Continuity of GNSS "INTDLY" values of Group 1 geodetic receivers in successive Group 1 trips

Introduction

TM243 has described the procedure to choose reference values for GPS "INTDLY" of Group 1 (hereafter G1) geodetic receivers participating in the initial G1 trip 1001-2014, covering P1/P2 as well as C1 values.

The Calibration Guidelines state:" *Because we do not have (so far) an absolute reference, we propose to consider that the ensemble of the "Group 1" systems is itself the reference. There are several possible implementations: e.g. for each new "Group 1" calibration trip, the delay values will be set so as to minimize, for the ensemble of participating "Group 1" systems, the variations of the values with respect to the previous calibration results.*"

This TM describes the procedure used to realize this goal.
Part A explains the general methodology. In Part B, the procedure is applied to derive the results of the second G1 trip (1001-2016) in continuity to the first trip (1001-2014). In Part C, the procedure is applied to derive the results of the third G1 trip (1001-2018) in continuity to the second trip (1001-2016).

In June 2020, the CCTF WG on GNSS decided to extend the G1/G2 calibration scheme to Galileo and fixed the initial reference for G1 Galileo results. This TM is then extended accordingly.

Version history
V0 2016/12/16: Continuity of 1001-2016 results with respect to 1001-2014: Draft
V1 2017/01/17: Corrected minor typos. Added Median in Table 3, following Pascale Defraigne's suggestion, for future studies.
V1.2 2017/02/10: Results for NC5G and NC4C changed to account for measured CABDLY values.
V1.3 2017/06/22: Corrected minor typos. Inclusion of SIM results in section B.4 and new statistical study in B5. Annex 2 completed for SIM results.
V2.1 2018/10/19: Continuity of 1001-2018 results with respect to 1001-2016 for APMP (section C.1).
V2.2 2019/03/15: Continuity of 1001-2018 results with respect to 1001-2016 for EURAMET (section C.3).
V2.3 2019/10/21: Continuity of 1001-2018 results with respect to 1001-2016 for COOMET (section C.2) and SIM (section C.4).
V2.4 2020/03/13: Statistical study on the continuity of 1001-2018 results with respect to 1001-2016 (section C.5).
V2.5 2020/06/30: Reformulation to extend the procedure from GPS to GNSS, with first application to Galileo. Publication of 1001-2018 Galileo results (section C.6).
V3.1 2021/01/29: Continuity of 1001-2020 results with respect to 1001-2018 for APMP (section D.1).
V3.2 2021/06/23: Continuity of 1001-2020 results with respect to 1001-2018 for EURAMET (section D.2).
V3.3 2022/05/05: Continuity of 1001-2020 results with respect to 1001-2018 for SIM (section D.3) and statistical study on the continuity of 1001-2020 results with respect to 1001-2018 (section D.4).
V3.4 2022/06/10: Correction of a typo for NC4S E5a value in Annex 4.
V3.5 2022/10/13: Continuity of 1001-2020 results with respect to 1001-2018 for COOMET (section D.5).
V3.6 2023/03/09: Corrigendum: SU04 delays value.
V3.7 2023/04/04: Mention of the unchanged reference for COOMET values.

A. Methodology

Let IDXXp(k) be the previous value of INTDLY for receiver k for code XX (P1,P2,C1…), obtained from previous calibration, and IDXXn(k) the desired new value of INTDLY, result of the new calibration.

The principle is to define IDXXn(k) as follows:

1. Obtain intermediate results IDXXi(k) for the new calibration using as a reference IDXXp(REF) where REF is a receiver at the BIPM which was part of the results of the previous calibration and is now used to compute a closure of the new calibration;
2. Compute the changes dIDXX(k) = (IDXXi(k)- IDXXp(k));
3. Compute an average change DIDXX(K) = <dIDXX(k)> on a set K of receivers that took part to both the previous and the new calibration;
4. Set IDXXn(k) = IDXXi(k) - DIDXX(K) for all receivers in the new calibration.

Several questions may be explored and some of them are examined in this document:

a) Should the set K represent the maximum possible set of G1 receivers (all of them)? A complete G1 trip involves, so far, three continents, 10 international travels, and numerous customs. It has been found more secure and practical to break it into several sub-trips with intermediate returns at the BIPM, which still adds to the total duration. If K should represent all G1, final results cannot be provided before the full completion of the trip which total duration is not anticipated to be below 6 months in any foreseeable future. It is likely that the full 2016 trip will last close to one year so that some labs could wait final results for one year. An alternative is to provide results for subsets K corresponding to each intermediate return to the BIPM, i.e. in 2016 successive results for APMP, EURAMET and SIM.
b) How should the average change DIDXX(K) be computed exactly? Should all available receivers have the same weight? Should it be a simple average or some other norm?
c) Should this procedure be applied independently for each code? An alternative for P1/P2 may be to add an additional constraint based on P3 (this would be redundant in case a simple average is used because P3 is a linear combination of P1 and P2).
d) Should receivers for which only TOTDLY is available be included if the set-up has not changed?
e) Should receivers which were not part to the previous calibration, but have been aligned to calibrated receivers, be included?

In practice, the most important question is (a) because it conditions the availability of new calibration results to the G1 labs. In principle, it is proposed to publish the results of a G1 trip for each subset K between two successive returns at the BIPM and to study the effect of this choice after the full completion of the trip. For the 2016 trip, however, the first two legs (APMP and EURAMET) have been joined in a subset to obtain the first release of results (V1 of this TM). Then this TM will be updated after each subset and after the completion of the trip.

B. Results of 1001-2016 from 1001-2014 (GPS)

Group 1 laboratories were chosen during 2014. They are

- For EURAMET: OP, PTB, ROA
- For APMP: NICT, NIM, TL
- For SIM: NIST, USNO
- For COOMET: SU

Final results of the 1001-2014 calibration are recalled in Annex 1 for P1, P2 and C1.

B.1. The APMP part of 1001-2016

The report of the APMP part of 1001-2016 is here. It includes three Group 1 laboratories and ten receivers, some of them were present in 1001-2014, or were directly aligned to receivers present in 1001-2014 (see Table B.1). The BIPM reference receiver (BP0R) is also common to both trips.

Table B.1 indicates under **IDXXp** the 1001-2014 results and under **dIDXX** the change in INTDLY (1001-2016 minus 1001-2014). The last line provides **DIDXX(APMP)** computed as the simple average of all **dIDXX** values. Note that DIDP3 is equal to 0.1 ns when computed with TLT1 and equal to 0.2 ns when computed without TLT1. In the following, TLT1 will not be considered as its values for P1, P2 and C1 are not available because TLT1 was aligned only in P3.

Table B.1. List of 1001-2014 INTDLY values and differences **dIDXX** (1001-2016 – 1001-2014) for APMP.

System	Note	P1		P2		C1		P3	
		IDP1p	**dIDP1**	**IDP2p**	**dIDP2**	**IDC1p**	**dIDC1**	**IDP3p**	**dIDP3**
BIPM									
BP0R	REF	222.6	0.0	224.8	0.0	225.8	0.0		0.0
TL									
TLT1	(1) TWTF	N/A	N/A	N/A	N/A	N/A	N/A	400.8	-0.3
NICT									
NC01	(2) NC02	217.4	+1.0	222.3	+0.4	???	???	209.8	+1.9
NIM									
IMEJ	(3)	0.0	+0.8	0.0	+1.3	-1.3	+0.8	0.0	-0.1
IMEU		-25.7	-1.7	-12.7	-1.4	-23.8	-1.9	-45.8	-2.0
BJNM		74.0	+1.4	81.7	+1.6	75.8	+1.4	62.1	+1.0
Average			+0.3		+0.4		+0.1		+0.1/+0.2

(1) Calibration transferred from TWTF to TLT1 by TL. Values are TOTDLY and only P3 is meaningful.
(2) Calibration transferred from NC02 to NC01 by NICT
(3) P1/P2 results of 1001-2014 are entered and used in the receiver (GTR50), thus appear as 0.0.

Computing IDXXn(k) = IDXXi(k) - DIDXX(APMP) for each code, one would obtain results based on minimizing the changes on APMP.

B.2. The EURAMET part of 1001-2016

The report of the EURAMET part of 1001-2016 is here. It includes three Group 1 laboratories and thirteen receivers, some of them were present in 1001-2014, or were directly aligned to receivers present in 1001-2014 (see Table B.2). The BIPM reference receiver (BP0R) is also common to both trips.
Table B.2 indicates under **IDXXp** the 1001-2014 results and under **dIDXX** the change in INTDLY (1001-2016 minus 1001-2014). The last line provides **DIDXX(EURAMET)** computed as the simple average of all **dIDXX** values.

Table B.2. List of 1001-2014 INTDLY values and differences **dIDXX** (1001-2016 – 1001-2014) for EURAMET.

System	Note	P1		P2		C1		P3	
		IDP1p	**dIDP1**	**IDP2p**	**dIDP2**	**IDC1p**	**dIDC1**	**IDP3p**	**dIDP3**
BIPM									
BP0R	REF	222.6	0.0	224.8	0.0	225.8	0.0		0.0
OP									
OPMT		310.2	-1.1	321.6	-0.3	311.0	-1.3	292.6	-2.4
PTB									
PT02		303.9	+0.7	319.3	+0.9	304.4	+0.8	280.1	+0.5
PT03		301.0	+0.6	323.5	+0.8	301.1	+0.7	266.2	+0.2
ROA									
RO_5	(1)	0.0	+0.0	0.0	+0.5	+1.7	-0.1	0.0	-0.7
RO_6	(2)	50.0	-0.3	48.4	+0.4	N/A		52.5	-1.4
Average			+0.0		+0.4		+0.0		-0.6

(1) P1/P2 results of 1001-2014 are entered and used in the receiver (GTR50), thus appear as 0.0.
(2) Firmware was upgraded on MJD 57582, resulting in changes of -4.8 ns in P1 and -3.6 ns in P2 (info from H. Esteban, ROA). This change is taken into account in the IDP1p and IDP2p values.

Computing IDXXn(k) = IDXXi(k) - DIDXX(EURAMET) for each code, one would obtain results based on minimizing the changes on EURAMET.

B.3. 1001-2016 results from merging APMP and EURAMET

From the results in the previous sections, we see that the final values will vary by fractions of a nanosecond (e.g. 0.0 to +0.3 ns in P1, -0.6 to +0.2 ns in P3) between minimizing the changes on APMP only, on EURAMET only, or on (APMP+EURAMET). Assembling all ten receivers for which continuity can be traced between 1001-2014 and 1001-2016 in a single ensemble in principle provides the most robust solution. In Table B.3.1, we summarize the individual changes and statistical estimators related to this choice.

Table B.3.1. List of differences **dIDXX** (1001-2016 – 1001-2014) and statistical values (all in ns).

System	dIDP1	dIDP2	dID(P1-P2)	dIDC1	dIDP3
BP0R	0.0	0.0	0.0	0.0	0.0
NC01	+1.0	+0.4	+0.6	N/A	+1.9
IMEJ	+0.8	+1.3	-0.5	+0.8	-0.1
IMEU	-1.7	-1.4	-0.3	-1.9	-2.0
BJNM	+1.4	+1.6	-0.2	+1.4	+1.0
OPMT	-1.1	-0.3	-0.8	-1.3	-2.4
PT02	+0.7	+0.9	-0.2	+0.8	+0.5
PT03	+0.6	+0.8	-0.2	+0.7	+0.2
RO_5	+0.0	+0.5	-0.5	-0.1	-0.7
RO_6	-0.3	+0.4	-0.7	N/A	-1.4
Mean	**+0.1**	**+0.4**	**-0.3**	**+0.1**	**-0.3**
Std Dev	1.0	0.9	0.4	1.1	1.3
Median	**(0.0,0.6)**	**(0.4,0.5)**	**(-0.3,-0.2)**	**(0.0,0.7)**	**(-0.1,0.0)**

Computing IDXXn(k) = IDXXi(k) - DIDXX(APMP+EURAMET) for each code, using for DIDXX the **Mean** values of Table B.3.1, one obtains results for the APMP+EURAMET parts of the 1001-2016 campaign shown in Table B.3.2. Results for the Group 2 laboratory NTSC are also indicated for completeness.

Table B.3.2. Results of the APMP+EURAMET parts of the 1001-2016 Group 1 calibration (all values in ns).

System	Date	INTDLY P1	INTDLY P2	INTDLY C1
BP0R		222.5	224.4	225.7
BP1J	2016.9	53.0	52.6	54.4
TLT1 (1)	2016.2	415.0	424.1	414.9
TLT2	2016.2	-35.2	-36.2	-33.4
TLT3 (3)	2016.2	-5.7	-9.6	-6.9
NC01	2016.3	218.3	222.4	221.4
NC5G (3)	2016.3	5.9	12.7	-1.5
NC4C	2016.3	54.9	53.3	56.4
NC4S (2)	2016.3	276.8	276.3	278.2
IMEJ (3)	2016.5	0.7	0.9	-0.6
IMEU	2016.5	-27.5	-14.5	-25.8
BJNM	2016.5	75.3	82.9	77.1
NTP1	2016.6	55.7	55.1	57.4
NTP2	2016.6	55.5	54.2	57.3
NTP3	2016.6	53.1	52.2	54.6
RO_5 (3)	2016.8	-0.1	0.1	1.5
RO_6	2016.8	49.6	48.5	51.0
RO_7	2016.8	54.9	53.8	56.2
RO_8 (3)	2016.8	-0.3	0.2	-42.3
RO_9	2016.8	55.9	55.1	56.6
PT02	2016.8	304.5	319.8	305.1
PT03	2016.8	301.5	323.9	301.7
PT07 (3)	2016.8	-0.6	-0.5	-3.0
PT09	2016.8	56.0	55.2	57.3
PT10 (3)	2016.8	0.3	0.0	-4.0
OPMT	2016.9	309.0	320.9	309.6
OP71	2016.9	55.7	54.4	57.1
OPM9	2016.9	-33.7	-37.0	-31.7

(1) Results for TLT1 are Total Delay values (TOTDLY).
(2) Results for NC4S are System Delay values (SYSDLY).
(3) Results are changes with respect to values entered in the receiver

B.4. The SIM part of 1001-2016

The report of the SIM part of 1001-2016 is here. It includes two Group 1 laboratories and six receivers, some of them were present in 1001-2014, or were directly aligned to receivers present in 1001-2014 (see Table B.4). The BIPM reference receiver (BP0R) is also common to both trips.
Table B.4 indicates under **IDXXp** the 1001-2014 results and under **dIDXX** the change in INTDLY (provisional 1001-2016 minus 1001-2014). The last two lines provide **DIDXX(SIM)** computed as the simple average of **dIDXX** values. In the first of the two lines all **dIDXX** values are used while in the second one NIS3 is excluded from the average, as it appears that NIS3 results seem affected by a significant offset.

Table B.4.1. List of 1001-2014 INTDLY values and differences **dIDXX** (1001-2016 – 1001-2014) for SIM.

System	Note	P1		P2		C1		P3	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDP3p	dIDP3
BIPM									
BP0R	REF	222.6	0.0	224.8	0.0	225.8	0.0		0.0
USNO									
USN6		-6.5	+0.7	-9.6	+1.4	-6.5	+1.1	-1.8	-0.2
USN7		-6.1	+0.9	-9.1	+1.4	-4.9	+1.0	-1.4	+0.1
NIST									
NIST		-72.0	-0.6	-71.8	+0.1	-72.0	-0.2	-72.4	-1.5
NIS3		-8.6	+2.5	-20.6	+3.7	-8.6	+3.0	10.0	+0.7
NIS4		-9.8	-0.2	-21.3	+0.1	-9.8	+0.3	8.0	-0.8
Average			+0.5		+1.1		+0.9		-0.3
NIS3 excl.			+0.2		+0.6		+0.4		-0.5

Computing IDXXn(k) = IDXXi(k) - DIDXX(SIM) for each code, one obtains results based on minimizing the changes on SIM. Final results for SIM are listed in Table B.4.2 and are based on DIDXX(SIM) excluding the receiver NIS3, i.e. the values in the last line of Table B.4.1.

Table B.4.2. Results of the SIM part of the 1001-2016 Group 1 calibration (all values in ns).

System	Date	INTDLY P1	INTDLY P2	INTDLY C1
BP0R		222.4	224.2	225.4
USN6 (1)	2017.2	-6.0	-8.8	-5.8
USN7 (1)	2017.2	-5.4	-8.3	-4.3
NIST	2017.3	-72.8	-72.3	-72.6
NISS	2017.3	44.4	44.8	46.1
NIS3	2017.3	-6.3	-17.5	-6.1
NIS4	2017.3	-10.2	-21.8	-10.0

(1) For USN6 and USN7, results are changes with respect to values entered in the receiver.

B.5. Statistical study of merging APMP, EURAMET and SIM

From the results in Tables B.1 (APMP), B.2 (EURAMET) and B.4.1 (SIM), we see that the final values will vary by fractions of a nanosecond (e.g. 0.0 to +0.5 ns in P1, -0.6 to +0.2 ns in P3) between minimizing the changes on APMP only, on EURAMET only, or on SIM only. Assembling all fourteen receivers for which continuity can be traced between 1001-2014 and 1001-2016 in a single ensemble in principle provides the most robust solution. In Table B.5, we summarize the individual changes and statistical estimators related to this choice. We see that the statistical results obtained from 14 receivers are similar to those obtained for 10 receivers in section B.3.

Table B.5. List of differences **dIDXX** (1001-2016 – 1001-2014) and statistical values (all in ns).

System	dIDP1	dIDP2	dID(P1-P2)	dIDC1	dIDP3
BP0R	0.0	0.0	0.0	0.0	0.0
NC01	+1.0	+0.4	+0.6	N/A	+1.9
IMEJ	+0.8	+1.3	-0.5	+0.8	-0.1
IMEU	-1.7	-1.4	-0.3	-1.9	-2.0
BJNM	+1.4	+1.6	-0.2	+1.4	+1.0
OPMT	-1.1	-0.3	-0.8	-1.3	-2.4
PT02	+0.7	+0.9	-0.2	+0.8	+0.5
PT03	+0.6	+0.8	-0.2	+0.7	+0.2
RO_5	+0.0	+0.5	-0.5	-0.1	-0.7
RO_6	-0.3	+0.4	-0.7	N/A	-1.4
USN6	0.7	1.4	-0.7	1.1	-0.2
USN7	0.9	1.4	-0.5	1	0.1
NIST	-0.6	0.1	-0.7	-0.2	-1.5
NIS4	-0.2	0.1	-0.3	0.3	-0.8
Mean	**+0.2**	**+0.5**	**-0.3**	**+0.2**	**-0.4**
Unc of mean	0.3	0.3	0.1	0.4	0.4
Std Dev	1.0	0.9	0.4	1.1	1.3
Median	**(0.0,0.6)**	**(0.4,0.5)**	**(-0.5,-0.3)**	**(0.3,0.7)**	**(-0.2,-0.1)**

B.6. The COOMET part of 1001-2016

It was not possible to include a trip to COOMET (SU) in the 1001-2016 exercise.

B.7. Comparison of results and discussion

As noted in section B.3 and B5, the final INTDLY values for each code will vary by fractions of a nanosecond depending on the ensemble of receivers on which it is chosen to minimize the changes between the previous and the current calibration exercises. Table B.7 summarizes the results obtained for 1001-2016 with respect to 1001-2014 for different choices of the ensemble of receivers taken as reference.
Obviously such a choice does not affect the results for links between G1 receivers in each subgroup. But it affects results for links between G1 receivers in different subgroups, or between G1 receivers and G2 receivers calibrated with respect to another subgroup. Nevertheless the variations associated to such choices remain well below 1 ns, even for the P3 combination, if using an ensemble of 4-5 receivers in three different laboratories as a reference. If using a single receiver as a reference, variations of order 1.0 ns RMS for each code and of order 1.3 ns RMS for P3 may be expected. This is to be compared to the standard uncertainties from calibration, which are presently of order 1.5 ns for links between Group 1 receivers and 2.5 ns for any link involving a Group 2.

It is thus expected that results for future Group1 trips may be provided for each sub-group at each intermediate closure at the BIPM, provided that an ensemble of order five receivers from some three laboratories is common to the current and previous trips.

Table B.7. List of differences **DIDXX** (1001-2016 – 1001-2014) computed with different ensembles (all in ns).

Ensemble	# rec	DIDP1	DIDP2	DIDC1	DIDP3
APMP	5	+0.3	+0.4	+0.1	+0.2
EURAMET	6	0.0	+0.4	0.0	-0.6
APMP+EURAMET	10	+0.1	+0.4	+0.1	-0.3
SIM	5	+0.2	+0.6	+0.4	-0.5
APMP+EURAMET+SIM	14	+0.2	+0.5	+0.2	-0.4
COOMET					

Final results for 1001-2016 are shown in Annex 2

C. Results of 1001-2018 for GPS (from 1001-2016) and for Galileo

Group 1 laboratories have not changed since 2014. They are

- For EURAMET: OP, PTB, ROA
- For APMP: NICT, NIM, TL
- For SIM: NIST, USNO
- For COOMET: SU

Final results of the 1001-2016 calibration are recalled in Annex 2 for P1, P2 and C1. Sections C.1 to C.4 provide the GPS results for the four legs of the calibration trip. Section C.5 is a statistical study of the global stability of GPS IntDly values between 2016 and 2018. Section C.6 provides the Galileo results.

C.1. The APMP part of 1001-2018

The report of the APMP part of 1001-2018 is here. It includes three Group 1 laboratories and fourteen receivers, seven of them were present in 1001-2016 (see Table C.1). Note that receiver IMEU from NIM is present with the same acronym in 1001-2016 and 1001-2018 but had internal modifications and cannot be used in the comparison (communicated by K. Liang, NIM). The BIPM reference receiver (BP1J) and the former BIPM reference in 1001-2016 (BP0R) are also common to both trips and used in the adjustment.
Table C.1 indicates under **IDXXp** the 1001-2016 results and under **dIDXX** the change in INTDLY (1001-2018 minus 1001-2016). The last lines provides **DIDXX(APMP)** computed as the simple average of all **dIDXX** values and as the median value.

Table C.1. List of 1001-2016 INTDLY values and differences **dIDXX** (1001-2018 – 1001-2016) for APMP. All values in ns.

System	Note	P1		P2		C1		P3	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDP3p	dIDP3
BIPM									
BP1J	REF	53.0	0.0	52.6	0.0	54.4	0.0	53.6	0.0
BP0R		222.5	+0.2	224.4	+0.1	225.7	+0.2	219.6	+0.4
TL									
TLT1	(1)	415.0	+0.3	424.1	+0.2	414.9	+0.2	400.9	+0.5
TLT2		-35.2	-0.4	-36.2	-0.3	-33.4	-0.4	-33.7	-0.6
NICT									
NC01		218.3	+0.0	222.4	+0.1	221.4	+0.2	212.0	-0.2
NC5G	(3)	0.0	+0.1	0.0	+0.2	0.0	+0.0	0.0	-0.1
NC4S	(2)	276.8	-0.1	276.3	+0.1	278.2	-0.1	277.6	-0.4
NIM									
IMEJ	(3)	0.0	-0.5	0.0	-0.5	0.0	-0.6	0.0	-0.5
BJNM		75.3	-0.9	82.9	-1.2	77.1	-1.0	63.6	-0.4
Average			-0.14		-0.14		-0.17		-0.14
Median			0.0		+0.1		0.0		-0.2

(1) Values are TOTDLY.
(2) Values are SYSDLY
(3) Results of 1001-2016 are entered and used in the receiver (GTR50), thus appear as 0.0.

Computing IDXXn(k) = IDXXi(k) - DIDXX(APMP) for each code, one would obtain results based on minimizing the changes on APMP.
Because the values **DIDXX(APMP)** are so small (-0.1 to -0.2 ns for the mean, 0.0 to 0.1 ns for the median), we propose to take them as zero and to consider the results in the report of the APMP part of 1001-2018 (here) as final. See the list in Annex 3.

C.2. The COOMET part of 1001-2018

The report of the COOMET part of 1001-2018 is here. It includes only one Group 1 laboratory with only one receiver (outside the BIPM) previously calibrated, and that was in 1001-2014, not 1001-2016. The BIPM reference receiver (BP1J) and the former BIPM reference in 1001-2016 (BP0R) are also common to both trips. Given the low number of common receivers, no adjustment is performed and final values are taken from the report of the COOMET part of 1001-2018 (here).
Table C.2 is included for the record. It indicates under **IDXXp** the 1001-2016 results and under **dIDXX** the change in INTDLY (1001-2018 minus 1001-2016). The last lines provides **DIDXX(COOMET)** computed as the simple average of all **dIDXX** values and as the median value.

Table C.2. List of 1001-2016 INTDLY values and differences **dIDXX** (1001-2018 – 1001-2016) for COOMET. All values in ns.

System	Note	P1		P2		C1		P3	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDP3p	dIDP3
BIPM									
BP1J	REF	53.0	0.0	52.6	0.0	54.4	0.0	53.6	0.0
BP0R		222.5	+0.1	224.4	+0.0	225.7	+0.1	219.6	+0.3
SU									
SU19	(1)	-29.0	-1.3	-27.5	-1.4	-27.3	-1.0	-31.3	-1.1
Average			-0.40		-0.47		-0.30		-0.30
Median			0.0		+0.1		0.0		0.0

(1) Reference value for SU19 is from the 1001-2014 trip.

C.3. The EURAMET part of 1001-2018

The report of the EURAMET part of 1001-2018 is here. It includes three Group 1 laboratories and fourteen receivers, twelve of them were present in 1001-2016 (see Table C.3). However some changes occurred between 1001-2016 and 1001-2018 so that several receivers included in Table C.3 were not taken into account in computing average values DIDXX(EURAMET): PT10 was not part of 1001-2016 but was later aligned to PT07; Due to relocation of the ROA laboratory, the continuity could not be perfectly ensured for all ROA receivers. Seven receivers from PTB and ROA remain usable. The BIPM reference receiver (BP1J) and the former BIPM reference in 1001-2016 (BP0R) are also common to both trips and used in the adjustment.
Table C.3 indicates under **IDXXp** the 1001-2016 results and under **dIDXX** the change in INTDLY (1001-2018 minus 1001-2016). The last lines provides **DIDXX(EURAMET)** computed first as the simple average of all **dIDXX** values then as the median value.

Table C.3. List of 1001-2016 INTDLY values and differences **dIDXX** (1001-2018 – 1001-2016) for EURAMET. All values in ns.

System	Note	P1		P2		C1		P3	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDP3p	dIDP3
BIPM									
BP1J	REF	53.0	0.0	52.6	0.0	54.4	0.0	53.6	0.0
BP0R		222.5	0.0	224.4	-0.3	225.7	0.0	219.6	0.5
PTB									
PTBB		304.5	1	319.8	0.9	305.1	1	280.9	1.2
PTBG		301.5	0.7	323.9	1	301.7	0.9	266.9	0.2
PT07		-36.9	0.0	-24.3	-0.3	-35.4	-0.1	-56.4	0.5
PT09		56	0.7	55.2	0.5	57.3	0.8	57.2	1.0
PT10	(1)	-26.3	(-0.2)	-32.9	(-0.3)	-24.4	(-0.1)	-16.1	
ROA	(2)								
RO_5		10.3	(-1.9)	27.3	(-0.8)	8.5	(-1.5)	-16.0	
RO_6		56.7	(-2.0)	55.4	(-1.9)	58.1	(-1.7)	58.7	
RO_7		56.9	(-1.9)	55.7	(-1.8)	58.2	(-1.9)	58.8	
RO_8		-20.8	(-2.0)	-21.1	(-2.2)	-18.9	(-1.7)	-20.3	
RO_9		57	(-1.5)	55.9	(-1.5)	58.3	(-1.4)	58.7	

RO10		31.1	(-2.5)	29.9	(-2.5)	32.4	(-2.0)	33.0	
OP									
OPMT		309.0	-0.6	320.9	-0.7	309.6	-0.6	290.6	-0.4
OP71		55.7	-0.5	54.4	-0.6	57.1	-0.4	57.7	-0.3
OPM9		-33.7	-0.4	-37.0	-0.3	-31.7	-0.4	-28.6	-0.6
Average			0.10		0.02		0.13		0.22
Median			0.0		-0.3		0.0		0.3

(1) Not used. Not part of 1001-2016, was aligned to PT07 in 10/2017.
(2) Not used. The ROA laboratory was entirely moved in 2018 and the continuity cannot be ensured to the required level.

Computing IDXXn(k) = IDXXi(k) - DIDXX(EURAMET) for each code, one would obtain results based on minimizing the changes on EURAMET.
Because the values **DIDXX(EURAMET)** are so small (0.0 to +0.2 ns for the mean, -0.3 to 0.3 ns for the median), we propose to take them as zero and to consider the results in the report of the EURAMET part of 1001-2018 (here) as final. See the list in Annex 3.

C.4. The SIM part of 1001-2018

The report of the SIM part of 1001-2018 is here. It includes two Group 1 laboratories and four receivers that were present in 1001-2016 (see Table C.4). The BIPM reference receiver (BP1J) is also common to both trips and used in the adjustment.
Table C.4 indicates under **IDXXp** the 1001-2016 results and under **dIDXX** the change in INTDLY (1001-2018 minus 1001-2016). The last lines provides **DIDXX(SIM)** computed first as the simple average of all **dIDXX** values then as the median value.

Table C.4. List of 1001-2016 INTDLY values and differences **dIDXX** (1001-2018 – 1001-2016) for SIM. All values in ns.

System	Note	P1		P2		C1		P3	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDP3p	dIDP3
BIPM									
BP1J	REF	53.0	0.0	52.6	0.0	54.4	0.0	53.6	0.0
USNO									
USN6		-6.0	-1.4	-8.8	-1.3	-5.8	-1.2	-1.7	-1.6
NIST									
NIST		-72.8	-0.4	-72.3	0.2	-72.6	0.0	-73.6	-1.3
NIS4		-10.2	0.4	-21.8	0.4	-10	0.6	7.7	0.4
NISS		44.4	1.6	44.8	1.6	46.1	1.8	43.8	1.6
Average			0.04		0.18		0.24		-0.18
Median			0.0		+0.2		0.0		0.0

Computing IDXXn(k) = IDXXi(k) - DIDXX(SIM) for each code, one would obtain results based on minimizing the changes on SIM.
Because the number of common receivers is rather small, and the values **DIDXX(SIM)** are also small (-0.2 to +0.2 ns for the mean, 0.0 to 0.2 ns for the median), we propose to take them as zero and to consider the results in the report of the SIM part of 1001-2018 (here) as final. See the list in Annex 3.

C.5. Statistical study of merging APMP, EURAMET and SIM GPS results

From the results in Tables C.1 (APMP), C.3 (EURAMET) and C.4 (SIM), we see that the final values will vary by less than 0.3 ns between minimizing the changes on APMP only, on EURAMET only, or on SIM only. Even

COOMET results, based on a single visited receiver, are consistent to within 0.5 ns. However assembling all 20 receivers for which continuity can be traced between 1001-2016 and 1001-2018 in a single ensemble in principle would provide the most robust solution. In Table C.5, we summarize the individual changes and statistical estimators related to this choice. We see that the mean change is very consistent with zero and the distribution of results for individual receivers has a standard deviation of order 0.7 ns for each code (0.8 ns for the P3 combination).
This reinforces the conclusions already brought in section B.7 for the 1001-2014 to 1001-2016 continuity:

- If using any single G1 receiver as a reference in a G2 trip, variations of less than 1.0 ns RMS for each code and for P3 may be expected for the G2 INTDLY results with respect to the G1 reference. This is well in line with the current (early 2020) standard uncertainty of G2 links.
- Furthermore this confirms that any change in INTDLY due to ageing is limited to a level below 1 ns RMS over a 2-year interval. This is well below the current (early 2020) uncertainty due to ageing, which is of order 2.4 ns for 2 years.

Table C.5. List of differences **dIDXX** (1001-2018 – 1001-2016) and statistical values (all in ns).

System	dIDP1	dIDP2	dID(P1-P2)	dIDC1	dIDP3
BP1J	0	0	0	0	0
BP0R	0.2	0.1	0.1	0.2	0.4
TLT1	0.3	0.2	0.1	0.2	0.5
TLT2	-0.4	-0.3	-0.1	-0.4	-0.6
NC01	0	0.1	-0.1	0.2	-0.2
NC5G	0.1	0.2	-0.1	0	-0.1
NC4S	-0.1	0.1	-0.2	-0.1	-0.4
IMEJ	-0.5	-0.5	0	-0.6	-0.5
BJNM	-0.9	-1.2	0.3	-1	-0.4
PTBB	1	0.9	0.1	1	1.2
PTBG	0.7	1	-0.3	0.9	0.2
PT07	0	-0.3	0.3	-0.1	0.5
PT09	0.7	0.5	0.2	0.8	1
OPMT	-0.6	-0.7	0.1	-0.6	-0.4
OP71	-0.5	-0.6	0.1	-0.4	-0.3
OPM9	-0.4	-0.3	-0.1	-0.4	-0.6
USN6	-1.4	-1.3	-0.1	-1.2	-1.6
NIST	-0.4	0.2	-0.6	0	-1.3
NIS4	0.4	0.4	0	0.6	0.4
NISS	1.6	1.6	0	1.8	1.6
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Unc of mean	0.2	0.2	0.05	0.2	0.2
Std Dev	0.7	0.7	0.2	0.7	0.8
Median	**0.0**	**0.1**	**0.0**	**0.0**	**(-0.2,-0.1)**

C.6. Galileo results for 1001-2018

The CCTF working group on GNSS, at its meeting held June 3, 2020, decided that the Galileo reference for Group 1 calibrations would be realized through the absolute calibration of the BIPM receiver BP21 performed by ESTEC in 2019 (see the report by ESTEC).
In order to provide in retrospect Galileo INTDLY values for 1001-2018 whenever possible, i.e. for Galileo-capable receivers visited by a Galileo-capable traveling receiver (in the EURAMET and SIM legs), BP21 has been added to the set of 1001-2018 receivers. In doing so, we transfer the Galileo absolute calibration from BP21 to the 1001-2018 reference BP1J, then to all possible receivers. In addition, we obtain 1001-2018 GPS INTDLY values for BP21, which will be used as a reference system at the BIPM for the G1 trips starting 1001-2020.

The receivers BP1J and BP21 have been compared in common clock at the BIPM over five periods between February 2018 (opening of the 1001-2018 first trip) and November 2019 (after the closure of the 1001-2018 last trip). The report of measurements may be found here and the computation of ΔIntDly values may be found here. Table C.6.1 lists the results of the common clock comparisons and Table C.6.2 lists the inferred 1001-2018 GPS and Galileo INTDLY values for both receivers, where the source (values in red in the table) is BP1J 1001-2018 for GPS codes and BP21 ESTEC absolute values for Galileo codes. The value of CABDLY associated with these INTDLY results is also indicated for reference.

From the BP1J 1001-2018 Galileo reference value in Table C.6.2, results of 1001-2018 have been updated for all possible receivers in phase 3 (see report here) and phase 4 (see report here), the results are shown in Annex 3 and appear in the summary report of 1001-2018. Note that the results for BP21 in Table C.6.2 have a bias of about 0.8 ns with respect to values found in the phase 4 report, this is because the phase 4 report used a BIPM-measured CABDLY value (141.6 ns) different from the CABDLY value (140.8 ns) later obtained in the absolute calibration.

Table C.6.1. List of differences **ΔIntDly** (BP1J - BP21) in common clock at the BIPM and statistical values (all in ns).

Period	**ΔIntDly P1**	**ΔIntDly P2**	**ΔIntDly C1**	**ΔIntDly E1**	**ΔIntDly E5**
58172-58184	24.86	25.40	24.01	23.37	32.80
58423-58428	24.60	25.28	23.75	23.13	32.74
58564-58582	24.90	25.55	24.08	23.40	33.04
58648-58651	24.40	25.27	23.57	22.97	32.74
58798-58803	24.15	24.74	23.32	22.68	32.25
Mean	**24.58**	**25.25**	**23.75**	**23.11**	**32.71**
Std Dev	0.25	0.20	0.24	0.23	0.19
Median	**24.60**	**25.28**	**23.75**	**23.13**	**32.74**

Table C.6.2. List of 1001-2018 **IntDly** values for BP1J and BP21 (all in ns).

Receiver	**IntDly P1**	**IntDly P2**	**IntDly C1**	**IntDly E1**	**IntDly E5**	**CabDly**
BP1J	53.0	52.6	54.4	53.8	63.6	128.7
BP21	28.4	27.3	30.6	30.7	30.9	140.8

D. Results of 1001-2020 for GPS and Galileo (from 1001-2018)

Group 1 laboratories have not changed since 2014. They are

- For EURAMET: OP, PTB, ROA
- For APMP: NICT, NIM, TL
- For SIM: NIST, USNO
- For COOMET: SU

Final results of the 1001-2018 calibration are recalled in Annex 3 for P1, P2, C1, E1, E5a. Sections D.1 to D.4 provide the GPS results for the four legs of the calibration trip. Section D.5 is a statistical study of the global stability of GPS and Galileo IntDly values between 2018 and 2020.

D.1. The APMP part of 1001-2020

The APMP part of 1001-2020 was split into two sub-trips which reports are 1001-2020-phase1-report.pdf and 1001-2020-phase1b-report.pdf. It includes three Group 1 laboratories and thirteen receivers, nine of them were present in 1001-2018 (see Table D.1). Note that receivers BJNM and IM21 from NIM changed internal set-up since 1001-2018 and were kept calibrated by transfer of calibration (Cal_Id 1105-2020 for BJNM and 1102-2020 for IM21). The BIPM reference receiver (BP21) is also common to both trips and used in the adjustment.
Table D.1 indicates under **IDXXp** the 1001-2018 results and under **dIDXX** the change in INTDLY (1001-2020 minus 1001-2018). The last lines provides **DIDXX(APMP)** computed as the simple average of all **dIDXX** values and as the median value.

Table D.1. List of 1001-2018 INTDLY values and differences **dIDXX** (1001-2020 – 1001-2018) for APMP. All values in ns.

System	Note	P1		P2		C1		P3	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDP3p	dIDP3
BIPM									
BP21	REF	28.4	0.0	27.3	0.0	30.6	0.0	30.1	0.0
TL									
TLT1	(1)	415.3	-0.3	424.3	-0.5	415.1	-0.4	401.4	0.0
TLT3		-35.7	-0.1	-32.2	0.0	-34.5	-0.2	-41.1	-0.3
NICT									
NC5G		-30.9	1.0	-19.0	0.9	-38.5	1.0	-49.3	1.2
NC4S	(2)	276.7	0.7	276.4	0.4	278.1	0.5	277.2	1.2
NIM									
IMEJ		-31.8	0.1	-18.4	0.1	-31.0	0.2	-52.5	0.1
BJNM 1105-2020		69.2	0.3	76.4	0.2	70.8	0.3	58.1	0.5
IM21 1102-2020		-38.8	-0.2	-43.6	0.6	-37.9	0.0	-31.4	-1.4
IMEU		-24.8	0.2	-12.1	0.3	-23.4	0.1	-44.4	0.0
Average			**0.19**		**0.22**		**0.17**		**0.14**
Median			**0.1**		**0.2**		**0.1**		**0.0**

(1) Values are TOTDLY.
(2) Values are SYSDLY

Computing IDXXn(k) = IDXXi(k) - DIDXX(APMP) for each code, one would obtain results based on minimizing the changes on APMP.
Because the values **DIDXX(APMP)** are small (0.2 ns for the mean, 0.0 to 0.2 ns for the median), we propose to take them as zero and to consider the results in the reports of the APMP part of 1001-2020 (1001-2020-phase1-report.pdf and 1001-2020-phase1b-report.pdf) as final. See the list in Annex 4.

D.2. The EURAMET part of 1001-2020

The report of the EURAMET part of 1001-2020 is here. It includes three Group 1 laboratories and thirteen receivers, twelve of them were present in 1001-2018 (see Table D.2). However three receivers included in Table D.2 were not taken into account in computing average values DIDXX(EURAMET) because their set-up changed and their "1001-2018 compatible" INTDLY values were re-determined only in 2021. The BIPM reference receiver (BP21) is also common to both trips and used in the adjustment.
Table D.2 indicates under **IDXXp** the 1001-2018 results and under **dIDXX** the change in INTDLY (1001-2020 minus 1001-2018). The last lines provides **DIDXX(EURAMET)** computed first as the simple average of all **dIDXX** values then as the median value.

Table D.2. List of 1001-2018 INTDLY values and differences **dIDXX** (1001-2020 – 1001-2018) for EURAMET. All values in ns.

System	Note	P1		P2		C1		E1		E5a	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDE1p	dIDE1	IDE5p	dIDE5
BIPM											
BP21		28.4	0.0	27.3	0.0	30.6	0.0	30.7	0.0	30.9	0.0
PTB											
PT13	(1)	29.7	1.9	27.2	2.1	31.7	1.9	32.0	1.6	31.7	1.9
PT07		-36.9	-0.3	-24.6	-0.3	-35.5	-0.4				
PT09		56.7	-0.7	55.7	-0.5	58.1	-0.7	57.6	-0.7	66.3	-0.4
PT10	(2)										
ROA											
RO_5		8.4	-0.4	26.5	-0.2	5.9	-1.0				
RO_6		54.7	-0.4	53.5	-0.3	56.3	-0.4				
RO_7		55	-0.7	53.9	0.0	56.3	-0.8	55.6	-0.5	64.2	-0.4
RO_8	(2,3)	29.6	(-0.4)	27.9	(-0.3)	31.3	(-0.2)	32.6	(-0.1)	24.6	(-0.4)
RO_9		55.5	-0.6	54.4	-0.4	56.9	-0.6	56.2	-0.4	65.3	-0.6
RO10	(3)	29.0	(-0.8)	26.3	(-0.6)	30.7	(-0.8)	30.6	(-0.5)	30.5	(-0.8)
OP											
OPMT		308.4	0.5	320.2	0.7	309	0.3				
OP71		55.2	-0.3	53.8	0.0	56.7	-0.4	56.0	-0.2	64.8	0.1
Average			-0.10		0.11		-0.21		-0.03		0.10
Median			-0.3		-0.3		-0.4		-0.3		-0.3

(1) Included on 1001-2018 by Transfer of calibration in 2019.
(2) Not used. Updated following.GPS week rollover problem in April 2019.
(3) Not used. The 1001-2018 value was lost due to set-up change and was newly determined in February 2021 by Transfer of calibration from RO_9 (1101-2021).

Computing IDXXn(k) = IDXXi(k) - DIDXX(EURAMET) for each code, one would obtain results based on minimizing the changes on EURAMET.
Because the values **DIDXX(EURAMET)** are relatively small (-0.2 to 0.1 ns for the mean, -0.4 to -0.3 ns for the median), we propose to take them as zero and to consider the results in the report of the EURAMET part of 1001-2020 (here) as final. See the list in Annex 4.

D.3. The SIM part of 1001-2020

The report of the SIM part of 1001-2020 is here. It includes two Group 1 laboratories and eight receivers, six of them were present in 1001-2018 (see Table D.3). However, one receiver included in Table D.3 was not taken into account in computing average values DIDXX(SIM) because its set-up must have changed. The BIPM reference receiver (BP21) is also common to both trips and used in the adjustment.
Table D.3 indicates under **IDXXp** the 1001-2018 results and under **dIDXX** the change in INTDLY (1001-2020 minus 1001-2018). The last lines provide **DIDXX(SIM)** computed first as the simple average of all **dIDXX** values then as the median value.

Table D.3. List of 1001-2018 INTDLY values and differences **dIDXX** (1001-2020 – 1001-2018) for SIM. All values in ns.

System	Note	P1		P2		C1		E1		E5a	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDE1p	dIDE1	IDE5p	dIDE5
BIPM											
BP21		28.4	0.0	27.3	0.0	30.6	0.0	30.7	0.0	30.9	0.0
USNO											
USN6		-7.4	0.9	-10.1	1.1	-7.0	1.2				
USN7	(1)	204.8	(-51.5)	200.8	(-51.5)	207.1	(-51.5)	207.1	(-51.5)	208.8	(-51.7)
USN8		199.5	0.8	196.4	1.0	201.8	1.3	201.8	0.9	203.6	0.8
NIST											
NIST		-73.2	-0.6	-72.1	-0.8	-72.6	-0.5				
NISG		30.2	-0.7	28.5	-0.6	32.8	-1.0	32.5	-0.7	33.0	-1.5
NISS		46.0	-0.8	46.4	-0.5	47.9	-1.0				
Average			-0.07		0.03		0.00		0.07		-0.23
Median			-0.3		-0.25		-0.25		0.0		0.0

(1) Not used. Set-up changes suspected.

Computing IDXXn(k) = IDXXi(k) - DIDXX(SIM) for each code, one would obtain results based on minimizing the changes on SIM.
Because the values **DIDXX(SIM)** are relatively small (-0.2 to 0.1 ns for the mean, -0.3 to 0.0 ns for the median), we propose to take them as zero and to consider the results in the report of the SIM part of 1001-2020 (here) as final. See the list in Annex 4.

D.4. Statistical study of merging APMP, EURAMET and SIM GPS and Galileo results

From the results in Tables D.1 (APMP), D.2 (EURAMET) and D.3 (SIM), we see that the final values will vary by less than 0.3 ns between minimizing the changes on APMP only, on EURAMET only, or on SIM only. Assembling all receivers for which continuity can be traced between 1001-2018 and 1001-2020 (23 for GPS, 8 for Galileo) in a single ensemble in principle would provide the most robust solution. In Table D.4, we summarize the individual changes and statistical estimators related to this choice. We see that the mean change is very consistent with zero and the distribution of results for individual receivers has a standard deviation of order 0.6 to 0.7 ns for each code or for the dual-frequency combination.
This reinforces the conclusions already brought in section B.7 for the 1001-2014 to 1001-2016 continuity and in section C.5 for the 1001-2016 to 1001-2018 continuity:

- If using any single G1 receiver as a reference in a G2 trip, variations of less than 1.0 ns RMS for each code and for P3/E3 may be expected for the G2 INTDLY results with respect to the G1 reference. This is well in line with the current (2022) standard uncertainty of UTC links G2 to G1 which is set to 2.5 ns vs 1.5 ns for G1-G1 UTC links.
- Furthermore, this confirms that any change in INTDLY due to ageing is limited to a level below 1 ns RMS over a 2-year interval. This is in line with the current (2022) uncertainty due to ageing, which is of order 1.0 ns for the first 2 years.

Table D.4. List of differences **dIDXX** (1001-2020 – 1001-2018) and statistical values (all in ns).

System	dIDP1	dIDP2	dIDC1	dIDP3	dIDE1	dIDE5a	dIDE3
BP21	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TLT1	-0.3	-0.5	-0.4	0.0			
TLT3	-0.1	0.0	-0.2	-0.3			
NC5G	1.0	0.9	1.0	1.2			
NC4S	0.7	0.4	0.5	1.2			
IMEJ	0.1	0.1	0.2	0.1			
BJNM	0.3	0.2	0.3	0.5			

IM21	-0.2	0.6	0.0	-1.4			
IMEU	0.2	0.3	0.1	0.0			
PT13)	1.9	2.1	1.9	1.6	1.6	1.9	1.2
PT07	-0.3	-0.3	-0.4	-0.3			
PT09	-0.7	-0.5	-0.7	-1.0	-0.7	-0.4	-1.1
RO_5	-0.4	-0.2	-1.0	-0.7			
RO_6	-0.4	-0.3	-0.4	-0.6			
RO_7	-0.7	0.0	-0.8	-1.8	-0.5	-0.4	-0.6
RO_9	-0.6	-0.4	-0.6	-0.9	-0.4	-0.6	-0.1
OPMT	0.5	0.7	0.3	0.2			
OP71	-0.3	0.0	-0.4	-0.8	-0.2	0.1	-0.6
USN6	0.9	1.1	1.2	0.6			
USN8	0.8	1.0	1.3	0.5	0.9	0.8	1.0
NIST	-0.6	-0.8	-0.5	-0.3			
NISG	-0.7	-0.6	-1.0	-0.9	-0.7	-1.5	0.3
NISS	-0.8	-0.5	-1.0	-1.3			
Mean	**0.01**	**0.14**	**-0.03**	**-0.19**	**0.00**	**-0.01**	**0.02**
Std Dev	0.6	0.5	0.6	0.7	0.6	0.7	0.6
Median	**-0.2**	**0.0**	**-0.2**	**-0.25**	**-0.3**	**-0.2**	**-0.05**

D.5. The COOMET part of 1001-2020

The report of the COOMET part of 1001-2020 is here. It includes one Group 1 laboratory and five receivers, two of them were present in 1001-2018 (see Table D.5). The BIPM reference receiver (BP21) is also common to both trips and used in the adjustment.
Table D.5 indicates under **IDXXp** the 1001-2018 results and under **dIDXX** the change in INTDLY (1001-2020 minus 1001-2018). The last lines provide **DIDXX(SIM)** computed first as the simple average of all **dIDXX** values then as the median value.

Table D.5. List of 1001-2018 INTDLY values and differences **dIDXX** (1001-2020 – 1001-2018) for SIM. All values in ns.

System	Note	P1		P2		C1		E1		E5a	
		IDP1p	dIDP1	IDP2p	dIDP2	IDC1p	dIDC1	IDE1p	dIDE1	IDE5p	dIDE5
BIPM											
BP21		28.4	0.0	27.3	0.0	30.6	0.0	30.7	0.0	30.9	0.0
SU											
SU19	(1)	-30.3	(87.8)	-28.9	(87.9)	-28.3	(87.5)				
SU31		36.5	-1.2	34.5	-0.7	38.8	-1.6				
Average			-1.2		-0.7		-1.6				
Median			-1.2		-0.7		-1.6				

(1) Not used. Firmware changes due GPS week rollover

The COMEET phase provided just one usable receiver more for the statistical analysis in section D.4. For this reason, the analysis is not updated, and the final COOMET DLY values are computed using the unchanged BIPM reference.

References

TM243: Determination of reference GPS “INTDLY” values of Group 1 geodetic receivers in the initial Group 1 trip (Cal_Id = 1001-2014), Version 7 available at
ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/group1/1001-2014/

BIPM guidelines for GNSS calibration, Version 4.0 available at
ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/guidelines/

Annex 1: Results of 1001-2014

P1/P2 and C1 INTDLY values from the Initial Group 1 trip (Cal_Id=1001-2014) taken from Table 8 (P1/P2) and Table 9 (C1) of TM243. P1 and P2 are indicated with 2-digit numeric precision for internal consistency of P3. Values of REFDLY and CABDLY at the epoch of calibration and of TOTDLY(P3) are also indicated for reference (all values in ns).

System	Date	INTDLY P1	INTDLY P2	INTDLY C1	REFDLY	CABDLY	TOTDLY P3
BP0R		222.55	224.79	225.8			
TWTF (1)	2014.0	305.75	314.05	305.9	52.0	119.8	360.7
NC02	2014.2	219.71	225.87	222.8	429.7	248.5	29.0
SEPA	2014.2	217.44	222.33	220.4	406.1	213.4	17.2
IMEJ	2014.4	2.39	4.48	-1.3	0.0	0.0	-0.8
IMEU	2014.4	-25.67	-12.70	-23.8	115.5	250.3	89.1
BJNM	2014.4	74.00	81.72	75.8	315.3	125.0	-128.2
RO_4	2014.7	199.68	203.97	203.0	218.9	217.5	191.7
RO_5	2014.7	2.19	-0.40	1.7	0.3	0.0	5.9
RO_6	2014.7	54.81	51.97	56.1	218.3	66.7	-92.4
RO_7	2014.7	55.56	53.35	56.7	171.5	61.9	-50.6
NIST	2015.1	-72.03	-71.79	-72.0	80.0	275.5	123.1
NIS3	2015.1	-8.59	-20.60	-8.6	1545.8	298.5	-1237.3
NIS4	2015.1	-9.79	-21.29	-9.8	1516.5	298.0	-1210.5
USN6	2015.2	-6.53	-9.60	-6.5	0.0	0.0	-1.8
USN7	2015.2	-6.11	-9.13	-4.9	0.0	0.0	-1.4
OPMT	2015.4	310.21	321.60	311.0	100.1	156.5	349.0
OPM7	2015.4	270.69	273.87	272.1	128.1	0.0	137.7
OPM8	2015.4	270.76	273.95	272.2	124.6	0.0	141.2
PTBB	2015.4	303.89	319.28	304.4	74.0	301.7	507.8
PTBG	2015.4	300.97	323.47	301.1	46.3	251.4	471.3
SU19	2015.5	-28.98	-27.50	-27.3	194.5	48.2	-177.6

(1) Results for TWTF are expressed as INTDLY for consistency with the CGGTTS V2 format. **However they should NOT be used as true INTDLY values**: Only "Total delay" as defined in CGTTS V3 format (TOTDLY = INTDLY + CABDLY – REFDLY) has a physical meaning for TWTF. Note also that the REFDLY value in the CGGTTS files of TWTF (TL1Z) was changed to 46.3 ns on MJD 56763.

Annex 2: Results of 1001-2016

P1/P2 and C1 INTDLY values from the second Group 1 trip (Cal_Id=1001-2016) taken from Table B3.2 for APMP and EURAMET, and for B4.2 for SIM. Values of REFDLY and CABDLY at the epoch of calibration and of TOTDLY(P3) are also indicated for reference (all values in ns). NTSC receivers included for completeness.

System	Date	INTDLY P1	INTDLY P2	INTDLY C1	REFDLY	CABDLY	TOTDLY P3
BP0R		222.5	224.4	225.7			
BP1J	2016.9	53.0	52.6	54.4			
TLT1 (1)	2016.2	415.0	424.1	414.9	N/A	N/A	400.9
TLT2	2016.2	-35.2	-36.2	-33.4	24.5	140.3	82.1
TLT3 (3)	2016.2	-5.7	-9.6	-6.9	0.0	0.0	0.3
NC01	2016.3	218.3	222.4	221.4	407.6	213.4	17.8
NC5G (3)	2016.3	-31.1	-24.3	-38.5	-40.1	-37.0	-1.5
NC4C	2016.3	212.4	210.8	213.9	599.9	157.5	-385.0
NC4S (2)	2016.3	276.8	276.3	278.2	314.3	N/A	-36.7
IMEJ (3)	2016.5	0.7	0.9	-0.6	0.0	0.0	0.4
IMEU	2016.5	-27.5	-14.5	-25.8	112.8	66.7	-93.7
BJNM	2016.5	75.3	82.9	77.1	319.7	61.9	-194.2
NTP1	2016.6	55.7	55.1	57.4	373.8	209.0	-108.2
NTP2	2016.6	55.5	54.2	57.3	378.0	221.0	-99.5
NTP3	2016.6	53.1	52.2	54.6	192.6	198.0	59.9
RO_5 (3)	2016.8	-0.1	0.1	1.5	0.0	0.0	-0.4
RO_6	2016.8	49.6	48.5	51.0	234.4	66.7	-116.4
RO_7	2016.8	54.9	53.8	56.2	194.6	81.9	-56.1
RO_8 (3)	2016.8	-0.3	0.2	-42.3	0.0	0.0	-1.1
RO_9	2016.8	55.9	55.1	56.6	112.4	118.7	63.4
PT02	2016.8	304.5	319.8	305.1	73.9	301.7	508.7
PT03	2016.8	301.5	323.9	301.7	46.1	251.4	472.2
PT07 (3)	2016.8	-0.6	-0.5	-3.0	-0.8	0.0	0.0
PT09	2016.8	56.0	55.2	57.3	161.8	223.7	119.1
PT10 (3)	2016.8	0.3	0.0	-4.0	-0.2	0.0	1.0
OPMT	2016.9	309.0	320.9	309.6	155.9	156.5	291.2
OP71	2016.9	55.7	54.4	57.1	191.6	128.7	-5.2
OPM9	2016.9	-33.7	-37.0	-31.7	60.5	173.3	84.2
USN6 (1,3)	2017.2	-6.0	-8.8	-5.8	N/A	N/A	-1.7
USN7 (1,3)	2017.2	-5.4	-8.3	-4.3	N/A	N/A	-0.9
NIST	2017.3	-72.8	-72.3	-72.6	87.3	275.5	114.6
NISS	2017.3	44.4	44.8	46.1	1736.9	298.9	-1394.2
NIS3	2017.3	-6.3	-17.5	-6.1	1597.0	298.5	-1287.4
NIS4	2017.3	-10.2	-21.8	-10.0	1566.4	298.0	-1260.7

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

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

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

Annex 3: Results of 1001-2018

GPS P1, P2, C1 and Galileo E1, E5a INTDLY values from the third Group 1 trip (Cal_Id=1001-2018). Values of REFDLY and CABDLY at the epoch of calibration are also indicated for reference (all values in ns).

System	Date	INTDLY P1	INTDLY P2	INTDLY C1	INTDLY E1	INTDLY E5	REFDLY	CABDLY
BP1J	2019	53.0	52.6	54.4	53.8	63.6		128.7
BP0R	2019	222.5	224.1	225.7				
BP21	2019	28.4	27.3	30.6	30.7	30.9		140.8
TLT1 (1)	2018/04/21	415.3	424.3	415.1			N/A	N/A
TLT2	2018/04/21	-35.6	-36.5	-33.8			24.5	140.3
TLT4 (2)	2018/04/21	117.8	117.3	119.2			0.0	N/A
NC01	2018/06/01	218.3	222.3	221.4			406.0	213.4
NC5G (3)	2018/06/01	0.1	0.2	0.0			168.3	268.7
NC4S (2)	2018/06/01	276.7	276.4	278.1			312.7	N/A
IM05 (BJNM)	2018/08/15	74.4	81.7	76.1			331.6	125.0
IM20	2018/08/15	-22.0	-3.6	-20.5			147.1	205.1
IM21	2018/08/15	-25.9	-33.4	-24.9			131.5	215.0
IM06 (IMEJ) (3)	2018/08/15	-0.5	-0.5	-0.6			121.7	248.7
IM12 (IMEL) (3)	2018/08/15	-7.4	-5.2	-11.5			147.1	201.4
IM03 (IMEU)	2018/08/15	-24.8	-12.1	-23.4			120.1	250.3
TF10	2018/08/15	-26.6	-37.8	-25.7			153.0	215.0
TF11	2018/08/15	-29.8	-40.3	-28.6			130.5	215.0
SU19	2018/05/26	-30.2	-28.9	-28.3			194.5	48.2
SU31 (3)	2018/05/26	-1.8	-2.3	-0.7			207.5	143.2
SUCL (3)	2018/05/26	-1.0	-0.9	0.2			207.5	128.2
PT02 (PTBB)	2018/11/20	305.5	320.7	306.1			74.6	301.7
PT03 (PTBG)	2018/11/20	302.2	324.9	302.6			46.5	251.4
PT07 (3)	2018/11/20	0.0	-0.3	-0.1			43.4	245.8
PT09	2018/11/20	56.7	55.7	58.1	57.6	66.3	183.2	198.7
PT10	2018/11/20	-26.5	-33.2	-24.5	-23.0	-34.4	52.0	250.0
RO_5 (3)	2018/12/14	-1.9	-0.8	-1.5			306.9	91.5
RO_6	2018/12/14	54.7	53.5	56.3			484.9	82.0
RO_7	2018/12/14	55.0	53.9	56.3	55.6	64.2	452.3	89.9
RO_8	2018/12/14	-22.8	-23.3	-20.6	-19.5	-22.5	20.4	202.7
RO_9	2018/12/14	55.5	54.4	56.9	56.2	65.3	451.8	59.7
RO10	2018/12/14	28.6	27.5	30.4	30.4	31.3	5.1	204.8
OP02 (OPMT)	2019/01/17	308.4	320.2	309.0			155.9	156.5
OP71	2019/01/17	55.2	53.8	56.7	56.0	64.8	191.7	128.7
OPM9	2019/01/17	-34.1	-37.3	-32.1			60.5	173.3
USN6 (1)	2019/04/11	-7.4	-10.1	-7.0			N/A	N/A
USN7 (1)	2019/04/11	204.8	200.8	207.1	207.1	208.8	N/A	N/A
USN8 (1)	2019/04/11	199.5	196.4	201.8	201.8	203.6	N/A	N/A
NIST	2019/08/04	-73.2	-72.1	-72.6			65.9	275.5
NISG	2019/08/04	30.2	28.5	32.8	32.5	33.0	452.9	185.0
NIS4	2019/08/04	-9.8	-21.4	-9.4			129.4	298.0
NISS	2019/08/04	46.0	46.4	47.9			301.0	298.9

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

(2) Results are System Delay values (SYSDLY).

(3) INTDLY results are changes with respect to values entered in the receiver.

Annex 4: Results of 1001-2020

GPS P1, P2, C1 and Galileo E1, E5a INTDLY values from the third Group 1 trip (Cal_Id=1001-2020). Values of REFDLY and CABDLY at the epoch of calibration are also indicated for reference (all values in ns).

System	Date	INTDLY P1	INTDLY P2	INTDLY C1	INTDLY E1	INTDLY E5	REFDLY	CABDLY
BP21		28.4	27.3	30.6	30.7	30.9		140.8
NC5S (1)	2020/08/18	393.4	392.6	395.7	395.8	395.5	266.6	N/A
NC5G	2020/08/18	-29.9	-18.1	-37.5	-38.5	-38.5	171.3	268.7
NC4S (1)	2020/08/18	277.4	276.8	278.6	278.2	287.4	315.7	N/A
TLT0 (TWTF)	2020/10/31	60.4	62.7	61.7	61.6	N/A	157.9	119.8
TLT1 (2)	2020/10/31	415.0	423.8	414.7	N/A	N/A	N/A	N/A
TLT3	2020/10/31	-35.6	-32.2	-34.7	N/A	N/A	25.6	143.6
TLT5 (2)	2020/10/31	204.0	202.9	206.1	206.3	204.1	N/A	N/A
IM15	2020/09/20	-27.6	-38.3	-26.5	-27.1	-36.4	119.4	212.4
IM06 (IMEJ)	2020/09/20	-31.7	-18.3	-30.8	-31.0	-31.0	121.7	248.7
IM05 (BJNM)	2020/09/20	69.5	76.6	71.1	71.5	N/A	324.8	125.0
IM21	2020/09/20	-39.0	-43.0	-37.9	-38.5	-40.8	119.8	212.3
IM03 (IMEU)	2020/09/20	-24.6	-11.8	-23.3	N/A	N/A	120.1	250.3
RO_5	2021/03/08	8.0	26.3	4.9	N/A	N/A	306.8	91.5
RO_6	2021/03/08	54.3	53.2	55.9	N/A	N/A	485.1	82.0
RO_7 (ROAP)	2021/03/08	54.3	53.9	55.5	55.1	63.8	452.4	89.9
RO_8	2021/03/08	29.2	27.6	31.1	32.5	24.2	20.4	197.1
RO_9	2021/03/08	54.9	54.0	56.3	55.8	64.7	451.8	59.7
RO10 (ROAG)	2021/03/08	28.2	25.7	29.9	30.1	29.7	5.1	199.0
PT13 (PTBB)	2021/03/30	31.6	29.3	33.6	33.6	33.6	56.2	205.7
PT07	2021/03/30	-37.2	-24.9	-35.9	N/A	N/A	43.4	245.8
PT09	2021/03/30	56.0	55.2	57.4	56.9	65.9	182.9	198.7
PT10	2021/03/30	31.4	24.8	33.2	34.7	23.6	36.6	250.0
OP71	2021/04/22	54.9	53.8	56.3	55.8	64.9	192.1	128.7
OP73	2021/04/22	29.5	26.3	31.7	31.7	31.3	85.2	129.6
OP02 (OPMT)	2021/04/22	308.9	320.9	309.3	N/A	N/A	137.2	156.5
NISG	2021/10/23	29.5	27.9	31.8	31.8	31.5	1592.2	298.5
NIST	2021/10/23	-73.8	-72.9	-73.1			65.9	275.5
NISS	2021/10/23	45.2	45.9	46.9			299.4	298.9
NISX	2021/10/23	28.2	26.3	30.3	30.5	31.2	452.3	185.0
US06 (USN6) (2)	2021/12/21	-6.5	-9.0	-5.7			N/A	N/A
US09 (USN7) (2)	2021/12/21	153.3	149.3	155.6	155.6	157.1	N/A	N/A
US10 (USN8) (2)	2021/12/21	200.3	197.4	202.6	202.7	204.4	N/A	N/A
USN9 (2)	2021/12/21	202.3	219.6	203.1	204.2	229.0	N/A	N/A
SU19	2021/11/27	57.4	59.0	59.2	59.5	75.1	193.9	122.4
SU31	2021/11/27	35.3	33.8	37.2	38.6	33.8	193.9	143.2
SU22	2021/12/06	35.6	34.4	37.4	38.8	34.4	135.5	122.6
SU52	2021/12/06	28.7	25.5	30.9	31.0	28.8	134.8	149.1
SU04	2021/12/15	34.6	30.8	36.5	37.9	30.9	259.0	122.5

(1) Results are System Delay values (SYSDLY).

(2) Results are Total Delay values (TOTDLY).