G2 Calibration Report: Cal_Id 1012-2020

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Abstract

This report is a record of the calibration results of lrte, the site GNSS receiver of Universidade de Sao Paulo, GNSS receivers: nxrk, nxrm, nxra, nxrb, nxrl at INMETRO - Rio de Janeiro, and GNSS receivers: rj03, rj04 at ONRJ - Rio de Janeiro, using the NIST traveling receiver nb05 during the trip from NIST, Boulder to Brazil and back. Four sets of data–often with multiple GNSS receivers in each set–were collected between MJD58850-59134 (January 2, 2020 and October 12, 2020) by simultaneous operation of a pair of co-located GNSS receivers. The purpose of this campaign was to measure the internal delay of the local(visited) GPS receivers and thereby calibrating the links comprising NIST and the visited laboratories for time transfer applications. The calibration campaign was initiated by NIST in consultation with the visited laboratories for fulfilling the G2 responsibility as per the guidelines set by BIPM [1].

Contents

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1 List of Acronyms

Table 1: List of acronyms used in this report

BIPM	Bureau International des Poids et Mesures, Sèvres, France
CCTF	Consultative Committee on Time and Frequency
CGGTTS	CCTF Global GNSS Time Transfer Standard format
CIPM	Comité International des Poids et Mesures
GNSS	Global Navigation Satellite System
ITRF	International Terrestrial Reference Frame
nb05	NIST-owned GPS traveling system
NIST	National Institute of Standards and Technology
nist	Four-letter code of NIST primary receiver
labv	Generic four-letter code assiged to a receiver at the visited lab
lrte	Four-letter code for the site receiver at Universidade de Sao Paulo
INMETRO	National Institute of Metrology, Standardization and Industrial Quality
nxrk,nxrm,nxra,nxrb,nxrl	Four-letter code of INMETRO receivers
ONRJ	National Observatory in Rio de Janeiro
rj03,rj04	Four-letter code of ORNJ receivers
PPS	Pulse per second
RINEX	Receiver Independent Exchange format
TIC	Time Interval Counter

2 Description of the traveling GNSS receiver

The NIST Traveling System consists of Septentrio PolaRx3eTR PRO GNSS receiver unit (nb05), a choke-ring antenna and antenna cable (LMR 100A), a laptop, a time interval counter and two auxiliary cables (RG223 with BNC connectors) to be used for measuring the REFDLY for the traveling receiver. An HP53132A time interval counter is provided for meausring REFDLY at each station in a consistent manner. For more information, please refer to the NIST traveling receiver operator's manual.

3 Results of the calibration campaign

The notation for various delays are same as suggested in the BIPM guidelines for GNSS calibrations[1]. A brief discussion of the various delays and their values for each pair (traveling- and station-receiver) are detailed next, followed by a discussion about computing raw difference of GPS code measurements.

3.1 Computing delays in the measurement setup

The difference of the total delay for a pair of co-located receivers is the sum of the delays incurred in the antenna cable(CABDLY) and the internal delay(INTDLY), minus the time offset at the latching point of the receiver as referenced to a fixed point, usually UTC(k)(REFDLY). The internal delay is comprised of both code- and frequency-dependent delays in the antenna and the receiver. After accounting for the baseline geometry, the difference in pseudoranges between a pair of receivers, say for P1, is given by

$$\mathrm{RAWDIF(P1)}_{\mathrm{A-B}} = \Delta\mathrm{CABDLY}_{\mathrm{A-B}} + \Delta\mathrm{INTDLY}_{\mathrm{A-B}} - \Delta\mathrm{REFDLY}_{\mathrm{A-B}}, \quad (1)$$

where $\mathrm{RAWDIF(P1)}_{\mathrm{A-B}}$ is the raw difference of pseudorange measurements of two receivers. Similarly for C1 and P2, $\mathrm{RAWDIF(P2)}_{\mathrm{A-B}}$ is given by using the corresponding set of delays on the right hand side of Eq.(1). The notation for the receivers A and B correspond to the traveling- and station-receiver. $\Delta\mathrm{CABDLY}_{\mathrm{A-B}}$ and $\Delta\mathrm{REFDLY}_{\mathrm{A-B}}$ for nb05(A) and labv/nist(B) are given in Table 2, referenced from Annex 1-10. We will refer to the visited laboratory receiver as labv. nist and nb05 are NIST station- and traveling-receivers respectively. In this calibration campaign, we calibrate a total of eight receivers in the visited laboratories. The INTDLY values used for nist are from the latest G1 campaign as described in [2]. The procedure for measuring nb05 REFDLY (both $\mathrm{X_P}$ and $\mathrm{X_O}$) is outlined in the operating manual. The visited laboratories are responsible for the REFDLY and CABDLY values for their station receivers. REFDLY and CABDLY differences are obtained by differencing the values given in the annexes for corresponding receivers.

Table 2: REFDLY and CABDLY and their differences between traveling and station receivers

Pair	MJD	$\mathrm{REF_{DLY}}$ (nb05)	$\mathrm{REF_{DLY}}$ (labv)	$\mathrm{CAB_{DLY}}$ (nb05)	$\mathrm{CAB_{DLY}}$ (labv)	$\Delta\mathrm{REF_{DLY}}$ (ns)	$\Delta\mathrm{CAB_{DLY}}$ (ns)
nb05-nist	58850-58860	612.2	65.9	199.6	275.5	546.3	-75.9
nb05-lrte	58912-58920	257.3	212.1	199.6	126.8	45.2	72.8
nb05-nxrk	58926-58938	209.7	154.6	199.6	124.7	55.1	74.9
nb05-nxrm	58926-58938	209.7	53.1	199.6	81.4	156.6	118.2
nb05-nxra	58926-58938	209.7	211.9	199.6	124.9	-2.2	74.7
nb05-nxrb	58926-58938	209.7	48.3	199.6	70.2	161.4	129.4
nb05-nxrl	58926-58938	209.7	211.1	199.6	70.2	-1.4	129.4
nb05-rj03	59001-59011	275.4	26.8	199.6	194.4	248.6	5.2
nb05-rj04	59001-59011	275.4	32.9	199.6	182.8	242.5	16.8
nb05-nist	59125-59134	611.6	65.9	199.6	275.5	545.7	-75.9

3.2 Computing raw difference of GPS psuedoranges

The RINEX files for a pair of co-located receivers during the data acquisition period, MJD column in Table 2, are processed using a script provided by the BIPM which invokes a call to a fortran executable that solves for the baseline between the phase centers of the two antennas from L1 and L2 phase differences[3, 4]. Subsequently, the P1 and P2 pseudorange differences are formed after accounting for the baseline. For

the Novatel NIST station receiver(nist), the RINEX files were corrected for C1P1 bias[5]. The results are given in Table 3. The values for ΔINTDLY between a given pair of receivers are computed using Eq.(1) and are given in Table 4.

Table 3: Computed raw P1, C1, and P2 differences between station and traveling receivers

Pair	MJD	RAWDIF(P1) (ns)	RAWDIF(C1) (ns)	RAWDIF(P2) (ns)
nb05-nist	58850-58860	-509.14	-507.91	-504.41
nb05-lrte	58912-58920	97.43	98.95	102.51
nb05-nxrk	58926-58938	12.93	13.41	17.71
nb05-nxrm	58926-58938	-66.60	-67.35	-59.71
nb05-nxra	58926-58938	74.55	74.76	72.47
nb05-nxrb	58926-58938	-53.76	-54.29	-45.96
nb05-nxrl	58926-58938	124.14	124.40	123.60
nb05-rj03	59001-59011	-203.22	-202.59	-196.99
nb05-rj04	59001-59011	-182.83	-181.81	-171.65
nb05-nist	59125-59134	-509.84	-508.68	-505.52

Table 4: INTDLY differences between traveling and station receivers.

Pair	MJD	ΔINTDLY(P1) (ns)	ΔINTDLY(C1) (ns)	ΔINTDLY(P2) (ns)
nb05-nist	58850-58860	113.06	114.29	117.79
nb05-lrte	58912-58920	69.83	71.35	74.91
nb05-nxrk	58926-58938	-6.87	-6.39	-2.09
nb05-nxrm	58926-58938	-28.20	-28.95	-21.31
nb05-nxra	58926-58938	-2.35	-2.14	-4.43
nb05-nxrb	58926-58938	-21.76	-22.29	-13.96
nb05-nxrl	58926-58938	-6.66	-6.40	-7.20
nb05-rj03	59001-59011	40.18	40.81	46.41
nb05-rj04	59001-59011	40.87	43.89	54.05
nb05-nist	59125-59134	112.36	113.51	116.67

Table 5: Assigned uncertainties to INTDLY differences between traveling and station receivers are the first minimum of the TDEV.

Pair	MJD	TDEV(ns)		
		RAWDIF(P1)	RAWDIF(C1)	RAWDIF(P2)
nb05-nist	58850-58860	0.33	0.34	0.44
nb05-lrte	58912-58920	0.10	0.18	0.07
nb05-nxrk	58926-58938	0.11	0.11	0.09
nb05-nxrm	58926-58938	0.08	0.12	0.09
nb05-nxra	58926-58938	0.10	0.08	0.14
nb05-nxrb	58926-58938	0.08	0.11	0.08
nb05-nxrl	58926-58938	0.12	0.10	0.24
nb05-rj03	59001-59011	0.07	0.08	0.10
nb05-rj04	59001-59011	0.06	0.05	0.13
nb05-nist	59125-59134	0.30	0.30	0.40

4 Uncertainty estimates

The overall uncertainty of the differential calibration is the uncertainty of the link between two points(labs) over the duration of the calibration. The uncertainties, both statistical and systematic, associated with the GPS constellation and the traveling-receiver drop out. Therefore, for a link comprising a pair of locations(using their site receivers), say A and B, the total uncertainty is where $u_x = \left(u_{x,a}^2 + u_{x,b}^2\right)^{1/2}$, $x \equiv A, B$. $u_{x,a}$ is the total statistical uncertainty that arise due to the fluctuations in the RAWDIF. We have assumed that the total statistical and systematic uncertainties are orthogonal to each other owing to statistical independence. The total uncertainty for each location are given at the end of Table 7 and given in Table 8. Simillarly, $u_{x,b}$ is equal to the norm of the vector whose components are the various systematic uncertainties. Misclosure is added to the systematic uncertainty at the closure location NIST. For the RAWDIF, the values for the uncertainty corresponds to the first minimum of TDEV, see Table 5.

For the visited laboratory site receiver (labv), total uncertainty at each location can be computed using the values given in Table 6. The non-trivial case of computing the total uncertainty at NIST location– due mainly for including misclosure–is given in Table 7. We note that the systematic uncertainty assigned to multipath and receiver position are adopted from the resolutions passed by the CCTF working group on GNSS. Using the uncertainty estimates from Tables 7 and 8, and differencing the values computed

Table 6: Uncertainties for the common-clock, co-located measurements of nb05 and labv

quantity		uncertainty (ns)
$\mathrm{RAWDIF}_{\mathrm{nb05-labv}}$	u_a	from Table 5
nb05 antenna position	$\mathrm{u}_{b,11}$	0.05
labv antenna position	$\mathrm{u}_{b,12}$	0.05
nb05 multipath	$\mathrm{u}_{b,13}$	0.20
labv multipath	$\mathrm{u}_{b,14}$	0.20
$\mathrm{REFDLY}_{\mathrm{nb05}}$	$\mathrm{u}_{b,21}$	0.10
$\mathrm{REFDLY}_{\mathrm{labv}}$	$\mathrm{u}_{b,22}$	0.10
$\mathrm{CABDLY}_{\mathrm{nb05}}$	$\mathrm{u}_{b,31}$	0.10
$\mathrm{CABDLY}_{\mathrm{labv}}$	$\mathrm{u}_{b,32}$	0.10

in Table 4, ΔINTDLY(P1),ΔINTDLY(C1), and ΔINTDLY(P2) for time transfer links are obtained, see Table 9. Using the values for the internal delays for nist from the latest BIPM calibration of NIST receiver[2] (also given in Annex A for NIST) along with values from Table 9, the inferred internal delays for labv are given in Table 10.

Table 7: Uncertainties for the common-clock, co-located measurements of nb05 at NIST

Uncertainty		P1(ns)		C1(ns)		P2(ns)	
		begin	end	begin	end	begin	end
$\mathrm{RAWDIF}_{\mathrm{nb05-nist}}$	u_a	0.33	0.30	0.34	0.30	0.44	0.40
nb05 antenna position	$u_{b,11}$			0.05			
nist antenna position	$u_{b,12}$			0.05			
nb05 multipath	$u_{b,13}$			0.20			
nist multipath	$u_{b,14}$			0.20			
$\mathrm{REFDLY}_{\mathrm{nb05}}$	$u_{b,21}$			0.10			
$\mathrm{REFDLY}_{\mathrm{nist}}$	$u_{b,22}$			0.10			
$\mathrm{CABDLY}_{\mathrm{nb05}}$	$u_{b,31}$			0.10			
$\mathrm{CABDLY}_{\mathrm{nist}}$	$u_{b,32}$			0.10			
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-nist}}$		0.58	0.46	0.49	0.46	0.56	0.53
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-nist}}\vert_{\max}/\sqrt{2}$		0.41		0.35		0.39	
Misclosure/2	$u_{b,1}$	0.65		0.69		0.86	
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-nist}}$		0.76		0.77		0.94	

Table 8: Uncertainties for the common-clock, co-located measurements of nb05 at visited sites

Uncertainty	ΔP1 (ns)	ΔC1 (ns)	ΔP2 (ns)
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-lrte}}$	0.36	0.40	0.36
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-nxrm}}$	0.36	0.37	0.36
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-nxra}}$	0.36	0.36	0.38
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-nxrb}}$	0.36	0.37	0.36
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-nxrk}}$	0.37	0.47	0.36
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-nxrl}}$	0.37	0.36	0.43
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-rj03}}$	0.35	0.36	0.36
$\Delta\mathrm{INTDLY}_{\mathrm{nb05-rj04}}$	0.36	0.36	0.38

Table 9: ΔINTDLY for the links

Pair	ΔINTDLY(P1) (ns)	ΔINTDLY(C1) (ns)	ΔINTDLY(P2)
lrte-nist	42.6 ± 0.8	42.2 ± 0.9	42.0 ± 1.0
nxrk-nist	119.3 ± 0.8	120.0 ± 0.8	119.0 ± 1.0
nxrm-nist	140.6 ± 0.8	142.5 ± 0.8	138.2 ± 1.0
nxra-nist	114.8 ± 0.8	115.7 ± 0.8	121.4 ± 1.0
nxrb-nist	134.2 ± 0.8	135.9 ± 0.9	130.9 ± 1.0
nxrl-nist	119.1 ± 0.8	120.0 ± 0.8	124.1 ± 1.0
rj03-nist	72.2 ± 0.8	72.8 ± 0.8	70.5 ± 1.0
rj04-nist	69.5 ± 0.8	69.7 ± 0.8	62.9 ± 1.0

Table 10: Estimated INTDLY of visited receivers

Rcvr	Model	INTDLY(P1) (ns)	INTDLY(C1) (ns)	INTDLY(P2) (ns)
lrte	PolaRx3TR	-30.6	-30.3	-30.1
nxrk	PolaRx4TR PRO	46.1	47.4	46.9
nxrm	PolaRx5TR	67.4	69.9	66.1
nxra	PolaRx3TR	41.6	43.1	49.3
nxrb	PolaRx5TR	60.9	63.3	58.8
nxrl	PolaRx3TR PRO	45.9	47.4	52.0
rj03	PIKTIME TTS-5	-1.0	0.2	-1.6
rj04	PIKTIME TTS-5	-3.7	-2.9	-9.2

We note the importance of adopting the right procedure for the REFDLY measurement for some models of TTS-5 receivers[6]. The calibration result and its uncertainty for UTC are not affected as long as the receiver set-up doesn't change, even if the REFDLY is assigned incorrectly. This is because the REFDLY is not just the PPS delay from the reference point to the receiver input. Therefore, we suggest that the aggregate of all delays be reffered as TOTDLY in the CGGTTS files instead of referencing to individual components.

In summary, the larger than usual value for the uncertainty in Table 9 is due to the misclosure that was double than the nominal value of ~ 500 ps or less. It is worth noting that the round-trip took almost a year due to the ongoing covid-19 pandemic, which is double the time it takes for similar trips under normal conditions.

5 Secondary information

1. RAWDIF and TDev plots: Attached separately.
2. Annex A: Attached separately.
3. Data files: ftp//ftp.nist.gov/pub/pml/688gps/GNSS-Calibrations/cal_id_1012-2020.zip

References

[1] ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/guidelines/

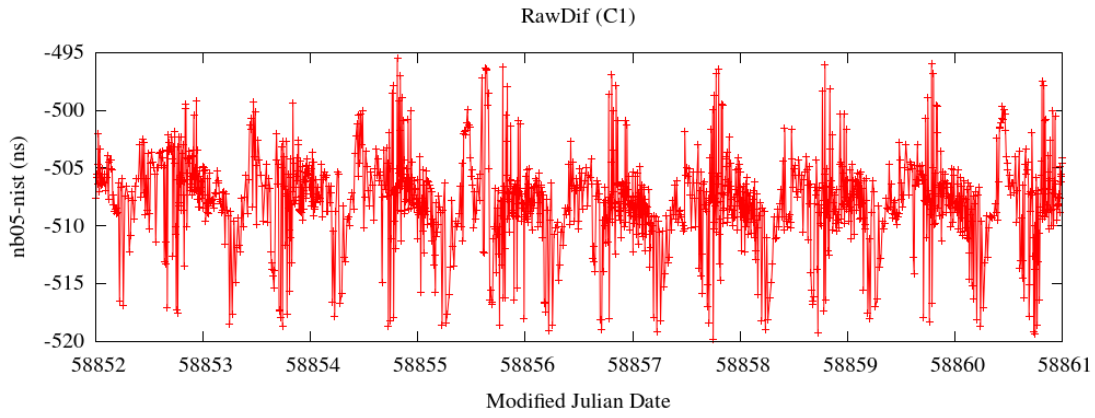
[2] ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/group1/1001-2018/1001-2018-phase4-report_V10.pdf

[3] ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/doc-soft/

[4] http://www.bipm.org/wg/CCTF/WGGNSS/Allowed/BIPM_guidelines_V3/Annex-3_Computation-procedure-Rinex_V2.pdf

[5] ftp://dgn6.esoc.esa.int/CC2NONCC/

[6] ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/guidelines/annex-1_operational-procedures-20190320.pdf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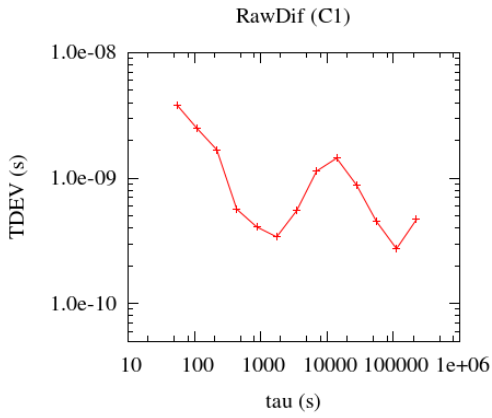
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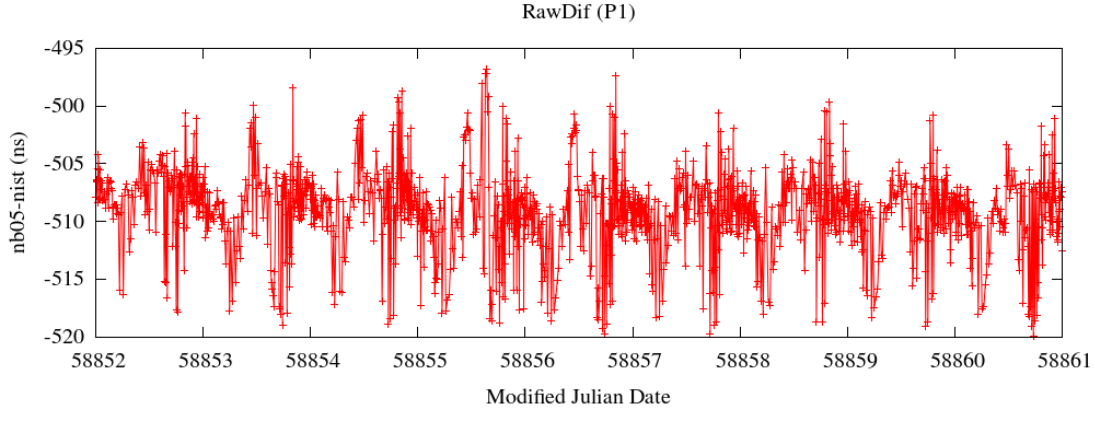
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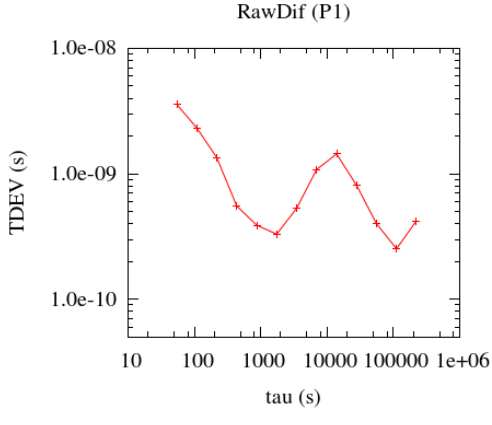
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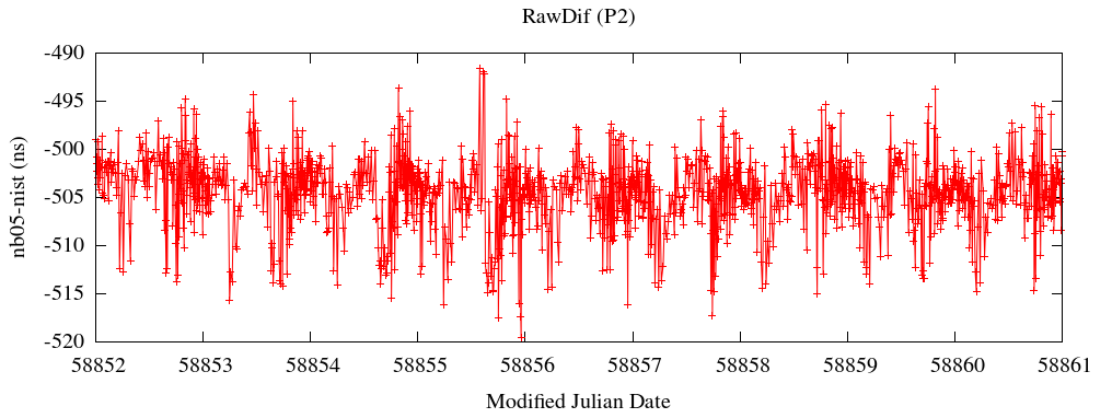
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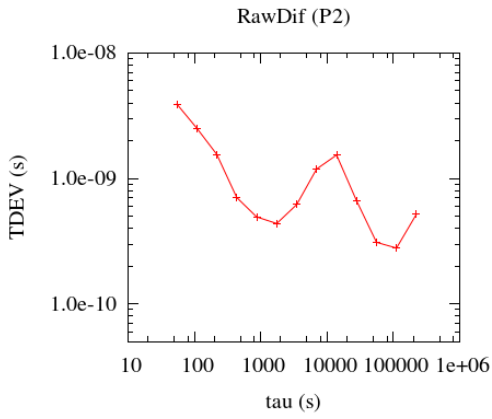
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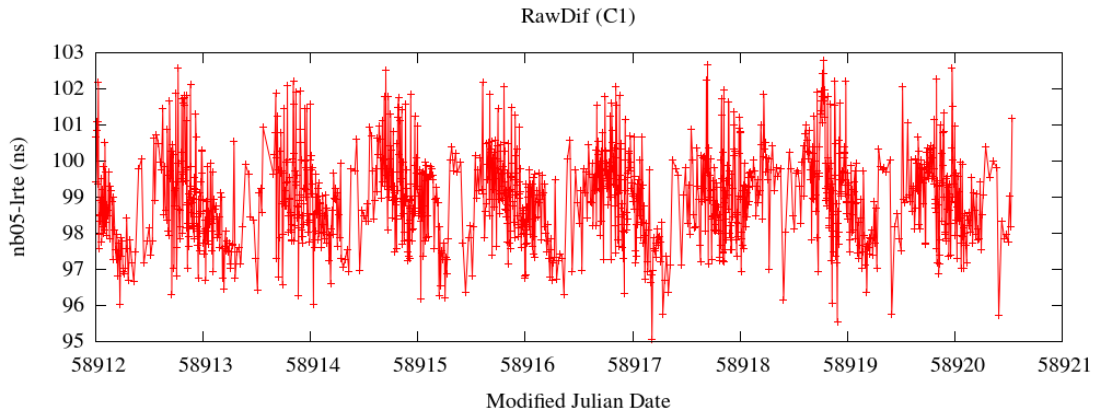
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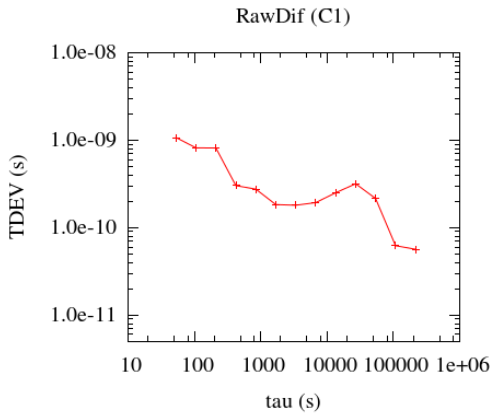
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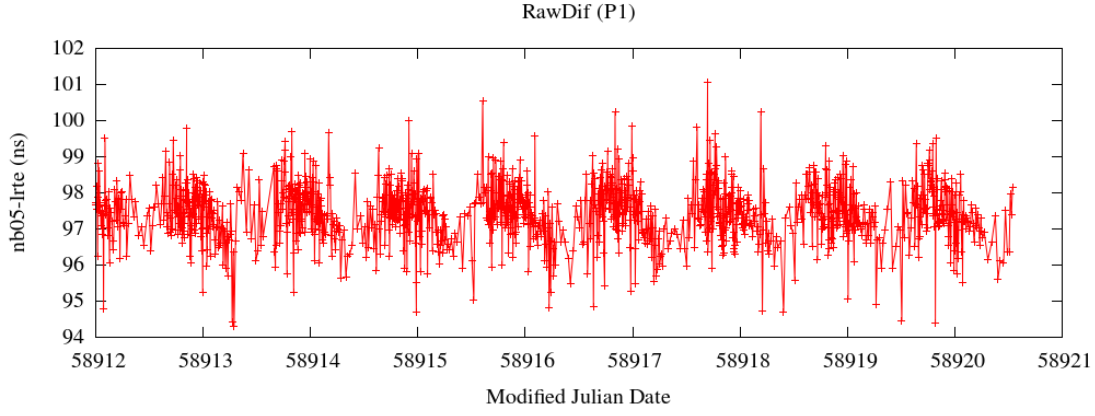
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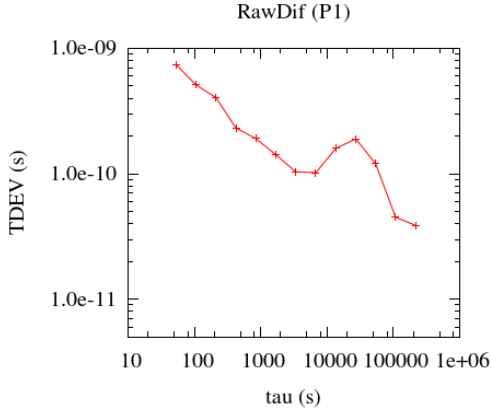
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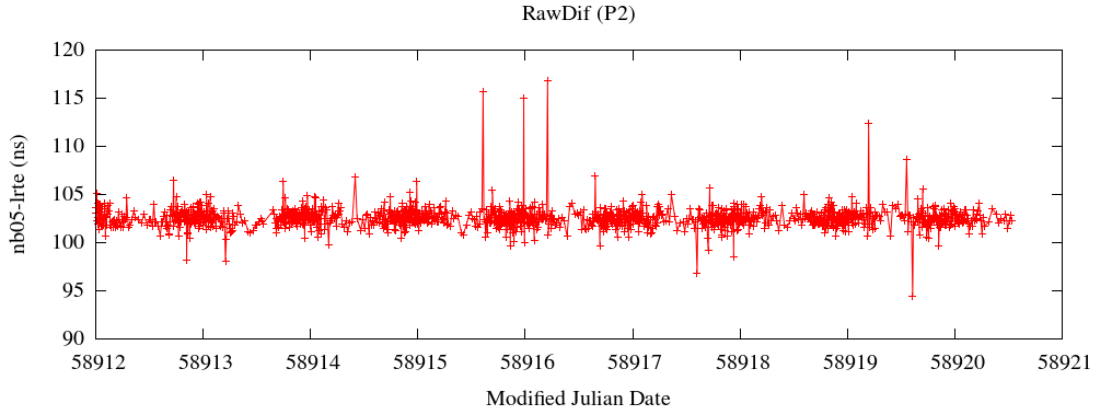
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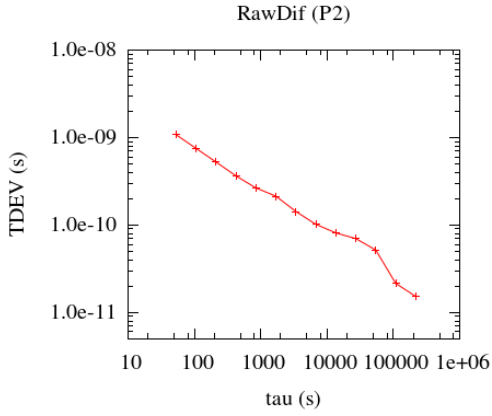
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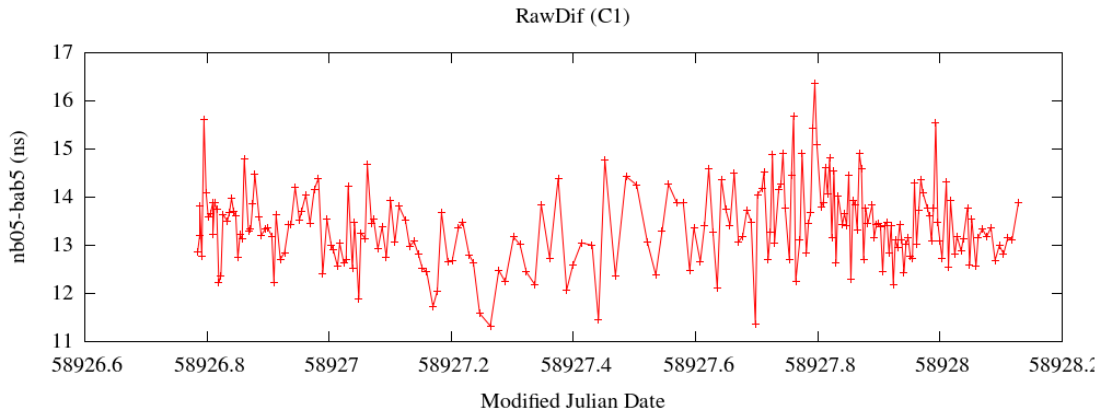
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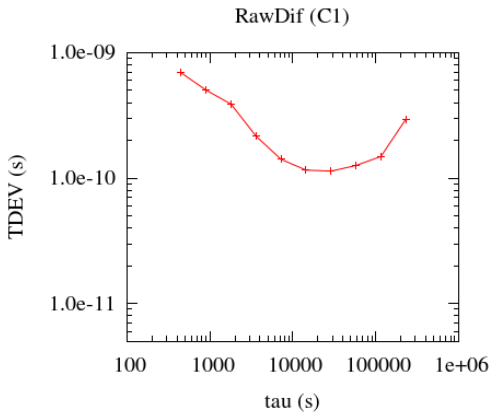
58928
Modified Julian Date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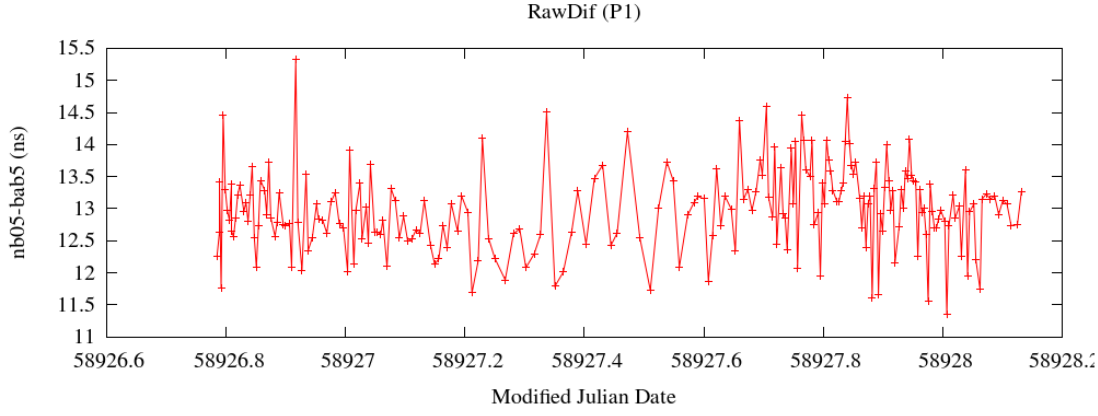
100000
1e+06
tau (s)


RawDif (P1)
nb05-bab5 (ns)
15.5
15
14.5
14
13.5
13
12.5
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11.5
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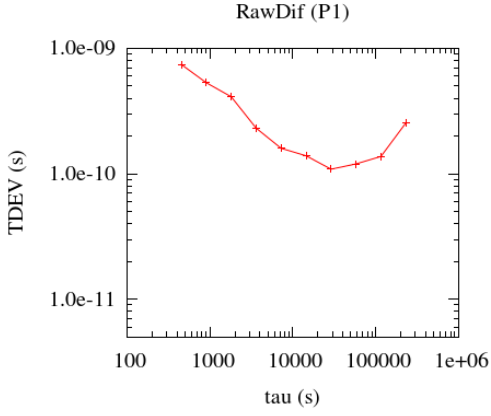
58926.8
58927
58927.2
58927.4
58927.6
58927.8
58928
Modified Julian Date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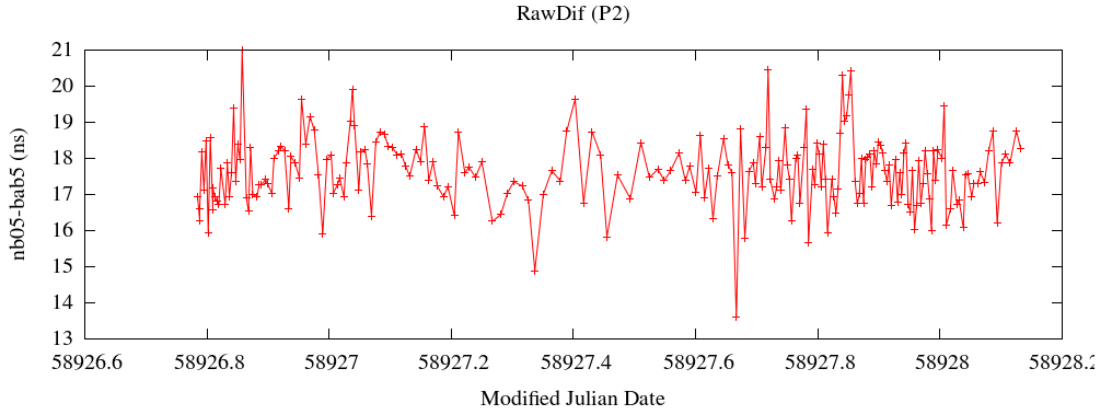
1e+06
tau (s)


RawDif (P2)
nb05-bab5 (ns)
21
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19
18
17
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58926.8
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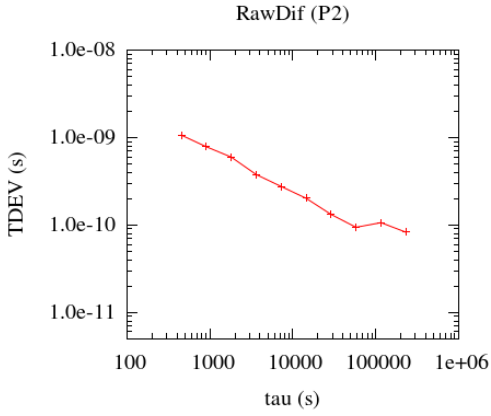
58927.2
58927.4
58927.6
58927.8
58928
Modified Julian Date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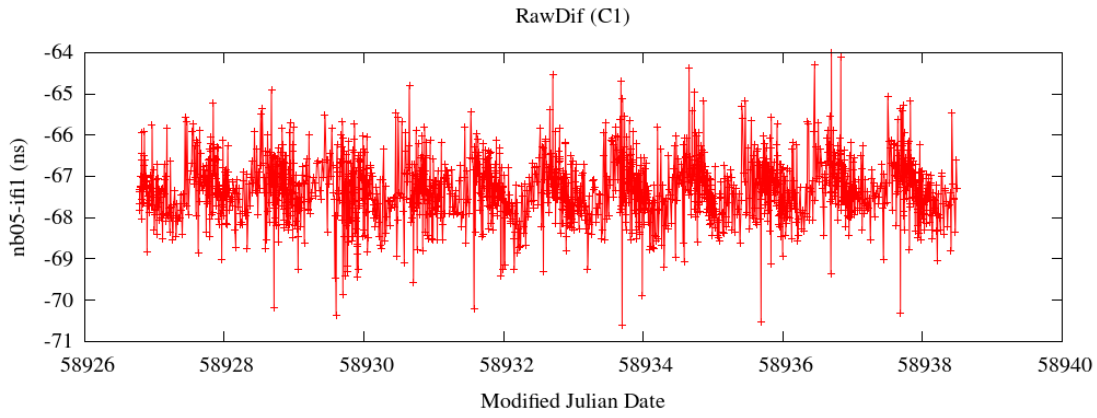
1e+06
tau (s)


RawDif (C1)
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-65
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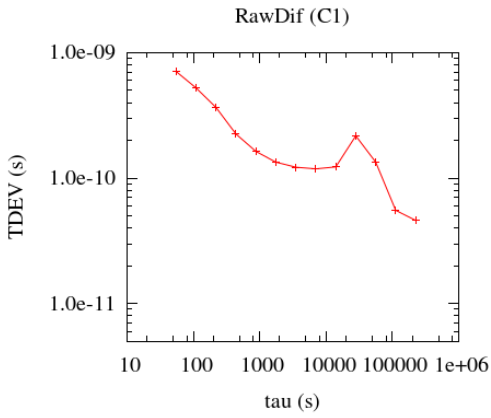
58940
Modified Julian Date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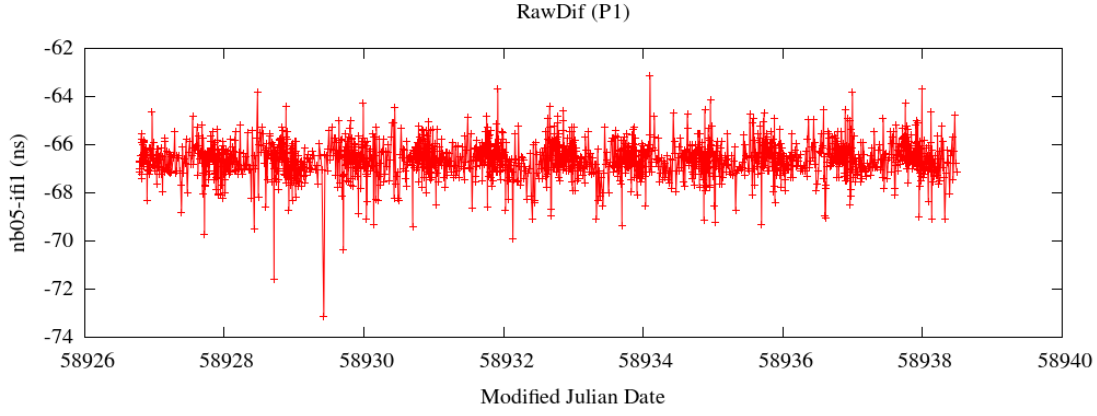
tau (s)


RawDif (P1)
nb05-ifl1 (ns)
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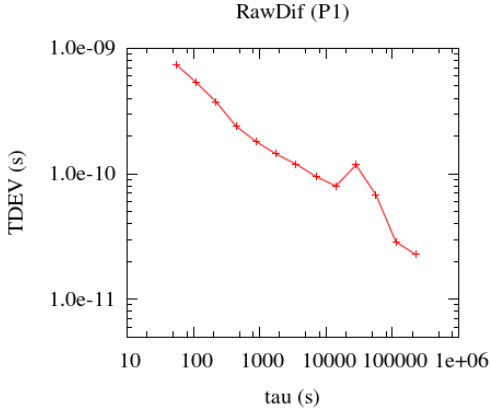
Modified Julian Date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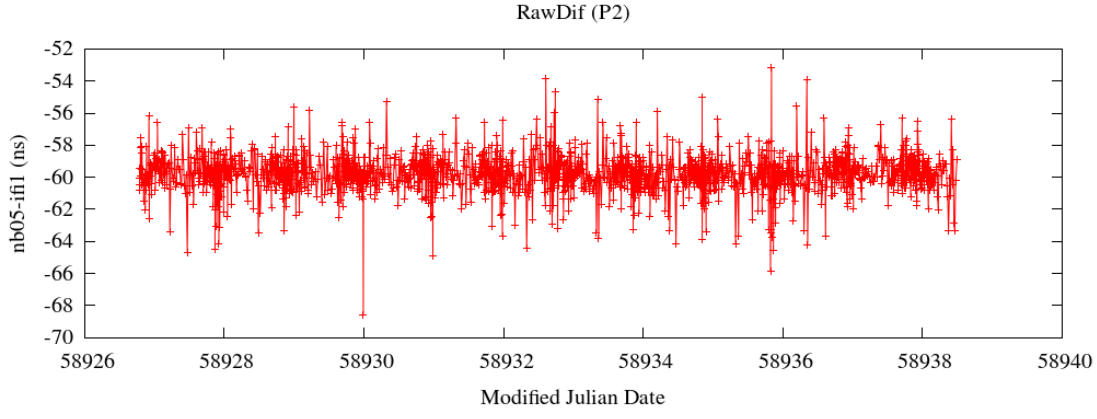
1e+06
tau (s)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nb05-ifl1 (ns)
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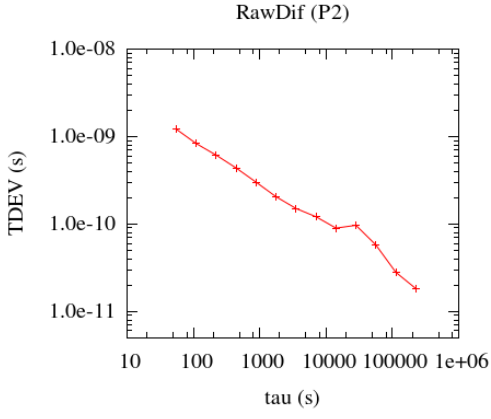
Modified Julian Date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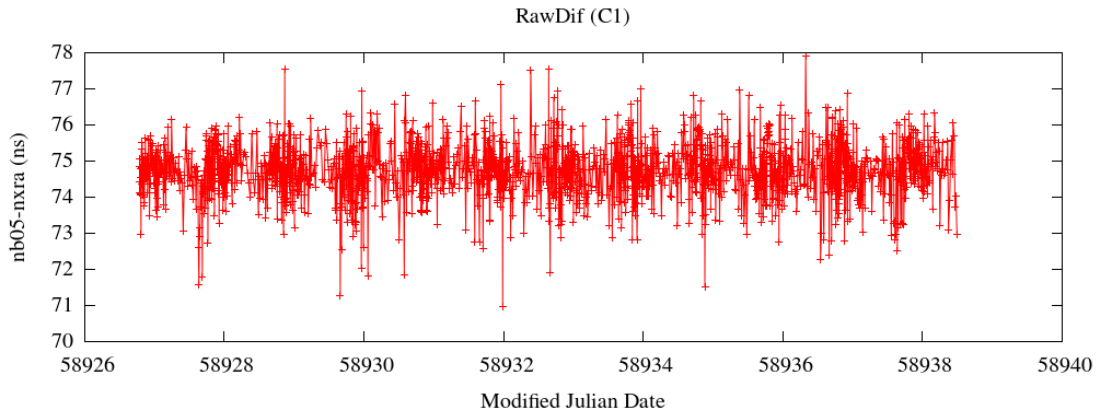
1000
10000
100000
1e+06
tau (s)


RawDif (C1)
nb05-nxra (ns)
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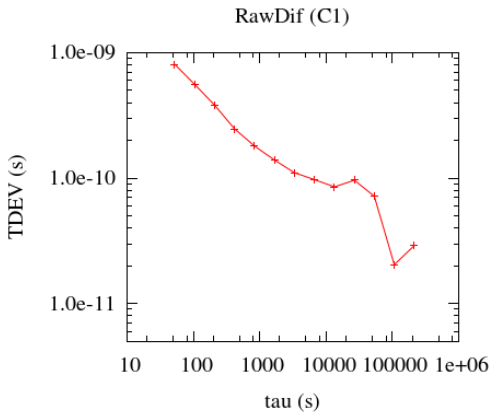
Modified Julian Date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TDEV (s)
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1.0e-11
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100
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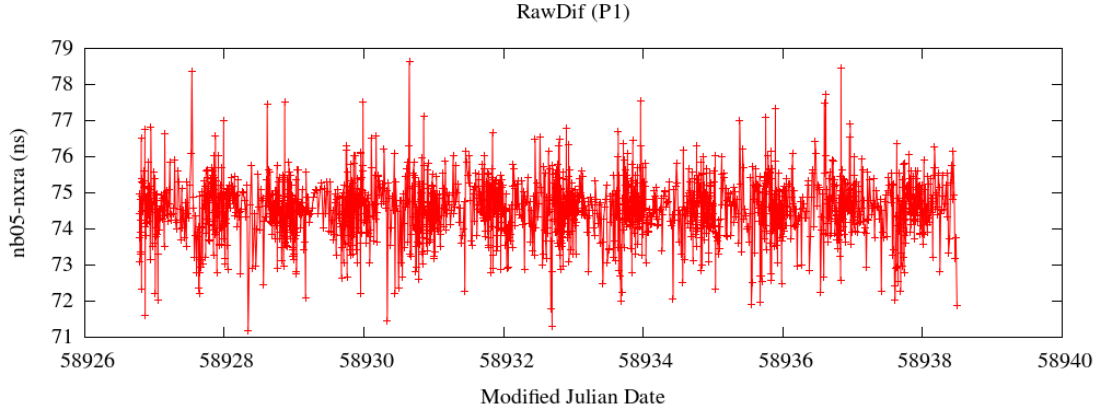
100000
1e+06
tau (s)


RawDif (P1)
nb05-nxra (ns)
79
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74
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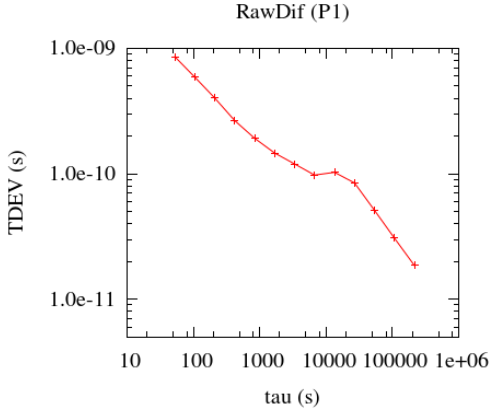
58938
58940
Modified Julian Date


RawDif (P1)
TDEV (s)
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1.0e-11
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100
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10000
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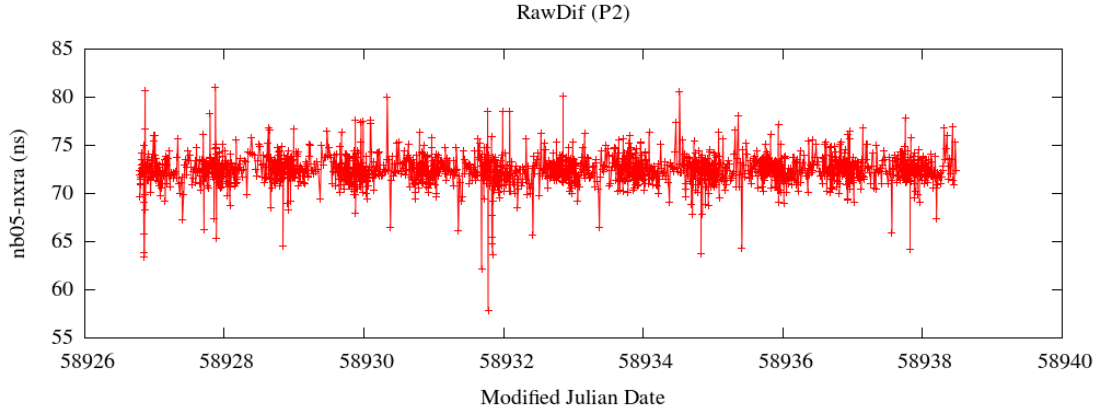
1e+06
tau (s)


RawDif (P2)
nb05-nxra (ns)
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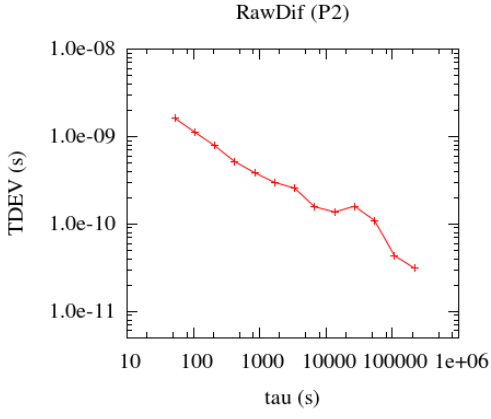
Modified Julian Date


RawDif (P2)
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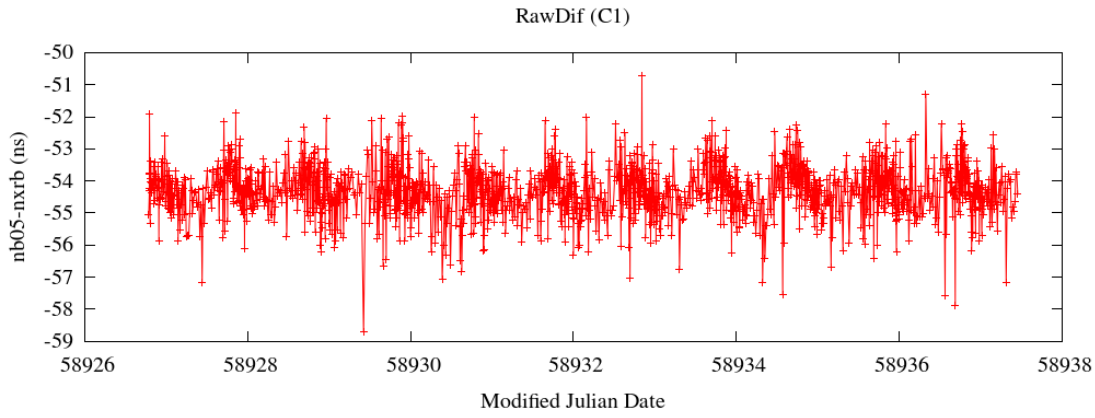
10000
100000
1e+06
tau (s)


RawDif (C1)
nb05-nxrb (ns)
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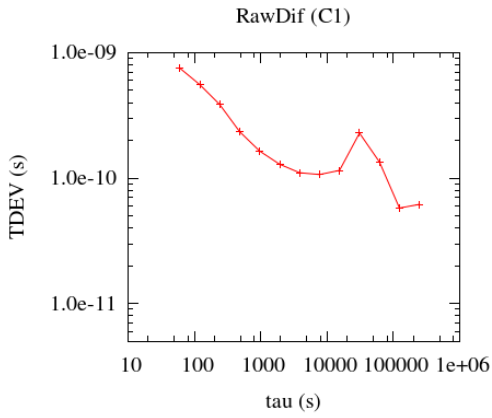
Modified Julian Date


RawDif (C1)
TDEV (s)
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1.0e-11
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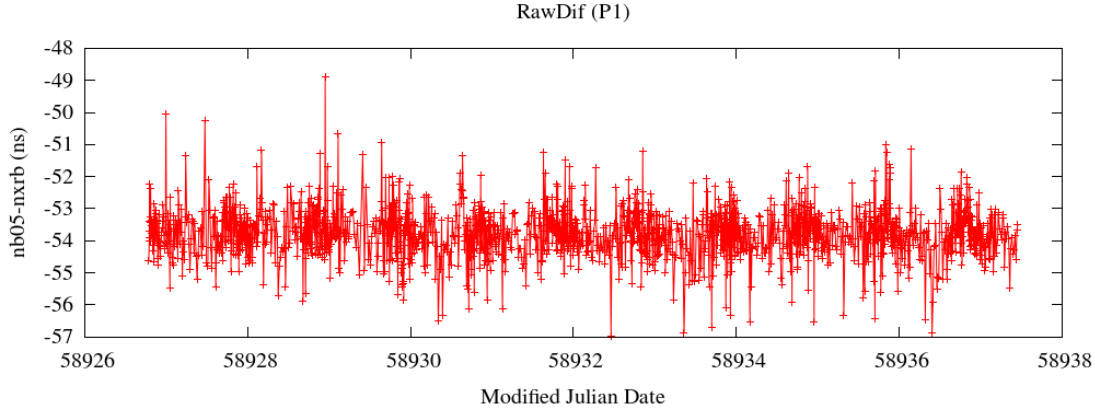
100000
1e+06
tau (s)


RawDif (P1)
nb05-nxrb (ns)
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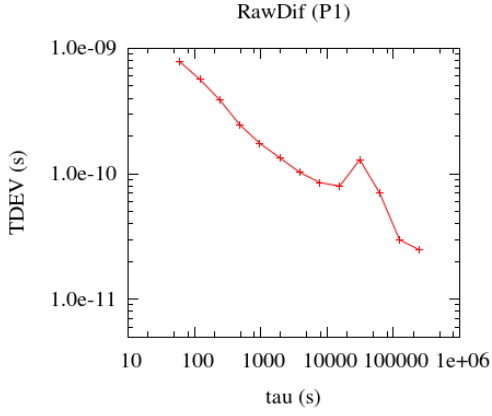
Modified Julian Date


RawDif (P1)
TDEV (s)
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1.0e-11
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10000
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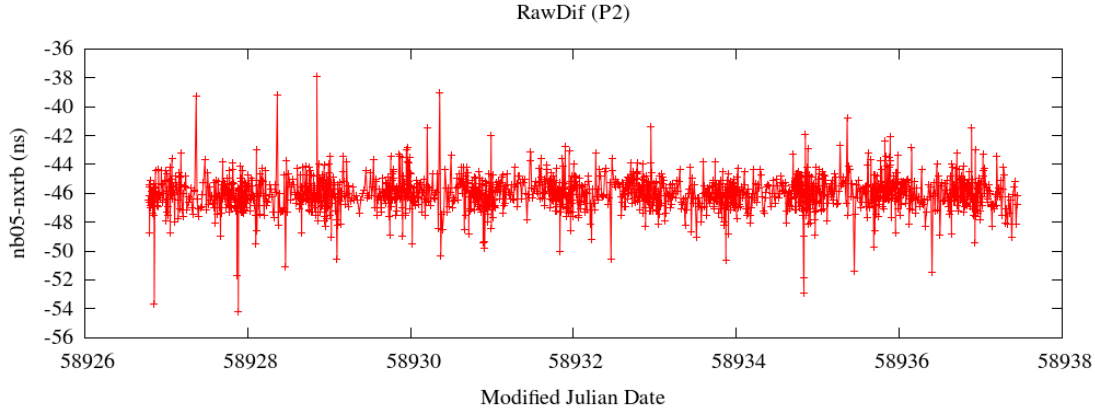
1e+06
tau (s)


RawDif (P2)
nb05-nxrb (ns)
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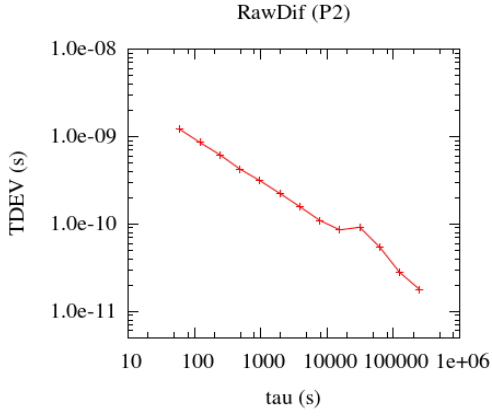
Modified Julian Date


RawDif (P2)
TDEV (s)
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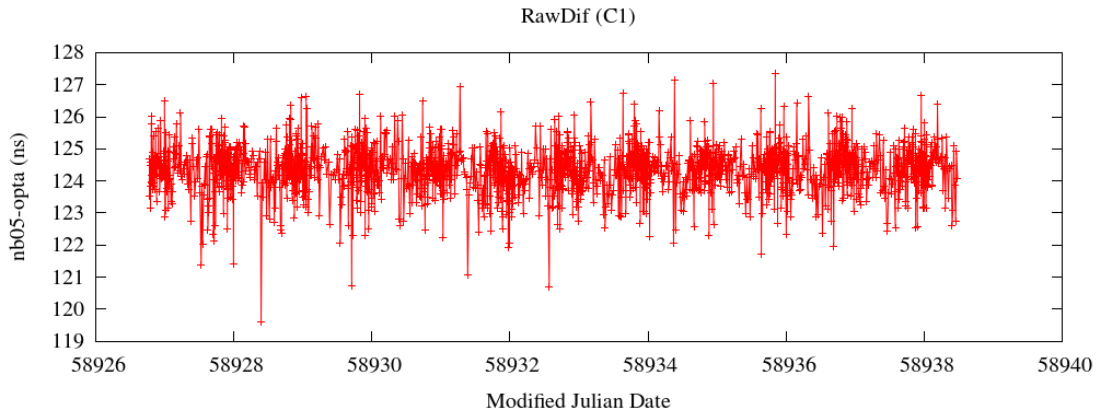
tau (s)


RawDif (C1)
nb05-opta (ns)
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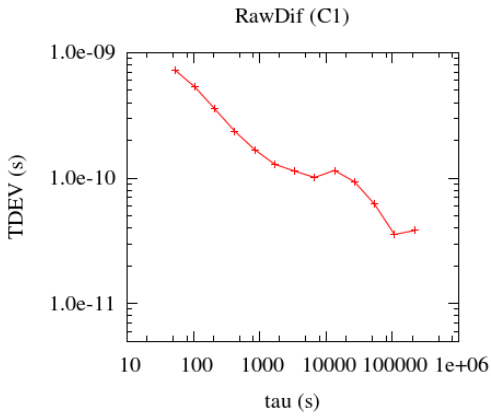
RawDif (C1)
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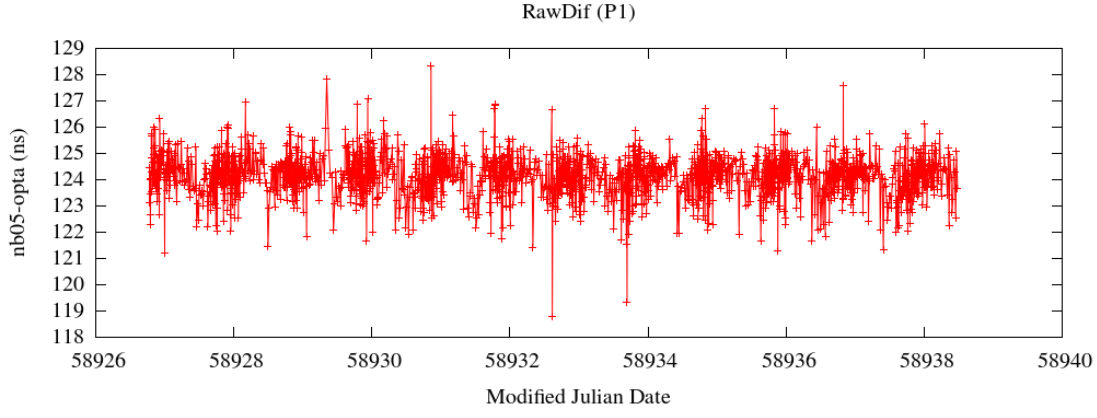
1e+06
tau (s)


RawDif (P1)
nb05-opta (ns)
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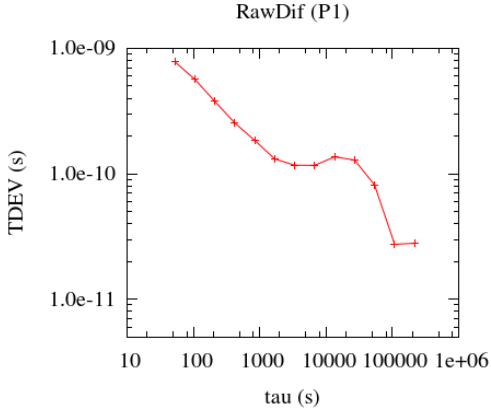
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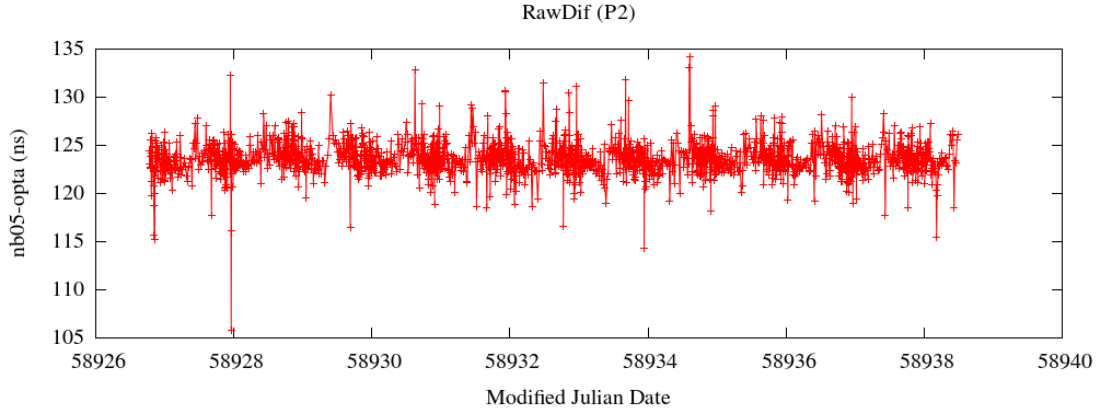
1e+06
tau (s)


RawDif (P2)
nb05-opta (ns)
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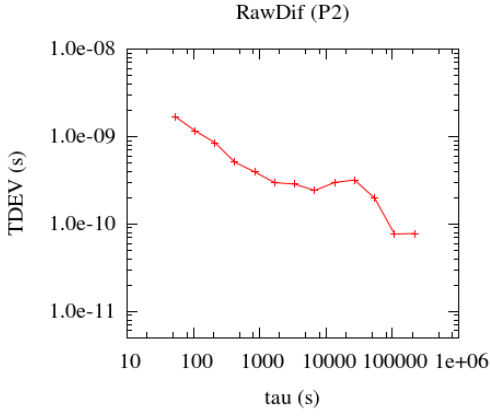
Modified Julian Date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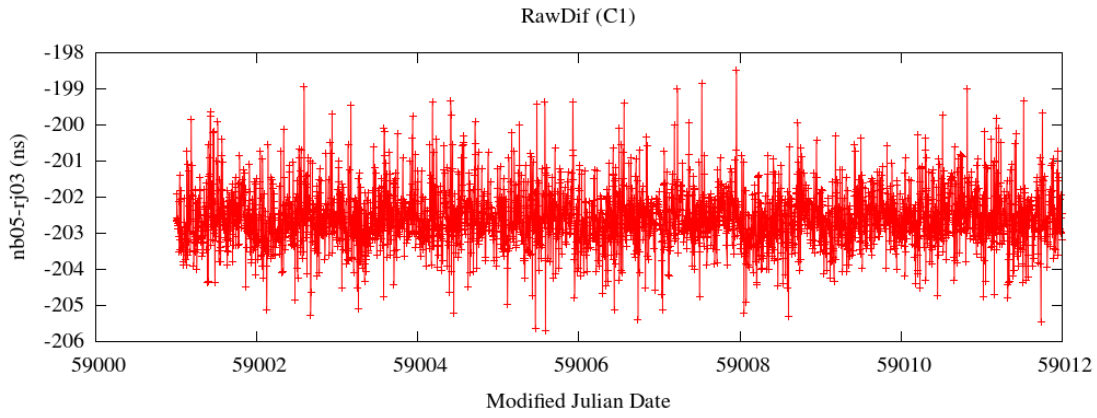
1e+06
tau (s)


RawDif (C1)
nb05-rj03 (ns)
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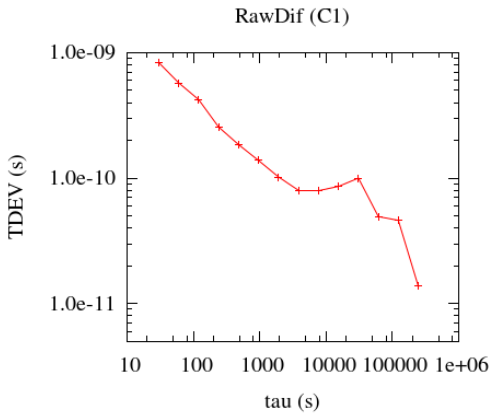
Modified Julian Date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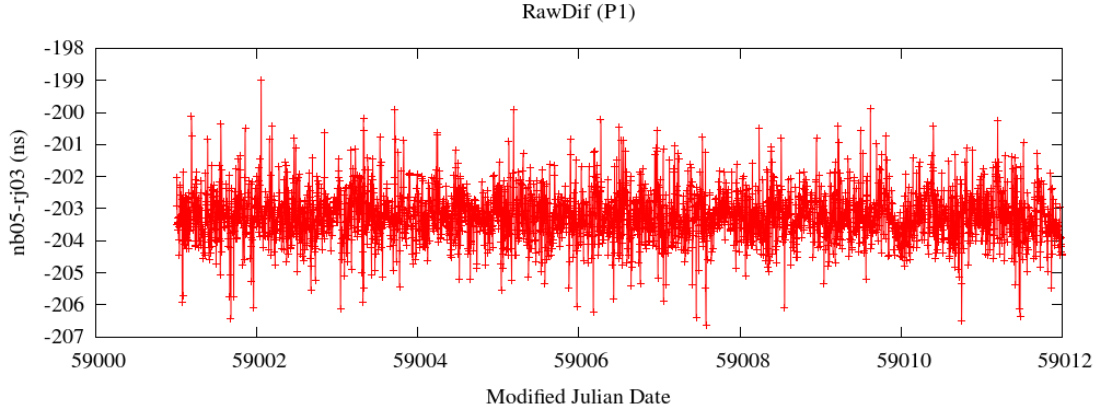
tau (s)


RawDif (P1)
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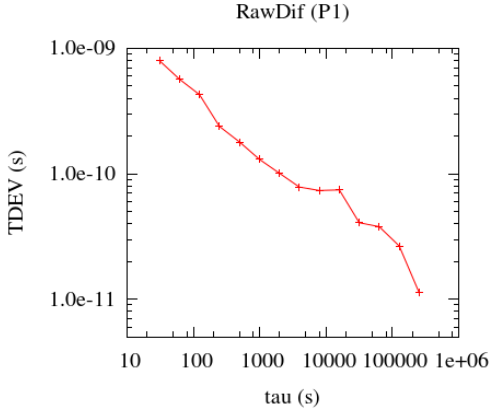
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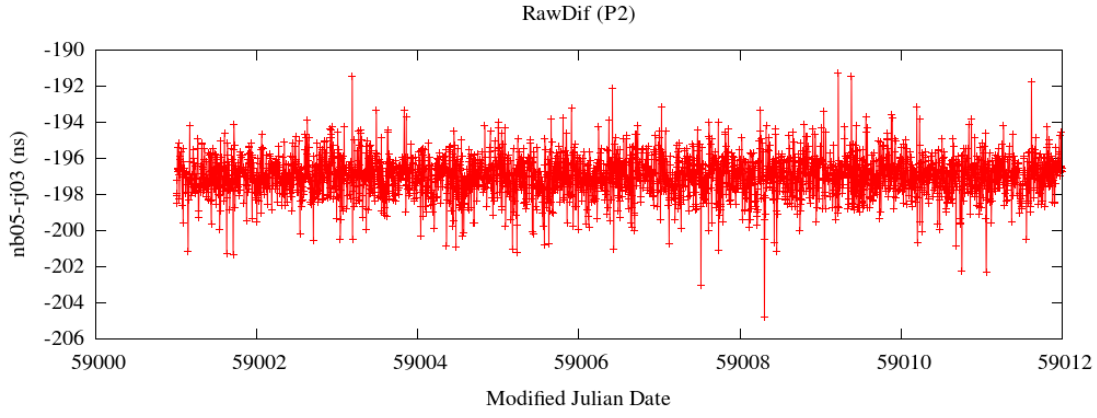
tau (s)


RawDif (P2)
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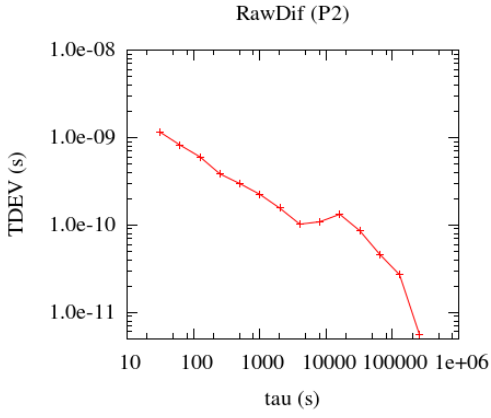
Modified Julian Date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TDEV (s)
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100
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10000
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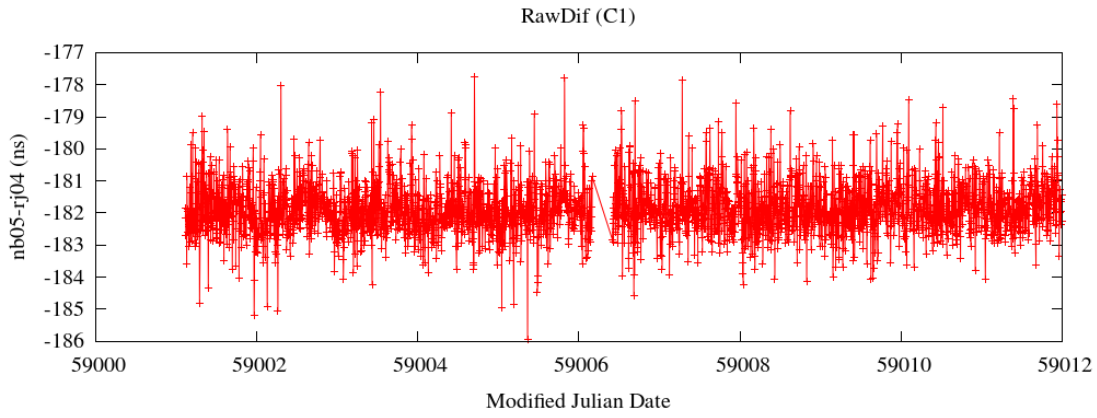
1e+06
tau (s)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nb05-rj04 (ns)
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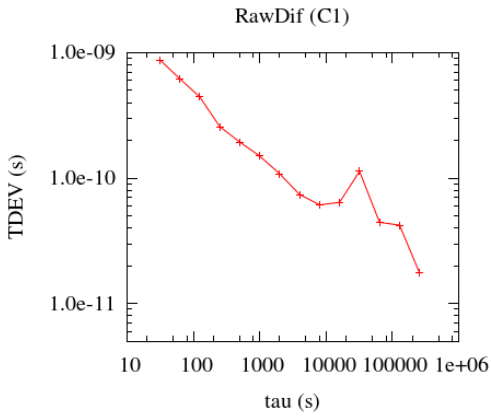
Modified Julian Date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TDEV (s)
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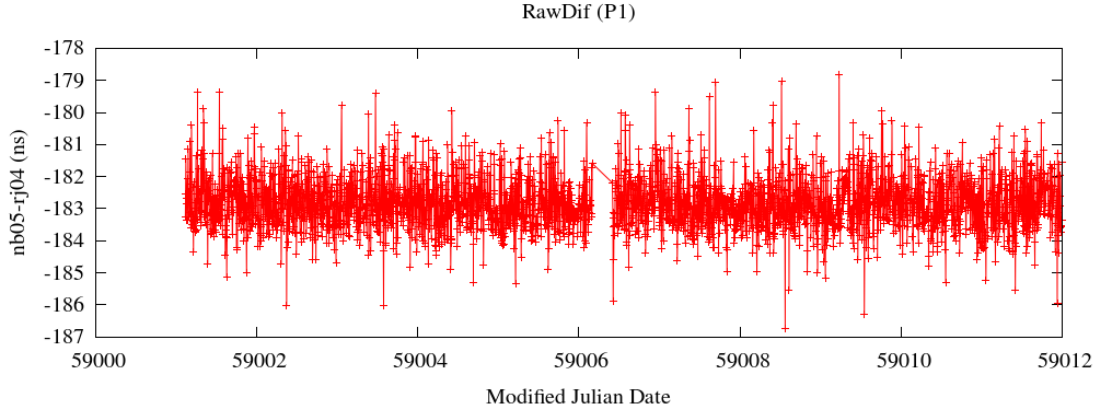
1e+06
tau (s)


RawDif (P1)
nb05-rj04 (ns)
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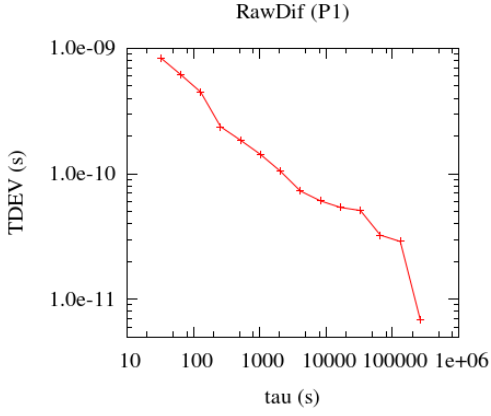
Modified Julian Date


RawDif (P1)
TDEV (s)
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1.0e-10
1.0e-11
10
100
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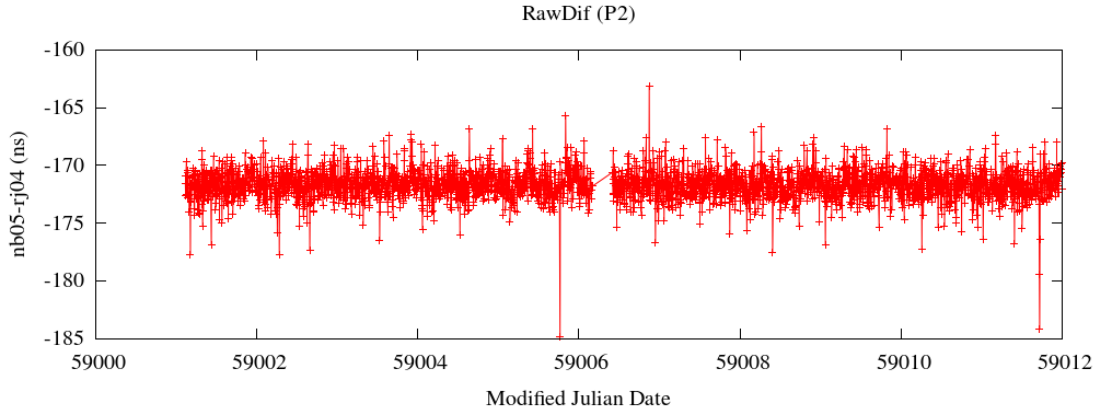
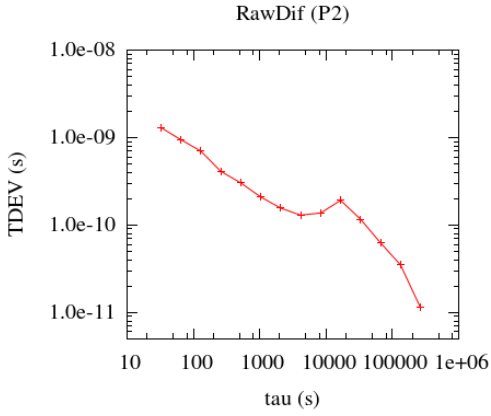
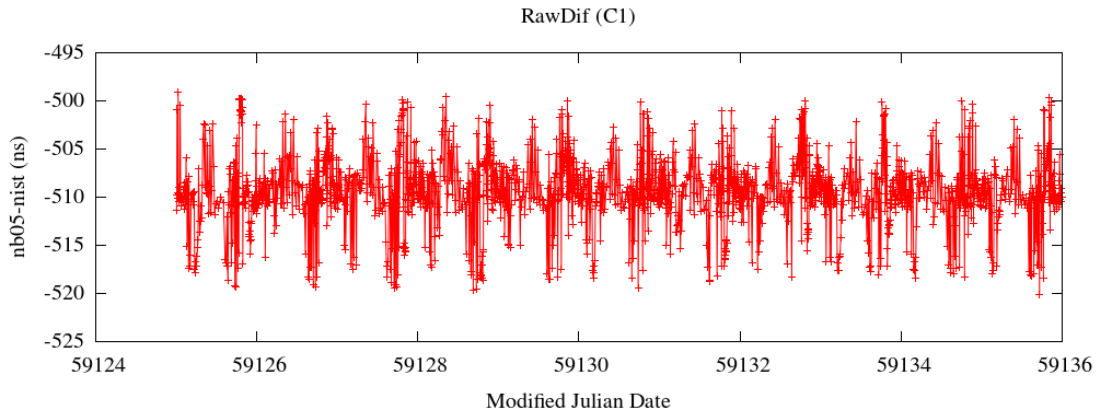
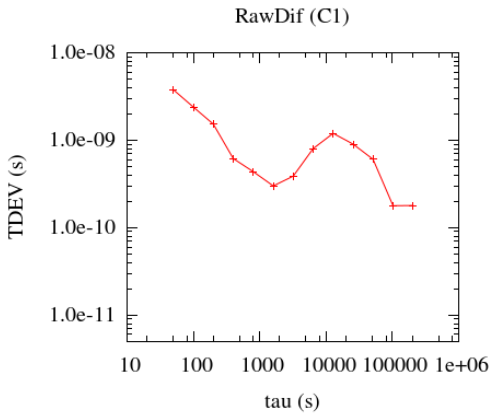
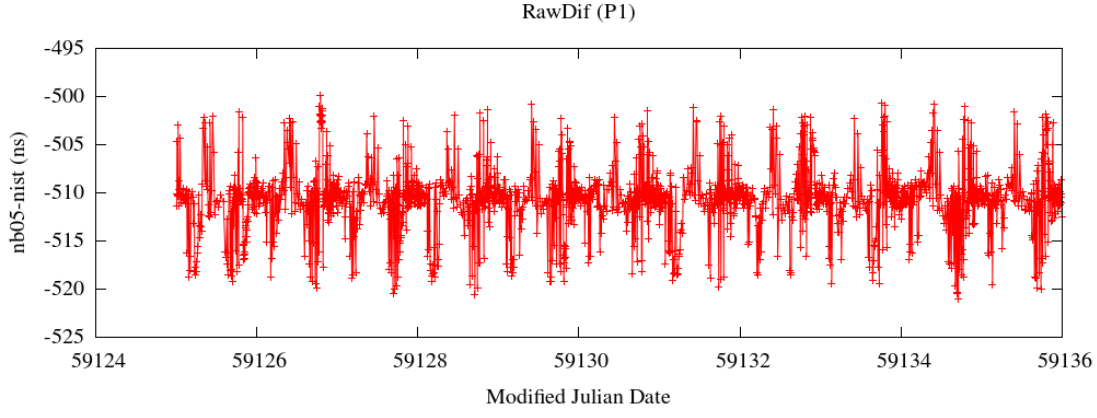
10000
100000
1e+06
tau (s)

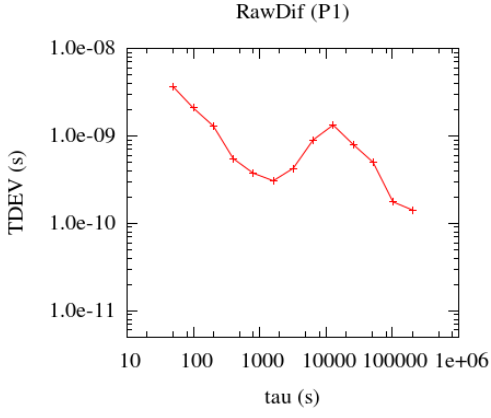

RawDif (P2)
nb05-rj04 (ns)
-160
-165
-170
-175
-180
-185
59000
59002
59004
59006
59008
59010
59012
Modified Julian Date

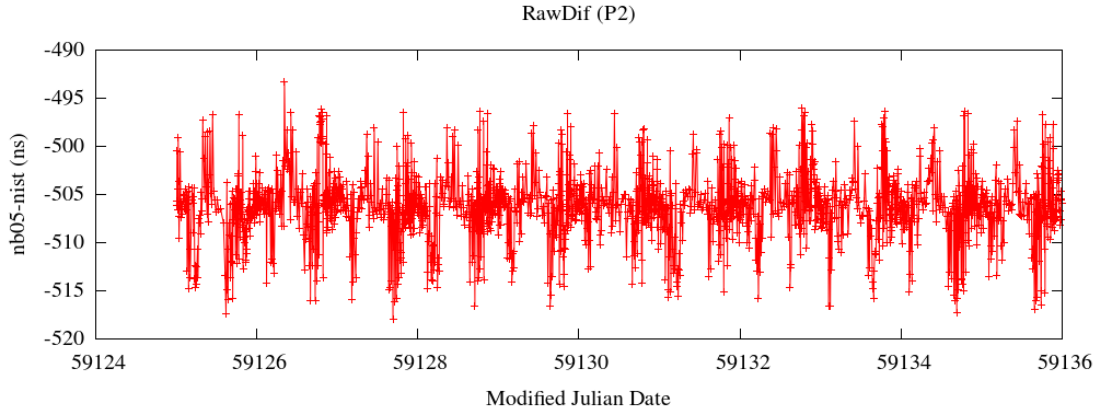

RawDif (P2)
TDEV (s)
1.0e-08
1.0e-09
1.0e-10
1.0e-11
10
100
1000
10000
100000
1e+06
tau (s)

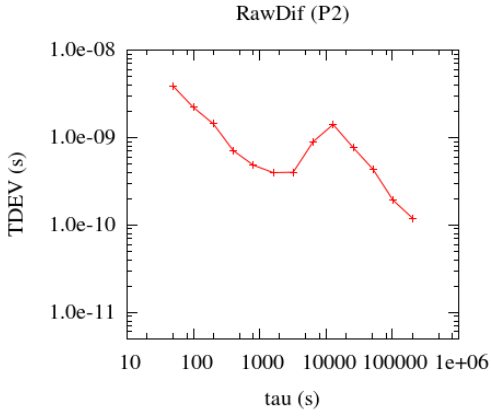

RawDif (C1)
nb05-nist (ns)
-495
-500
-505
-510
-515
-520
-525
59124
59126
59128
59130
59132
59134
59136
Modified Julian Date


RawDif (C1)
TDEV (s)
1.0e-08
1.0e-09
1.0e-10
1.0e-11
10
100
1000
10000
100000
1e+06
tau (s)


RawDif (P1)
nb05-nist (ns)
-495
-500
-505
-510
-515
-520
-525
59124
59126
59128
59130
59132
59134
59136
Modified Julian Date


RawDif (P1)
TDEV (s)
1.0e-08
1.0e-09
1.0e-10
1.0e-11
10
100
1000
10000
100000
1e+06
tau (s)


RawDif (P2)
nb05-nist (ns)
-490
-495
-500
-505
-510
-515
-520
59124
59126
59128
59130
59132
59134
59136
Modified Julian Date


RawDif (P2)
TDEV (s)
1.0e-08
1.0e-09
1.0e-10
1.0e-11
10
100
1000
10000
100000
1e+06
tau (s)

Annex A - Information Sheet

Laboratory:	**NIST**
Date and hour of the beginning of measurements:	MJD 58850
Date and hour of the end of measurements:	MJD 58860

Information on the system		
	Local:	**Traveling:**
4-character BIPM code	**NIST**	**nb05**
Receiver maker and type: Receiver serial number:	Novatel OEM4-G2 S/N	Septentrio PolaRx3eTR PRO
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	Andrew FSJ-50A N	Timesmicrowave LMR 100A
Length outside the building /m:	65	10
Antenna maker and type: Antenna serial number:	Novatel 702	Novatel 702 S/N 010017577
Temperature (if stabilised) /°C		

Measured delays /ns		
	Local:	**Traveling:**
Delay from local UTC to receiver 1 PPS-in (X_P)	65.9	405.5 (328.19+77.27)
Delay from 1 PPS-in to internal Reference (if different): (X_O)		206.7
Antenna cable delay: (X_C)	275.5	199.6
Splitter delay (if any):	N/A	
Additional cable delay (if any):	N/A	

Data used for the generation of CGGTTS files

• INT DLY (or X_R+X_S) (GPS)† /ns:	-73.2 (P1), -72.1 (P2), -72.6 (C1)
• INT DLY (or X_R+X_S) (GLONASS) /ns:	
• CAB DLY (or X_C) /ns:	275.5
• REF DLY (or X_P+X_O) /ns:	65.9
• Coordinates reference frame:	WGS84
X /m:	-1288398.51
Y /m:	-4721696.92
Z /m	4078625.35

General information

• Rise time of the local UTC pulse:	3 ns
• Is the laboratory air conditioned:	yes
Set temperature value and uncertainty:	
Set humidity value and uncertainty:	

† Based on Cal_Id 1001-2018, but still not implemented

Annex A - Information Sheet

Laboratory:	**Laboratory of References of Time and Space**	
Date and hour of the beginning of measurements	03/03/2020 - 12:00 UTC	
Date and hour of the end of measurements	12/03/2020 - 13:00 UTC	
Information on the system		
	Local	**Traveling**
4-character BIPM code	LRTE	NB05
Receiver maker and type Receiver serial number	Septentrio PolaRx3Tr - SN: 21092	Septentrio PolaRx3eTr Pro - SN: 2002994
1 PPS trigger level /V	1.5	1.0
Antenna cable maker and type Phase stabilized cable (Y/N)	Septentrio provided / N	Times microwave systems / N
Length outside the building /m:	20.0	20.0
Antenna maker, type, and serial number	Septentrio, PolaNT, SN: 5181	NovaTel, 702-GG, SN: 01017877
Temperature (if stabilized) /°C		
Measured delays /ns		
	Local	**Traveling**
Delay from local UTC to receiver 1 PPS-in (X_P)	12.1 ns	8.3 ns
Delay from 1 PPS-in to internal Reference (if different)(X_O)	200.0 ns	249.1 ns
Antenna cable delay (X_C)	126.8 ns	199.65 ns
Splitter delay (if any)		
Additional cable delay (if any)		
Data used for the generation of CGGTTS files		
INT DLY (or X_R+X_S) (GPS) /ns	53.9 ns (C1) / 49.8 ns (P2)	
CAB DLY (or X_C) /ns	126.8 ns	
REF DLY (or X_P+X_O) /ns	212.1 ns	
Coordinates reference frame		
X /m	3967031.9739	
Y /m	-4390026.7713	
Z /m	-2375646.6412	
General information		
Rise time of the local UTC pulse	5.0 ns	
Is the laboratory air conditioned ? (Y/N)	Y	
Set temperature value and uncertainty	22 ºC +- 0.1 ºC	
Set humidity value and uncertainty	35 % +- 3.0 %	

Schematic Diagram for USP GNSS comparison with NIST itinerant receiver

Daniel Varela Magalhães - daniel@sc.usp.br
Luiz Paulo Damaceno - ldamaceno@usp.br

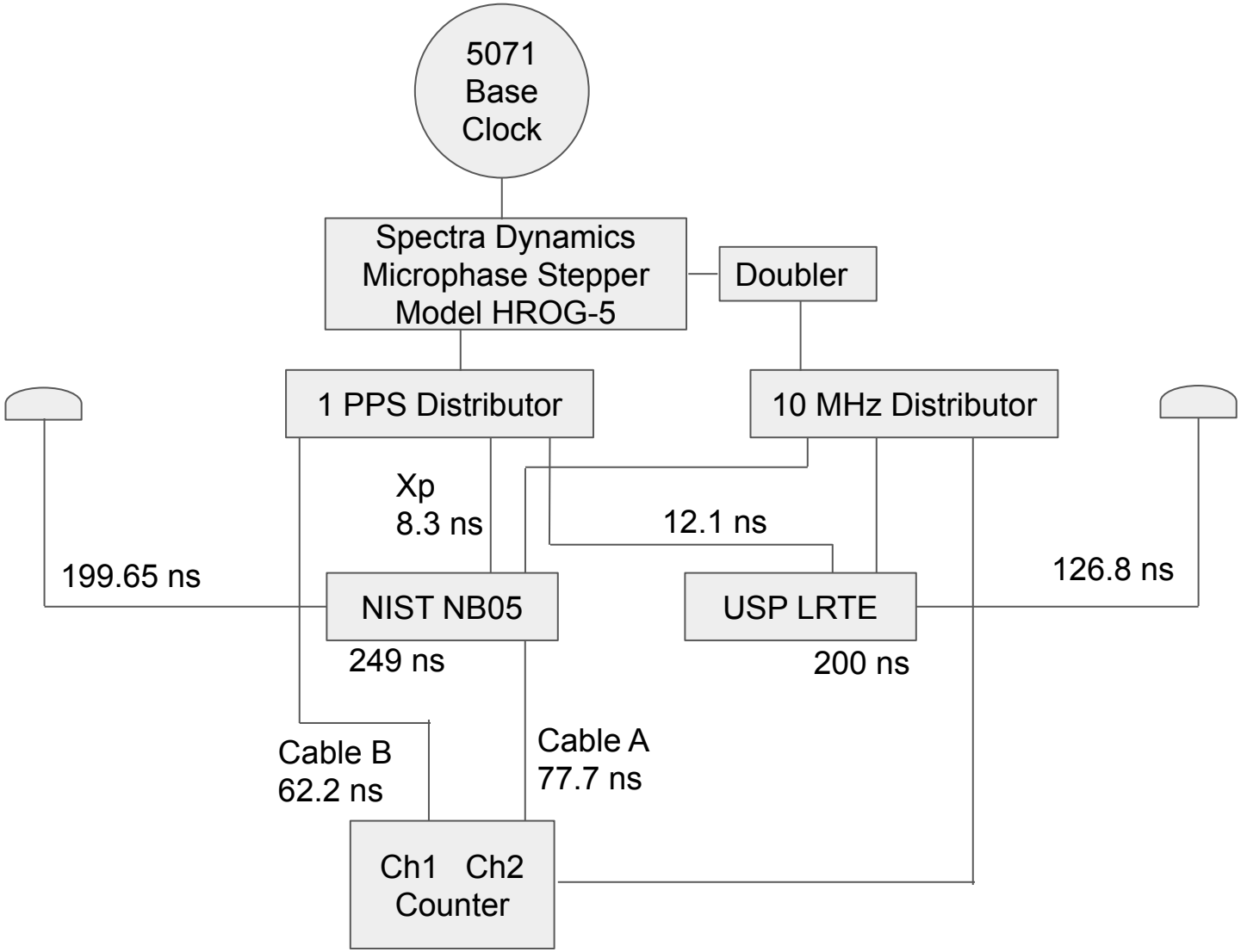
Base clock is a 5071 model

USP receiver is a Septentrio PolarX3TR

CGGTTS delay data is as follows:

REV DATE
2020-01-15
RCVR
POLARX3-TR
CH
27
LAB NAME
LRRC
X COORDINATE
3967035.91
Y COORDINATE
-4390028.51
Z COORDINATE
-2375644.69
COMMENTS
NO COMMENT
REF
UTC(LRTE)
CALIBRATION REFERENCE

INT DELAY C1 GPS (in ns)
53.9
INT DELAY P2 GPS (in ns)
49.8
ANT CAB DELAY (in ns)
126.8
CLOCK CAB DELAY XP+XO (in ns)
212.1
LEAP SECOND
18
30s FILES
YES


5071
Base
Clock
Spectra Dynamics
Microphase Stepper
Model HROG-5
Doubler
1 PPS Distributor
10 MHz Distributor
Xp
8.3 ns
12.1 ns
199.65 ns
126.8 ns
NIST NB05
USP LRTE
249 ns
200 ns
Cable B
62.2 ns
Cable A
77.7 ns
Ch1 Ch2
Counter

Information Sheet

Laboratory:	INMETRO - INXE
Date and hour of the beginning of measurements:	18:45 h (UTC) ; 18/march/2020
Date and hour of the end of measurements:	11:54 h (UTC) ; 30/march/2020

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NXRA	NB05
Receiver maker and type: Receiver serial number:	Septentrio PolaRx3TR s/n 0000449299	Septentrio PolaRx3eTR PRO s/n 2002994
1 PPS trigger level /V:	1.00 Volt	1.00 Volt
Antenna cable maker and type: Phase stabilized cable (Y/N):	Belden MRG213 Not phase stabilized	TMS LMR-400 Not phase stabilized
Length outside the building /m:	12 meters	17 meters
Antenna maker and type: Antenna serial number:	AERAT2775-43 SPKE s/n 5642	Novatel PinWheel 702-GG s/n 01017577
Temperature (if stabilised) /°C	-------	--------

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P):	8.6 ns	8.6 ns
Delay from 1 PPS-in to internal reference (if different) (X_O):	203.3 ns	201.1 ns
Antenna cable delay (X_C):	124.9 ns	199.3 ns
Splitter delay (if any):	-------	-------
Additional cable delay (if any):	-------	-------

Data used for the generation of CGGTTS files

INT DLY (or $X_R + X_S$) (GPS) /ns:	84.4 (P1) and 88.6 (P2)
CAB DLY (or X_C) /ns:	124.9
REF DLY (or $X_P + X_O$) /ns:	211.9
Coordinates reference frame:	ITRF
Latitude or X /m:	4289082.24
Longitude or Y /m:	-4039527.65
Height or Z /m:	-2434543.67

General information

Rise time of the local UTC pulse:	3.6 ns
Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(23 ± 3) °C
Set humidity value and uncertainty:	(50 ± 10) %RH

(1) For a trip with closure, not needed if the traveling equipment is used in the same set-up throughout.

Diagram of the experiment set-up:

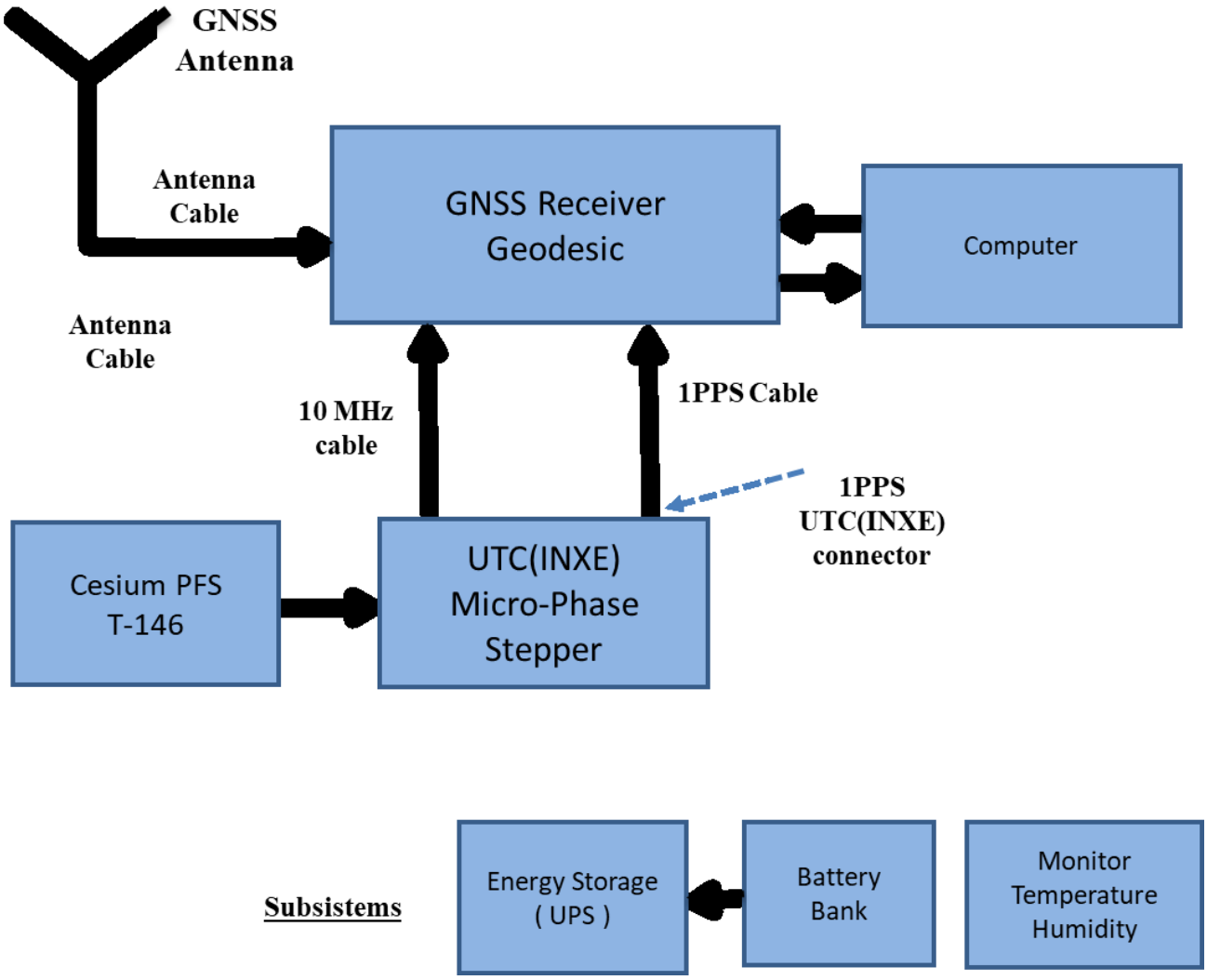


Figure – Diagram of connection for each GNSS receiver

Log of Events / Additional Information :

- GNSS receiver was synchronized with the same cable (LMR195, SMA to BNC), measured delay of 8.6 ns, directly from the 1PPS UTC(INXE) connector (SMA) to the 1PPS input (BNC) of the receiver.

Information Sheet

Laboratory:	INMETRO - INXE
Date and hour of the beginning of measurements:	18:45 h (UTC) ; 18/march/2020
Date and hour of the end of measurements:	11:54 h (UTC) ; 30/march/2020

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NXRB	NB05
Receiver maker and type: Receiver serial number:	Septentrio PolaRx5TR s/n 4701208	Septentrio PolaRx3eTR PRO s/n 2002994
1 PPS trigger level /V:	1.00 Volt	1.00 Volt
Antenna cable maker and type: Phase stabilized cable (Y/N):	TMS LMR-400 Not phase stabilized	TMS LMR-400 Not phase stabilized
Length outside the building /m:	10 meters	17 meters
Antenna maker and type: Antenna serial number:	SEPCHOKE_B3E6 s/n 5097	Novatel PinWheel 702-GG s/n 01017577
Temperature (if stabilised) /°C	-------	--------

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P):	8.6 ns	8.6 ns
Delay from 1 PPS-in to internal reference (if different) (X_O):	39.6 ns	201.1 ns
Antenna cable delay (X_C):	70.2 ns	199.3 ns
Splitter delay (if any):	-------	-------
Additional cable delay (if any):	-------	-------

Data used for the generation of CGGTTS files

INT DLY (or $X_R + X_S$) (GPS) /ns:	0.0 (P1) and 0.0 (P2)
CAB DLY (or X_C) /ns:	70.2
REF DLY (or $X_P + X_O$) /ns:	48.2
Coordinates reference frame:	ITRF
Latitude or X /m:	+4289085.5769
Longitude or Y /m:	-4039528.1278
Height or Z /m:	-2434547.9886

General information

Rise time of the local UTC pulse:	3.6 ns
Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(23 ± 3) °C
Set humidity value and uncertainty:	(50 ± 10) %RH

(1) For a trip with closure, not needed if the traveling equipment is used in the same set-up throughout.

Diagram of the experiment set-up:

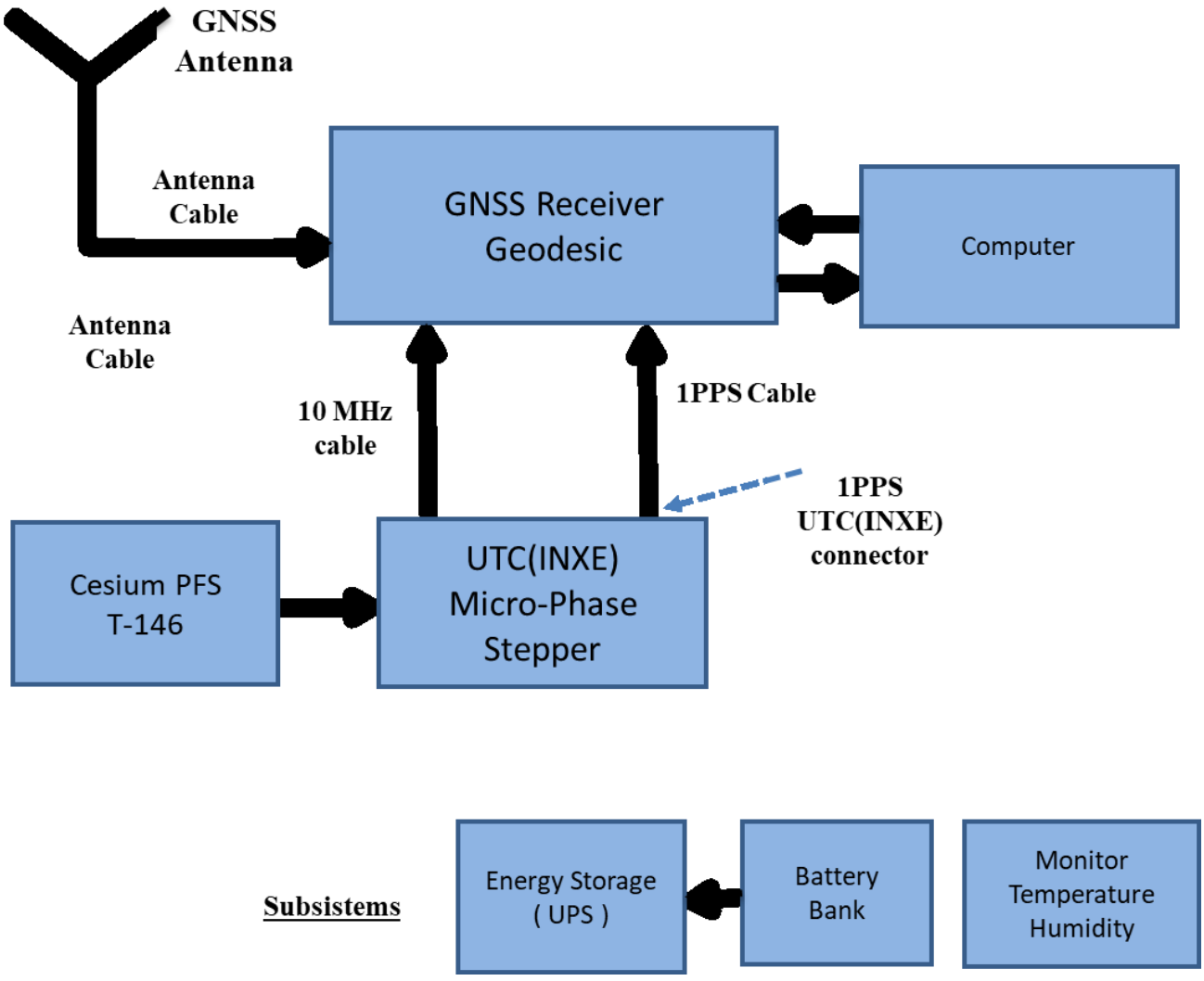


Figure – Diagram of connection for each GNSS receiver

Log of Events / Additional Information :

- GNSS receiver was synchronized with the same cable (LMR195, SMA to BNC), measured delay of 8.6 ns, directly from the 1PPS UTC(INXE) connector (SMA) to the 1PPS input (BNC) of the receiver.

Information Sheet

Laboratory:	INMETRO - INXE
Date and hour of the beginning of measurements:	18:45 h (UTC) ; 18/march/2020
Date and hour of the end of measurements:	11:54 h (UTC) ; 30/march/2020

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NXRK	NB05
Receiver maker and type: Receiver serial number:	Septentrio PolaRx4TR PRO s/n 16	Septentrio PolaRx3eTR PRO s/n 2002994
1 PPS trigger level /V:	1.00 Volt	1.00 Volt
Antenna cable maker and type: Phase stabilized cable (Y/N):	Belden MRG213 N	TMS LMR-400 N
Length outside the building /m:	16 meters	17 meters
Antenna maker and type: Antenna serial number:	SEPCHOKE_MC s/n 5088	Novatel PinWheel 702-GG s/n 01017577
Temperature (if stabilised) /°C	-------	--------

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P):	8.6 ns	8.6 ns
Delay from 1 PPS-in to internal reference (if different) (X_O):	146.0 ns	201.1 ns
Antenna cable delay (X_C):	124.7 ns	199.3 ns
Splitter delay (if any):	-------	-------
Additional cable delay (if any):	-------	-------

Data used for the generation of CGGTTS files

INT DLY (or $X_R + X_S$) (GPS) /ns:	0.0 (P1) and 0.0 (P2)
CAB DLY (or X_C) /ns:	124.7
REF DLY (or $X_P + X_O$) /ns:	154.6
Coordinates reference frame:	ITRF
Latitude or X /m:	+4289083.1604
Longitude or Y /m:	-4039529.1549
Height or Z /m:	-2434540.9845

General information

Rise time of the local UTC pulse:	3.6 ns
Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(23 ± 3) °C
Set humidity value and uncertainty:	(50 ± 10) %RH

(1) For a trip with closure, not needed if the traveling equipment is used in the same set-up throughout.

Diagram of the experiment set-up:

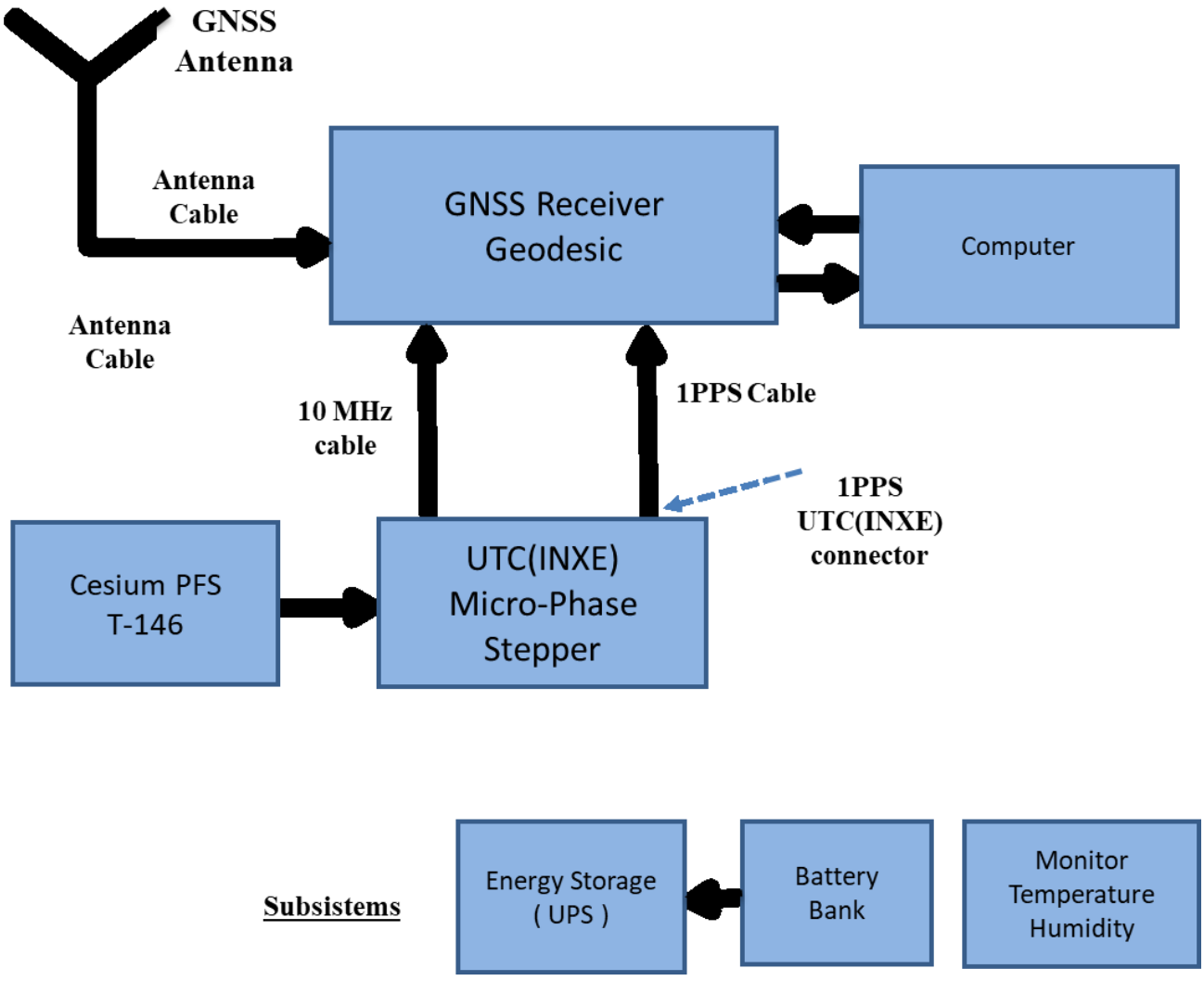


Figure – Diagram of connection for each GNSS receiver

Log of Events / Additional Information :

- GNSS receiver was synchronized with the same cable (LMR195, SMA to BNC), measured delay of 8.6 ns, directly from the 1PPS UTC(INXE) connector (SMA) to the 1PPS input (BNC) of the receiver.

Information Sheet

Laboratory:	INMETRO - INXE
Date and hour of the beginning of measurements:	18:45 h (UTC) ; 18/march/2020
Date and hour of the end of measurements:	11:54 h (UTC) ; 30/march/2020

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NXRL	NB05
Receiver maker and type: Receiver serial number:	Septentrio PolaRx3TR Pro s/n 0000451299	Septentrio PolaRx3eTR PRO s/n 2002994
1 PPS trigger level /V:	1.00 Volt	1.00 Volt
Antenna cable maker and type: Phase stabilized cable (Y/N):	TMS LMR-400 Not phase stabilized	TMS LMR-400 Not phase stabilized
Length outside the building /m:	14 meters	17 meters
Antenna maker and type: Antenna serial number:	AT2775-43W SPKE s/n 5641	Novatel PinWheel 702-GG s/n 01017577
Temperature (if stabilised) /°C	-------	--------

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P):	8.6 ns	8.6 ns
Delay from 1 PPS-in to internal reference (if different) (X_O):	202.5 ns	201.1 ns
Antenna cable delay (X_C):	70.2 ns	199.3 ns
Splitter delay (if any):	-------	-------
Additional cable delay (if any):	-------	-------

Data used for the generation of CGGTTS files

INT DLY (or $X_R + X_S$) (GPS) /ns:	0.0 (P1) and 0.0 (P2)
CAB DLY (or X_C) /ns:	70.2
REF DLY (or $X_P + X_O$) /ns:	211.1
Coordinates reference frame:	ITRF
Latitude or X /m:	4289076.86
Longitude or Y /m:	−4039531.54
Height or Z /m:	-2434547.86

General information

Rise time of the local UTC pulse:	3.6 ns
Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(23 ± 3) °C
Set humidity value and uncertainty:	(50 ± 10) %RH

(1) For a trip with closure, not needed if the traveling equipment is used in the same set-up throughout.

Information Sheet

Laboratory:	INMETRO - INXE
Date and hour of the beginning of measurements:	18:45 h (UTC) ; 18/march/2020
Date and hour of the end of measurements:	11:54 h (UTC) ; 30/march/2020

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NXRM	NB05
Receiver maker and type: Receiver serial number:	Septentrio PolaRx5TR s/n 4701337	Septentrio PolaRx3eTR PRO s/n 2002994
1 PPS trigger level /V:	1.00 Volt	1.00 Volt
Antenna cable maker and type: Phase stabilized cable (Y/N):	TMS LMR-400 Not phase stabilized	TMS LMR-400 Not phase stabilized
Length outside the building /m:	12 meters	17 meters
Antenna maker and type: Antenna serial number:	SEPCHOKE_B3E6 s/n 5587	Novatel PinWheel 702-GG s/n 01017577
Temperature (if stabilised) /°C	-------	--------

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P):	8.6 ns	8.6 ns
Delay from 1 PPS-in to internal reference (if different) (X_O):	44.5 ns	201.1 ns
Antenna cable delay (X_C):	81.4 ns	199.3 ns
Splitter delay (if any):	-------	-------
Additional cable delay (if any):	-------	-------

Data used for the generation of CGGTTS files

INT DLY (or $X_R + X_S$) (GPS) /ns:	0.0 (P1) and 0.0 (P2)
CAB DLY (or X_C) /ns:	81.4
REF DLY (or $X_P + X_O$) /ns:	53.1
Coordinates reference frame:	ITRF
Latitude or X /m:	4289079.98
Longitude or Y /m:	-4039528.49
Height or Z /m:	-2434547.63

General information

Rise time of the local UTC pulse:	3.6 ns
Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(23 ± 3) °C
Set humidity value and uncertainty:	(50 ± 10) %RH

(1) For a trip with closure, not needed if the traveling equipment is used in the same set-up throughout.

Diagram of the experiment set-up:

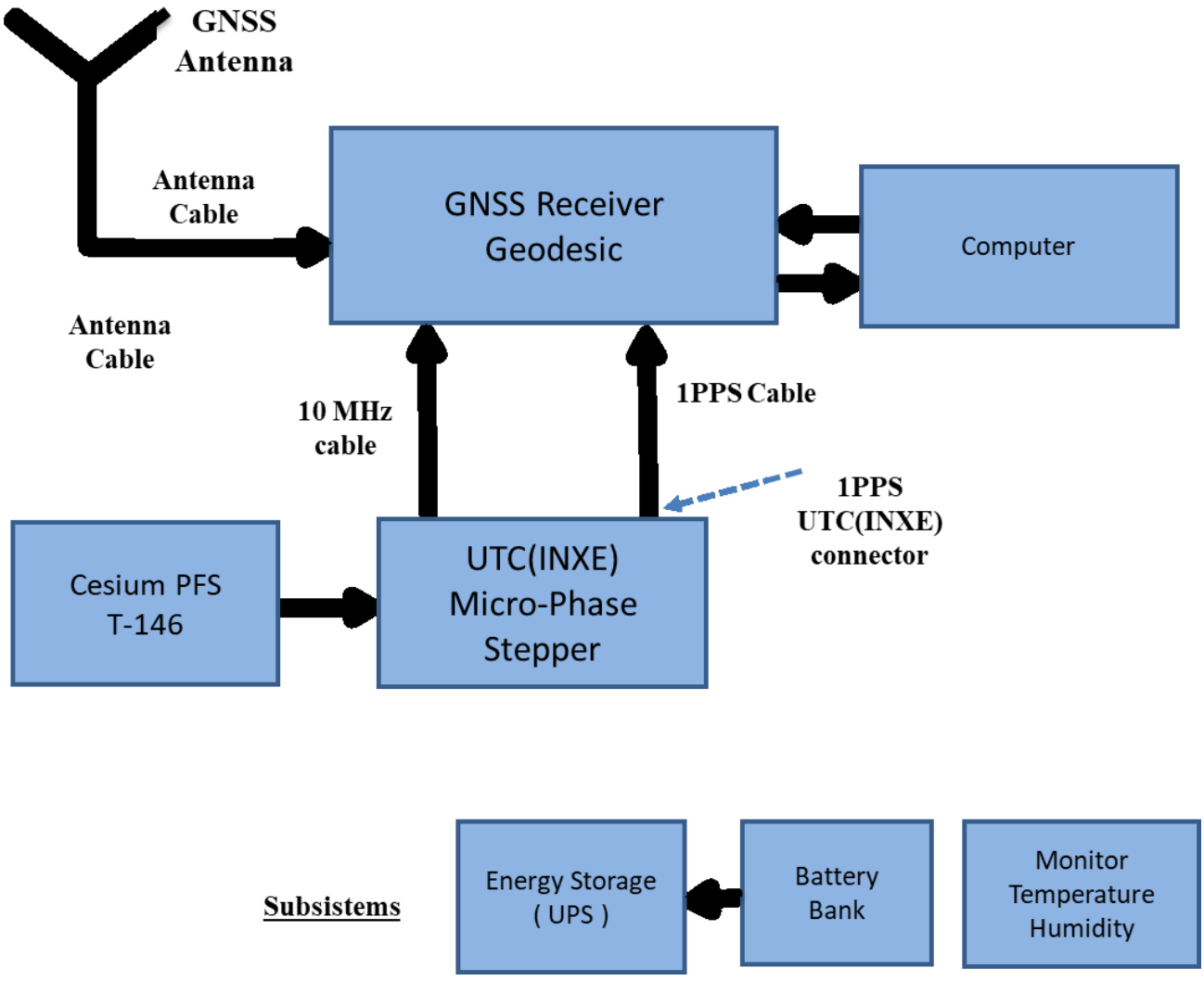


Figure – Diagram of connection for each GNSS receiver

Log of Events / Additional Information :

- GNSS receiver was synchronized with the same cable (LMR195, SMA to BNC), measured delay of 8.6 ns, directly from the 1PPS UTC(INXE) connector (SMA) to the 1PPS input (BNC) of the receiver.

Annex A - Information Sheet

Laboratory:	OBSERVATORIO NACIONAL - RJ
Date and hour of the beginning of measurements	04/04/2020 00:00 58943
Date and hour of the end of measurements	12/06/2020 23:59 59012

Information on the system		
	Local	**Traveling**
4-character BIPM code	ONRJ	NB05
Receiver maker and type Receiver serial number	PIKTIME TTS-5 1022	SEPTENTRIO PolaRx3eTR PRO S/N 2002994
1 PPS trigger level /V	0.5 V	
Antenna cable maker and type Phase stabilized cable (Y/N)	PIKTIME COAXIAL N	LMR - 400
Length outside the building /m:	13 m	5 m
Antenna maker, type, and serial number	Mira Vista Technologies TSA-100 PT-18	NOVATEL GPS-702-GG S/N 01017577
Temperature (if stabilized) /°C	25 oC	----------

Measured delays /ns		
	Local	**Traveling**
Delay from local UTC to receiver 1 PPS-in (X_P)	26.77 ns	57.3 ns
Delay from 1 PPS-in to internal Reference (if different)(X_O)		218.1 ns
Antenna cable delay (X_C)	194.409 ns	199.65 ns
Splitter delay (if any)	----------	----------
Additional cable delay (if any)	----------	----------

Data used for the generation of CGGTTS files	
INT DLY (or X_R+X_S) (GPS) /ns	
CAB DLY (or X_C) /ns	194.409 ns
REF DLY (or X_P+X_O) /ns	19.45 ns
Coordinates reference frame	
X /m	4283638.5918 m
Y /m	-4026027.7944 m
Z /m	-2466098.3443 m

General information	
Rise time of the local UTC pulse	1.4 ns
Is the laboratory air conditioned ? (Y/N)	Y
Set temperature value and uncertainty	25.35 oC +- 0.11 oC
Set humidity value and uncertainty	48.37 % +- 5.46 %

Annex A - Information Sheet

Laboratory:	OBSERVATORIO NACIONAL - RJ
Date and hour of the beginning of measurements	04/04/2020 00:00 58943
Date and hour of the end of measurements	12/06/2020 23:59 59012

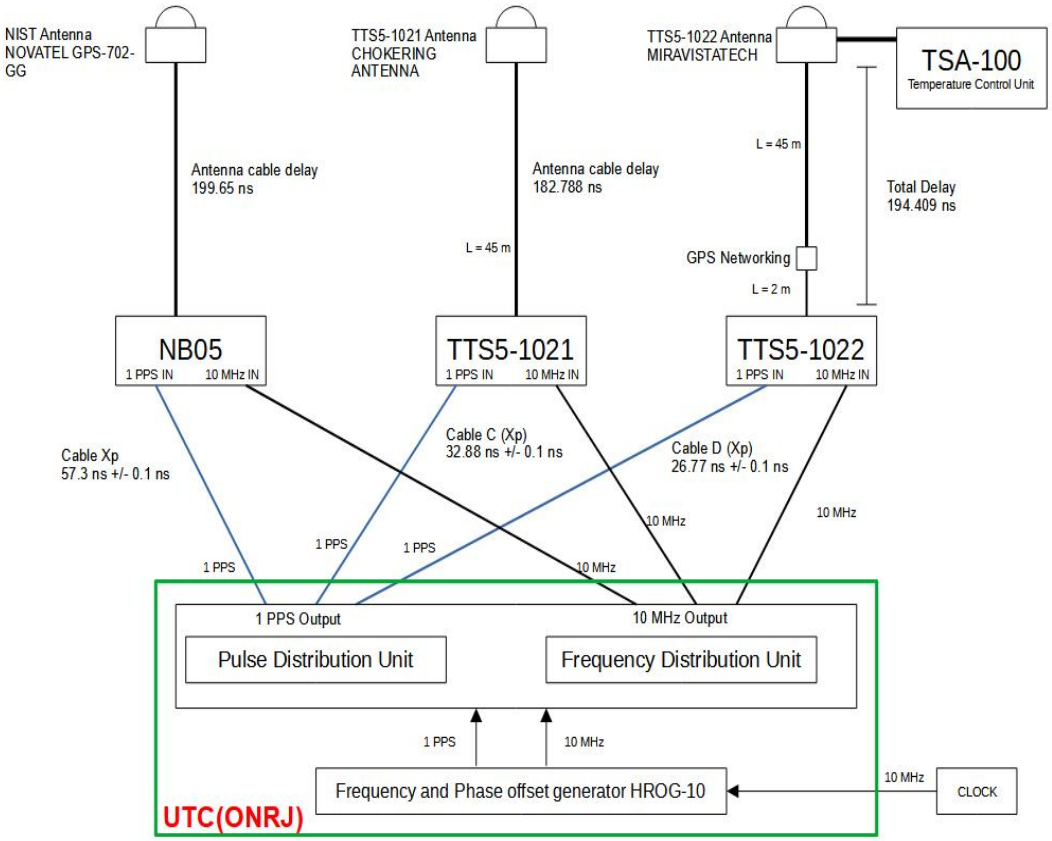
Information on the system		
	Local	**Traveling**
4-character BIPM code	ONRJ	NB05
Receiver maker and type Receiver serial number	PIKTIME TTS-5 1021	SEPTENTRIO PolaRx3eTR PRO S/N 2002994
1 PPS trigger level /V	0.5 V	
Antenna cable maker and type Phase stabilized cable (Y/N)	PIKTIME COAXIAL N	LMR - 400
Length outside the building /m:	8 m	5 m
Antenna maker, type, and serial number	Choke ring antenna	NOVATEL GPS-702-GG S/N 01017577
Temperature (if stabilized) /°C	N	----------

Measured delays /ns		
	Local	**Traveling**
Delay from local UTC to receiver 1 PPS-in (X_P)	32.88 ns	57.3 ns
Delay from 1 PPS-in to internal Reference (if different)(X_O)		218.1 ns
Antenna cable delay (X_C)	182.788 ns	199.65 ns
Splitter delay (if any)	----------	----------
Additional cable delay (if any)	----------	----------

Data used for the generation of CGGTTS files	
INT DLY (or X_R+X_S) (GPS) /ns	
CAB DLY (or X_C) /ns	182.788 ns
REF DLY (or X_P+X_O) /ns	30.475 ns
Coordinates reference frame	
X /m	4283639.1935 m
Y /m	-4026026.1240 m
Z /m	-2466099.6164 m

General information	
Rise time of the local UTC pulse	1.4 ns
Is the laboratory air conditioned ? (Y/N)	Y
Set temperature value and uncertainty	25.35 oC +- 0.11 oC
Set humidity value and uncertainty	48.37 % +- 5.46 %

Schematic of ONRJ GPS receivers calibration



Schematic setup diagram of the ONRJ GPS receivers calibration. The reference signals for the NB05 (traveling), TTS5-1021 and TTS5-1022 receivers are from the UTC(ONRJ) as shown in the figure above. The physical cables for the 1 pps signals are represented as the blue lines with the corresponding measured delays and the cables for the 10 MHz signals and the antena cables are represented as black lines. All the cable delay measurements shown in the diagram above were made before and after the calibration using both a system in ONRJ and the system described in the NIST GPS Traveling System Operator's Manual.

Annex A - Information Sheet

Laboratory:	**NIST**
Date and hour of the beginning of measurements:	MJD 59125
Date and hour of the end of measurements:	MJD 59134

Information on the system		
	Local:	**Traveling:**
4-character BIPM code	**NIST**	**nb05**
Receiver maker and type: Receiver serial number:	Novatel OEM4-G2 S/N	Septentrio PolaRx3eTR PRO
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	Andrew FSJ-50A N	Timesmicrowave LMR 100A
Length outside the building /m:	65	10
Antenna maker and type: Antenna serial number:	Novatel 702	Novatel 702 S/N 010017577
Temperature (if stabilised) /°C		

Measured delays /ns		
	Local:	**Traveling:**
Delay from local UTC to receiver 1 PPS-in (X_P)	65.9	405.2 (327.6+77.6)
Delay from 1 PPS-in to internal Reference (if different): (X_O)		206.4
Antenna cable delay: (X_C)	275.5	199.6
Splitter delay (if any):	N/A	
Additional cable delay (if any):	N/A	

Data used for the generation of CGGTTS files

• INT DLY (or X_R+X_S) (GPS)† /ns:	-73.2 (P1), -72.1 (P2), -72.6 (C1)
• INT DLY (or X_R+X_S) (GLONASS) /ns:	
• CAB DLY (or X_C) /ns:	275.5
• REF DLY (or X_P+X_O) /ns:	65.9
• Coordinates reference frame:	WGS84
X /m:	-1288398.51
Y /m:	-4721696.92
Z /m	4078625.35

General information

• Rise time of the local UTC pulse:	3 ns
• Is the laboratory air conditioned:	yes
Set temperature value and uncertainty:	
Set humidity value and uncertainty:	

† Based on Cal_Id 1001-2018, but still not implemented