BP2D as traveling system, the values in Tables 15 16 17 are the average of the two results, and the difference between the two is indicated. We note that the difference Δ(BP2G-BP2D) is typically of order X.X ns. It is taken into account in component ub,1 of the uncertainty budget in Tables 18,19 and 20.

Table 16: Provisional Galileo INTDLY values of Visited systems (all values in ns).

Pair	**Date**	**Note**	**E1** $\mathbf{INTDLY}_v$	**E5** $\mathbf{INTDLY}_v$	**E3** $\mathbf{INTDLY}_v$
NISQ vs BP21	2023.8		33.55	27.86	40.73
Δ(BP2G-BP2D)			-0.17	0.03	-0.41
NISP vs BP21	2023.8		35.13	31.11	40.19
Δ(BP2G-BP2D)			-0.03	0.20	-0.30
NISX vs BP21	2023.8		31.06	31.97	29.91
Δ(BP2G-BP2D)			-0.05	-0.00	-0.12
NISG vs BP21	2023.8		33.16	33.15	33.17
Δ(BP2G-BP2D)			-0.04	0.25	-0.41
NISK vs BP21	2023.8		27.01	26.11	28.13
Δ(BP2G-BP2D)			-0.07	0.12	-0.31
US09 vs BP21	2023.6	1	206.99	208.49	205.09
Δ(BP2G-BP2D)			0.06	-0.19	0.38
US10 vs BP21	2023.6	1	201.62	203.41	199.36
Δ(BP2G-BP2D)			0.06	-0.19	0.37

1: CABDLY of the receiver was not reported, values are SYSDLYs.

Table 17: Provisional Beidou INTDLY values of Visited systems (all values in ns).

Pair	**Date**	**Note**	**BC** $\mathbf{INTDLY}_v$	**B5** $\mathbf{INTDLY}_v$	**B3** $\mathbf{INTDLY}_v$
NISQ vs BP21	2023.8		33.55	27.27	41.45
Δ(BP2G-BP2D)			-0.16	0.00	-0.36
NISP vs BP21	2023.8		35.21	30.53	41.10
Δ(BP2G-BP2D)			-0.03	0.16	-0.26
NISX vs BP21	2023.8		30.80	31.32	30.16
Δ(BP2G-BP2D)			-0.05	-0.05	-0.05
NISG vs BP21	2023.8		32.78	32.23	33.48
Δ(BP2G-BP2D)			0.07	0.22	-0.12
NISK vs BP21	2023.8		26.37	25.22	27.81
Δ(BP2G-BP2D)			-0.00	0.08	-0.11
US09 vs BP21	2023.6	1	206.75	207.89	205.32
Δ(BP2G-BP2D)			0.05	-0.20	0.37

1: CABDLY of the receiver was not reported, values are SYSDLYs.

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.

$$u_{CAL0} = \sqrt{u_a^2 + u_b^2} \tag{4}$$

with the statistical uncertainty ua and the systematic uncertainty ub. (all are 1-sigma). For frequency dependent error the error are estimated for the single channel. In case a values for the ionofree combination can not be directly derived an upper bound considering the most unfavourable correlation is computed as:

$$u_{if} = \sqrt{(\alpha u_1)^2 + (\beta u_2)^2 + 2\alpha\beta min(u_1, u_2)} \tag{5}$$

where α and β are the ionofree coefficients ($\alpha = 2.5457$, $\beta = 1.5457$ for GPS and $\alpha = 2.2606$, $\beta = 1.2606$ for Galileo and Beidou).
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 18 for GPS, Table 19 for Galileo and 20 for Beidou 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 for GPS) so as to compute a value u_{CAL} applicable to P3 links. We choose to compute U_{CAL} using for ub the uncertainty ubSYS of ΔSYSDLY$_{V-R}$ from equation 2[1]. Tables 18,19,20 presents all components of the uncertainty budget along with the uncertainty u_{bSYS} of ΔSYSDLY$_{V-R}$ from equation 2 and the resulting uncertainty value U_{CAL}. The values u_{CAL} from Tables 18,19,20 are applicable either to single frequency code (C1,P1,E1 and BC) or dual-frequency code or PPP links (P3,E3 and B3). 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.
The components in Tables 18, 19 and 20 are separated in several categories:

- The u_a value for P3, E3, B3 is conservatively estimated from the linear combination of P1, E1, BC and P2, E5, B5 values. Lower values would be obtained from a statistical analysis of P3,E3,B3 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 (see Tables 6,7 and 8).

- $u_{b,11}$ and $u_{b,12}$ account for errors in the differential position (Travel – Local). They are conservatively estimated to be 1.5 cm (50 ps) to account for possible sub-nominal behavior of the baseline determination occasionally observed in the DCLRINEX software. The L5,E5 baseline used for Galileo processing is determined from L5,E5 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.

[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 18: Uncertainty contributions.

Unc.	**Value C1/P1 (ns)**	**Value 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	0.6	See text below
Misclosures				
$u_{b,1}$	0.2	0.1	0.8	observed misclosures
Systematic components related to RAWDIF				
$u_{b,11}$	0.05	0.05	0.2	Position error at reference
$u_{b,12}$	0.05	0.05	0.2	Position error at visited
$u_{b,13}$	0.2	0.2	0.8	Multipaths at reference
$u_{b,14}$	0.2	0.2	0.8	Multipaths at visited
Link of the Traveling system to the local UTC(k)				
$u_{b,21}$	0.5	0.5	0.5	REFDLY$_T$(at ref lab)
$u_{b,22}$	0.5	0.5	0.5	REFDLY$_T$(at visted lab)
$u_{b,TOT}$	0.8	0.8	1.6	
Link of the Reference system to its local UTC(k)				
$u_{b,31}$	0.5	0.5	0.5	REFDLY$_R$(at ref lab)
Link of the Visited system to its local UTC(k)				
$u_{b,32}$	0.5	0.5	0.5	REFDLY$_V$(at visited lab)
$u_{b,SYS}$	1.1	1.0	1.7	Components of equation 2
u_{CAL}	1.1		1.8	Composed of u_a and $u_{b,SYS}$

- $u_{b,31}$ 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.

Table 19: Uncertainty contribution.

Unc.	**Value E1 (ns)**	**Value 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	0.5	See text below
Misclosures				
$u_{b,1}$	0.2	0.4	0.1	observed misclosures
Systematic components related to RAWDIF				
$u_{b,11}$	0.05	0.05	0.2	Position error at reference
$u_{b,12}$	0.05	0.05	0.2	Position error at visited
$u_{b,13}$	0.2	0.2	0.7	Multipaths at reference
$u_{b,14}$	0.2	0.2	0.7	Multipaths at visited
Link of the Traveling system to the local UTC(k)				
$u_{b,21}$	0.5	0.5	0.5	REFDLY$_T$(at ref lab)
$u_{b,22}$	0.5	0.5	0.5	REFDLY$_T$(at visted lab)
$u_{b,TOT}$	0.8	0.9	1.3	
Link of the Reference system to its local UTC(k)				
$u_{b,31}$	0.5	0.5	0.5	REFDLY$_R$(at ref lab)
Link of the Visited system to its local UTC(k)				
$u_{b,32}$	0.5	0.5	0.5	REFDLY$_V$(at visited lab)
$u_{b,SYS}$	1.1	1.1	1.4	Components of equation 2
u_{CAL}	1.1		1.5	Composed of u_a and $u_{b,SYS}$

Table 20: Uncertainty contributions.

Unc.	**Value BC (ns)**	**Value B5 (ns)**	**Value B3 (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	0.5	See text below
Misclosures				
$u_{b,1}$	0.2	0.4	0.1	observed misclosures
Systematic components related to RAWDIF				
$u_{b,11}$	0.05	0.05	0.2	Position error at reference
$u_{b,12}$	0.05	0.05	0.2	Position error at visited
$u_{b,13}$	0.2	0.2	0.7	Multipaths at reference
$u_{b,14}$	0.2	0.2	0.7	Multipaths at visited
Link of the Traveling system to the local UTC(k)				
$u_{b,21}$	0.5	0.5	0.5	REFDLY$_T$(at ref lab)
$u_{b,22}$	0.5	0.5	0.5	REFDLY$_T$(at visted lab)
$u_{b,TOT}$	0.8	0.9	1.2	
Link of the Reference system to its local UTC(k)				
$u_{b,31}$	0.5	0.5	0.5	REFDLY$_R$(at ref lab)
Link of the Visited system to its local UTC(k)				
$u_{b,32}$	0.5	0.5	0.5	REFDLY$_V$(at visited lab)
$u_{b,SYS}$	1.1	1.1	1.4	Components of equation 2
u_{CAL}	1.1		1.5	Composed of u_a and $u_{b,SYS}$