Report for Calibration of G2 Laboratories BIRM, NTSC, SCL and HKO by NIM

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The report is organized into seven parts. Part 1 provides a brief introduction to the calibration. Parts 2 and 3 present the equipment and operational methods, along with the experimental setups used during the calibration campaign. Part 4 outlines the calibration data processing, followed by Part 5, which reports the final results. Part 6 explains the evaluation of calibration uncertainty, and Part 7 discusses the climatic parameters observed during the calibration.

1. Introduction

Time link calibration is the foundation of time transfer. Since 2012, the BIPM has been drafting new guidelines for GNSS link calibration and designated several NMIs, including NIM, as Group 1 laboratories. These laboratories are responsible for enabling the calibration of Group 2 laboratories within the local RMO (Regional Metrology Organization), thereby providing additional support to the BIPM.

The BIRM laboratory was unable to provide an antenna installation environment for the traveling receiver. Since BIRM is located in Beijing, close to NIM, its receiver was therefore directly transported to NIM for on-site calibration. Afterwards, NIM Cal-001 was circulated among laboratories following the route: NIM–NTSC–SCL–HKO–NIM. NIM Cal-001 was installed and put into operation at NTSC in July 2024, then sent from NTSC to SCL, arriving at SCL at the end of November 2024. Subsequently, NIM Cal-001 was transferred from SCL to HKO, where it arrived in early March 2025. Finally, it returned to NIM at the end of June 2025.

2. Description of the equipment and the operation method

The NIM transportable calibrator NIM Cal-001 is pictured in Figure 1 and depicted schematically in Figure 2.

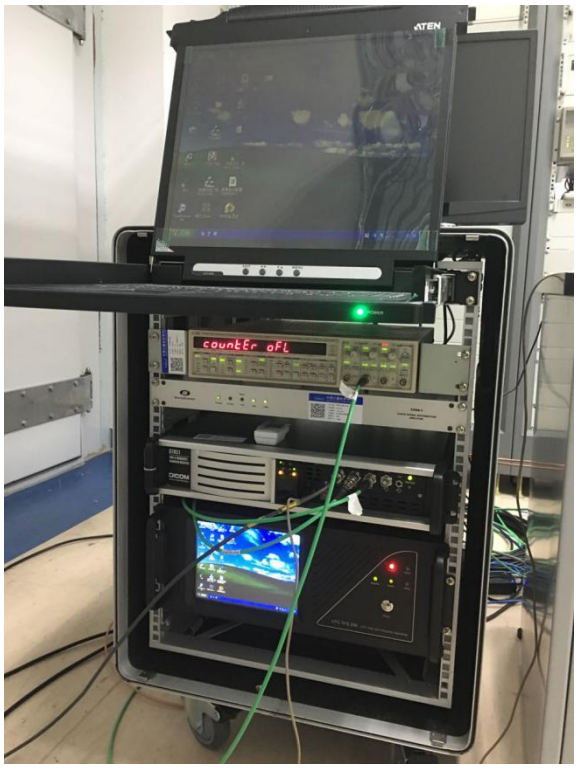


Figure 1. NIM calibrator(NIM Cal-001)

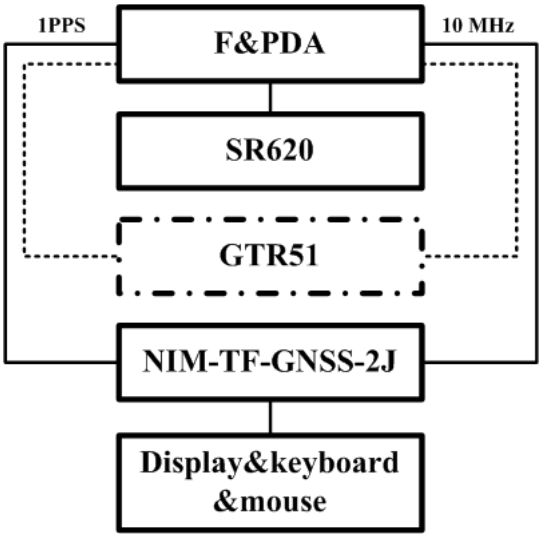


Figure 2. Schematic of NIM Cal-001

Referring to Figure 2, the function of each part is as follows.

1. **NIM-TF-GNSS-2J**: GNSS time and frequency transfer travelling receiver
2. SR620: Time interval counter used to measure the reference delay
3. P&FDA: phase and frequency distribution amplifier
4. Display & keyboard & mouse (KVM): Interface between PC and the user, the interface for control of the receiver and logging of GNSS measurement data
5. **GTR51**: Dicom company product
   Physical Size: 62cm(width)*78cm(height)*89cm(depth) (without the wheels)
   wheel height:12cm
   rough weight: 101 kg

List of supplied items
Receivers:
IM09: NIM-TF-GNSS-2J (with antenna AT1675 AT-200)
IM11: GTR51(with antenna NOV703GGG)
Others:
KVM(ATEN)
PDA and FDA(SDI)
SR620(SRS)
cables
Connectors

The participants are listed in Table 1, and the equipment for the calibrator and the receivers under calibration are detailed in Table 2.

Table 1. List of participants

Institute	Point of contact	Site address
NIM	Zhengsen Jia +861064525229 jiazs@nim.ac.cn	NIM, Time & Frequency Division No. 18, Bei San Huan Dong Rd, Beijing 100029, China
BIRM	Fan Yang +861088528611 birmtime@163.com	BIRM, P.O. Box 142, Sub - box 408, Beijing 100039, China
NTSC	Weixiong Wang +862983890337 wangweixiong@ntsc.ac.cn	NTSC, No. 3, Shuyuan East Road, Lintong District, Xi'an City, 710600, China
SCL	Alvis C. F. Au Yeung +852 3863 0255 alvis.auyeung@itc.gov.hk	SCL, 4/F, North Tower, Tseung Kwan O Government Offices, 30 Tong Yin Street, Tseung Kwan O, Sai Kung, New Territories, Hong Kong, China
HKO	David TW Hui +852 2926 8433 dhui@hko.gov.hk	Geophysics, Time and Marine Meteorological Services Division, Hong Kong Observatory, 134A, Nathan Road, Tsim Sha Tsui Kowloon, Hong Kong, China

Table 2. Sites used for the calibration

Timing lab	Site name	BIPM code	Model	Role	Notes
NIM	IM02	IM02	Navcompass TF-GNSS-NIM11	Reference receiver	Master
NIM	IM09	IM09	NIM-TF-GNSS-2	Traveling receiver	Traveling
NIM	IM11	IM11	GTR51	Traveling receiver	Traveling
BIRM	BI07	BI07	BM1308-52	Receiver to be calibrated	
JATC	JA01	JA01	Septentrio PolaRx4TR	Receiver to be calibrated	
JATC	JA02	JA02	GTR55	Receiver to be calibrated	
NTSC	NT02	NT02	GTR55	Receiver to be calibrated	
NTSC	NT03	NT03	GTR55	Receiver to be calibrated	
NTSC	NT05	NT05	Septentrio PolaRx5TR	Receiver to be calibrated	

SCL	SC05	SC05	Septentrio PolaRx5TR	Receiver to be calibrated	
SCL	SC07	SC07	Septentrio PolaRx5TR	Receiver to be calibrated	
SCL	SC08	SC08	Septentrio PolaRx5TR	Receiver to be calibrated	
HKO	HKO1	HKO1	PikTime TTS-4	Receiver to be calibrated	

The whole calibration tour includes start common clock difference measurement (CCD) before calibration, calibration on site and closure CCD as shown in Table 3.

Table 3. Measurements used for the calibration

Time period	Location	Operation
MJD 60463-MJD 60469	NIM	Start CCD before calibration
MJD 60463-MJD 60469	NIM	Calibration on site
MJD 60521-MJD 60527	NTSC	Calibration on site
MJD 60584-MJD 60590	NTSC	Calibration on site
MJD 60678-MJD 60684	SCL	Calibration on site
MJD 60764-MJD 60785	HKO	Calibration on site
MJD 60850-MJD 60856	NIM	Closure CCD after calibration

The data from MJD 60463 to MJD 60469, from MJD 60521 to MJD 60527, from MJD 60584 to MJD 60590, from MJD 60678 to MJD 60684 and from MJD 60764 to MJD 60785 after the signal transmitting was closed which looks normal are finally used for computation.

The calibration method, the differential calibration with closure of GPS (Global Positioning System) time and frequency transfer receiver, is used. Its principal concept is addressed in [1].

3. Experiment setup

In this comparison, the receivers used are listed in Table 2. IM02 serves as NIM's master GPS time and frequency transfer receiver for TAI contributions and also acts as the reference receiver. The receiver from BIRM undergoing calibration was sent directly to NIM. The traveling calibration stations IM09 and IM11 were deployed at NTSC and SCL, respectively. During the calibration process, the IM11 receiver malfunctioned, so only IM09 was deployed at HKO. Figures 4–8 illustrate the setups and sub-delay information for the start and closure experiments at NIM, as well as the on-site calibration experiments at NTSC, SCL, and HKO. Since IM11 failed to form a closed loop, only the calibration results of IM09 are presented in the report.

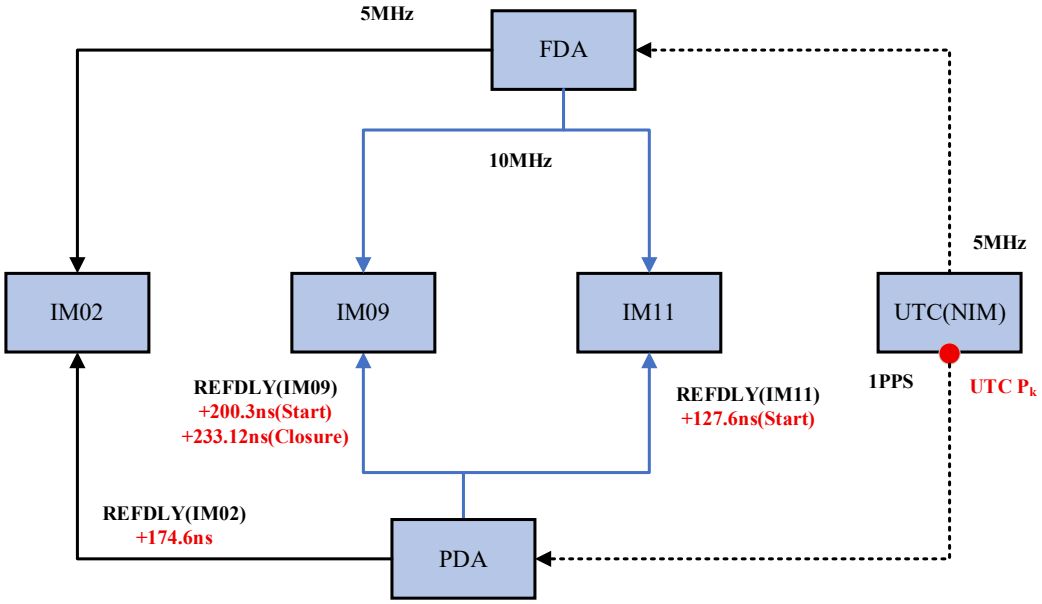


Figure 3. Experiment setup @ NIM (for CCD experiments)

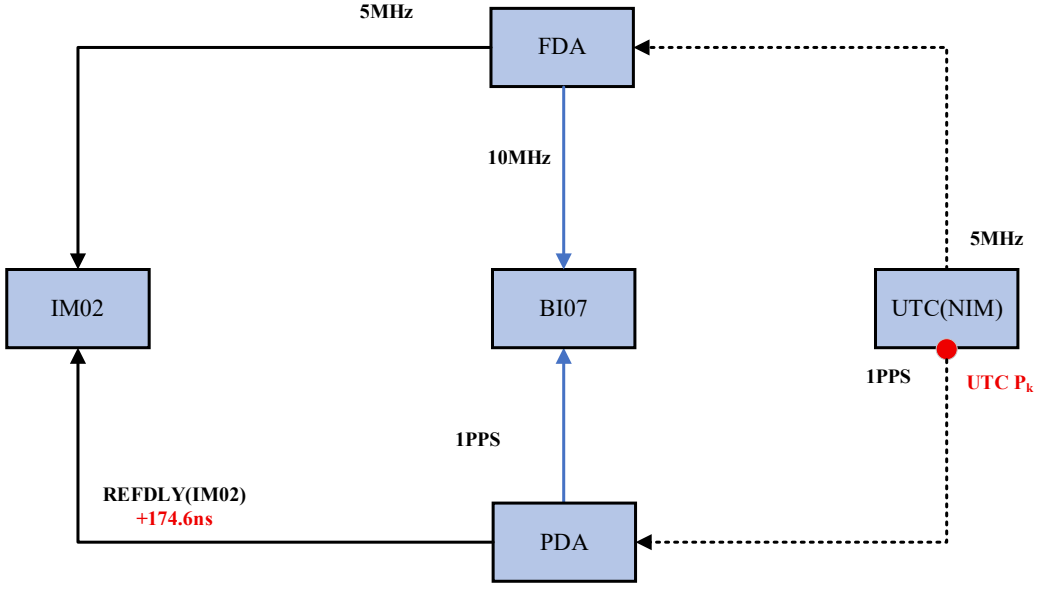
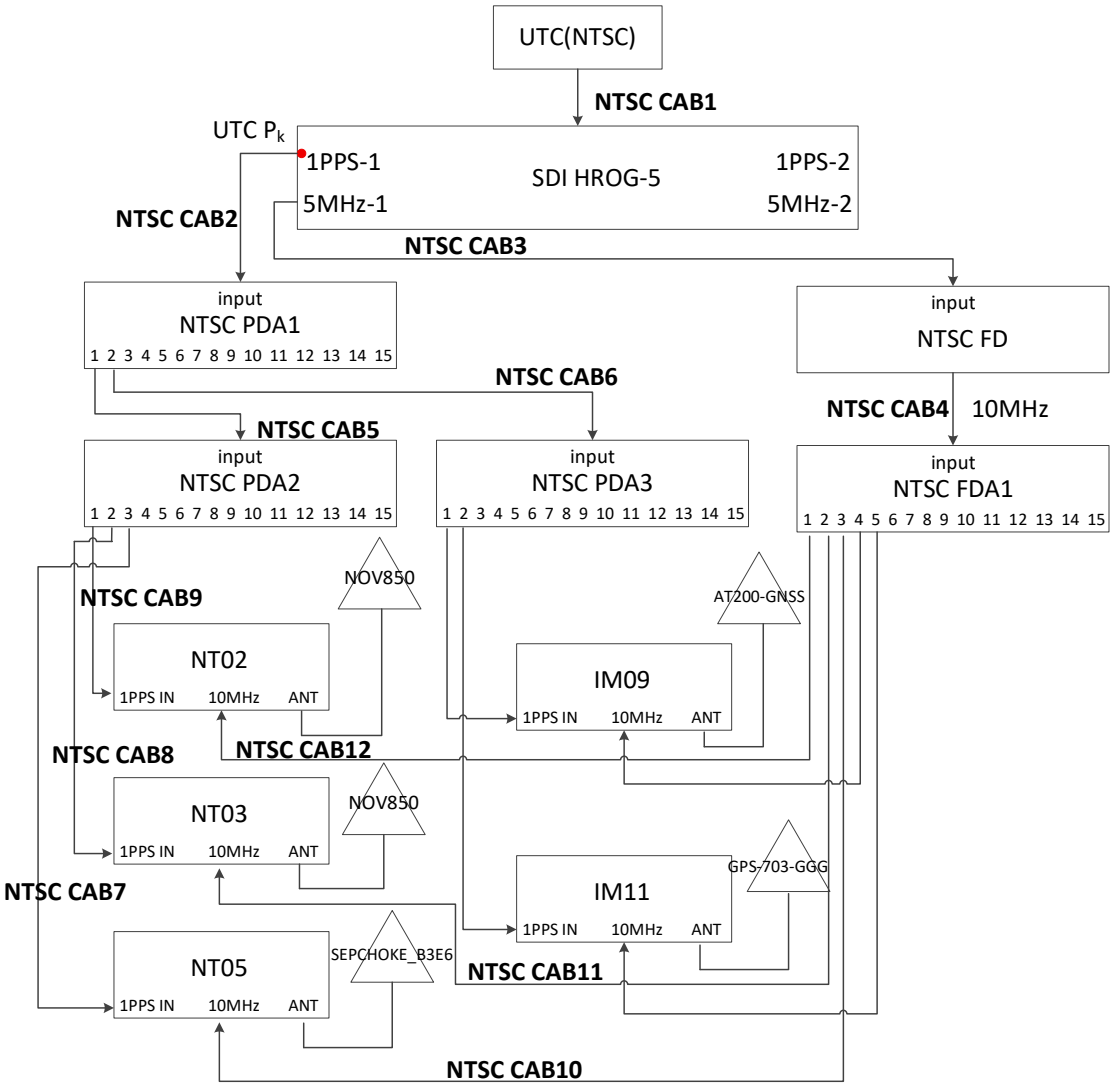
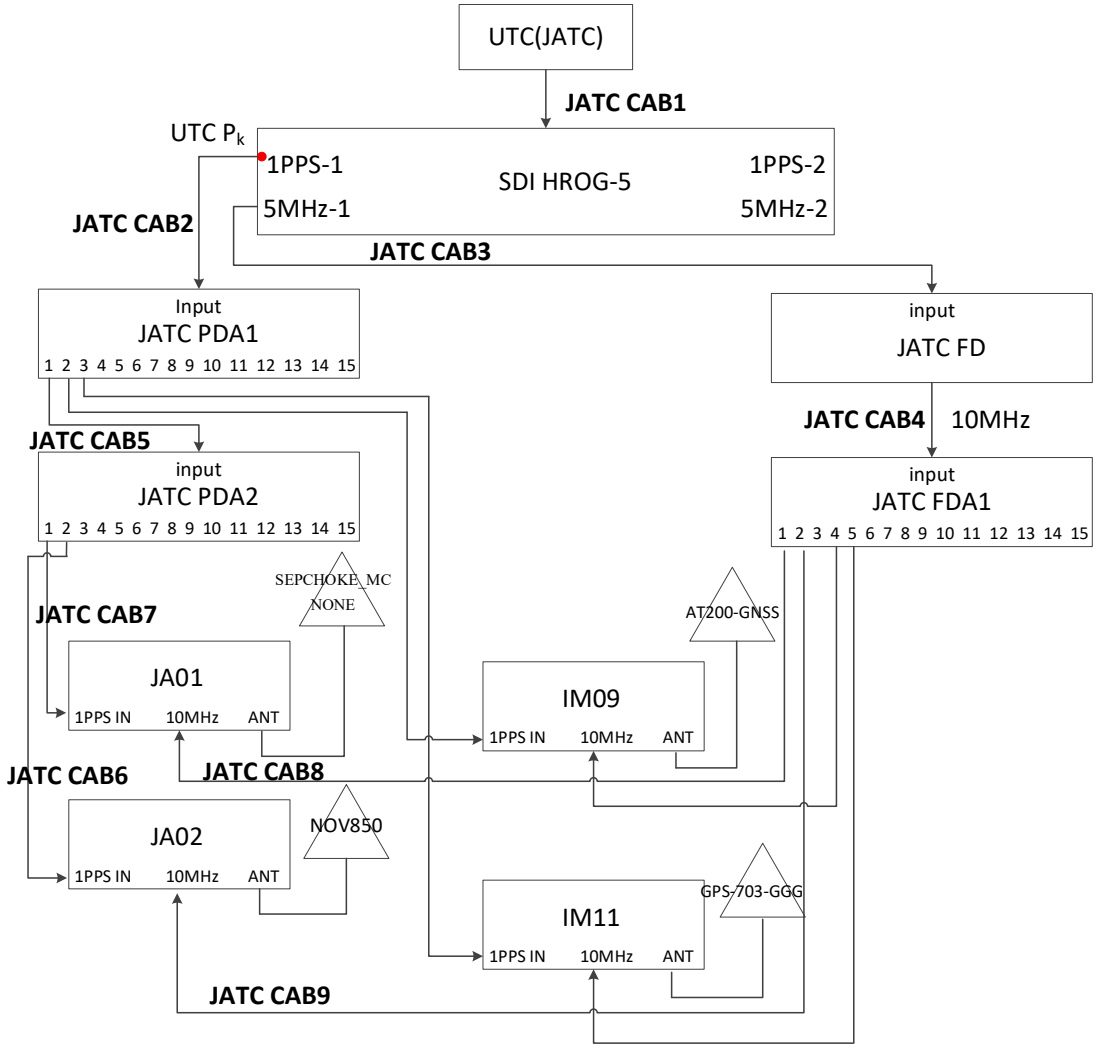


Figure 4. Experiment setup @ NIM (for CCD experiments)



UTC P_k is the UTC(NTSC) reference point(which is defined in the HROG output point).
FD is the frequency doubler. PDA is the pulse distribution amplifier; FDA is the frequency distribution amplifier.

Figure 5. Experiment setup @ NTSC (for CCD experiments)



UTC P_k is the UTC(JATC) reference point(which is defined in the HROG output point).
FD is the frequency doubler. PDA is the pulse distribution amplifier; FDA is the frequency distribution amplifier.

Figure 6. Experiment setup @JATC(for CCD experiments)

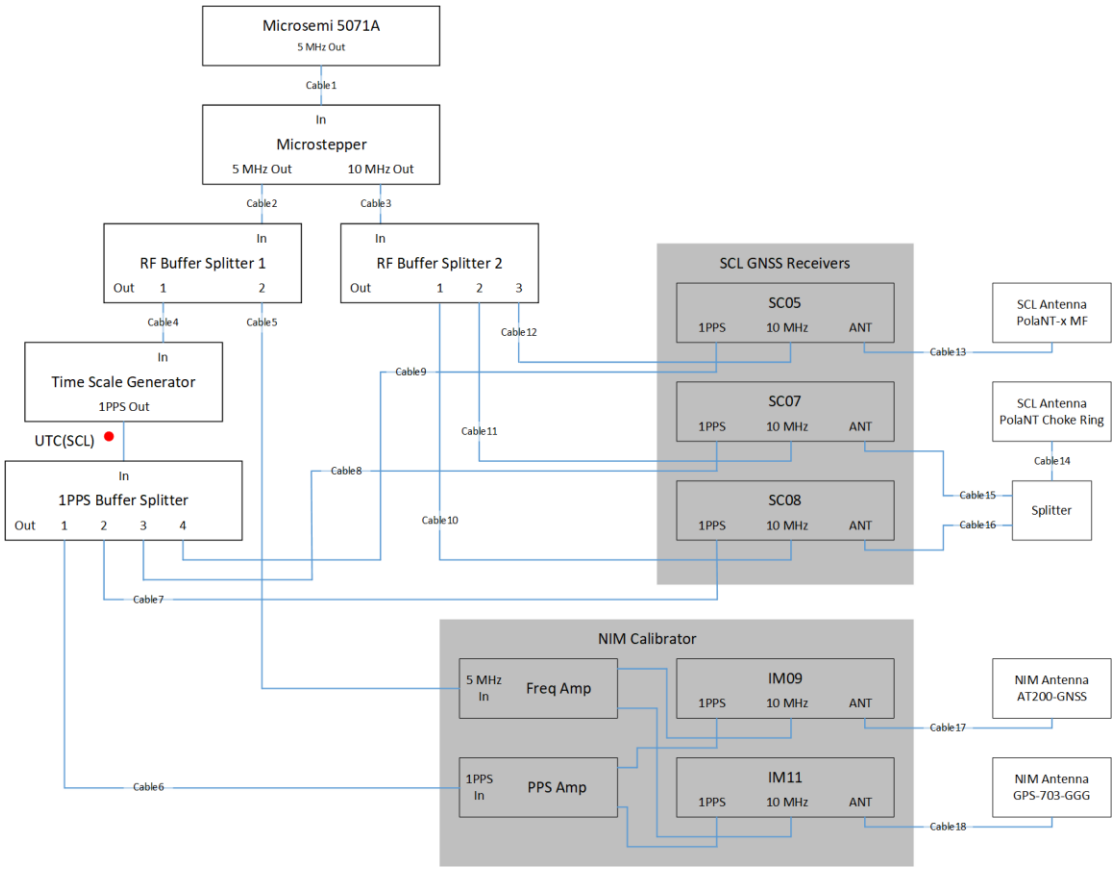


Figure 7. Experiment setup @ SCL (for CCD experiments)

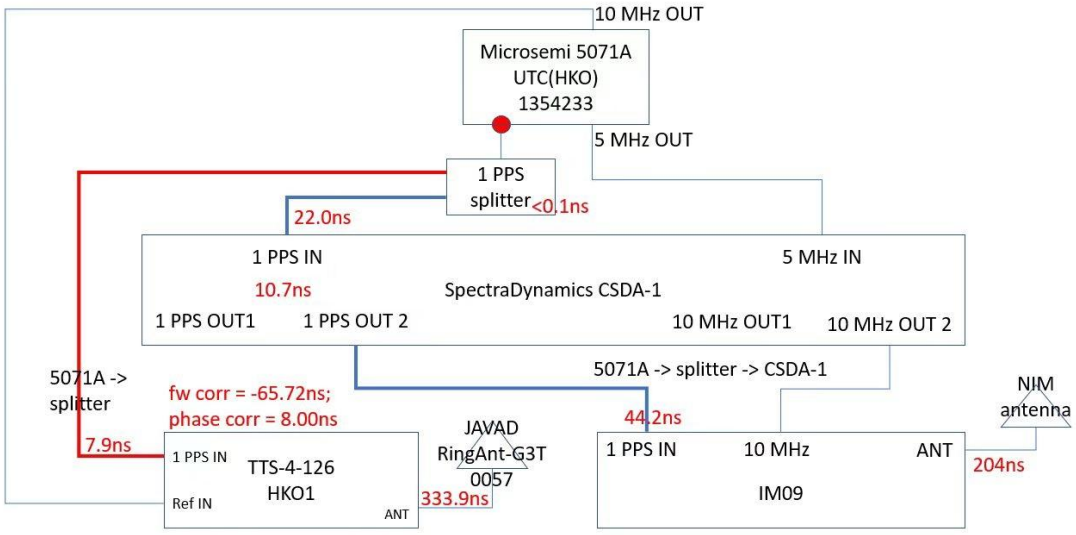


Figure 8. Experiment setup @ HKO (for CCD experiments)

4. Data processing

The raw differences $RAWDIF(P1/P2)_{A-B}$ between two receivers such as A and B, in the CCD experiments during the calibration, are given by

$$RAWDIF(P1/P2)_{A-B} = \Delta CABDLY_{A-B} + \Delta INTDLY(P1/P2)_{A-B} - \Delta REFDLY_{A-B} \quad (1)$$

where $RAWDIF(P1/P2)_{A-B}$ are the differences of code measurements from Rinex files without compensation of the antenna cable delay (CABDLY), the internal delay (INTDLY), and reference delay (REFDLY) from CGGTTS header. $\Delta CABDLY_{A-B}$, $\Delta REFDLY_{A-B}$ and $\Delta INTDLY_{A-B}$ are the differences of CABDLY, INTDLY, and REFDLY separately, given in Table 3. P3 results are calculated by the formula $P3$=$P1$*2.54573-$P2$*1.54573.

Table 3. REFDLY and CABDLY differences between station and traveling receivers

Pair	MJD	△REFDLY(ns)	△CABDLY(ns)
IM09-IM02	60463 - 60469	25.7	-0.7
BI07-IM09	60463 - 60469	29.1	0.8
JA01-IM09	60521 - 60527	136.5	-178.1
JA02-IM09	60521 - 60527	271.2	-178.1
NT02-IM09	60584 - 60590	-14.5	-204.1
NT03-IM09	60584 - 60590	-10.8	-204.1
NT05-IM09	60584 - 60590	-22.0	-204.1
SC05-IM09	60678 - 60684	-43.3	-187.9
SC07-IM09	60678 - 60684	2.3	-187.0

SC08-IM09	60678 - 60684	1.6	-186.9
HKO1-IM09	60779 - 60785	-94.0	129.8
IM09-IM02	60850 - 60856	58.5	-9.5

4.1 Calibration computation and calibration values

Table 4 presents the INTDLY results for station IM02. Table 5 lists the raw P1, P2, and P3 observations, as well as the P1–P2 differences between the station and the traveling receivers. The ΔINTDLY values for each receiver pair, calculated using Eq. (1), are shown in Table 6. Table 7 provides the closure values, defined as the differences between the mean values before and after calibration. The INTDLY values for receivers BI07, JA01, JA02, NT02, NT03, NT05, HKO1, SC05, SC07, and SC08 were derived from the ΔINTDLY between the receivers under calibration and the traveling receivers, together with the ΔINTDLY between the traveling receivers and IM02 (based on data from 1001-2022-phase 1). The final INTDLY results are summarized in Table 8.

Table 4. INTDLY for station IM02 from 1001-2020

Rcvr	C1(ns)	P1(ns)	P2(ns)	P3(ns)
IM02	-3.7	-5.6	-8.6	-0.96

4.1.1 Raw differences

Table 5. Raw differences between station and traveling receivers

Pair	MJD	△C1(ns)	△P1(ns)	△P2(ns)	△P3(ns)
IM09-IM02	60463 - 60469	-41.2	-40.0	-32.1	-52.3
BI07-IM09	60463 - 60469	-23.2	-24.5	-24.1	-25.1
JA01-IM09	60521 - 60527	-194.2	-196.8	-205.8	-182.8
JA02-IM09	60521 - 60527	-82.6	-84.9	-92.5	-73.0
NT02-IM09	60584 - 60590	22.7	22.1	21.4	23.2
NT03-IM09	60584 - 60590	20.7	20.0	14.5	28.6
NT05-IM09	60584 - 60590	32.6	30.6	22.8	42.6
SC05-IM09	60678 - 60684	-106.2	-108.3	-114.1	-99.3
SC07-IM09	60678 - 60684	-138.2	-139.6	-147.6	-127.2
SC08-IM09	60678 - 60684	-137.8	-139.1	-147.7	-125.7
HKO1-IM09	60779 - 60785	234.6	232.9	226.3	243.1
IM09-IM02	60850 - 60856	-82.8	-81.6	-73.2	-94.5

4.1.2 △INTDLY for receivers

Table 6. INTDLY differences between stations and traveling receivers

Pair	△INTDLY(C1) (ns)	△INTDLY(P1) (ns)	△INTDLY(P2) (ns)	△INTDLY(P3) (ns)
IM09-IM02	-14.8	-13.6	-5.7	-25.9
BI07-IM09	5.1	3.7	4.1	3.1
JA01-IM09	255.1	252.6	243.5	266.6
JA02-IM09	216.4	214.1	206.5	226.0
NT02-IM09	212.3	211.7	211.0	212.8
NT03-IM09	213.9	213.3	207.8	221.9

NT05-IM09	214.6	212.7	204.9	224.7
SC05-IM09	38.5	36.4	30.6	45.3
SC07-IM09	51.1	49.6	41.6	62.0
SC08-IM09	50.7	49.4	40.7	62.7
HKO1-IM09	10.7	9.1	2.4	19.3
IM09-IM02	-14.7	-13.5	-5.1	-26.4

4.1.3 Closure values

Table 7. Closure values

Pair	△C1(ns)	△P1(ns)	△P2(ns)	△P3(ns)
IM09-IM02	0.1	0.1	0.6	0.6

4.1.4 Calibration values

Table 8. INTDLY for stations BI07, JA01, JA02, NT02, NT03, NT05, SC05, SC07, SC08, and HKO1

Rcvr	C1(ns)	P1(ns)	P2(ns)	P3(ns)
BI07	-13.3	-15.4	-9.6	-24.3
JA01	236.7	233.5	229.8	239.2
JA02	198.0	195.0	192.7	198.6
NT02	193.9	192.6	197.3	185.4
NT03	195.5	194.2	194.0	194.5
NT05	196.2	193.6	191.2	197.3
SC05	20.1	17.3	16.8	17.9
SC07	32.6	30.5	27.9	34.6
SC08	32.3	30.3	27.0	35.3
HKO1	-7.7	-10.1	-11.3	-8.1

4.2 Uncertainty Evaluation

Here, we evaluated the uncertainties from different sources as follows. For BIRM, JATC, NTSC, SCL, and HKO, the combined uncertainty for P codes was conservatively estimated to be 1.9 ns. All measurements related to cable and reference delays were carried out using the SR620 with a trigger level of 1.0 V. The uncertainties arising from position references and multipath effects were assessed based on the descriptions provided in the guideline. The values of u_a were derived from the TDEV of the corresponding CCD results, as presented in Annex 6 to Annex 9. The associated uncertainties are derived from the TDEV at 50000 s. The default value of 0.2 ns is chosen if the measured TDEV is less than 0.2 ns.

Table 9. Uncertainty contributions

Unc.	C1 (ns)	P1 (ns)	P2 (ns)	P3 (ns)	Description
u_a (T-V)	0.2	0.2	0.2	0.3	RAWDIF (traveling-visited)
u_a (T-R)	0.2	0.2	0.2	0.3	RAWDIF (traveling-reference)
u_a	0.3	0.3	0.3	0.4	
	Misclosure				
$u_{b,1}$	0.1	0.1	0.6	0.6	observed mis-closure
	Systematic components related to RAWDIF				
$u_{b,11}$	0.05	0.05	0.05	0.2	Position error at reference
$u_{b,12}$	0.05	0.05	0.05	0.2	Position error at visited
$u_{b,13}$	0.3	0.3	0.3	0.8	Multipaths at reference
$u_{b,14}$	0.3	0.3	0.3	0.8	Multipaths at visited
	Link of the Traveling system to the local UTC(k)				
$u_{b,21}$	0.5	0.5	0.5	0.5	$REFDLY_T$ (at ref lab)
$u_{b,22}$	0.5	0.5	0.5	0.5	$REFDLY_T$ (at visited lab)
$u_{b,TOT}$	0.9	0.9	1.1	1.5	
	Link of the Reference system to its local UTC(k)				
$u_{b,31}$	0.5	0.5	0.5	0.5	$REFDLY_R$ (at ref lab)
	Link of the Visited system to its local UTC(k)				
$u_{b,32}$	0.5	0.5	0.5	0.5	$REFDLY_V$ (at visited lab)
	Antenna cable delays				
$u_{b,41}$	0.5	0.5	0.5	0.5	$CABDLY_R$
$u_{b,42}$	0.5	0.5	0.5	0.5	$CABDLY_V$
u_{CAL}	1.4	1.4	1.5	1.9	Composed of u_a and $u_{b,SYS}$
	Combined Uncertainty: 1.9 ns				

4.3 Climate parameters

3.1. Temperature and humidity

See Annex 5 in detail.

3.2. Reference signal

Rise time of the local UTC pulse: 2 ns

References:

[1] BIPM. BIPM guidelines for GNSS calibration (V3.2). 05, 02, 2016.

Annex 1. CCD results for BIRM

1. Calibration on site

BI07 – IM02

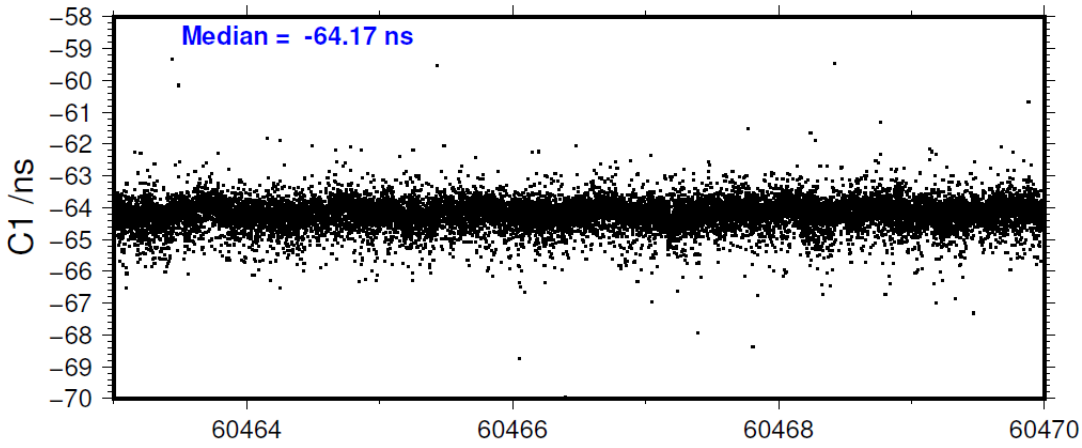


Figure 9. CCD between IM02 and BI07 at NIM(C1)

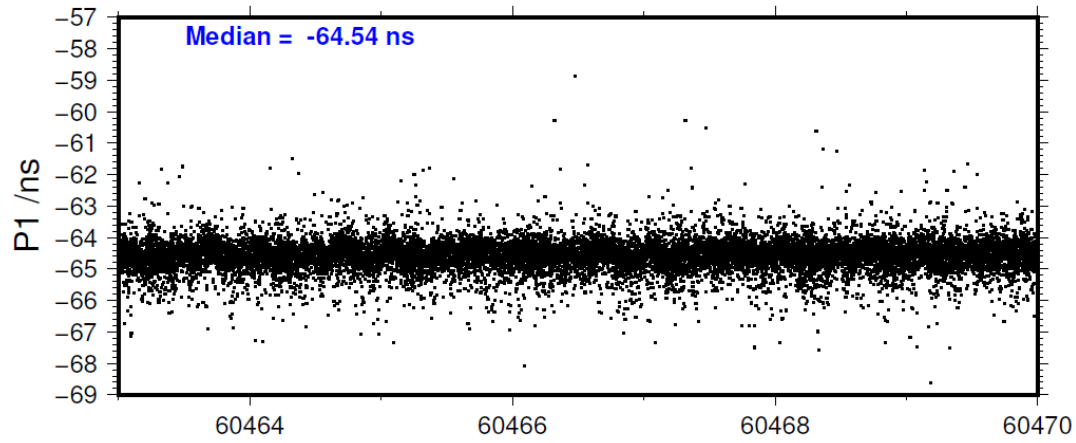


Figure 10. CCD between IM02 and BI07 at NIM(P1)

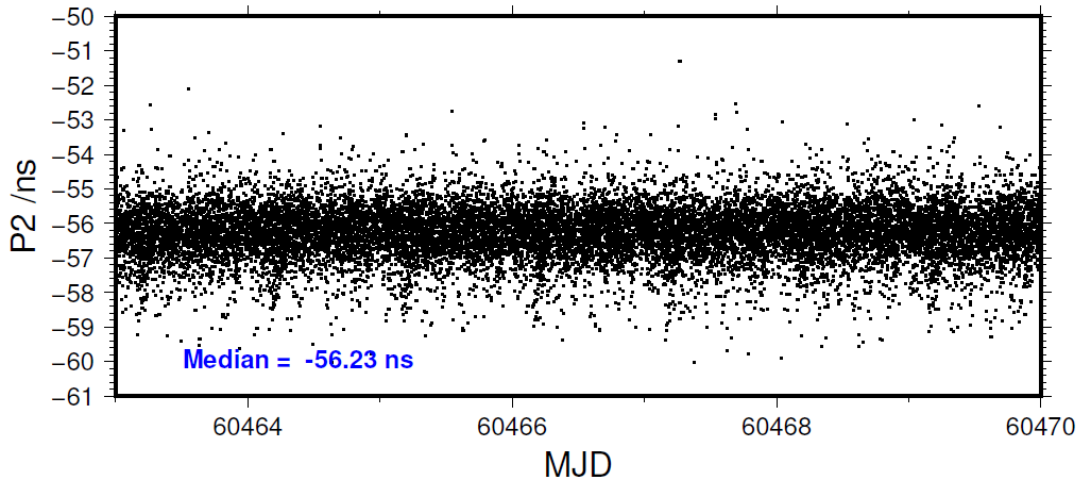


Figure 11. CCD between IM09 and BI07 at NIM (P2)

Annex 2. CCD results for JATC & NTSC

1. Start CCD before calibration

IM09-IM02

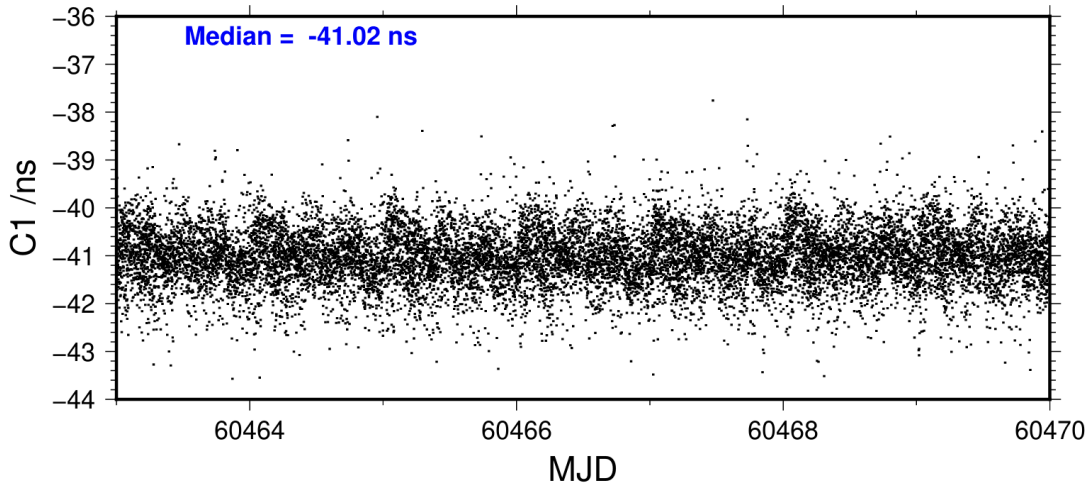


Figure 12. CCD between IM09 and IM02 at NIM(C1)

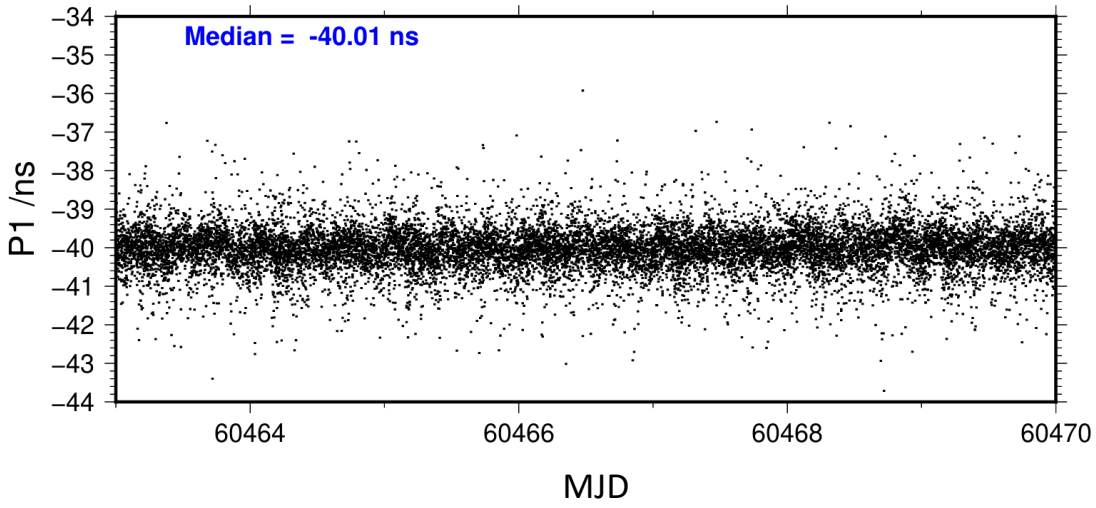


Figure 13. CCD between IM09 and IM02 at NIM(P1)

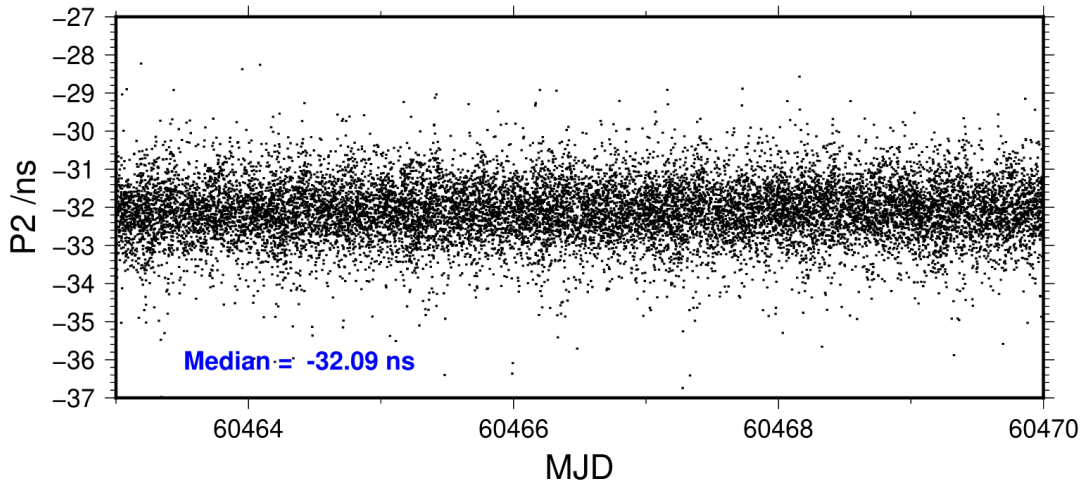


Figure 14. CCD between IM09 and IM02 at NIM(P2)

2. Calibration on site

JA01 – IM09

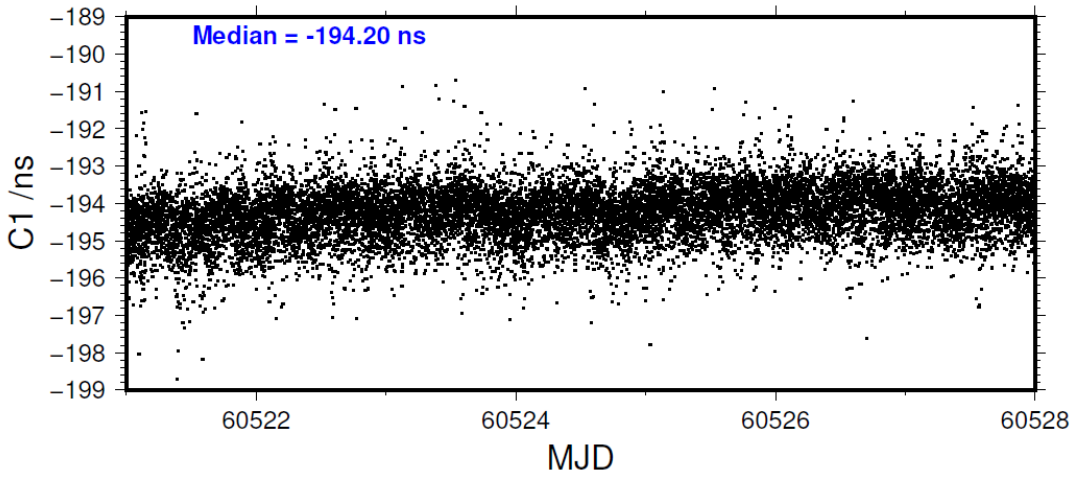


Figure 15. CCD between IM09 and JA01 at NTSC(C1)

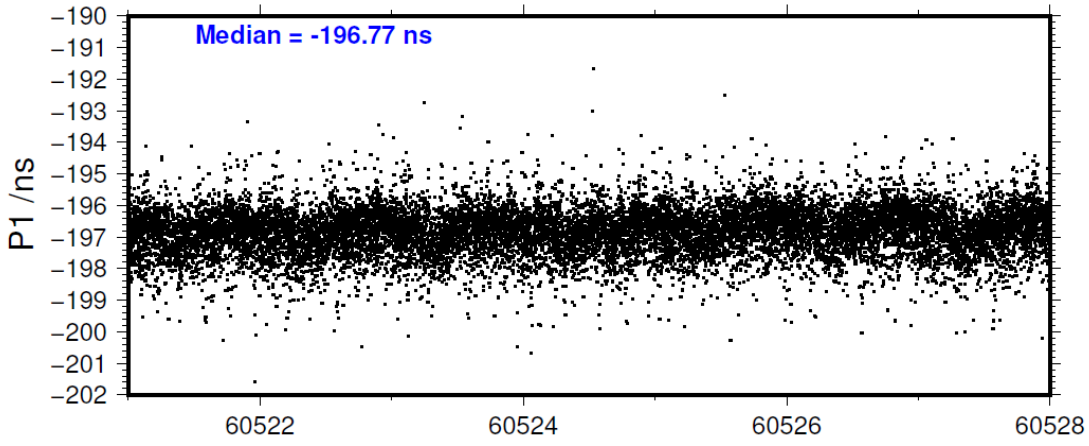


Figure 16. CCD between IM09 and JA01 at NTSC(P1)

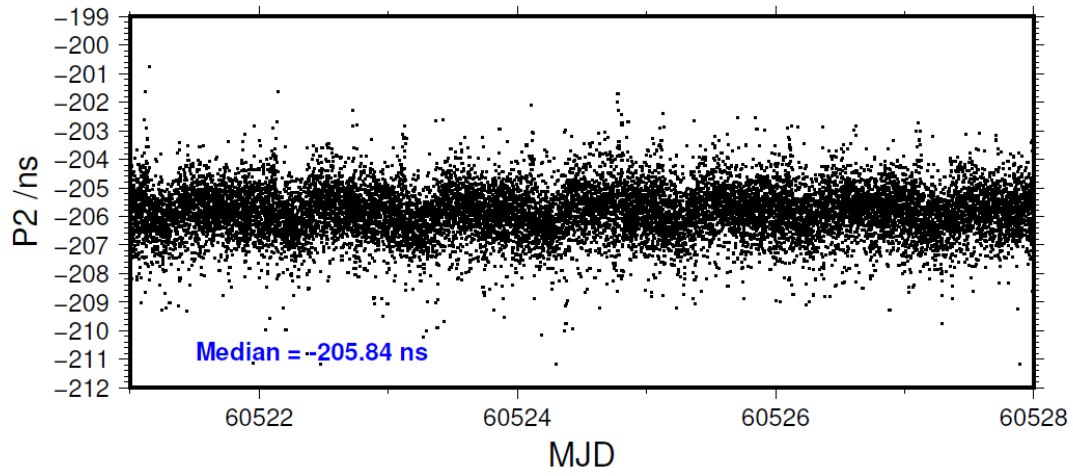


Figure 17. CCD between IM09 and JA01 at NTSC(P2)

JA02 – IM09

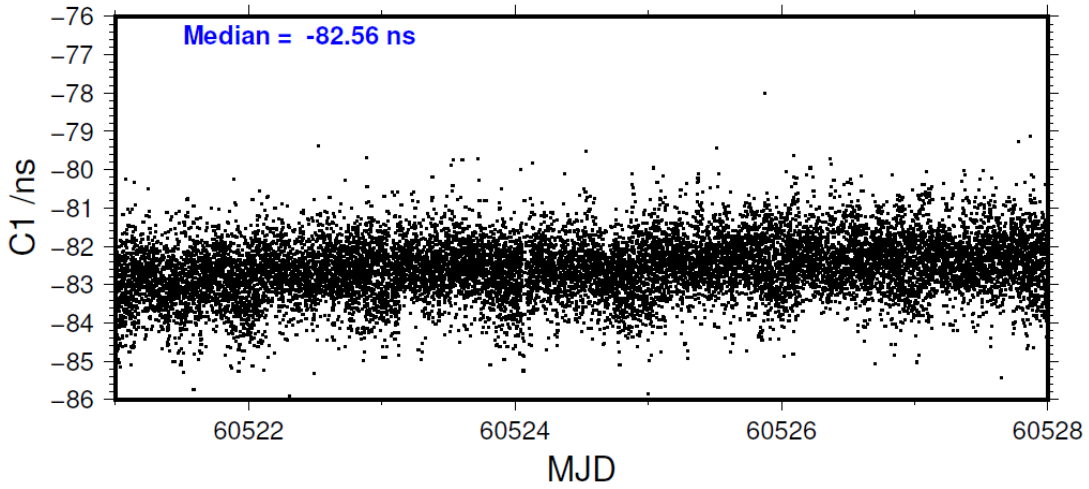


Figure 18. CCD between IM09 and JA02 at NTSC (C1)

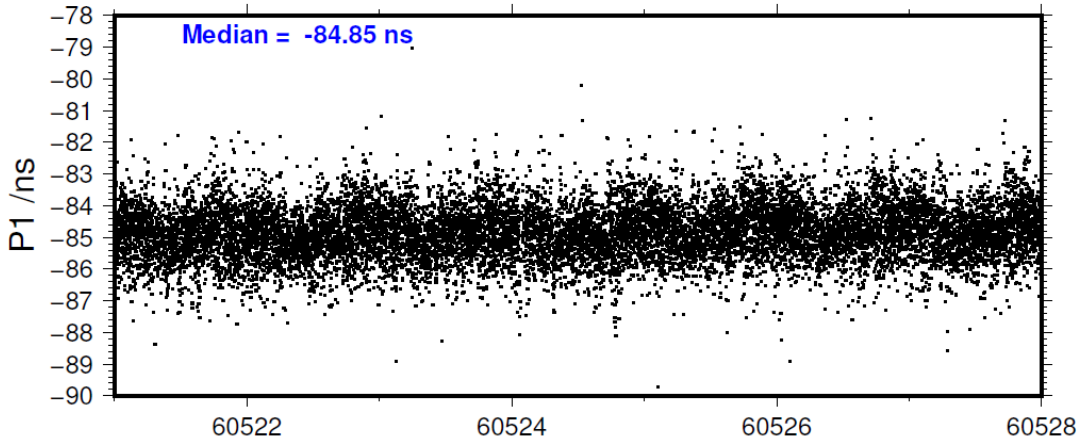


Figure 19. CCD between IM09 and JA02 at NTSC (P1)

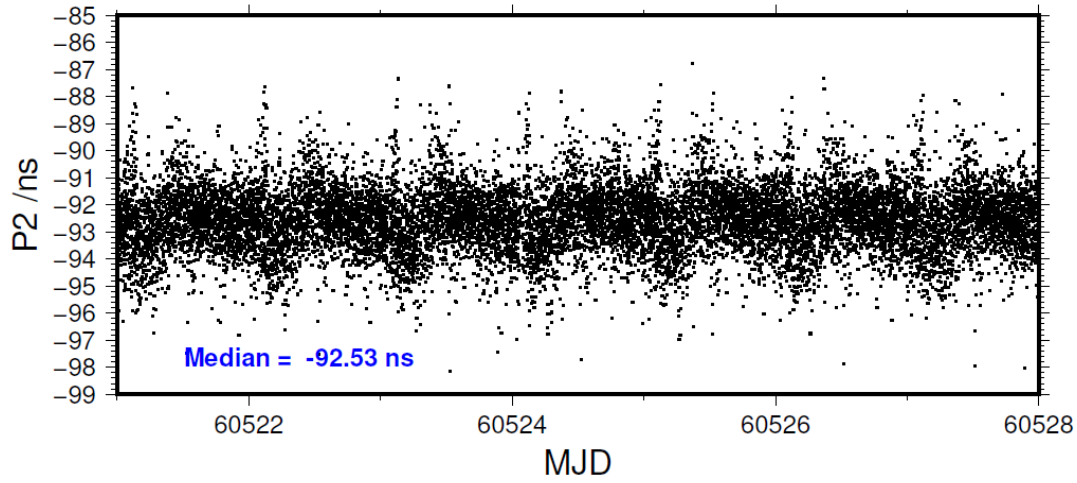


Figure 20. CCD between IM09 and JA02 at NTSC (P2)

NT02 – IM09

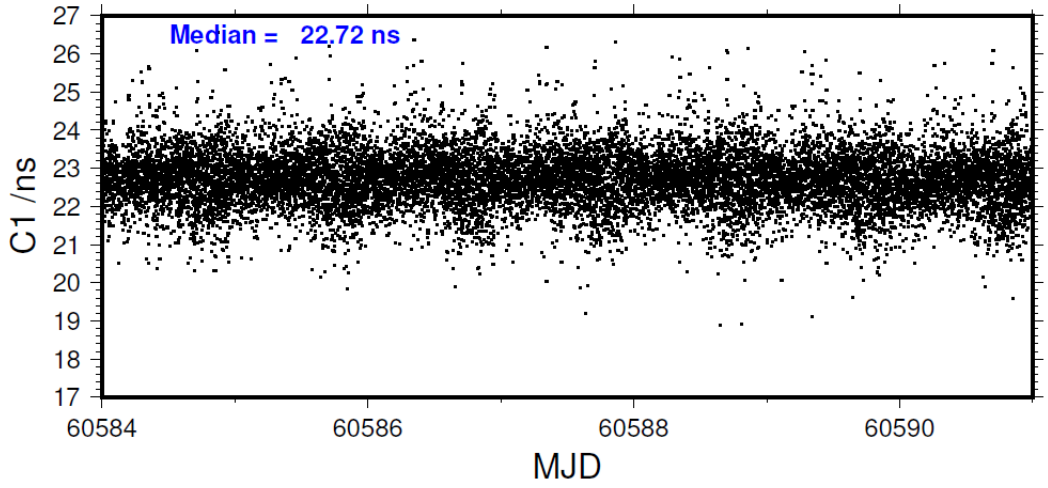


Figure 21. CCD between IM09 and NT02 at NTSC(C1)

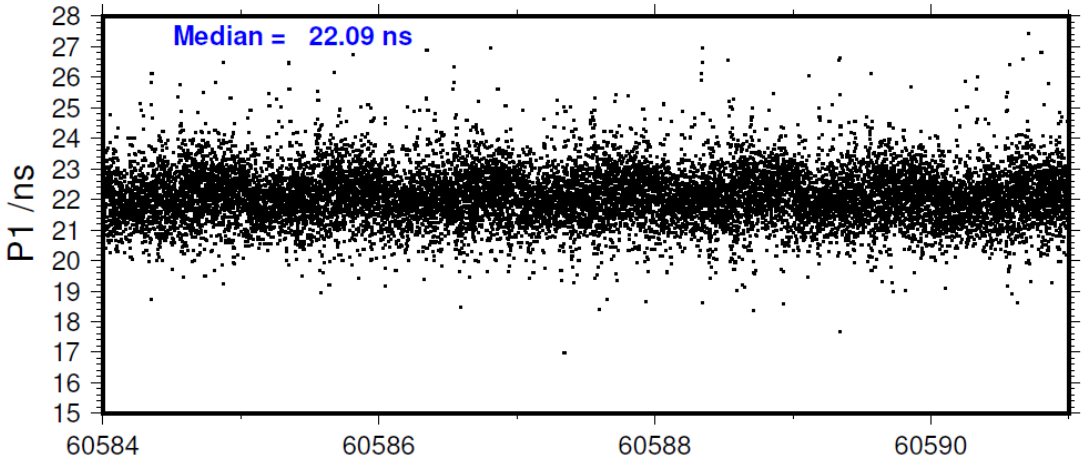


Figure 22. CCD between IM09 and NT02 at NTSC(P1)

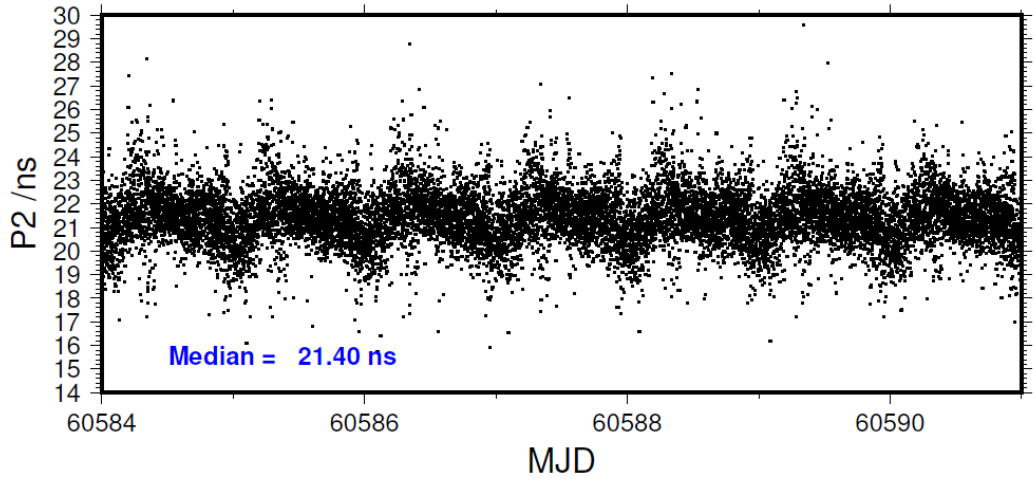


Figure 23. CCD between IM09 and NT02 at NTSC(P2)

NT03 – IM09

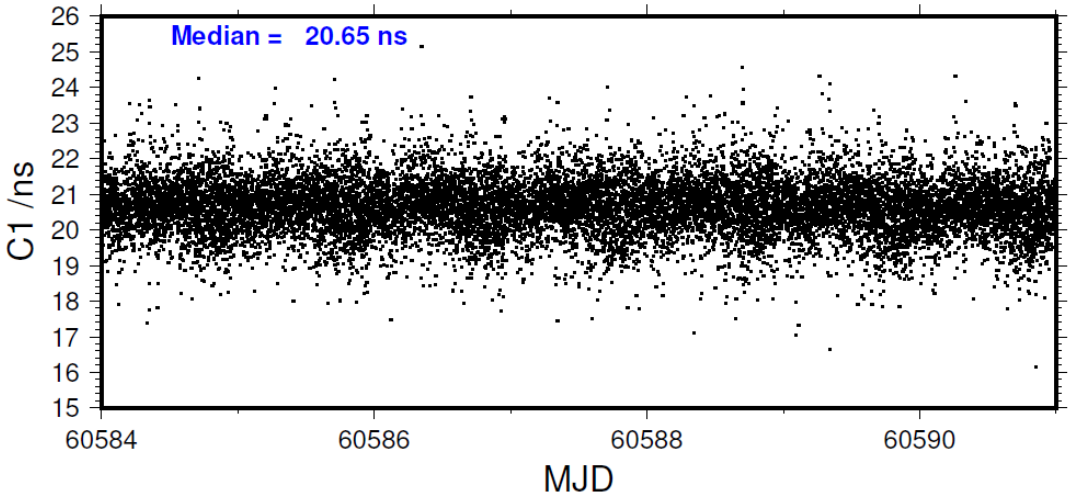


Figure 24. CCD between IM09 and NT03 at NTSC (C1)

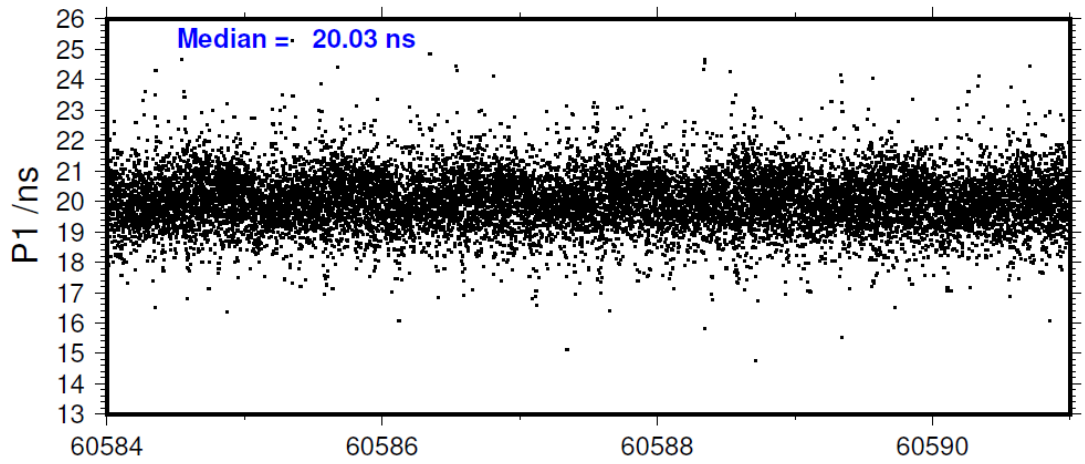


Figure 25. CCD between IM09 and NT03 at NTSC (P1)

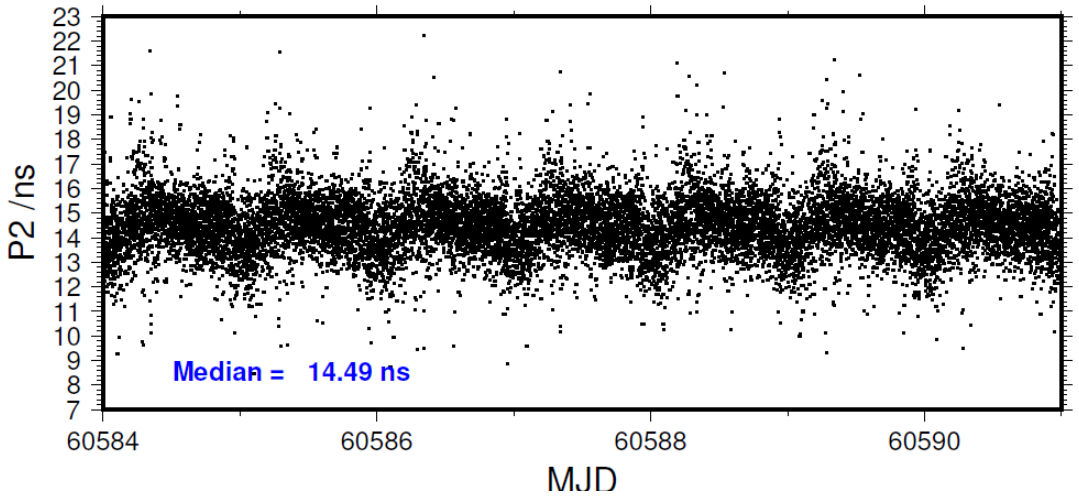


Figure 19. CCD between IM09 and NT03 at NTSC (P2)

NT05 – IM09

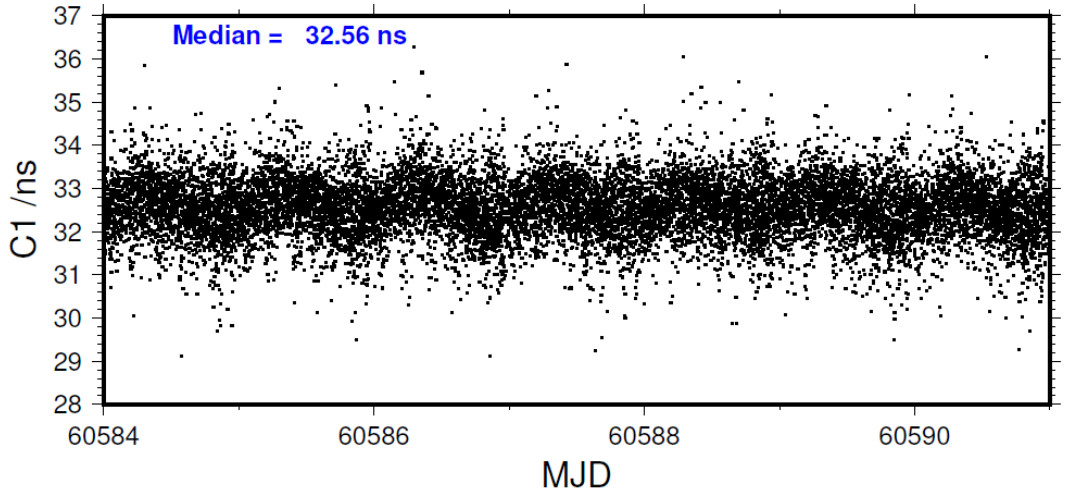


Figure 26. CCD between IM09 and NT05 at NTSC (C1)

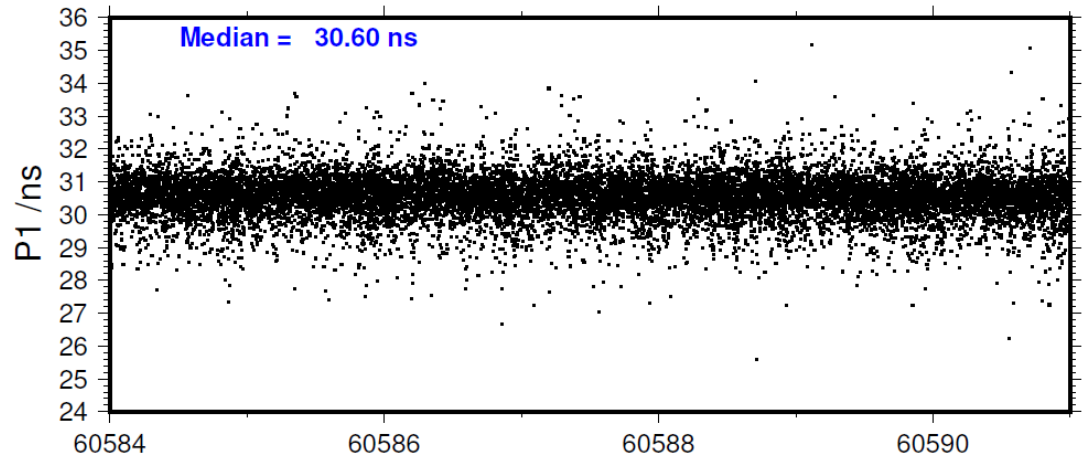


Figure 27. CCD between IM09 and NT05 at NTSC (P1)

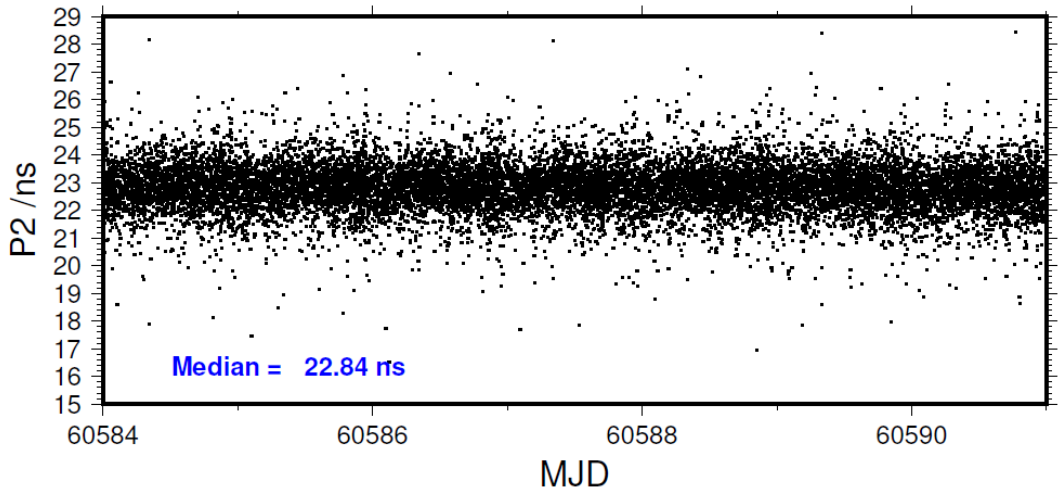


Figure 28. CCD between IM09 and NT05 at NTSC (P2)

3. Closure CCD after calibration

IM09-IM02

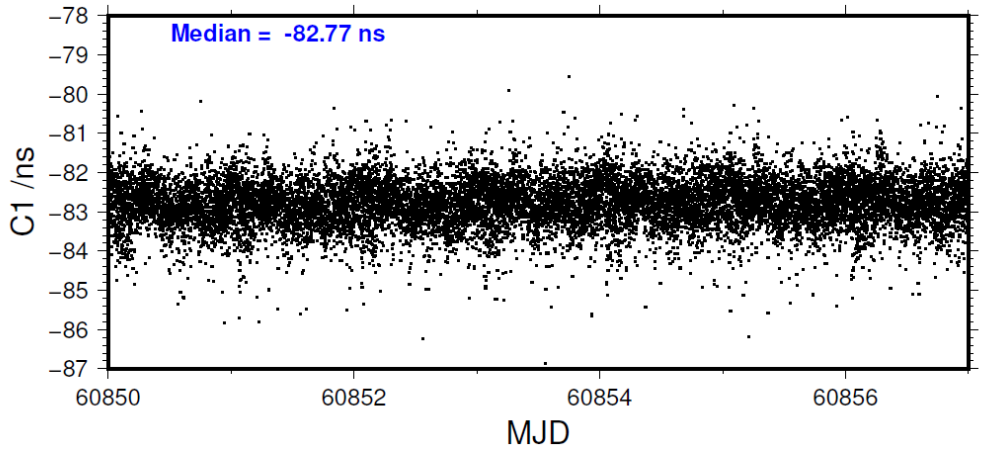


Figure 29. CCD between IM09 and IM02 at NIM(C1)

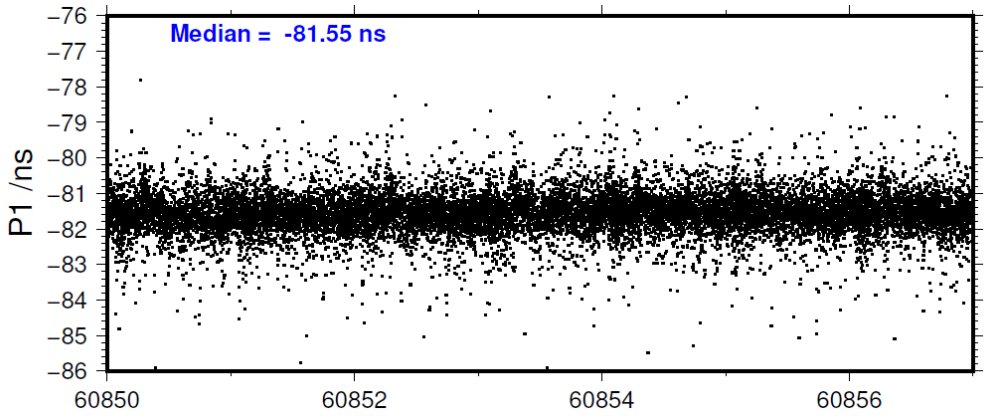


Figure 30. CCD between IM09 and IM02 at NIM(P1)

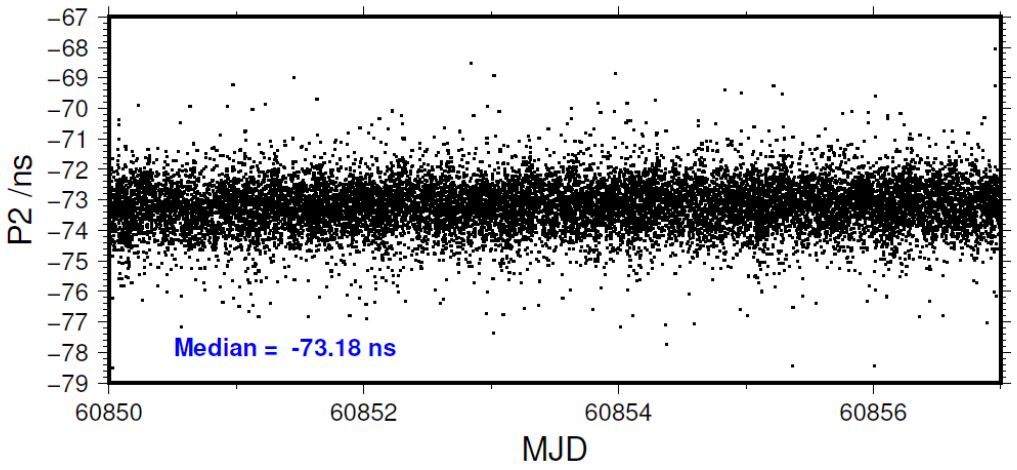


Figure 31. CCD between IM09 and IM02 at NIM(P2)

Annex 3. CCD results for SCL

1. Start CCD before calibration

IM09-IM02

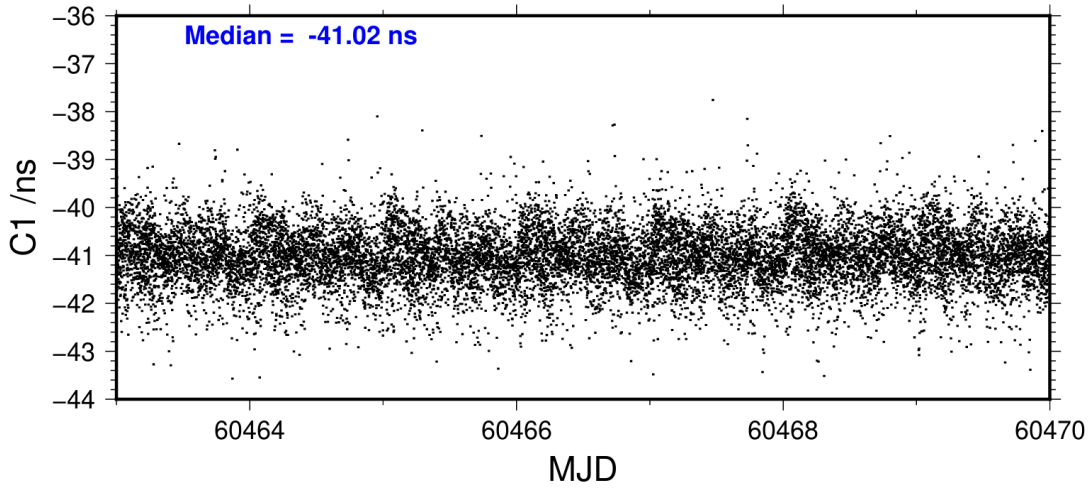


Figure 32. CCD between IM09 and IM02 at NIM(C1)

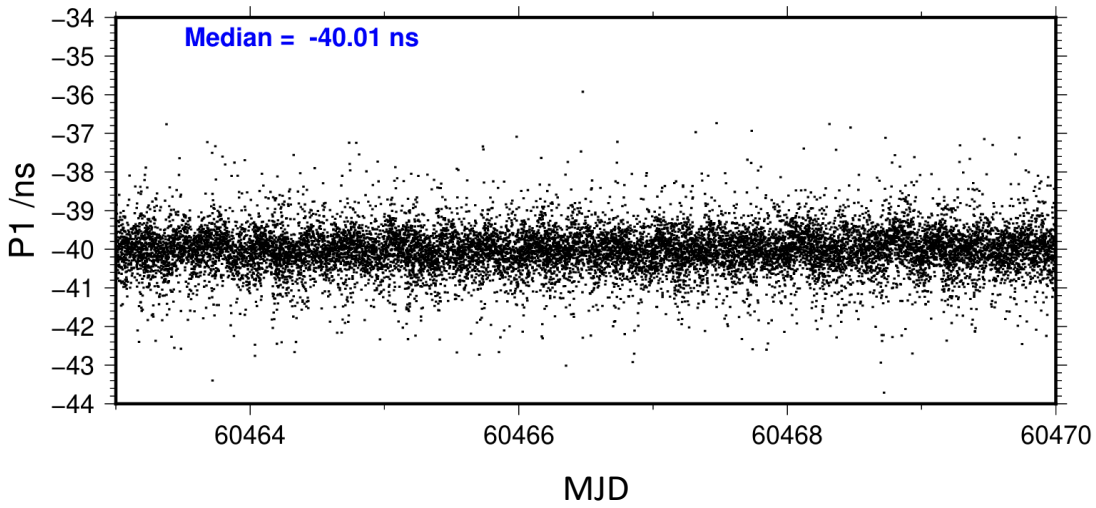


Figure 33. CCD between IM09 and IM02 at NIM(P1)

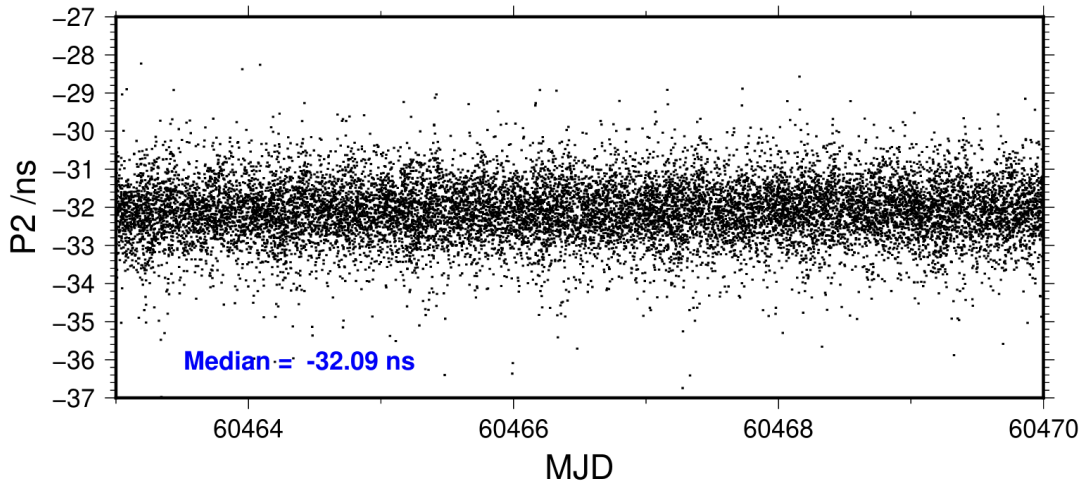


Figure 34. CCD between IM09 and IM02 at NIM(P2)

2. Calibration on site

SC05 – IM09

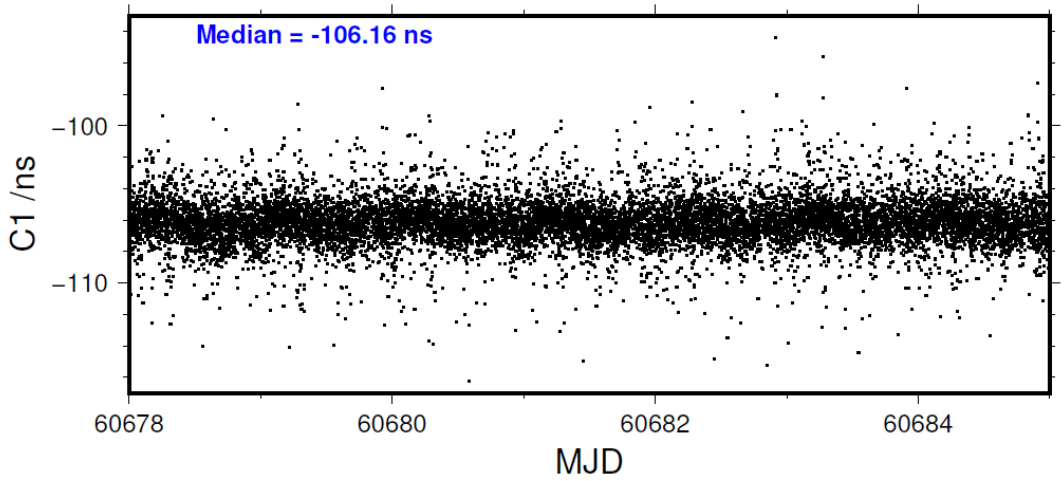


Figure 35. CCD between IM09 and SC05 at SCL(C1)

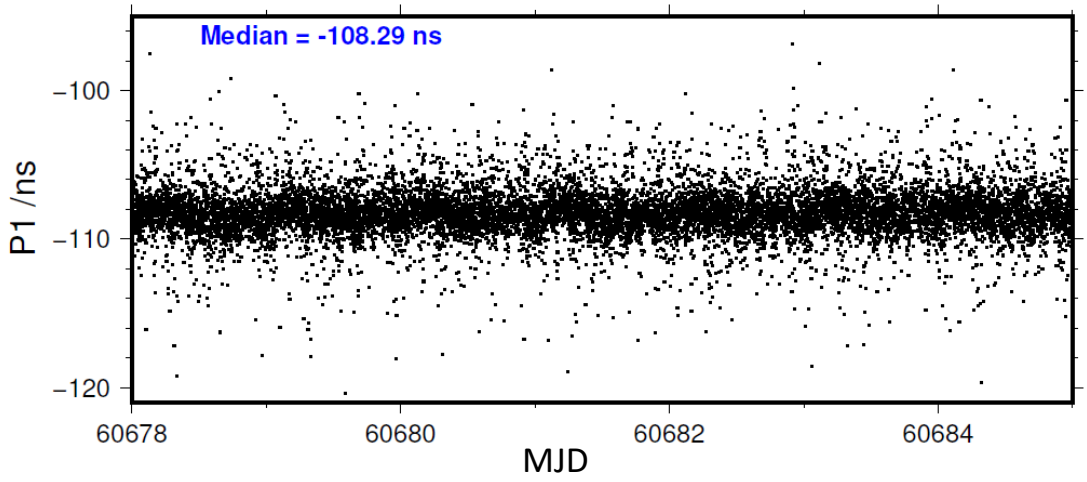


Figure 28. CCD between IM09 and SC05 at SCL(P1)

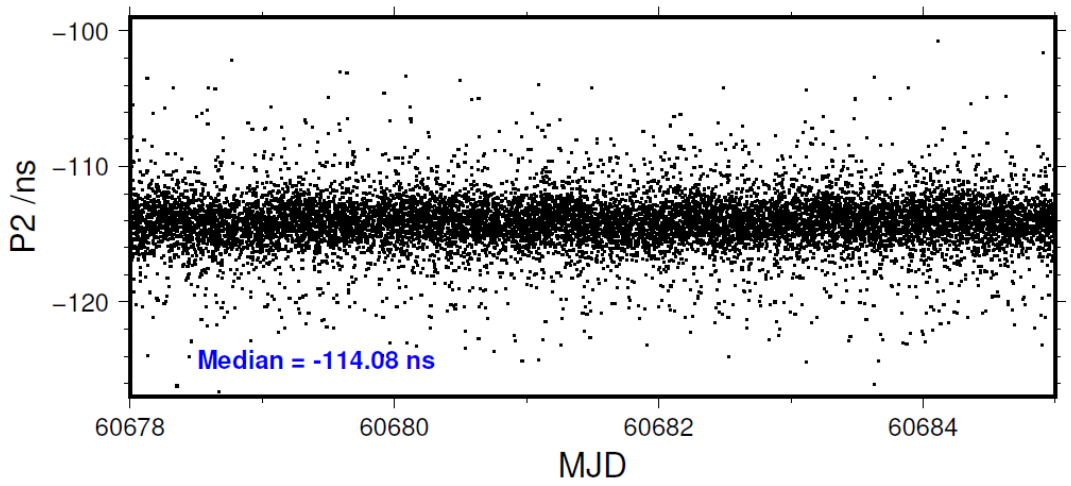


Figure 36. CCD between IM09 and SC05 at SCL(P2)

SC07 – IM09

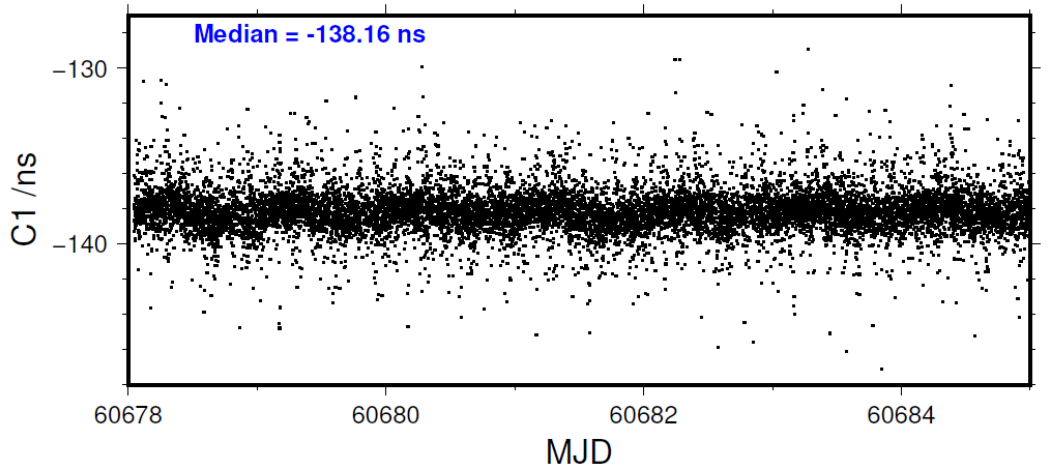


Figure 37. CCD between IM09 and SC07 at SCL (C1)

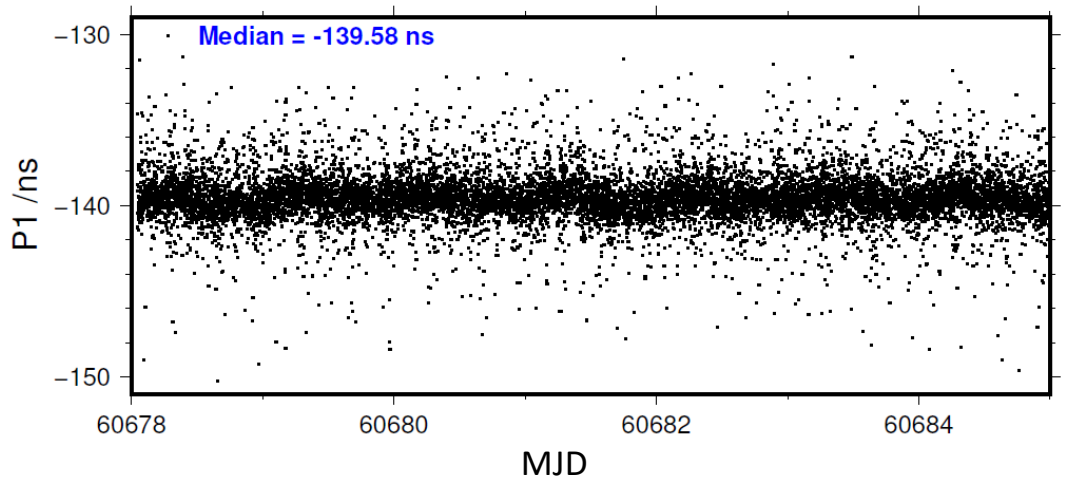


Figure 38. CCD between IM09 and SC07 at SCL (P1)

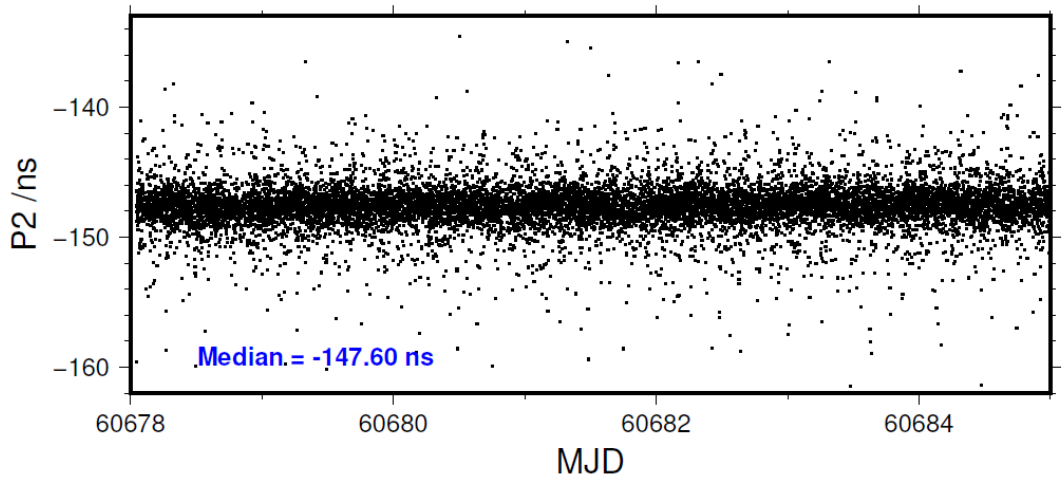


Figure 39. CCD between IM09 and SC07 at SCL (P2)

SC08– IM09

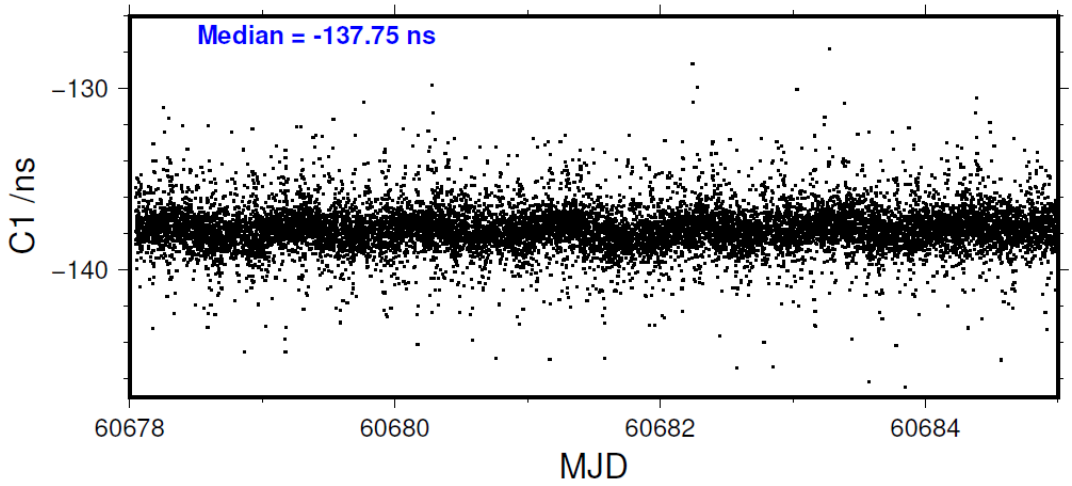


Figure 40. CCD between IM09 and SC08 at SCL (C1)

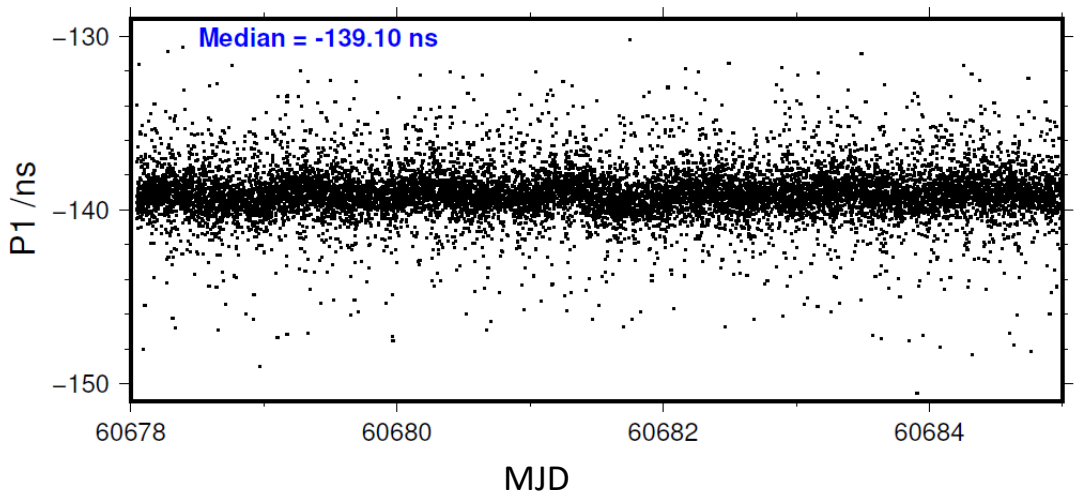


Figure 41. CCD between IM09 and SC08 at SCL (P1)

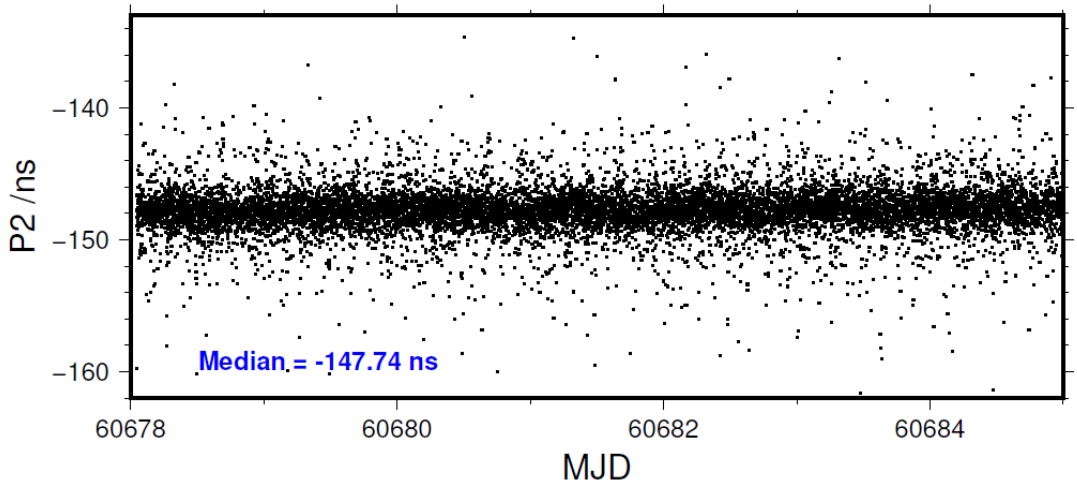


Figure 42. CCD between IM09 and SC08 at SCL (P2)

3. Closure CCD after calibration

IM09-IM02

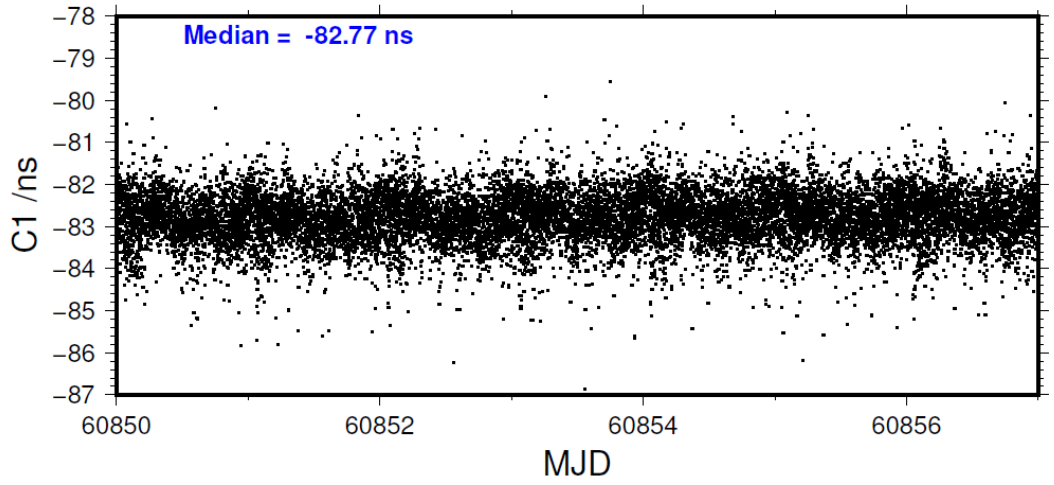


Figure 43. CCD between IM09 and IM02 at NIM(C1)

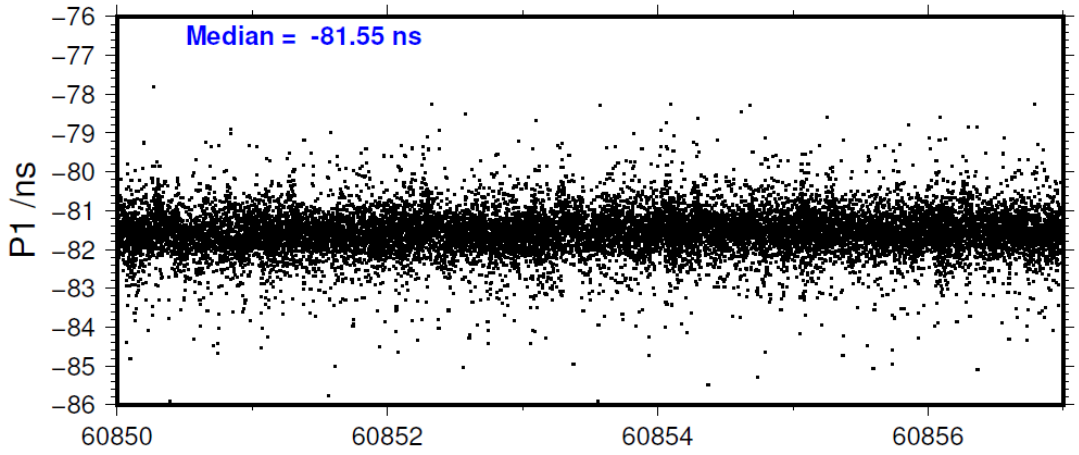


Figure 44. CCD between IM09 and IM02 at NIM(P1)

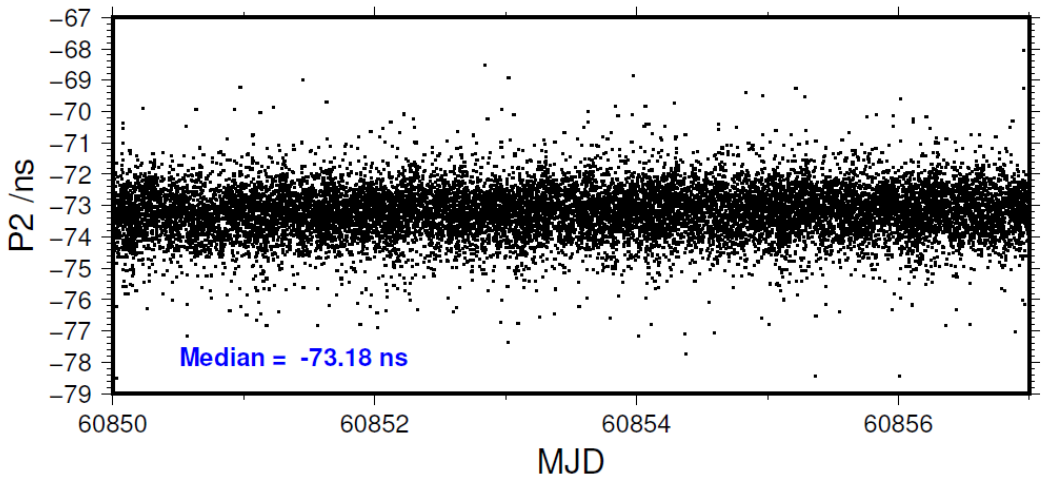


Figure 45. CCD between IM09 and IM02 at NIM(P2)

Annex 4. CCD results for HKO

1. Start CCD before calibration

IM09-IM02

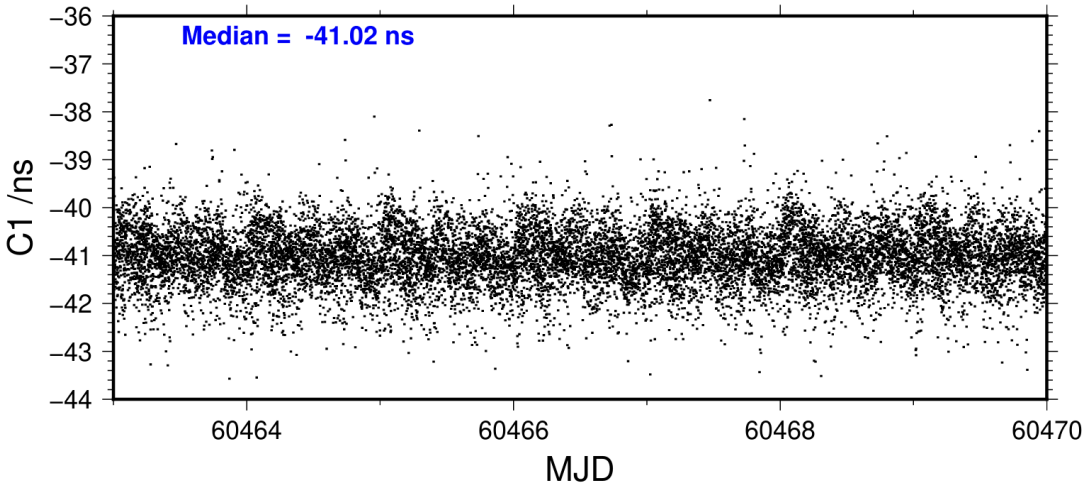


Figure 46. CCD between IM09 and IM02 at NIM(C1)

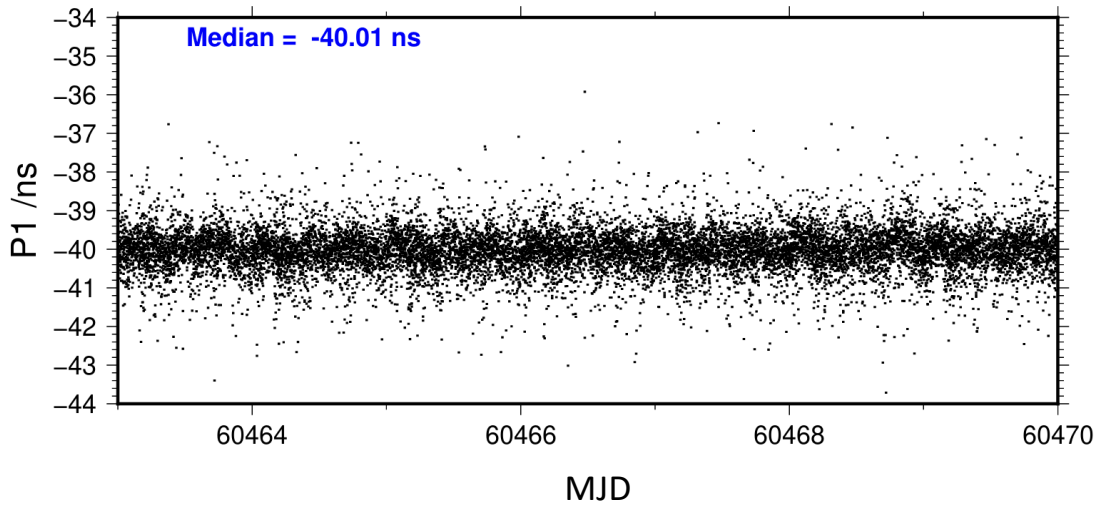


Figure 47. CCD between IM09 and IM02 at NIM(P1)

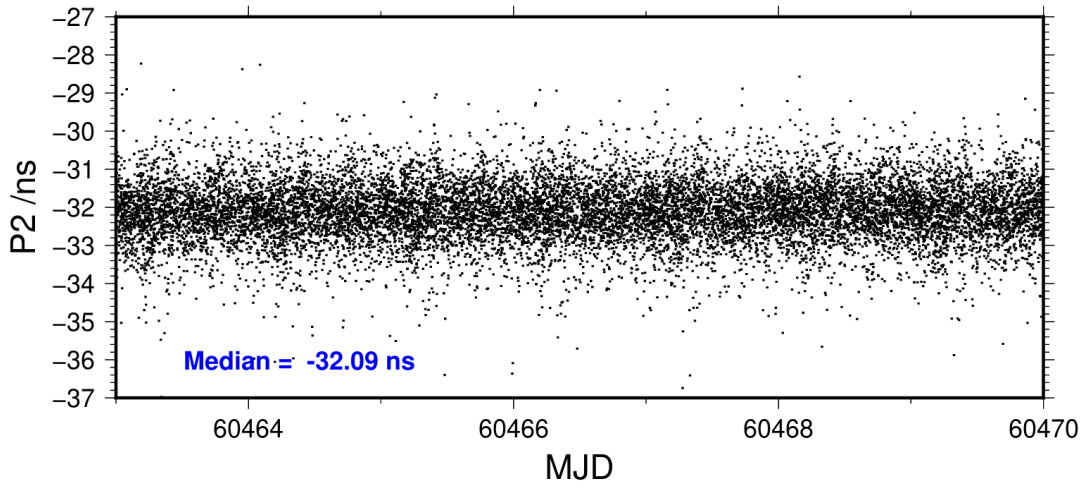


Figure 48. CCD between IM09 and IM02 at NIM(P2)

2. Calibration on site

HKO1 – IM09

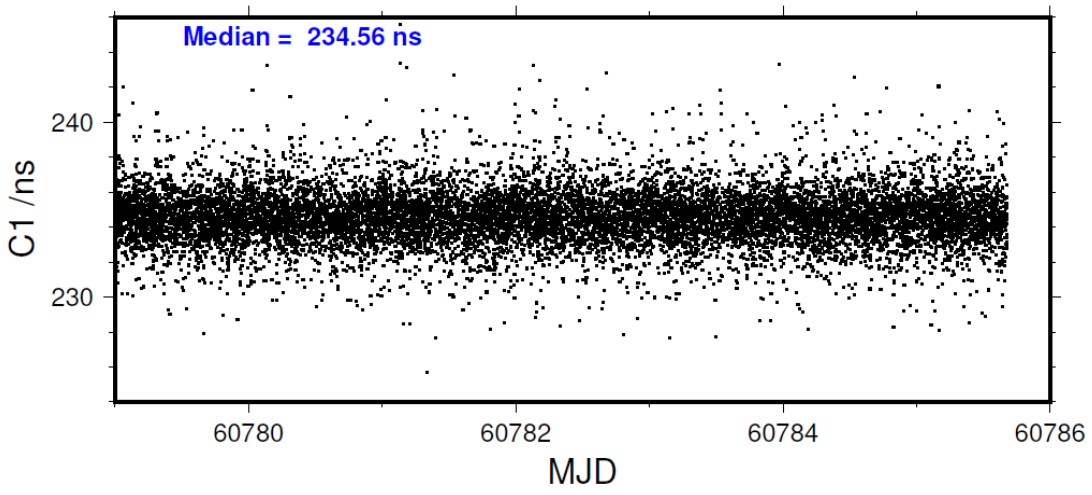


Figure 49. CCD between IM09 and HKO1 at HKO(C1)

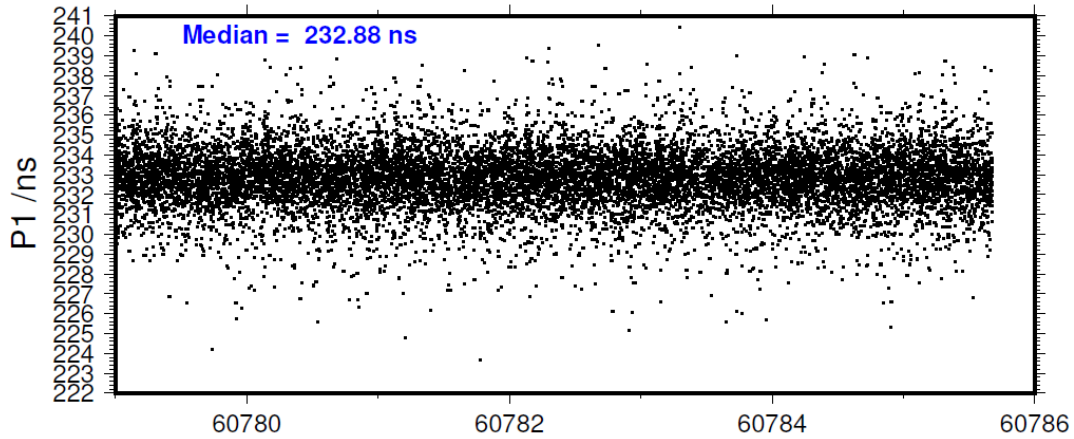


Figure 28. CCD between IM09 and HKO1 at HKO(P1)

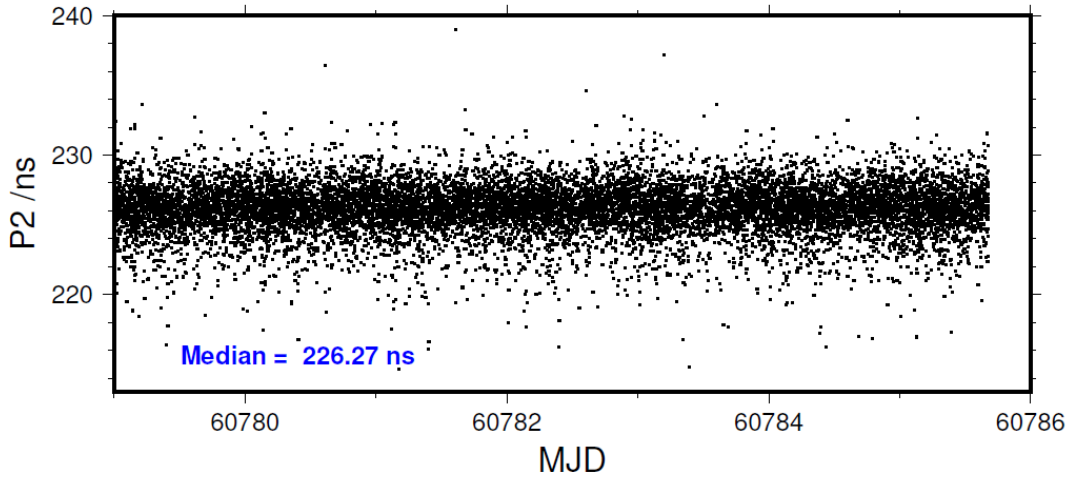


Figure 50. CCD between IM09 and HKO1 at HKO(P2)

3. Closure CCD after calibration

IM09-IM02

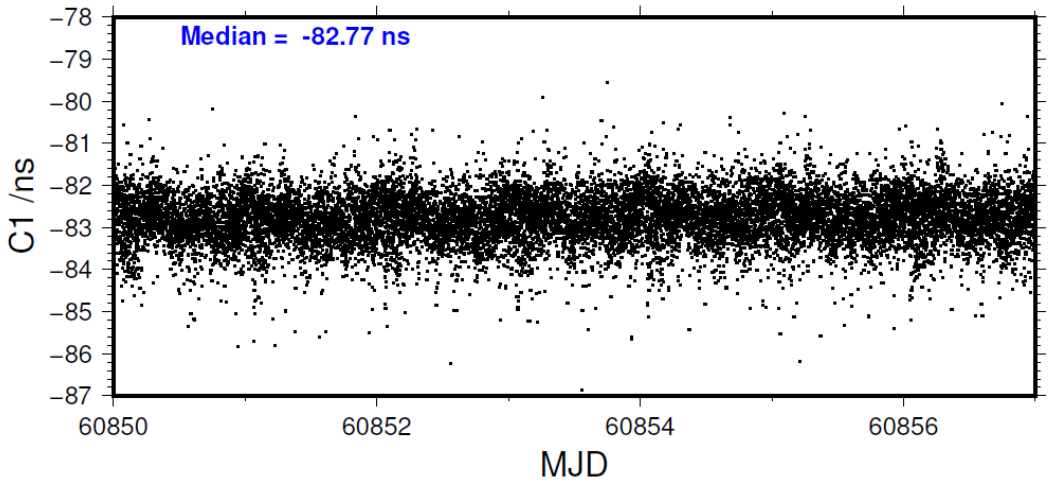


Figure 51. CCD between IM09 and IM02 at NIM(C1)

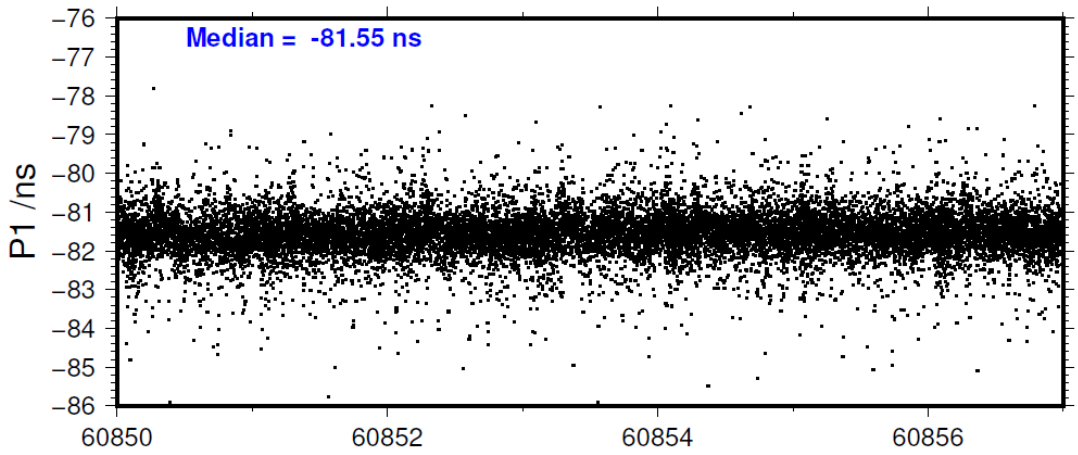


Figure 52. CCD between IM09 and IM02 at NIM(P1)

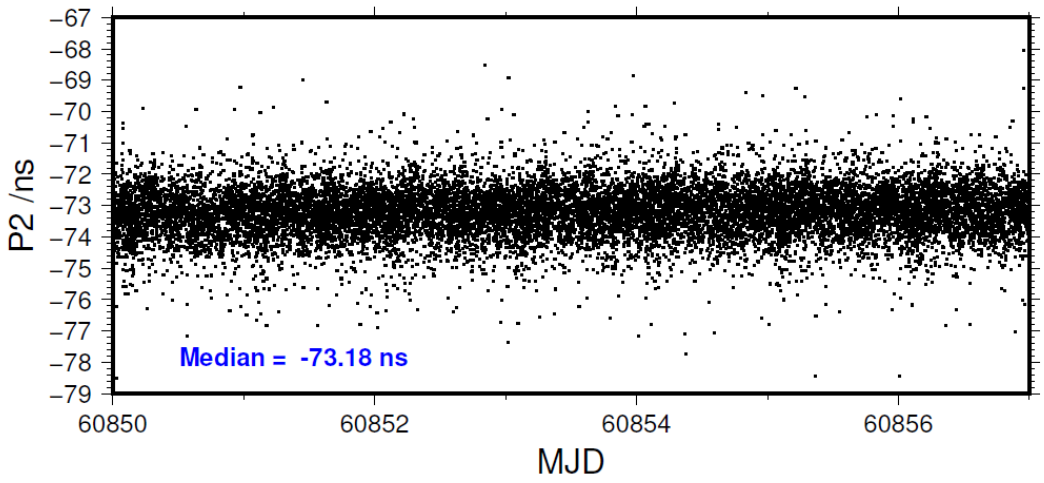


Figure 53. CCD between IM09 and IM02 at NIM(P2)

Annex 5 - Information Sheets

Information Sheet

(to be repeated for each calibrated system)

Laboratory：		BIRM
Date and hour of the beginning of measurements:		2024-6-2 00UTC
Date and hour of the end of measurements:		2024-6-9 00UTC
Information on the system		
	Local:	**Travelling:**
4-character BIPM code	BI07	（1）IM09 （2）IM11
Receiver maker and type: Receiver serial number：	BM1308-52 SN: 2001001	(1) maker: NIM type: NIM-TF-GNSS-2 serial number:SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	1.0	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	- -	- -
Length outside the building /m:	About 10m	About 10m
Antenna maker and type: Antenna serial number:	CRG-2D SN: 160405021	(1) type: AT200-GNSS serial number: 5098 (2) GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	23	23℃
Measured delays /ns		
	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	229.35	(1) IM09:200.3 (2) IM11:198.5
Delay from 1 PPS-in to internal Reference (if different):	-	-
Antenna cable delay:	213.7ns	(1) IM09:212.9 (2) IM11:213.5
Splitter delay (if any):	-	Less than 0.1ns
Additional cable delay (if any):	-	-
Data used for the generation of CGGTTS files		
INT DLY (GPS) /ns:		0
INT DLY (GLONASS) /ns:		0
CAB DLY /ns:		213.7
REF DLY /ns:		229.35
Coordinates reference frame:		ITRF
Latitude or X /m:		-2154289.4710
Longitude or Y /m:		4373435.9942
Height or Z /m:		4098889.3933
General information		
Rise time of the local UTC pulse		5ns
Is the laboratory air conditioned		Yes

Set temperature value and uncertainty:	23 ± 1℃
Set humidity value and uncertainty:	50 ± 5%

(to be repeated for each calibrated system)

Laboratory：	JATC
Date and hour of the beginning of measurements:	2024-7-30 00UTC
Date and hour of the end of measurements:	2024-8-5 00UTC

Information on the system

	Local:	**Travelling:**
4-character BIPM code	JA01	（1）IM09 （2）IM11
Receiver maker and type: Receiver serial number：	SEPT POLARX4TR 3009580	(1) maker: NIM type: NIM-TF-GNSS-2 serial number:SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	- -	- -
Length outside the building /m:	About 20m	About 20m
Antenna maker and type: Antenna serial number:	SEPCHOKE MC NONE	(1) type: AT200-GNSS serial number: 5098 (2) GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	23℃	23℃

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	207.53	(1) IM09:71.01 (2)IM11:72.01
Delay from 1 PPS-in to internal Reference (if different):	134.67	-
Antenna cable delay:	0	(1) IM09:178.13 (2) IM11:204.07
Splitter delay (if any):	-	Less than 0.1ns
Additional cable delay (if any):	-	-

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	SYS DLY (GPS P3) = 237.2
INT DLY (GLONASS) /ns:	/
CAB DLY /ns:	0
REF DLY /ns:	342.2
Coordinates reference frame:	ITRF 2008
Latitude or X /m:	-1735234.400
Longitude or Y /m:	+4976845.760
Height or Z /m:	+3580528.390

General information

Rise time of the local UTC pulse	3.2ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	23℃
Set humidity value and uncertainty:	55%

(to be repeated for each calibrated system)

Laboratory：	JATC
Date and hour of the beginning of measurements:	2024-7-30 00UTC
Date and hour of the end of measurements:	2024-8-5 00UTC

Information on the system

	Local:	**Travelling:**
4-character BIPM code	JA02	（1）IM09 （2）IM11
Receiver maker and type: Receiver serial number：	GTR55 1906002	(1) maker: NIM type: NIM-TF-GNSS-2 serial number:SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	- -	- -
Length outside the building /m:	About 20m	About 20m
Antenna maker and type: Antenna serial number:	NOV850 NMLK19180045U	(1) type:AT200-GNSS serial number:5098 (2) type:GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	23°C	23°C

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	191.87	(1) IM09:71.01 (2) IM11:72.01
Delay from 1 PPS-in to internal Reference (if different):	-	-
Antenna cable delay:	0	(1) IM09:178.13 (2) IM11:204.07
Splitter delay (if any):	-	Less than 0.1ns
Additional cable delay (if any):	-	-

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	Total DLY (GPS P3) =3.1
INT DLY (GLONASS) /ns:	0
CAB DLY /ns:	0
REF DLY /ns:	191.87
Coordinates reference frame:	ITRF 2008
Latitude or X /m:	-1735235.35
Longitude or Y /m:	+4976845.31
Height or Z /m:	+3580528.21

General information

Rise time of the local UTC pulse	3.2ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	23°C
Set humidity value and uncertainty:	55%

(to be repeated for each calibrated system)

Laboratory：	NTSC
Date and hour of the beginning of measurements:	2024-10-1 00UTC
Date and hour of the end of measurements:	2024-10-7 00UTC

Information on the system

	Local:	Travelling:
4-character BIPM code	NT02	（1）IM09 （2）IM11
Receiver maker and type: Receiver serial number：	GTR55 1803027	(1) maker: NIM type: NIM-TF-GNSS-2 serial number: SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	- -	- -
Length outside the building /m:	About 20m	About 20m
Antenna maker and type: Antenna serial number:	NOV850 NMLK17480024E	(1) type:AT200-GNSS serial number:5098 (2) type: GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	23°C	23°C

Measured delays /ns

	Local:	Travelling:
Delay from local UTC to receiver 1 PPS-in:	112.14	（1）IM09:126.6 （2）IM11:127.6
Delay from 1 PPS-in to internal Reference (if different):	-	-
Antenna cable delay:	0	（1）IM09:204.07 （2）IM11:128.68
Splitter delay (if any):	-	Less than 0.1ns
Additional cable delay (if any):	-	-

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	Total DLY (GPS P3) = 75.6
INT DLY (GLONASS) /ns:	0
CAB DLY /ns:	0
REF DLY /ns:	112.14
Coordinates reference frame:	ITRF 2008
Latitude or X /m:	-1735233.48
Longitude or Y /m:	+4976846.00
Height or Z /m:	+3580528.42

General information

Rise time of the local UTC pulse	3.2ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	23°C
Set humidity value and uncertainty:	55%

(to be repeated for each calibrated system)

Laboratory：	NTSC
Date and hour of the beginning of measurements:	2024-10-1 00UTC
Date and hour of the end of measurements:	2024-10-7 00UTC

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NT03	（1）IM09 （2）IM11
Receiver maker and type: Receiver serial number：	GTR55 1906001	(1) maker: NIM type: NIM-TF-GNSS-2 serial number:SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	- -	- -
Length outside the building /m:	About 20m	About 20m
Antenna maker and type: Antenna serial number:	NOV850 NMLK19180035F	(1) type:AT200-GNSS serial number:5098 (2) type: GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	23℃	23℃

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	115.81	（1）IM09:126.6 （2）IM11:127.6
Delay from 1 PPS-in to internal Reference (if different):	-	-
Antenna cable delay:	0	（1）IM09:204.07 （2）IM11:128.68
Splitter delay (if any):	-	Less than 0.1ns
Additional cable delay (if any):	-	-

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	Total DLY (GPS P3) = 81.1
INT DLY (GLONASS) /ns:	/
CAB DLY /ns:	0
REF DLY /ns:	115.81
Coordinates reference frame:	ITRF 2008
Latitude or X /m:	-1735234.77
Longitude or Y /m:	+4976845.08
Height or Z /m:	+3580529.02

General information

Rise time of the local UTC pulse	3.2ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	23℃
Set humidity value and uncertainty:	55%

(to be repeated for each calibrated system)

Laboratory：	NTSC
Date and hour of the beginning of measurements:	2024-10-1 00UTC
Date and hour of the end of measurements:	2024-10-7 00UTC

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NT05	（1）IM09 （2）IM11
Receiver maker and type: Receiver serial number：	SEPT POLARX5TR 4701420	(1) maker: NIM type: NIM-TF-GNSS-2 serial number: SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	- -	- -
Length outside the building /m:	About 20m	About 20m
Antenna maker and type: Antenna serial number:	SEPCHOKE B3E6 5589	(1) type: AT200-GNSS serial number:5098 (2) type: GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	23°C	23°C

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	104.61	（1）IM09:126.6 （2）IM11:127.6
Delay from 1 PPS-in to internal Reference (if different):	-	-
Antenna cable delay:	0	（1）IM09:204.07 （2）IM11:128.68
Splitter delay (if any):	-	Less than 0.1ns
Additional cable delay (if any):	-	-

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	Total DLY (GPS P3) = 94.7
INT DLY (GLONASS) /ns:	0
CAB DLY /ns:	0
REF DLY /ns:	104.61
Coordinates reference frame:	ITRF 2008
Latitude or X /m:	-1735236.430
Longitude or Y /m:	4976844.746
Height or Z /m:	3580529.188

General information

Rise time of the local UTC pulse	3.2ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	23°C
Set humidity value and uncertainty:	55%

(to be repeated for each calibrated system)

Laboratory:	SCL
Date and hour of the beginning of measurements:	2025-1-3 00UTC
Date and hour of the end of measurements:	2025-1-9 00UTC

Information on the system

	Local:	**Travelling:**
4-character BIPM code	SC05	（1）IM09 （2）IM11
• Receiver maker and type: Receiver serial number:	Septentrio PolaRx5TR s/n: 4701243	(1) maker: NIM type: NIM-TF-GNSS-2 serial number:SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	N/A	1
• Antenna cable maker and type: Phase stabilised cable (Y/N):	RFS LCF78-50JA and Suhner Sucoflex 104 Cables/N	- -
Length outside the building /m:	39 m	39m
• Antenna maker and type: Antenna serial number:	Septentrio PolaNT-x MF AT1675-540S s/n :12220	(1) type:AT200-GNSS serial number:5098 (2) type: GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	N/A	N/A

Measured delays /ns

	Local:	**Travelling:**
• Delay from local UTC to receiver 1 PPS-in:	10 ns	（1）IM09：53.25 （2）IM11：53.18
Delay from 1 PPS-in to internal Reference (if different):	N/A (Auto-cal mode)	-
• Antenna cable delay:	512 ns	（1）IM09：699.9 （2）IM11：616.99
Splitter delay (if any):	N/A	Less than 0.1ns
Additional cable delay (if any):	N/A	N/A

Data used for the generation of CGGTTS files

• INT DLY (GPS) /ns:	25.5 ns (GPS P1) 25.1ns (GPS P2)
• INT DLY (Galileo) /ns:	0
• INT DLY (GLONASS) /ns:	0
• CAB DLY /ns:	512 ns
• REF DLY /ns:	10 ns
• Coordinates reference frame:	ITRF
Latitude or X /m:	-2418047.390 m
Longitude or Y /m:	5387189.790 m
Height or Z /m:	2403187.080 m

General information

• Rise time of the local UTC pulse:	1.6 ns
• Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(23 ± 1) °C
Set humidity value and uncertainty:	(45 ± 8) %

(to be repeated for each calibrated system)

Laboratory:	SCL
Date and hour of the beginning of measurements:	2025-1-3 00UTC
Date and hour of the end of measurements:	2025-1-9 00UTC

Information on the system

	Local:	Travelling:
4-character BIPM code	SC07	（1）IM09 （2）IM11
• Receiver maker and type: Receiver serial number:	Septentrio PolaRx5TR s/n: 4701575	(1) maker: NIM type: NIM-TF-GNSS-2 serial number:SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	N/A	1
• Antenna cable maker and type: Phase stabilised cable (Y/N):	RFS LCF78-50JA and Suhner Sucoflex 104 cables/N	- -
Length outside the building /m:	39 m	39m 39m
• Antenna maker and type: Antenna serial number:	Septentrio PolaNt Choke Ring B3/E6 s/n :5897	(1) type:AT200-GNSS serial number:5098 (2) type: GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	N/A	N/A

Measured delays /ns

	Local:	Travelling:
• Delay from local UTC to receiver 1 PPS-in:	15.2 ns	（1）IM09：53.25 （2）IM11：53.18
Delay from 1 PPS-in to internal Reference (if different):	40.3 ns	-
• Antenna cable delay:	503.03 ns	（1）IM09：699.9 （2）IM11：616.99
Splitter delay (if any):	0.93 ns	Less than 0.1ns
Additional cable delay (if any):	8.97 ns	N/A

Data used for the generation of CGGTTS files

• INT DLY (GPS) /ns:	0
• INT DLY (Galileo) /ns:	0
• INT DLY (GLONASS) /ns:	0
• CAB DLY /ns:	512.9 ns
• REF DLY /ns:	55.5 ns
• Coordinates reference frame:	ITRF
Latitude or X /m:	-2418046.481 m
Longitude or Y /m:	5387190.185 m
Height or Z /m:	2403187.109 m

General information

• Rise time of the local UTC pulse:	1.6 ns
• Is the laboratory air conditioned:	Yes

Set temperature value and uncertainty:	(23 ± 1) °C
Set humidity value and uncertainty:	(45 ± 8) %

(to be repeated for each calibrated system)

Laboratory:	SCL
Date and hour of the beginning of measurements:	2025-1-3 00UTC
Date and hour of the end of measurements:	2025-1-9 00UTC

Information on the system

	Local:	Travelling:
4-character BIPM code	SC08	（1）IM09 （2）IM11
• Receiver maker and type: Receiver serial number:	Septentrio PolaRx5TR s/n : 4701576	(1) maker: NIM type: NIM-TF-GNSS-2 serial number:SN201401 (2) maker: DICOM type: GTR51 serial number:1405004
1 PPS trigger level /V:	N/A	1
• Antenna cable maker and type: Phase stabilised cable (Y/N):	RFS LCF78-50JA and Suhner Sucoflex 104 cables/N	- -
Length outside the building /m:	39 m	39m 39m
• Antenna maker and type: Antenna serial number:	Septentrio PolaNt Choke Ring B3/E6 s/n :5897	(1) type:AT200-GNSS serial number:5098 (2) GPS-703-GGG serial number: NEG14100010
Temperature (if stabilised) /°C	N/A	N/A

Measured delays /ns

	Local:	Travelling:
• Delay from local UTC to receiver 1 PPS-in:	15.20 ns	（1）IM09：53.25 （2）IM11：53.18
Delay from 1 PPS-in to internal Reference (if different):	39.66 ns	-
• Antenna cable delay:	503.03 ns	（1）IM09：699.9 （2）IM11：616.99
Splitter delay (if any):	0.93 ns	Less than 0.1ns
Additional cable delay (if any):	9.09 ns	N/A

Data used for the generation of CGGTTS files

• INT DLY (GPS) /ns:	0
• INT DLY (Galileo) /ns:	0
• INT DLY (GLONASS) /ns:	0
• CAB DLY /ns:	513.1 ns
• REF DLY /ns:	54.9 ns
• Coordinates reference frame:	ITRF
Latitude or X /m:	-2418046.481 m
Longitude or Y /m:	5387190.185 m
Height or Z /m:	2403187.109 m

General information

• Rise time of the local UTC pulse:	1.6 ns
• Is the laboratory air conditioned:	Yes

Set temperature value and uncertainty:	(23 ± 1) °C
Set humidity value and uncertainty:	(45 ± 8) %

(to be repeated for each calibrated system)

Laboratory：	HKO
Date and hour of the beginning of measurements:	2025-4-14 00UTC
Date and hour of the end of measurements:	2025-4-21 00UTC

Information on the system		
	Local:	**Travelling:**
4-character BIPM code	HKO1	IM09
Receiver maker and type: Receiver serial number：	PikTime TTS-4 126	
1 PPS trigger level /V:	1.0	1.0
Antenna cable maker and type: Phase stabilised cable (Y/N):		
Length outside the building /m:	~5	30
Antenna maker and type: Antenna serial number:	JAVAD RingAnt-G3T 00577	
Temperature (if stabilised) /°C	21-23	

Measured delays /ns		
	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	7.92ns	44.2ns (UTC to receiver) 22.0ns (UTC to amp) 10.7ns (amp)
Delay from 1 PPS-in to internal Reference (if different):	phase corr: 8.00 ns, fw corr: -65.72 ns	-
Antenna cable delay:	333.9ns	204ns
Splitter delay (if any):	-	Less than 0.1ns
Additional cable delay (if any):	-	-

Data used for the generation of CGGTTS files	
INT DLY (GPS) /ns:	-22.5 (L1C), 0.0 (L2C), 0.0 (L1P), 0.0 (L1P), 0.0 (L5P)
INT DLY (GLONASS) /ns:	-228.06 (L1C), 0.0 (L2C), 0.0 (L1P), 0.0 (L2P)
CAB DLY /ns:	333.89
REF DLY /ns:	7.92
Coordinates reference frame:	ITRF
Latitude or X /m:	-2417749.45
Longitude or Y /m:	+5386168.60
Height or Z /m:	+2405440.33

General information	
Rise time of the local UTC pulse	5ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	21 ± 1°C
Set humidity value and uncertainty:	70 ± 5%

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

Annex 6 – TDEV for CCD results at BIRM

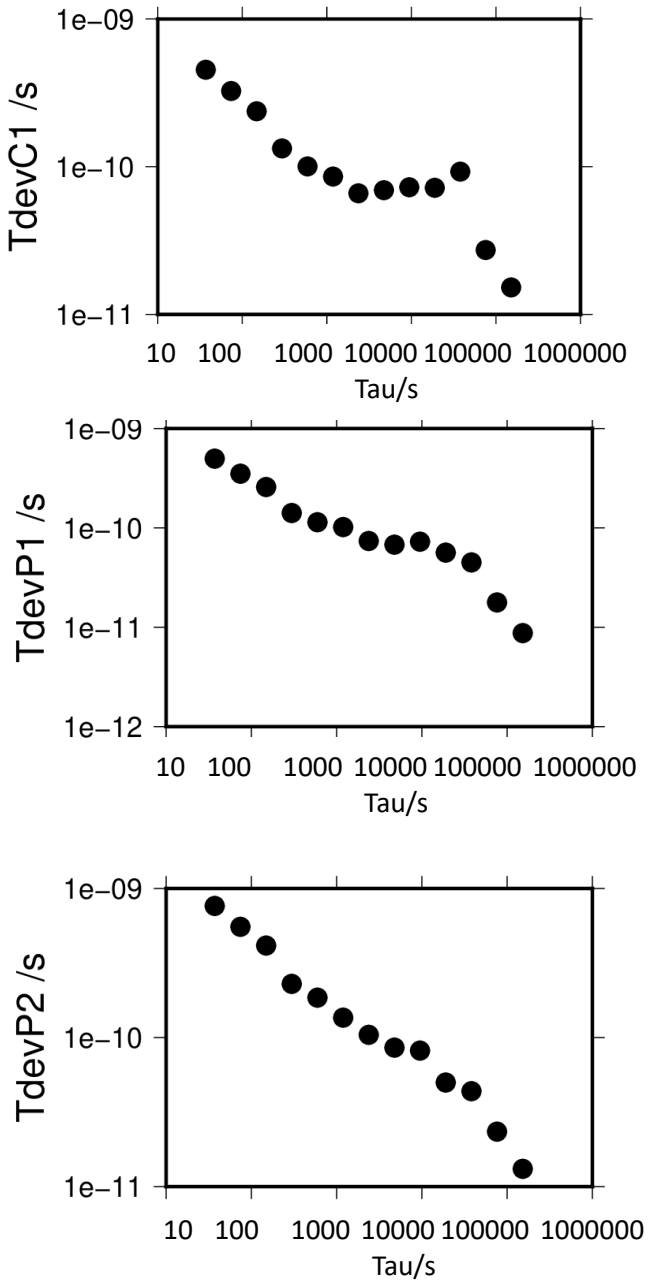


Figure 54. TDEV between BI07 and IM02 receivers at NIM during calibration

Annex 7 – TDEV for CCD results at NTSC

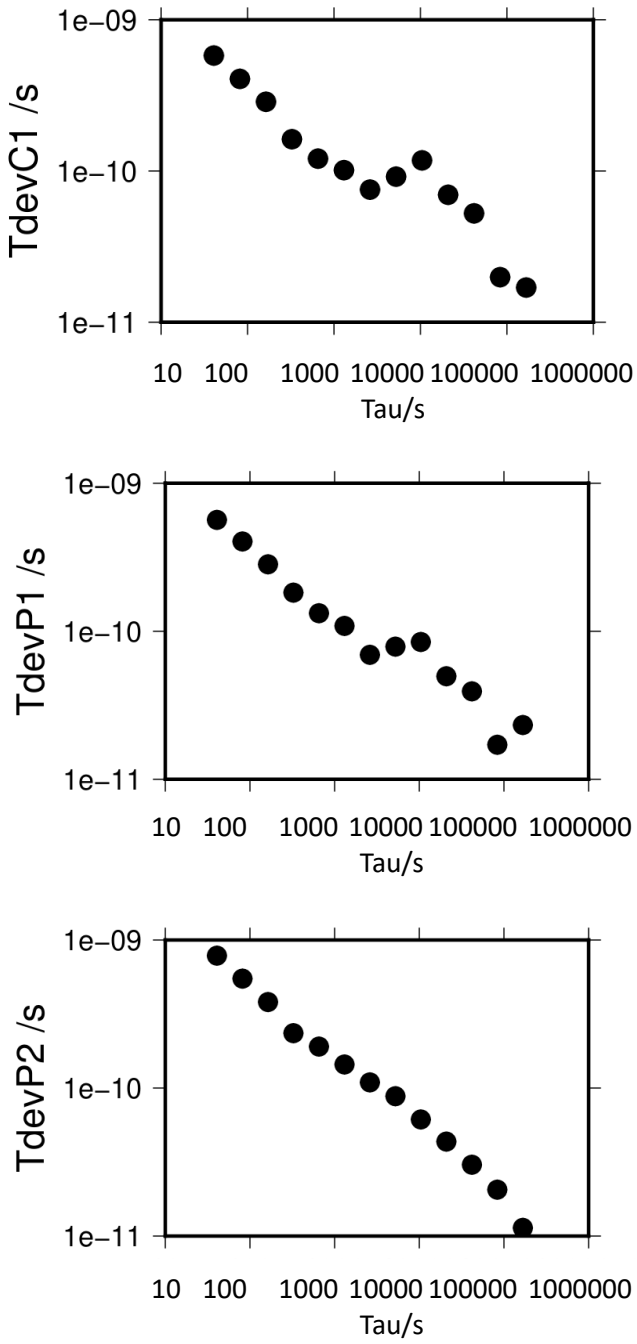


Figure 55. TDEV between IM09 and IM02 receivers at NIM before calibration

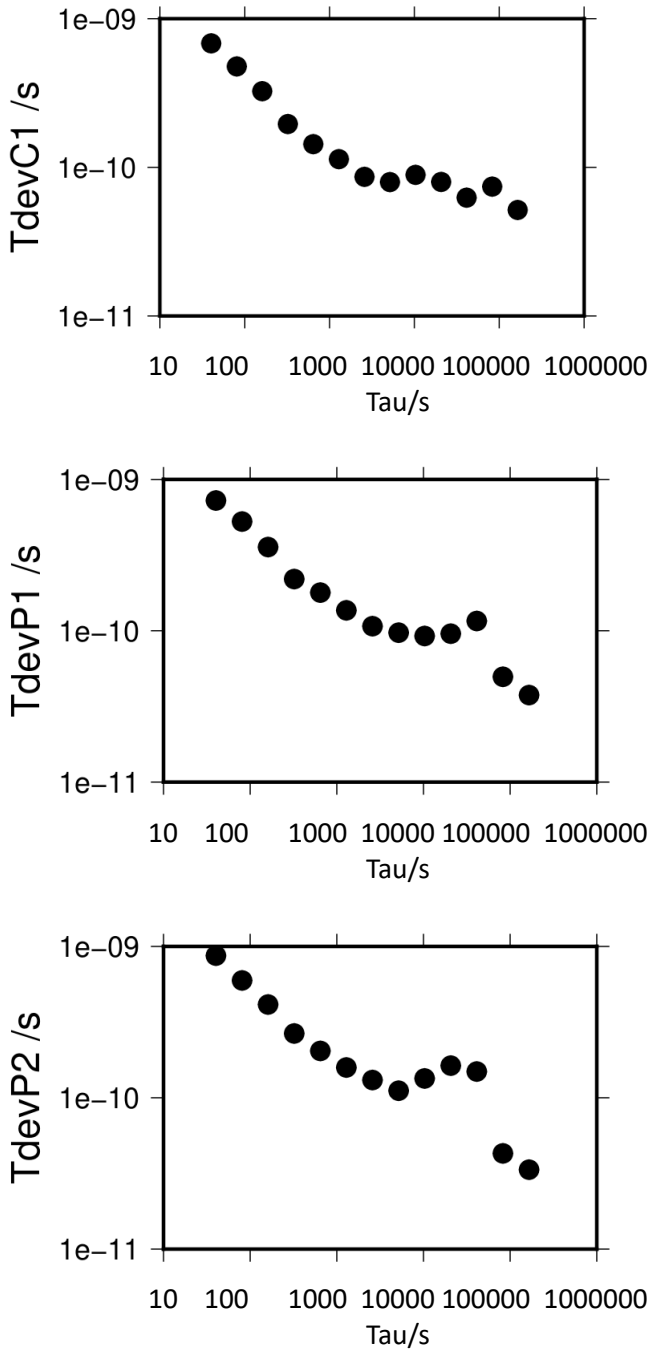


Figure 56. TDEV between JA01 and IM09 receivers at NTSC during calibration

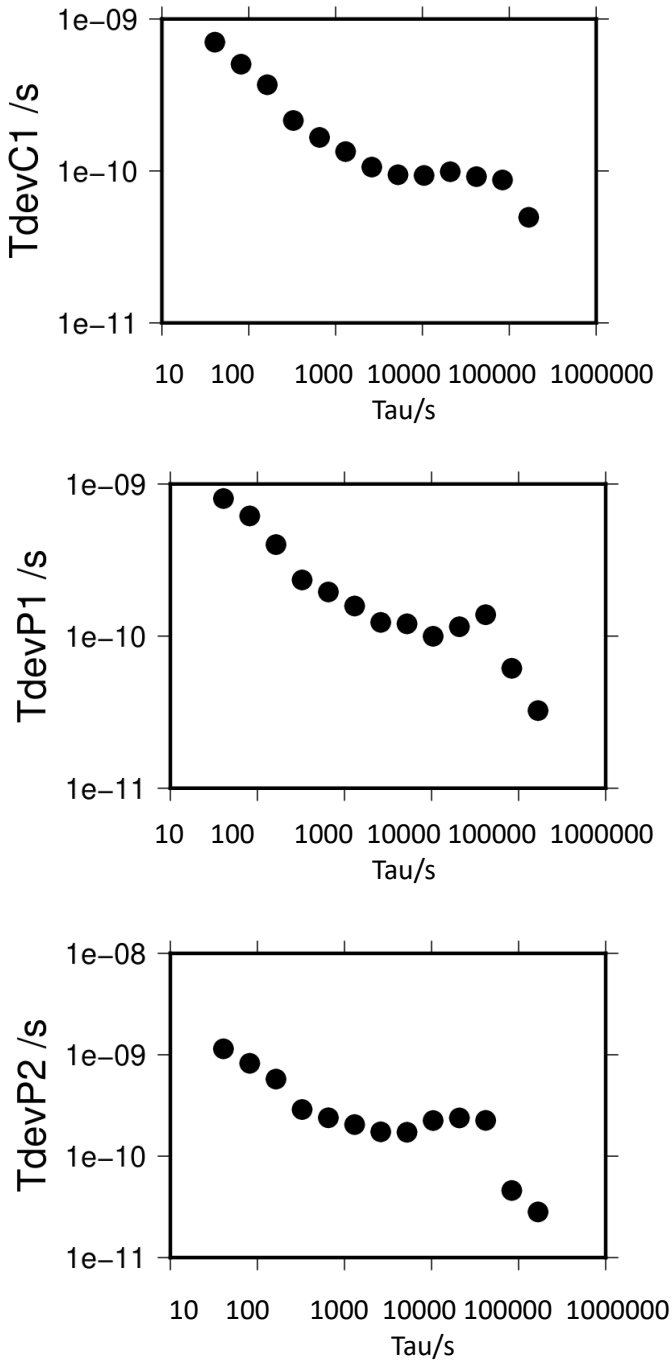


Figure 57. TDEV between JA02 and IM09 receivers at NTSC during calibration

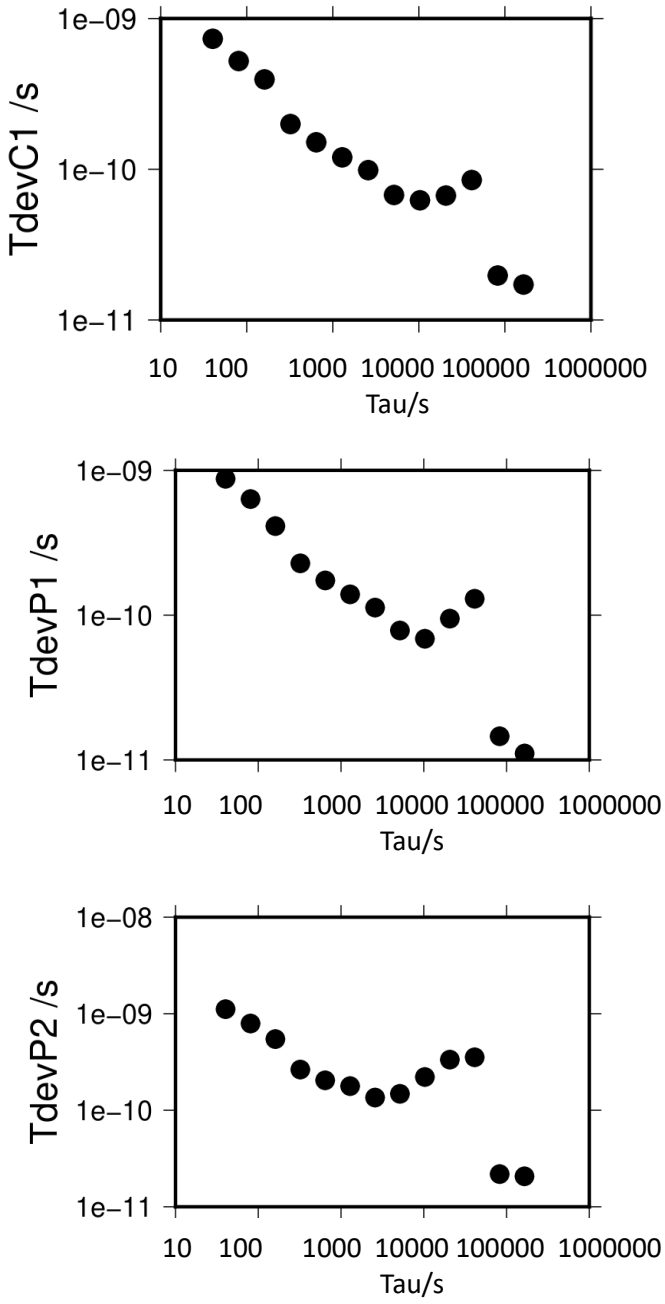


Figure 58. TDEV between NT02 and IM09 receivers at NTSC during calibration

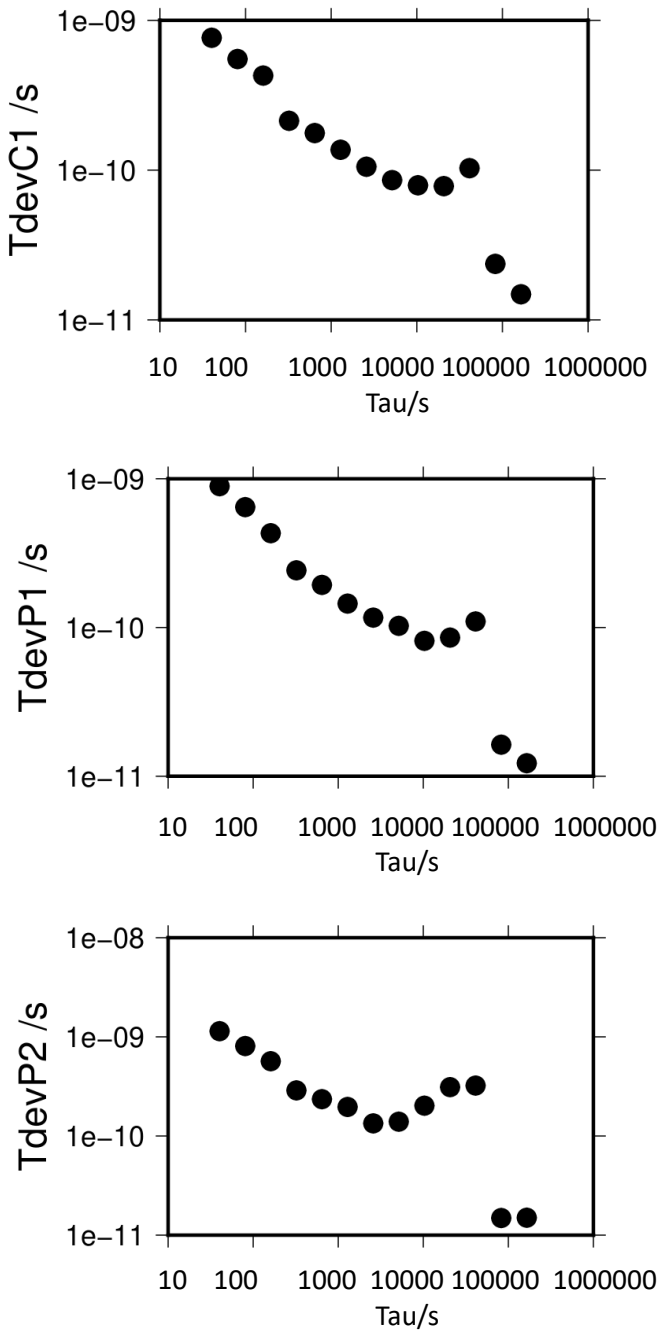


Figure 59. TDEV between NT03 and IM09 receivers at NTSC during calibration

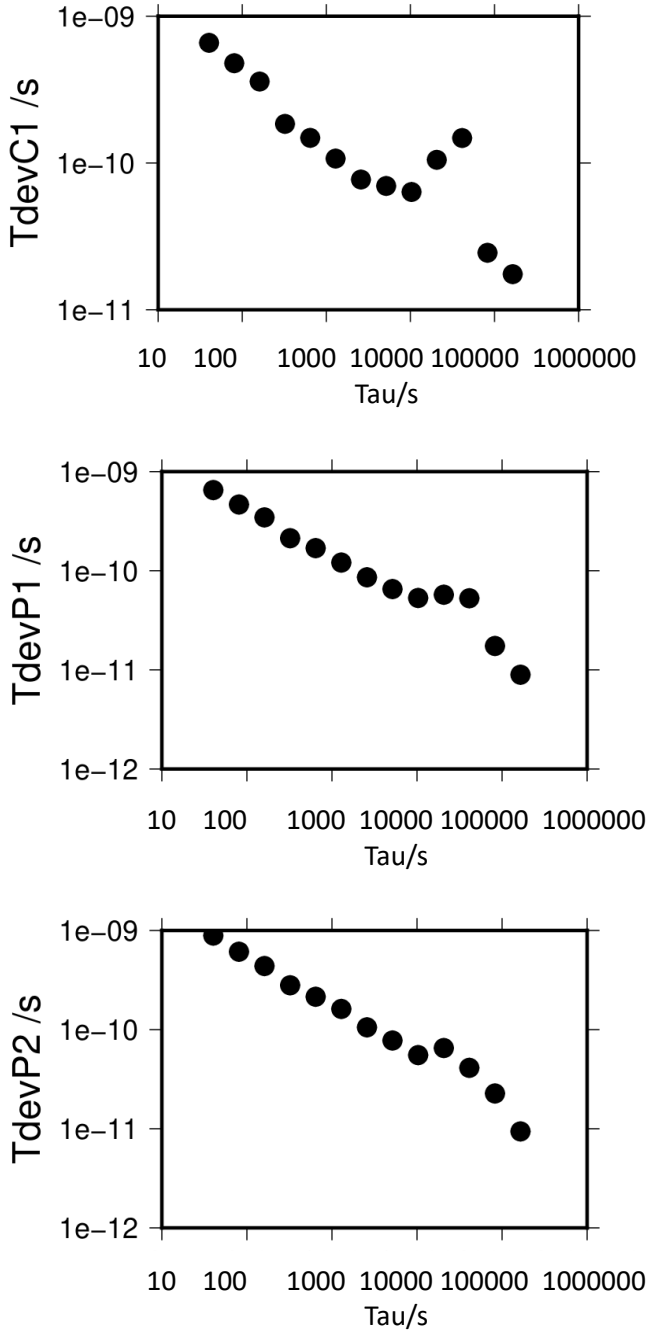


Figure 60. TDEV between NT05 and IM09 receivers at NTSC during calibration

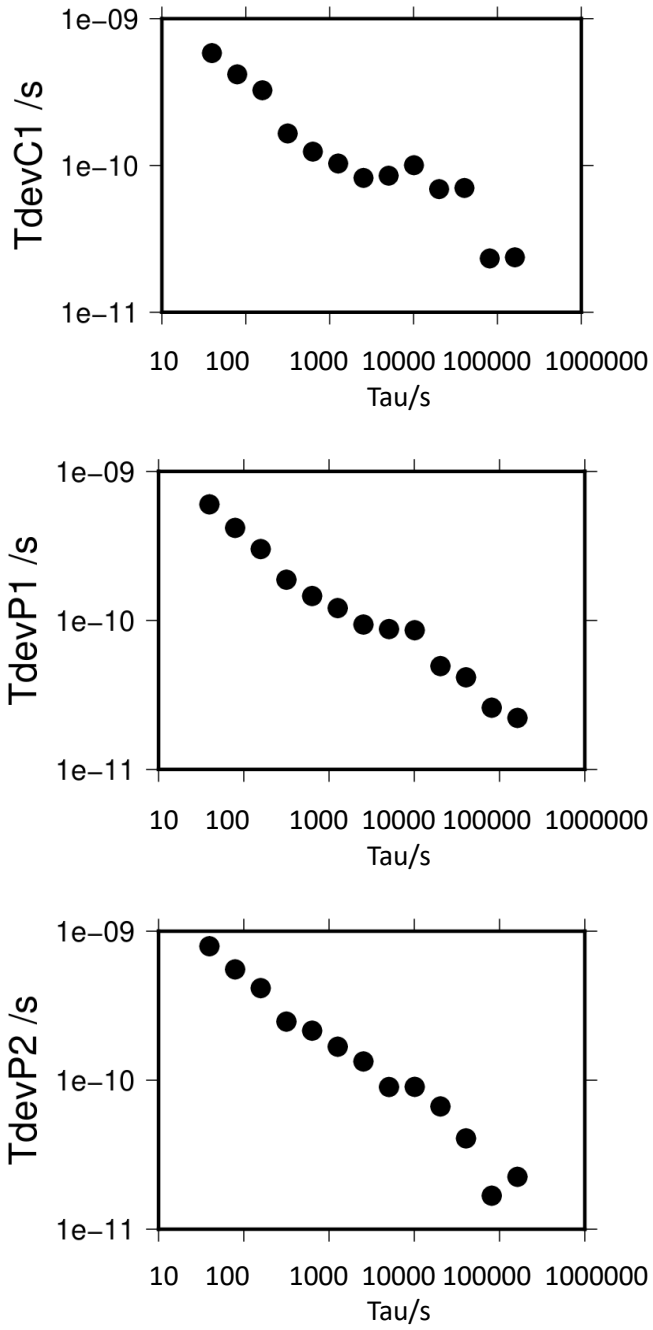


Figure 61. TDEV between IM09 and IM02 receivers at NIM after calibration

Annex 8 – TDEV for CCD results at SCL

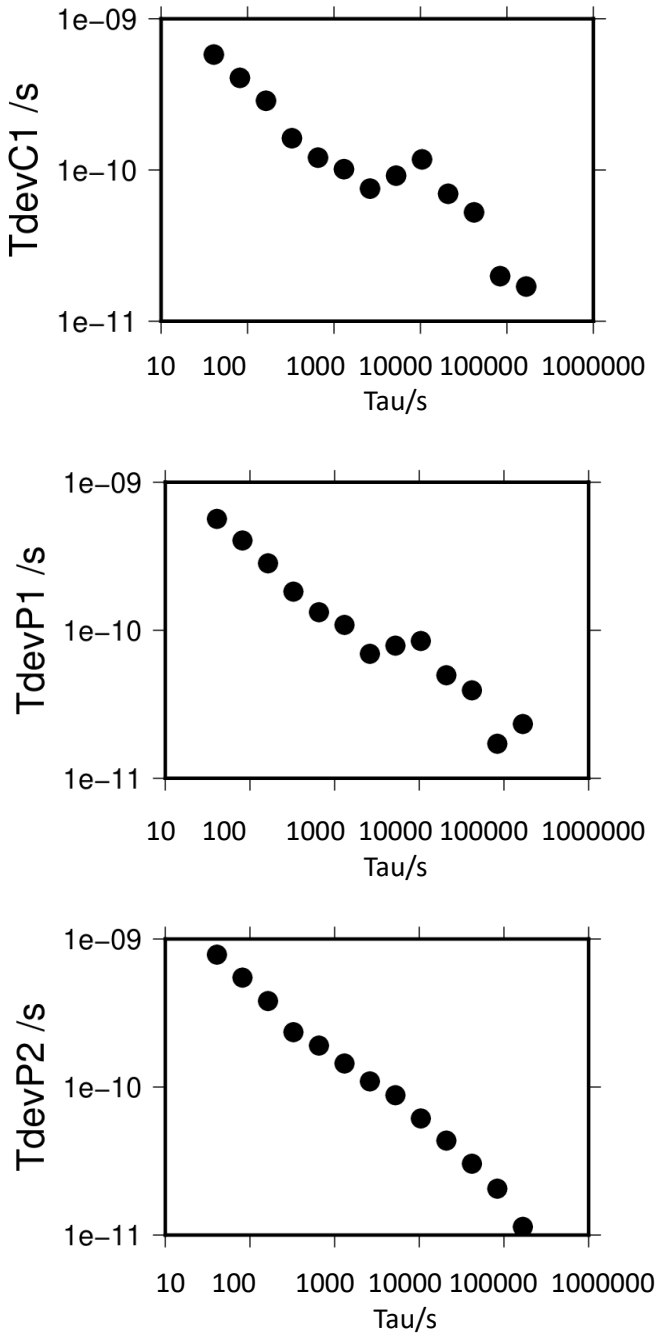


Figure 62. TDEV between IM09 and IM02 receivers at NIM before calibration

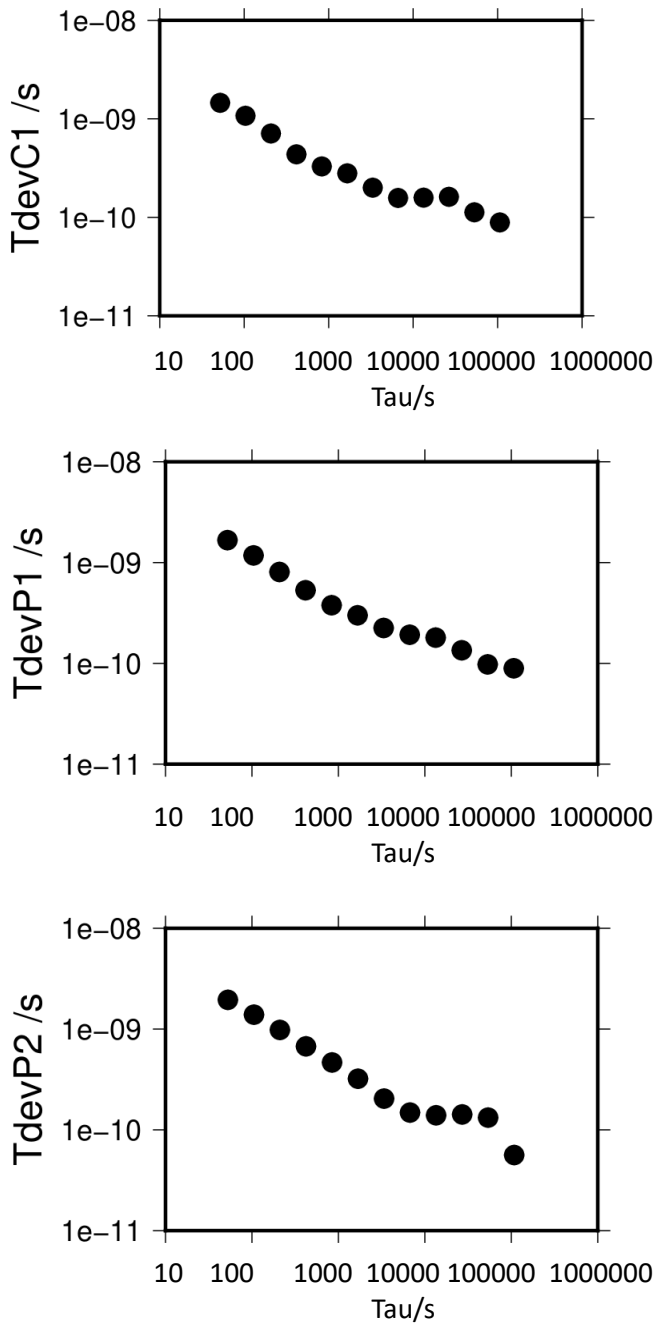


Figure 63. TDEV between SC05 and IM09 receivers at SCL during calibration

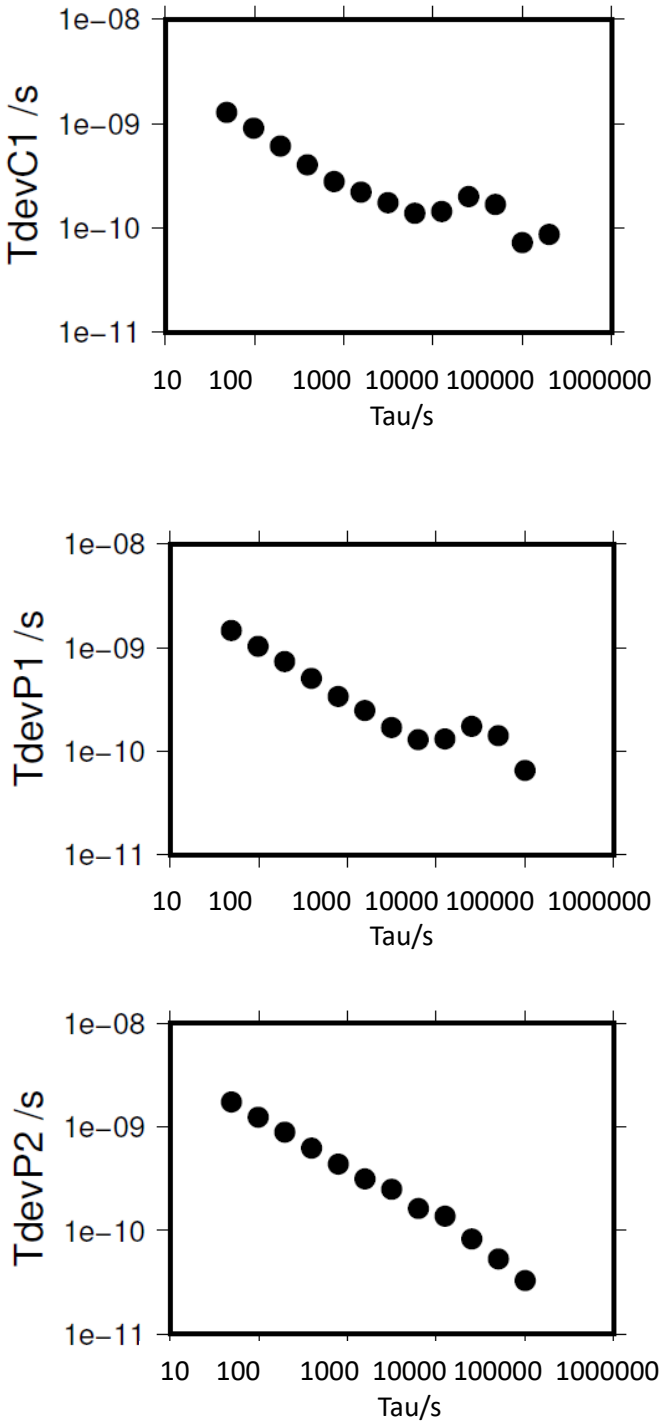


Figure 64. TDEV between SC07 and IM09 receivers at SCL during calibration

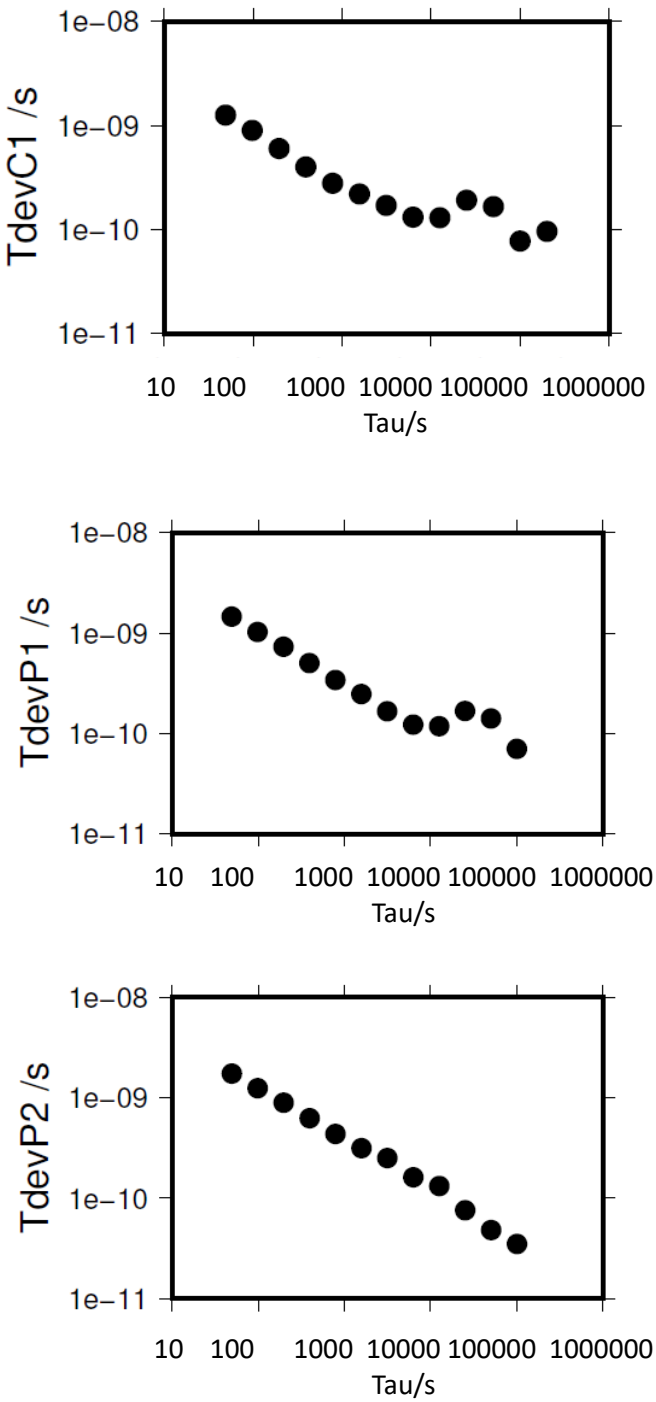


Figure 65. TDEV between SC08 and IM09 receivers at SCL during calibration

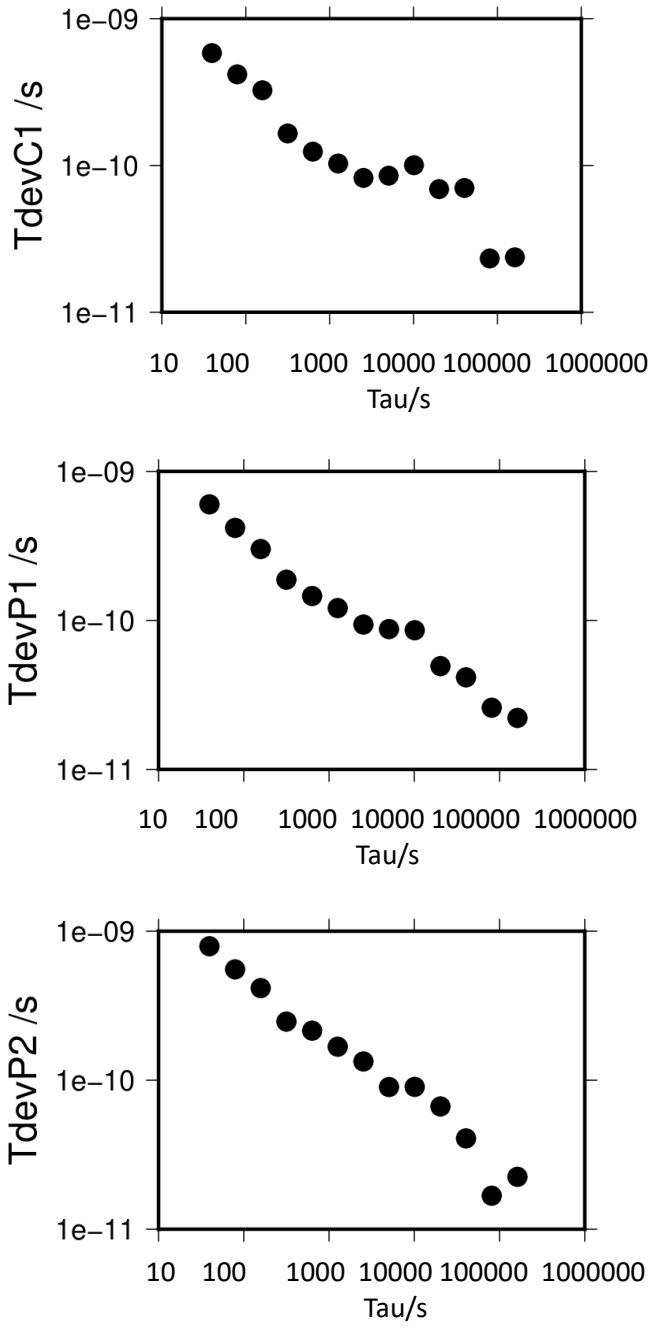


Figure 66. TDEV between IM09 and IM02 receivers at NIM after calibration

Annex 9 – TDEV for CCD results at HKO

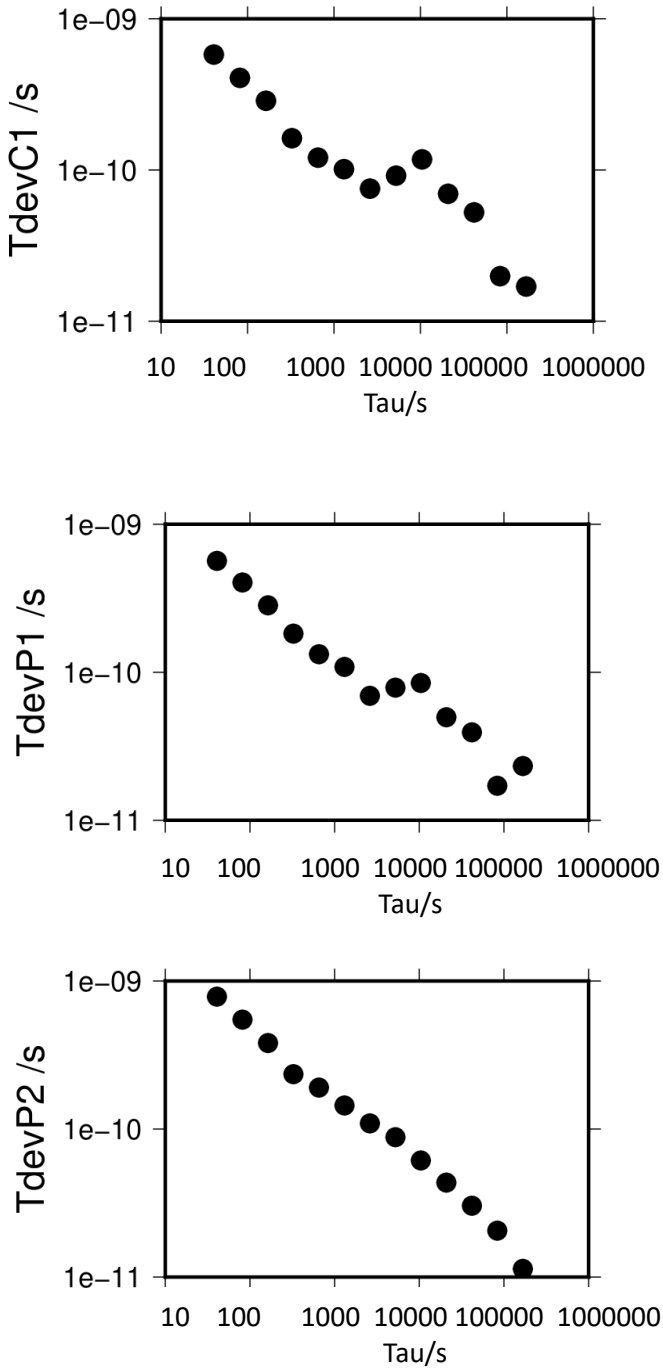


Figure 67. TDEV between IM09 and IM02 receivers at NIM before calibration

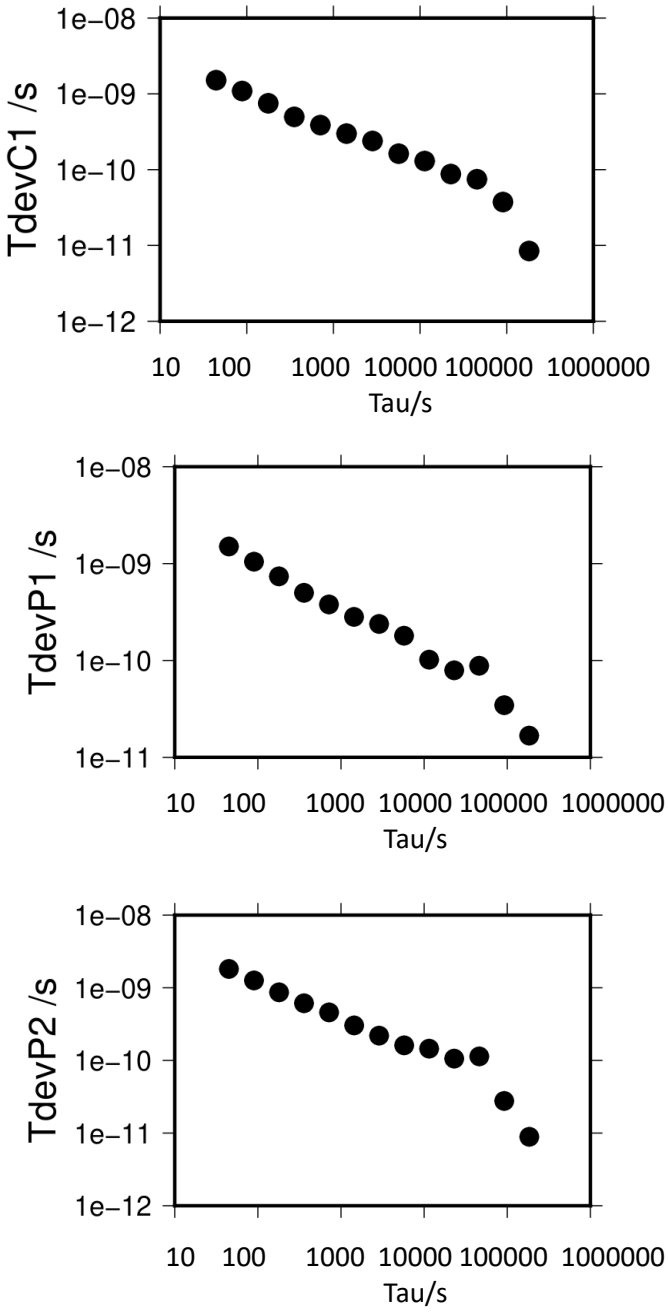


Figure 68. TDEV between HKO1 and IM09 receivers at NTSC during calibration

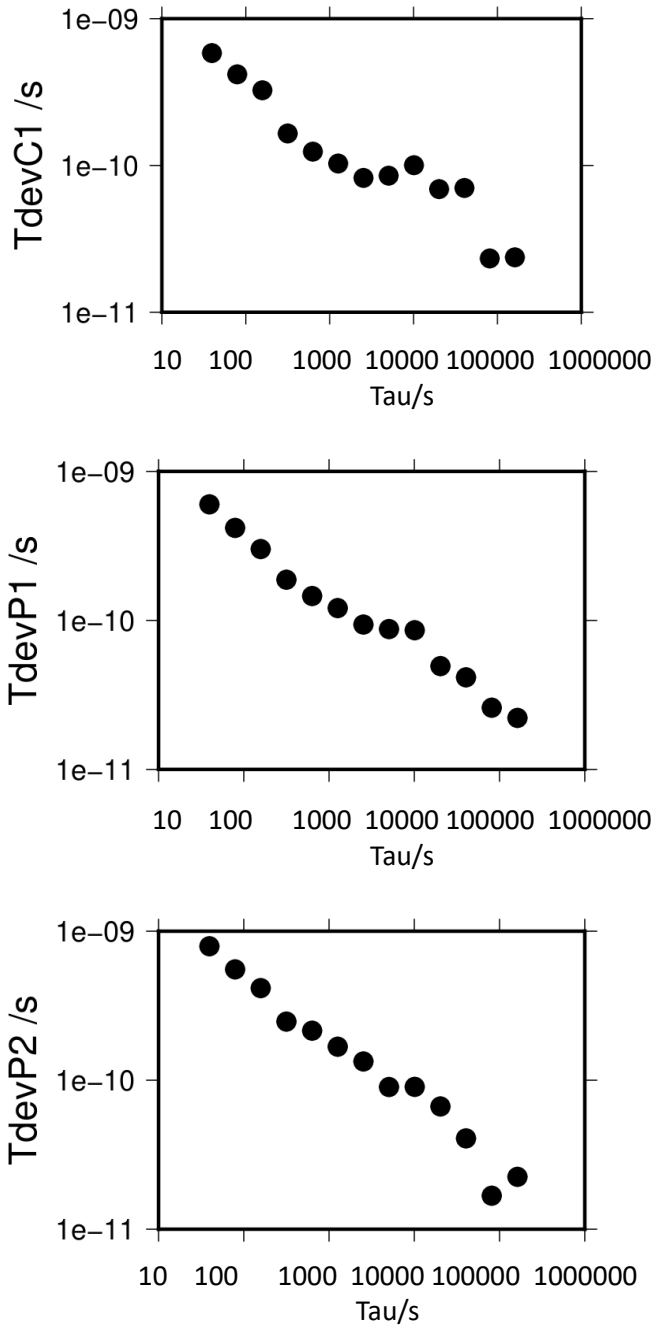


Figure 69. TDEV between IM09 and IM02 receivers at NIM after calibration