Report for Calibration of G2 Laboratories MASM and NMC A*STAR by NIM

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The report is divided by seven parts. The first part introduces the calibration briefly. And the second and third parts describe separately the equipments and the operation methods, and the experiment setups during the calibration campaign. Part 4 introduce the data processing of the calibration. Then the fifth part describe the final results by processing. In part 6, it is shown how the calibration uncertainties are evaluated. Climate parameters during the calibration is involved in part 7.

1. Introduction

Time link calibration is the premise of time transfer. Since 2012, BIPM has started to draw up the new guideline for GNSS link calibration and assigned several NMIs including NIM as the group 1 laboratories to implement the possibility of calibration of group 2 laboratories in the local RMO (Regional Metrology Organization) that might give some assist to BIPM.

NIM Cal-002 has been installed and operated at MASM since the middle of November of 2018. NIM Cal-002 was sent to NMC A*STAR (abbreviated to NMC) from MASM and arrived at NMC in the end of December of 2018. Finally, it came back to NIM in early March.

2. Description of the equipments and the operation method

The NIM transportable calibrator NIM Cal-002 is pictured in figure 1 and depicted schematically in figure 2.

Figure 1. NIM calibrator(NIM Cal-002)

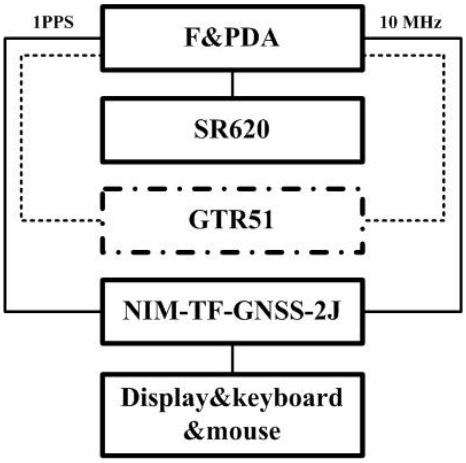


Figure 2. Schematic of NIM Cal-002

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

1. **NIM-TF-GNSS-2J**: GNSS time and frequency transfer travelling receiver developed by NIM
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:
   IM20(site name for CGGTTS is IM20): NIM-TF-GNSS-2J(with antenna

AT1675 AT-200)
IM12(site name for CGGTTS is IM12): GTR51(with antenna NOV703GGG)
Others:
KVM(ATEN)
PDA and FDA(SDI)
SR620(SRS)
cables
Connectors

All information about the equipments for the calibrator and the receivers to be calibrated are list in table 1.

Table 1. Sites used for the calibration

Timing lab	Site name	BIPM code	Model	Role	Notes
NIM	IM06	IM06	Dicom GTR50	Reference receiver	Master
NIM	IM20	IM20	NIM-TF-GNSS-2J	Traveling receiver	Traveling
NIM	IM12	IM12	GTR51	Traveling receiver	Traveling
MASM	MN__	MN__	GTR51	Receiver to be calibrated	
NMC	SG01	SG01	Septentrio PolaRx5TR	Receiver to be calibrated	
NMC	SG02	SG02	Septentrio PolaRx5TR	Receiver to be calibrated	
NMC	SG2P	SG2P	Septentrio PolaRx2eTR	Receiver to be calibrated	
NMC	SGBK	SGBK	Septentrio PolaRx2eTR	Receiver to be calibrated	

The whole calibration tour includes start CCD before calibration, calibration on site and closure CCD as shown in table 2.

Table 2. Measurements used for the calibration

Time period	Location	Operation
MJD 58373-MJD 58379	NIM	Start CCD before calibration
MJD 58403-MJD 58409	MASM	Calibration on site
MJD 58481-MJD 58486	NMC	Calibration on site
MJD 58548 -MJD 58553	NIM	Closure CCD after calibration

The data from MJD 58403 to MJD 58409 and from MJD 58481 to MJD 58486 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 principle concept is addressed in [1].

3. Experiment setups

In the campaign, the receivers used were as follows in table 1. IMEJ (site name for CGGTTS is IM06) is the master GPS time and frequency transfer receiver of NIM for TAI contribution and the reference receiver. The calibrator at MASM and NMC was installed and the setups and the sub-delay information for start and closure experiments at NIM and calibration experiments on site at MASM and NMC were depicted in figure 4 and 5.

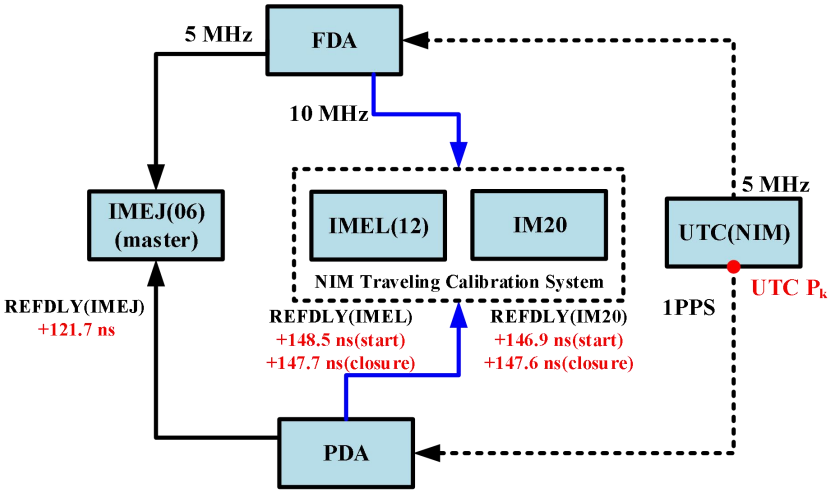


Figure 3. Experiment setup @NIM(for CCD experiments)

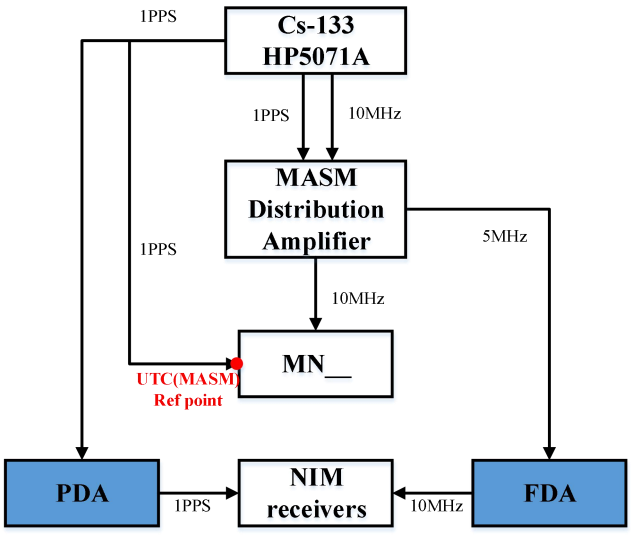


Figure 4. Experiment setup @MASM(for CCD experiments)

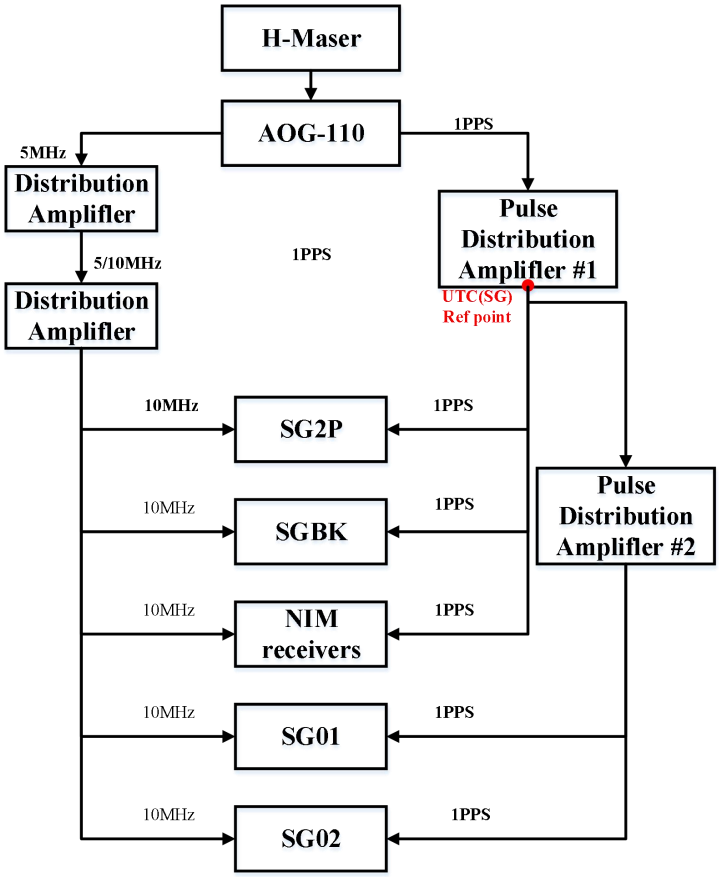


Figure 5. Experiment setup @NMC(for CCD experiments)

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)

IM12-IM06	58373-58379	26.8	-47.3
IM20-IM06	58373-58379	25.2	-43.6
MN__-IM12	58403-58409	-47.9	-70.0
MN__-IM20	58403-58409	-47.4	-73.7
SG01-IM12	58481-58486	1.1	9.5
SG01-IM20	58481-58486	1.1	34.2
SG02-IM12	58481-58486	1.2	-38.5
SG02-IM20	58481-58486	1.1	-13.8
SG2P-IM12	58481-58486	206.7	-94.5
SG2P-IM20	58481-58486	206.6	-69.8
SGBK-IM12	58481-58486	199.5	46.5
SGBK-IM20	58481-58486	199.4	71.2
IM12-IM06	58548-58553	26.0	-47.3
IM20-IM06	58548-58553	25.9	-43.6

5. Calibration computation and calibration values

Table 4 shows INTDLY for station IM06. Raw P1, P2, P3 and P1-P2 differences calculated between station and traveling receivers are given in table 5. The values for ΔINTDLY between a given pair of receivers are computed using Eq.(1) and given in table 6. Closure values(the difference between the mean values before calibration and after calibration) are given in table 7. The values of INTDLY for receiver MN__, SG01, SG02, SG2P and SGBK are computed using ΔINTDLY between receivers to be calibrated and the traveling receivers and ΔINTDLY between the traveling receivers and IM06 (values from 1001-2018). The values of INTDLY are given in table 8.

Table 4. INTDLY for station IM06 from 1001-2018

Rcvr	P1(ns)	P2(ns)	P3(ns)
IM06	-31.8	-18.4	-52.5

5.1. Raw differences

Table 5. Raw differences between station and traveling receivers

Pair	MJD	△P1(ns)	△P2(ns)	△P3(ns)
IM12-IM06	58373-58379	-82.0	-94.8	-62.1
IM20-IM06	58373-58379	-59.1	-54.1	-67.0
MN__-IM12	58403-58409	-4.4	-4.7	-4.1
MN__-IM20	58403-58409	-28.0	-45.8	-0.6
SG01-IM12	58481-58486	108.9	105.1	114.9
SG01-IM20	58481-58486	116.9	94.7	151.2
SG02-IM12	58481-58486	68.2	63.6	75.4
SG02-IM20	58481-58486	76.2	53.2	111.7
SG2P-IM12	58481-58486	-40.6	-41.4	-39.3

SG2P-IM20	58481-58486	-32.6	-51.8	-2.9
SGBK-IM12	58481-58486	105.3	102.2	110.2
SGBK-IM20	58481-58486	113.3	91.7	146.5
IM12-IM06	58548-58553	-82.2	-95.2	-62.1
IM20-IM06	58548-58553	-59.1	-54.3	-66.6

5.2. △INTDLY for recivers

Table 6. INTDLY differences between stations and traveling receivers

Pair	△INTDLY(P1)(ns)	△INTDLY(P2)(ns)	△INTDLY(P3)(ns)
IM12-IM06$\|_{before}$	-7.9	-20.7	12.0
IM20-IM06$\|_{before}$	9.7	14.7	1.8
MN__-IM12	17.7	17.4	18.0
MN__-IM20	-1.7	-19.5	25.7
SG01-IM12	100.5	96.7	106.5
SG01-IM20	83.8	61.6	118.1
SG02-IM12	107.9	103.3	115.1
SG02-IM20	91.1	68.1	126.6
SG2P-IM12	260.6	259.8	261.9
SG2P-IM20	243.8	224.6	273.5
SGBK-IM12	258.3	255.2	263.2
SGBK-IM20	241.5	219.9	274.7
IM12-IM06$\|_{after}$	-8.9	-21.9	11.2
IM20-IM06$\|_{after}$	10.4	15.2	2.9

5.3. Closure values

Table 7. Closure values

Pair	△P1(ns)	△P2(ns)	△P3(ns)
IM12-IM06	1.0	1.2	0.7
IM20-IM06	-0.7	-0.5	-1.0

5.4. Calibration values

Table 8. INTDLY for stations MN_, SG01, SG02, SG2P and SGBK

Rcvr	P1(ns)	P2(ns)	P3(ns)
MN__$\|_{IM12}$	-22.1	-21.7	-22.6
MN__$\|_{IM20}$	-23.9	-23.1	-25.3
SG01$\|_{IM12}$	60.8	57.6	65.9
SG01$\|_{IM20}$	61.6	57.8	67.3
SG02$\|_{IM12}$	68.2	64.2	74.5
SG02$\|_{IM20}$	69.0	64.4	75.9

$SG2P\|_{IM12}$	220.9	220.7	221.4
$SG2P\|_{IM20}$	221.7	220.9	222.8
$SGBK\|_{IM12}$	218.6	216.0	222.6
$SGBK\|_{IM20}$	219.3	216.3	224.0
MN__	-23.0	-22.4	-24.0
SG01	61.2	57.7	66.6
SG02	68.6	64.3	75.2
SG2P	221.3	220.8	222.1
SGBK	219.0	216.2	223.3

6. Uncertainty Evaluation

Here we evaluated the uncertainty from the sources as follows and got the combined uncertainty as 1.8 ns conservatively for P codes. All the measurements related to the cable and reference delays were done with SR620 on the trigger level 1.0 V. And the uncertainties from position references and multipaths are just referenced to the description of the guideline. The u_a values are from TDEV of the corresponding CCD results shown in the figures in Annex 6. For NMC A*STAR calibration, the original antenna cables were not used. So the additional uncertainties for measurements of the original cable and the really used cable should be taken into account, which are both estimated as 0.5 ns (ub,43). So u_{CAL} of P1 and P2 calibration values for NMC A*STAR should be calculated as 1.9 ns and 2.0 ns.

Table 9. Uncertainty contributions

Unc.	P1 (ns)	P2 (ns)	P3 (ns)	Description
u_a (T-V)	0.2	0.2	0.3	RAWDIF (traveling-visited)
u_a (T-R)	0.2	0.2	0.3	RAWDIF (traveling-reference)
u_a	0.3	0.3	0.4	
Misclosure				
$u_{b,1}$	1.0	1.2	1.0	observed mis-closure
Systematic components related to RAWDIF				
$u_{b,11}$	0.05	0.05	0.05	Position error at reference
$u_{b,12}$	0.05	0.05	0.05	Position error at visited
$u_{b,13}$	0.3	0.3	0.3	Multipaths at reference
$u_{b,14}$	0.3	0.3	0.3	Multipaths at visited
Link of the Traveling system to the local UTC(k)				
$u_{b,21}$	0.5	0.5	0.5	$REFDLY_T$ (at ref lab)
$u_{b,22}$	0.5	0.5	0.5	$REFDLY_T$ (at visited lab)
$u_{b,TOT}$	1.4	1.5	1.4	
Link of the Reference system to its local UTC(k)				
$u_{b,31}$	0.5	0.5	0.5	$REFDLY_R$ (at ref lab)
Link of the Visited system to its local UTC(k)				
$u_{b,32}$	0.5	0.5	0.5	$REFDLY_V$ (at visited lab)
$u_{b,SYS}$	1.6	1.7	1.6	Components of equation (2)

u_{CAL}	1.7	1.8	1.7	Composed of u_a and $u_{b,SYS}$
Antenna cable delays				
$u_{b,41}$	0.5	0.5	0.5	$CABDLY_R$
$u_{b,42}$	0.5	0.5	0.5	$CABDLY_V$
Combined Uncertainty: 1.8 ns				

7. Climate parameters

7.1. Temperature and humidity

23.3°C~24.3°C ±0.5°C
32.1%~42.3% ±3%

7.2. 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 MASM

1. Start CCD before calibration

IM12-IM06

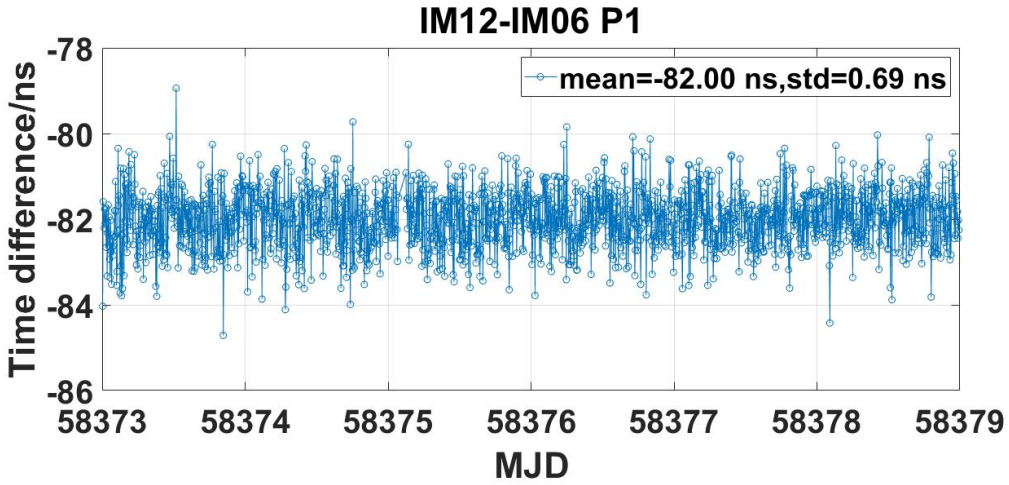


Figure 6. CCD between IM12 and IM06 at NIM(P1)

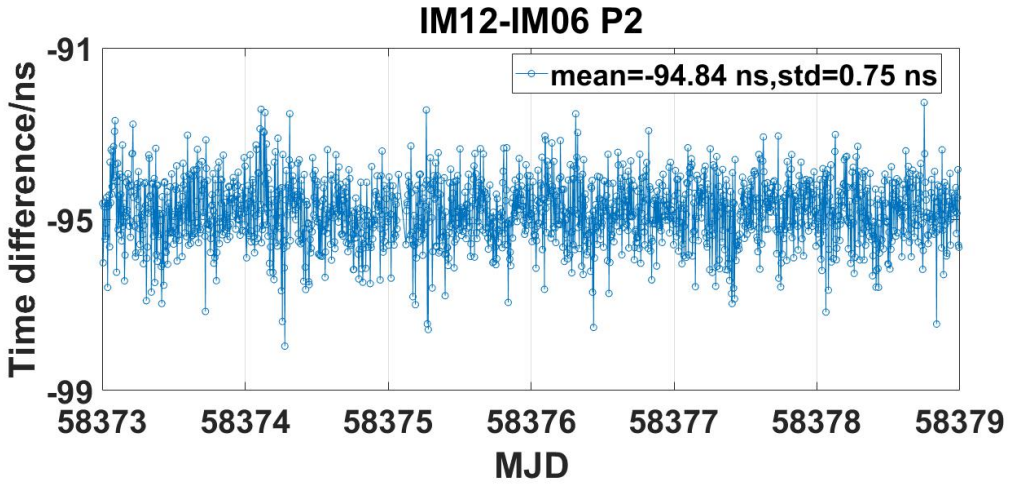


Figure 7. CCD between IM12 and IM06 at NIM(P2)

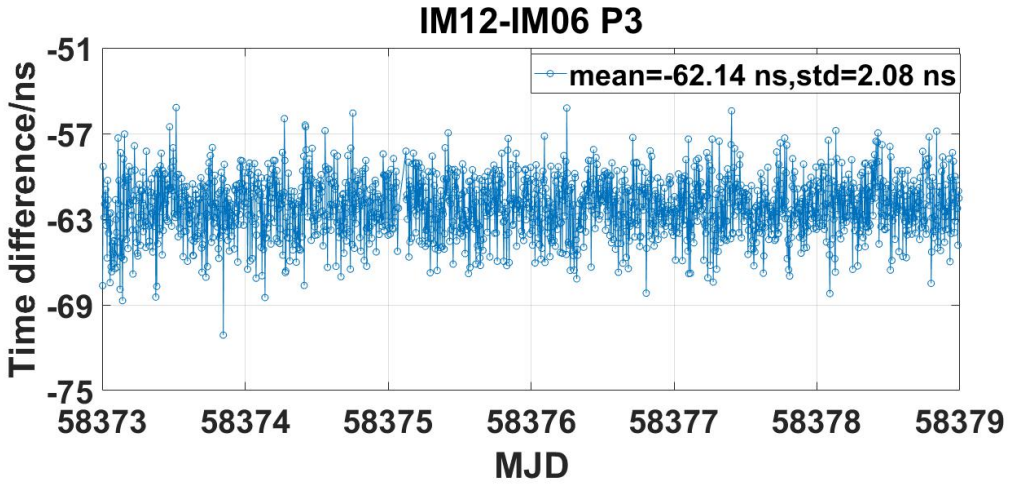


Figure 8. CCD between IM12 and IM06 at NIM(P3)

IM20-IM06

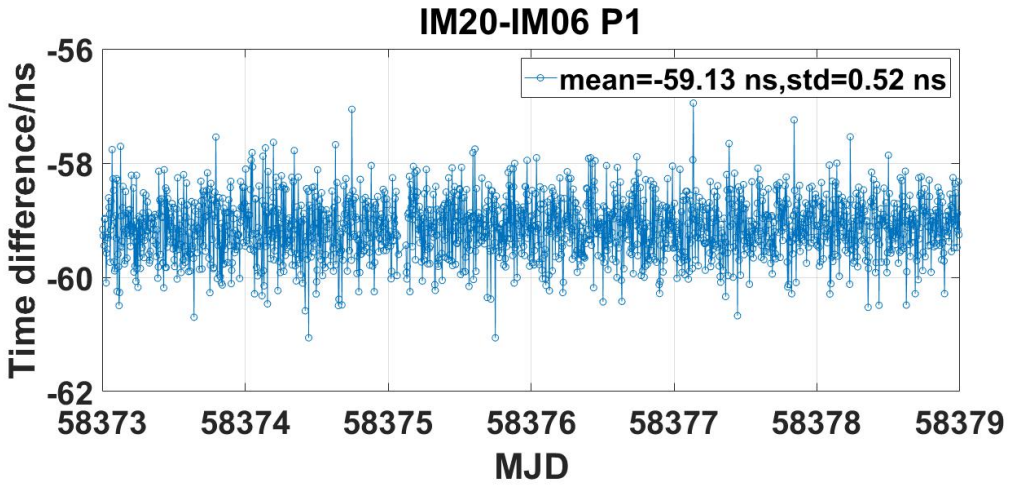


Figure 9. CCD between IM20 and IM06 at NIM(P1)

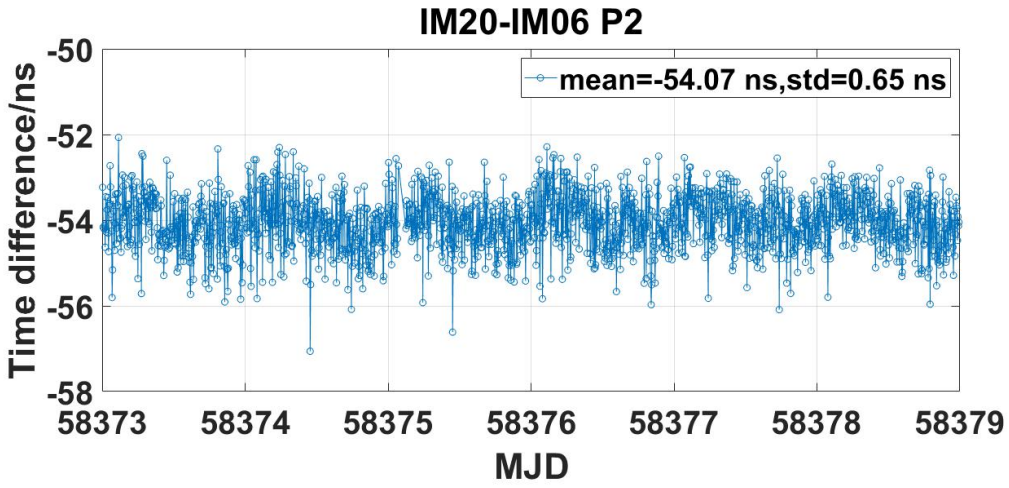


Figure 10. CCD between IM20 and IM06 at NIM(P2)

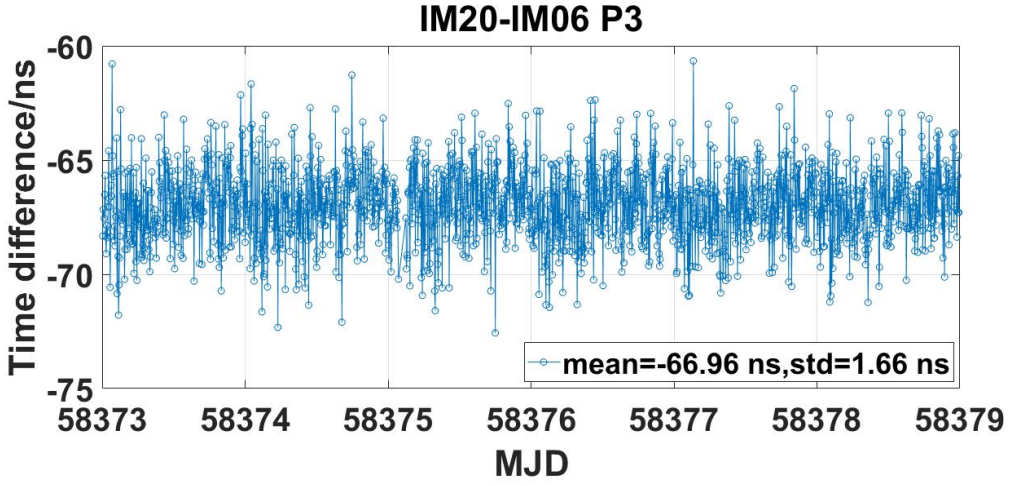


Figure 11. CCD between IM20 and IM06 at NIM(P3)

IM12-IM20

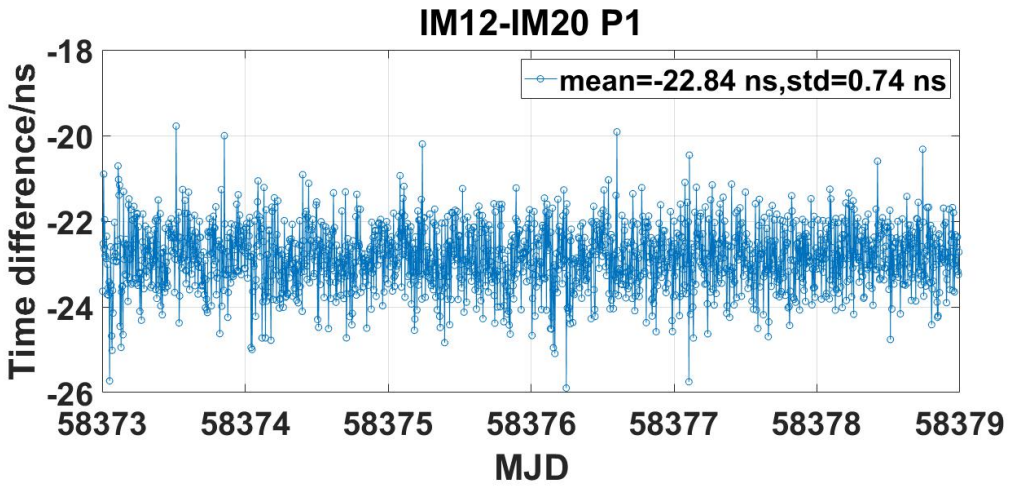


Figure 12. CCD between IM12 and IM20 at NIM(P1)

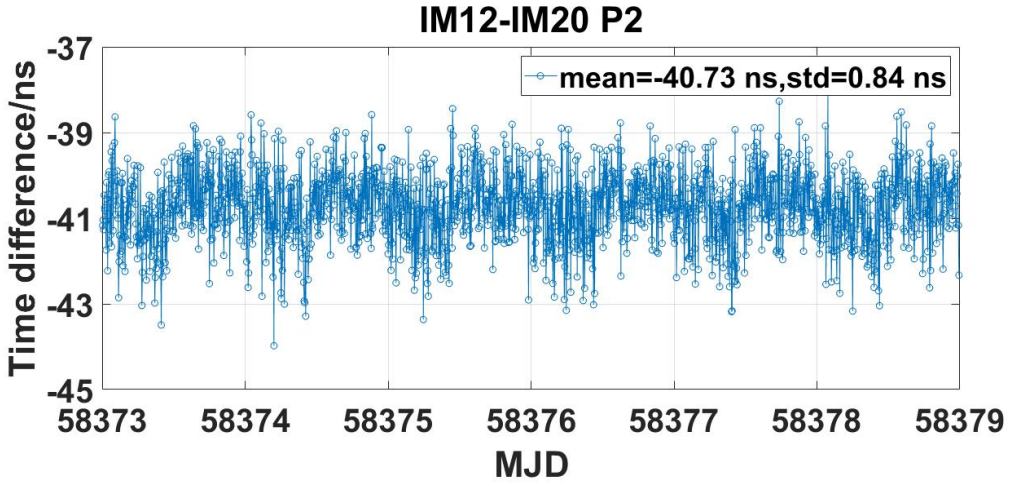


Figure 13. CCD between IM12 and IM20 at NIM(P2)

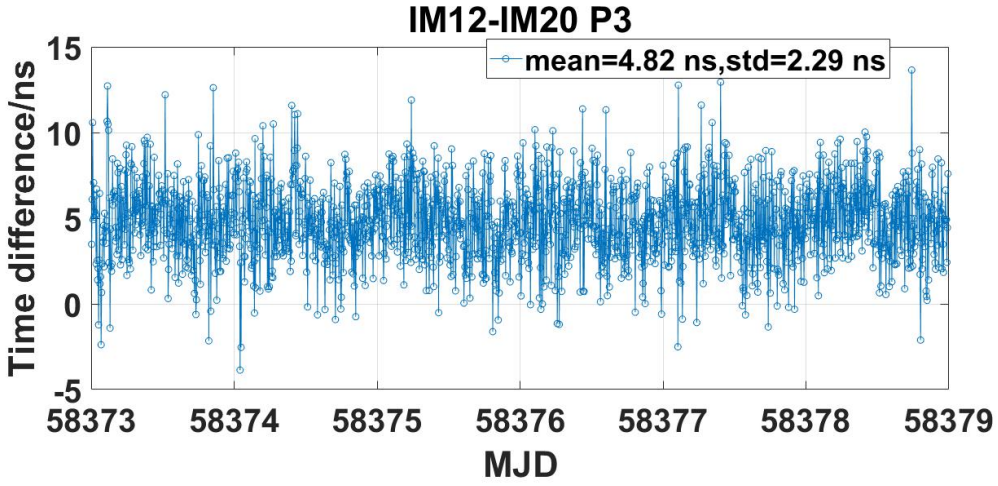


Figure 14. CCD between IM12 and IM20 at NIM(P3)

2. Calibration on site

IM12 – IM20

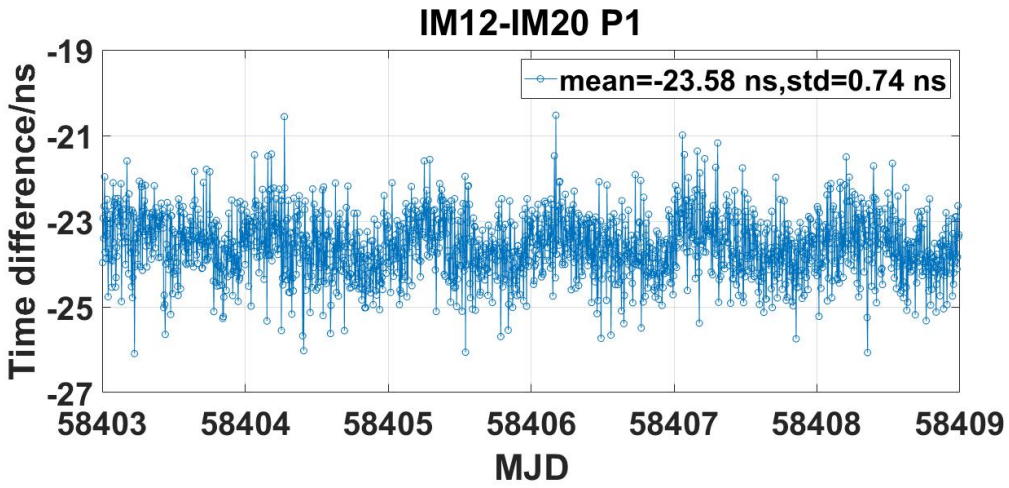


Figure 15. CCD between IM12 and IM20 at MASM (P1)

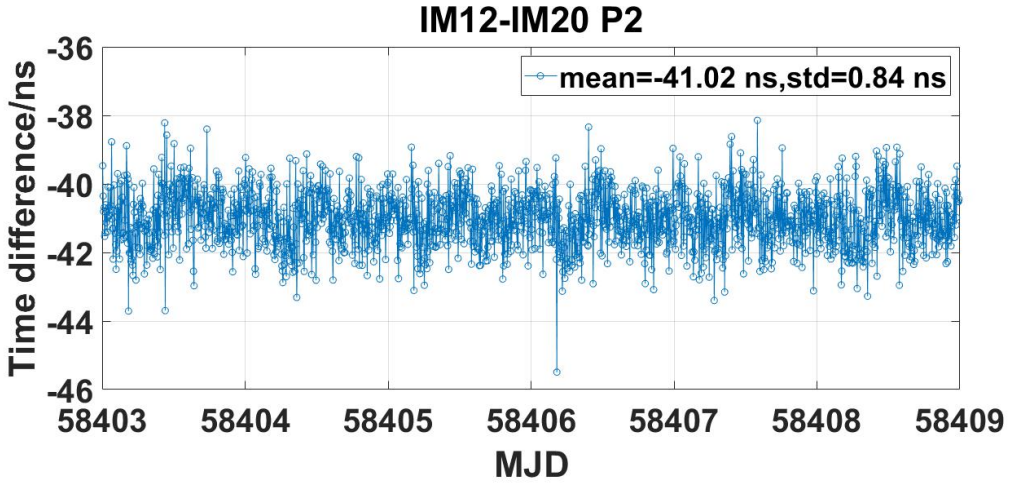


Figure 16. CCD between IM12 and IM20 at MASM(P2)

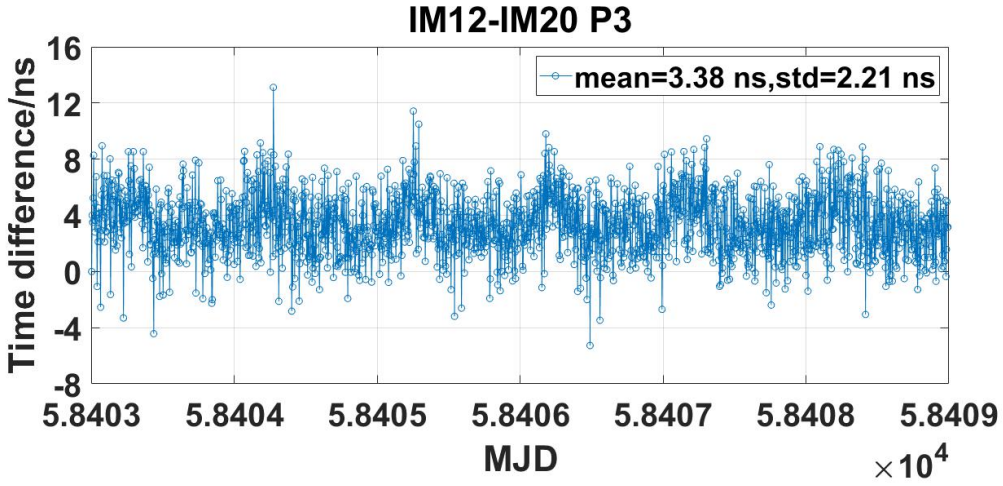


Figure 17. CCD between IM12 and IM20 at MASM(P3)

IM12 – MN__

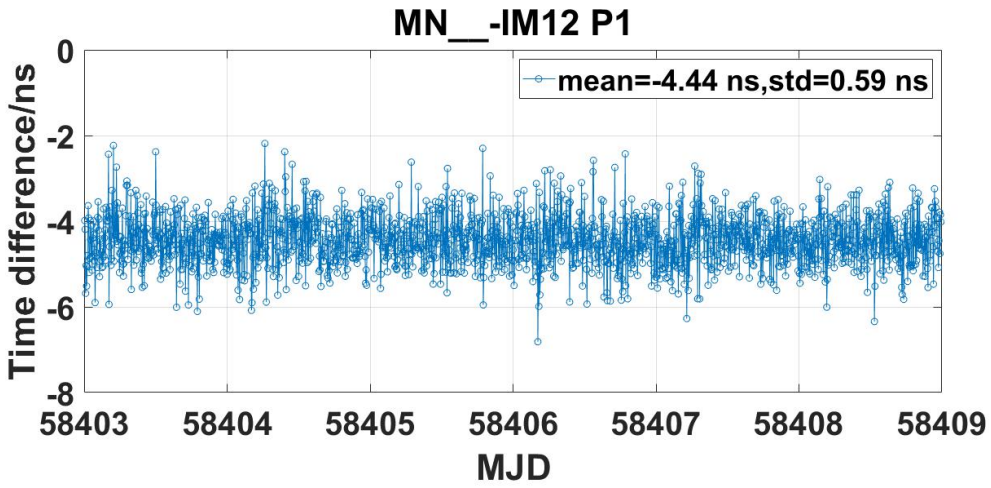


Figure 18. CCD between IM12 and MN__ at BIRM(P1)

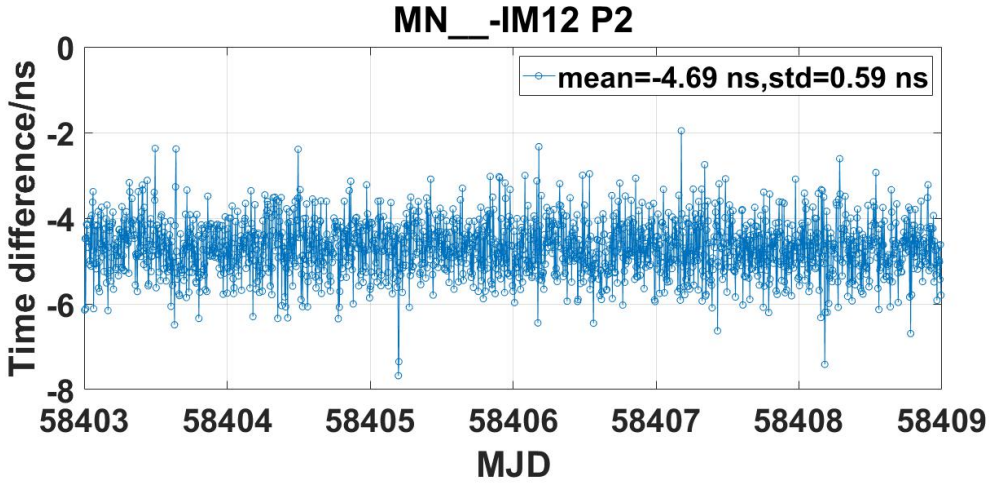


Figure 19. CCD between IM12 and MN__ at MASM(P2)

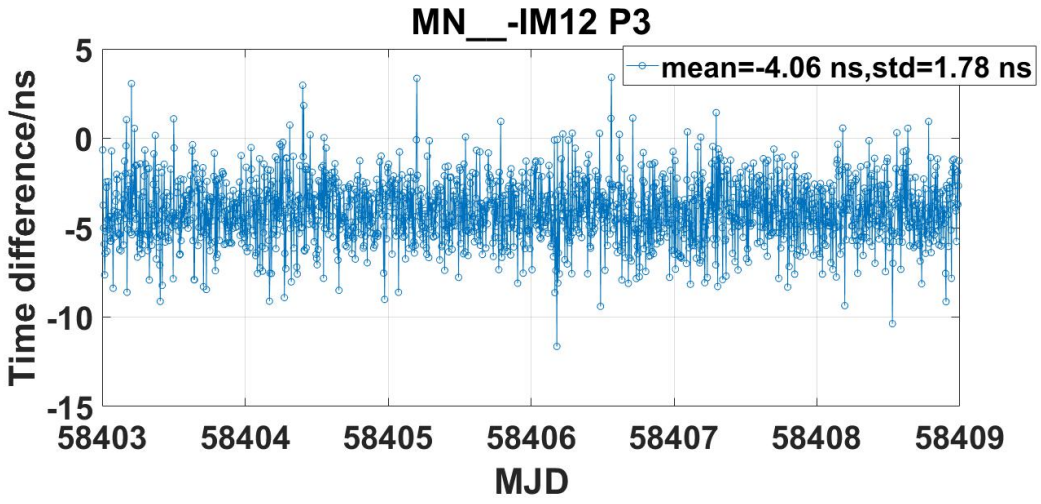


Figure 20. CCD between IM12 and MN__ at MASM(P3)

IM20 – MN__

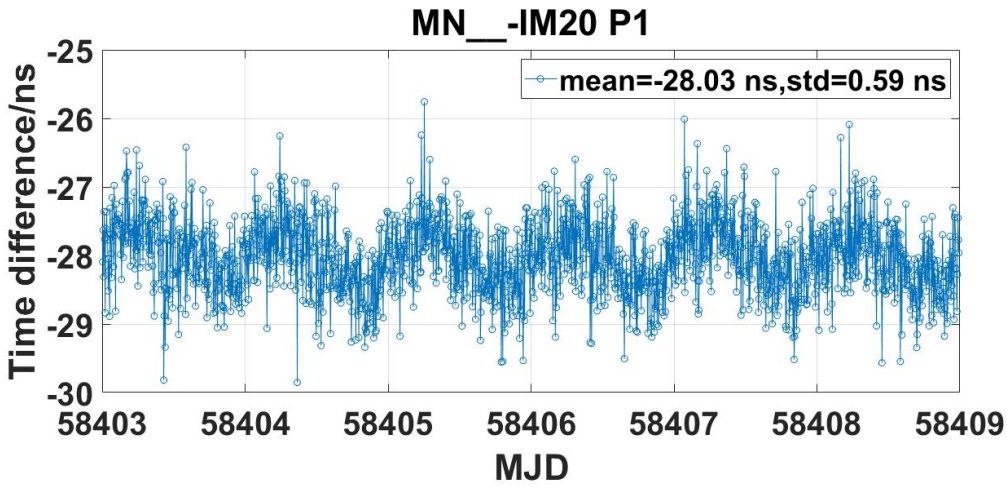


Figure 21. CCD between IM20 and MN__ at MASM(P1)

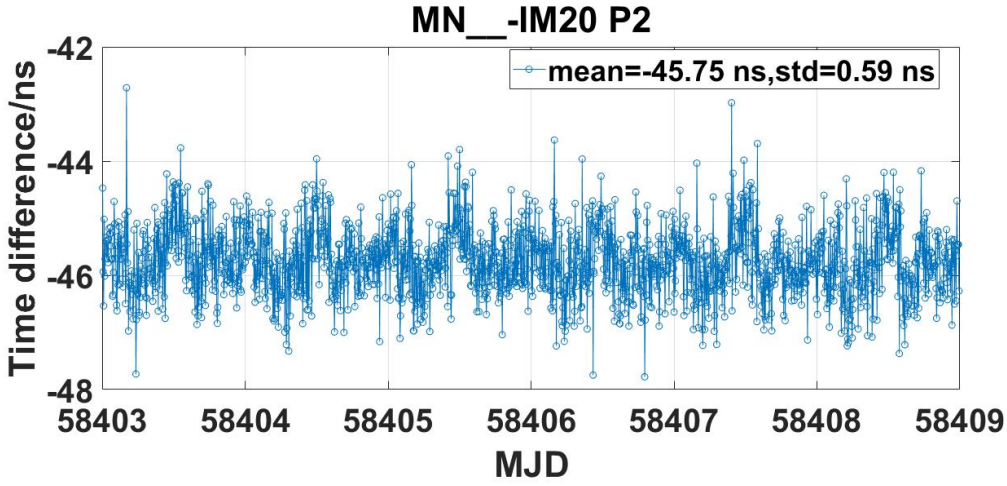


Figure 22. CCD between IM20 and MN__ at MASM(P2)

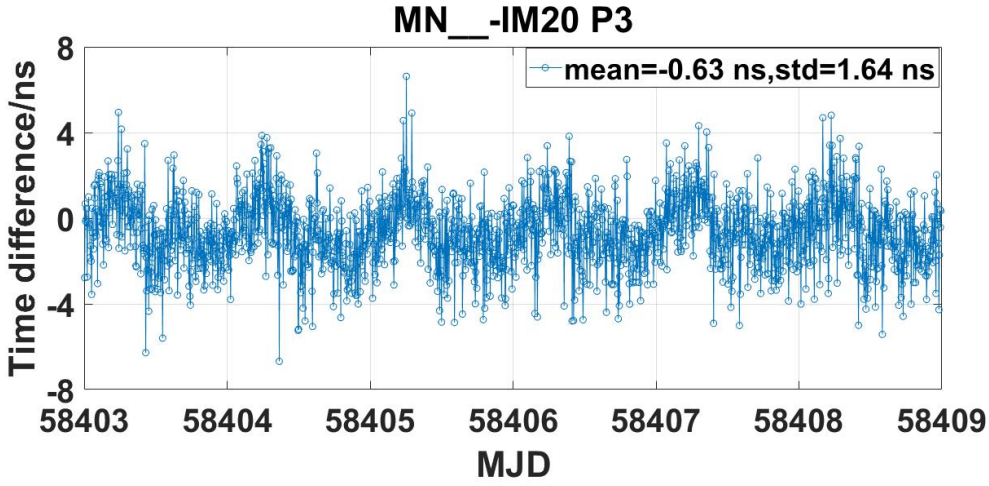


Figure 23. CCD between IM20 and MN__ at MASM(P3)

3. Closure CCD after calibration

IM06-IM12

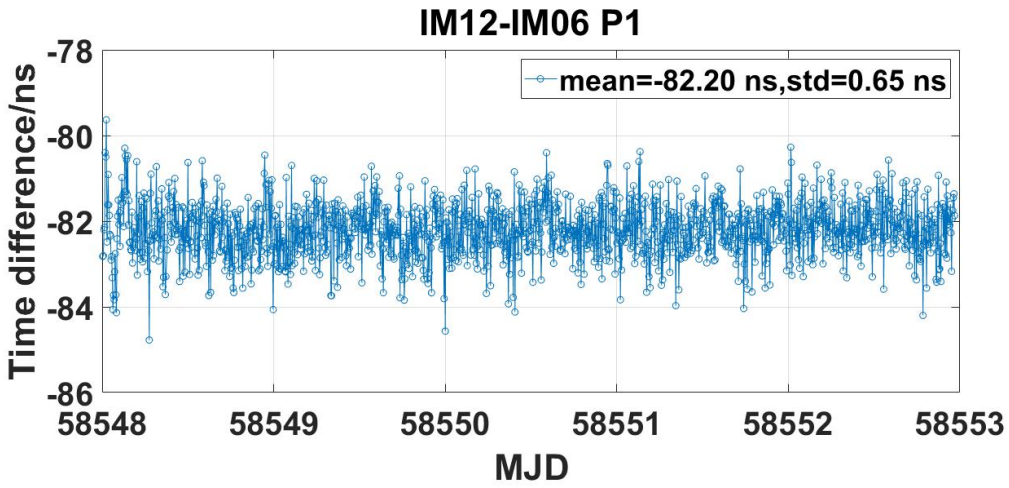


Figure 24. CCD between IM06 and IM12 at NIM(P1)

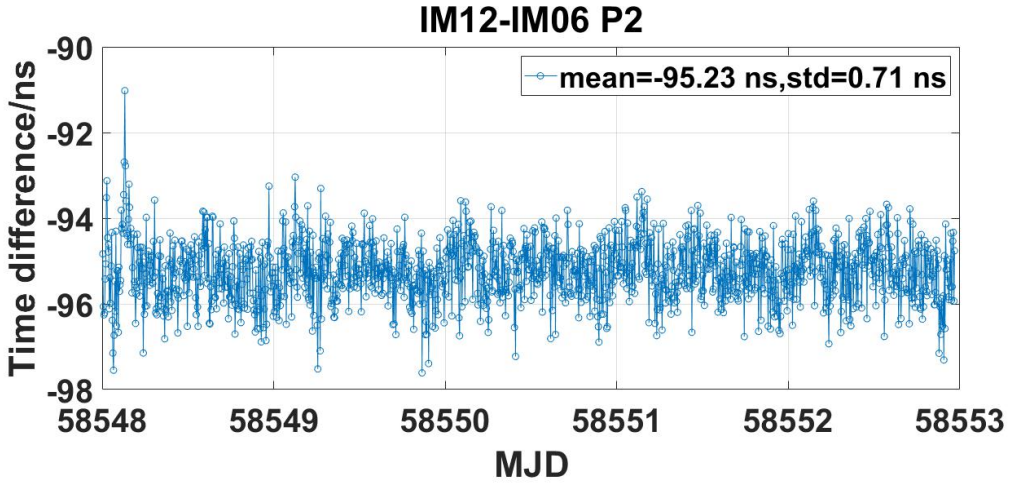


Figure 25. CCD between IM06 and IM12 at NIM(P2)

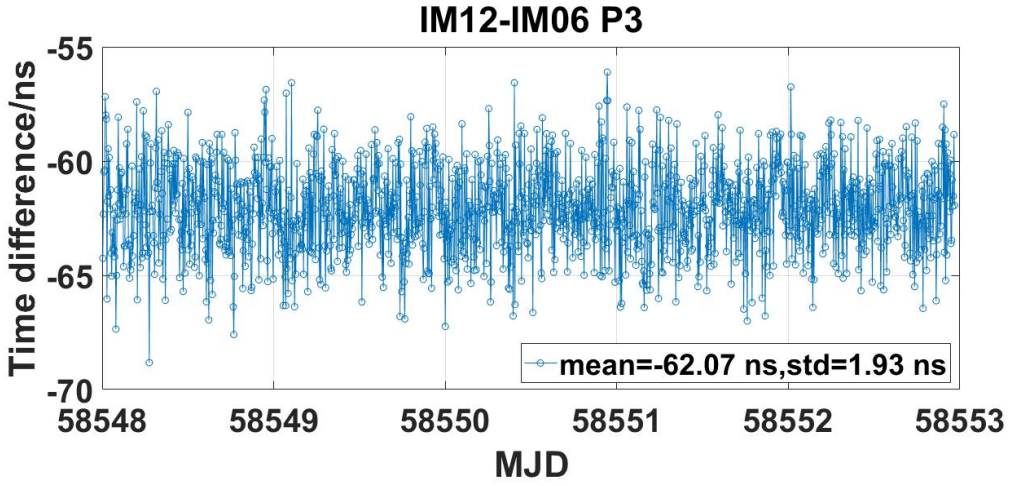


Figure 26. CCD between IM06 and IM12 at NIM(P3)

IM20-IM06

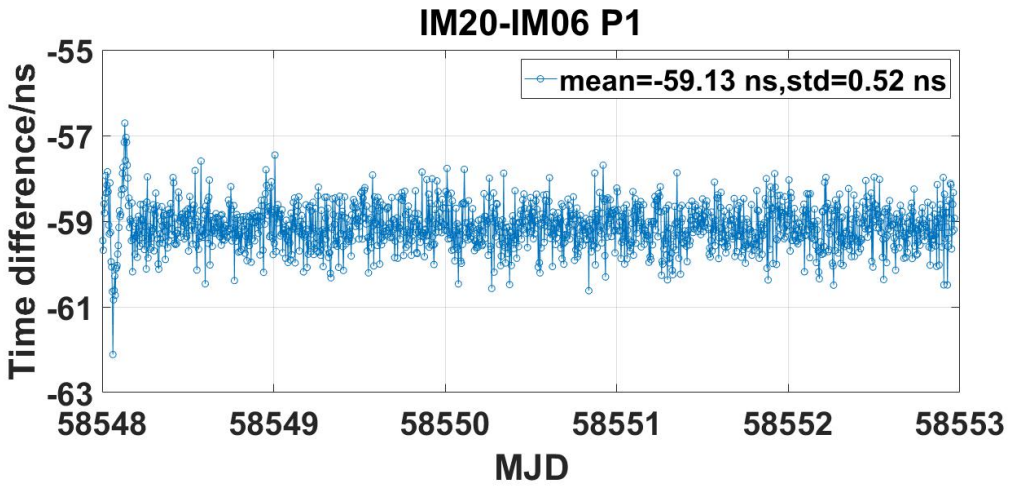


Figure 27. CCD between IM20 and IM06 at NIM(P1)

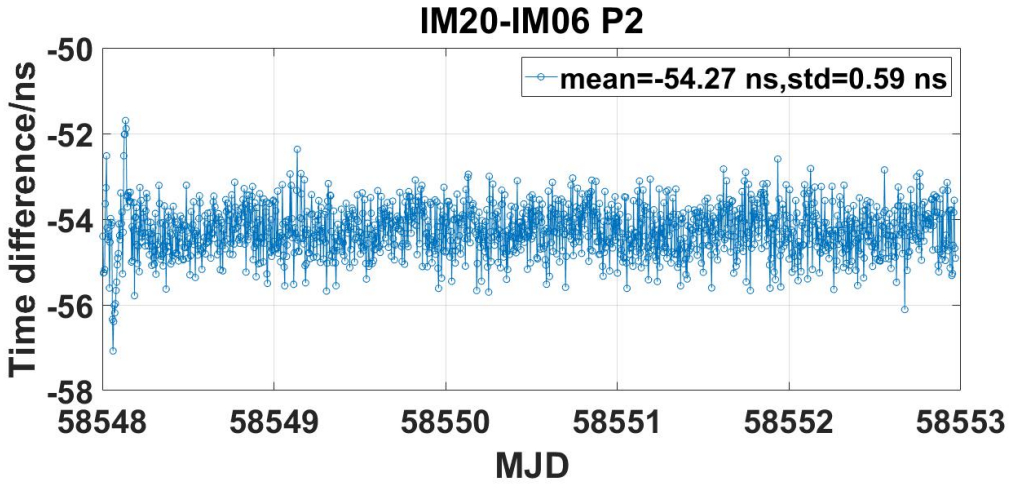


Figure 28. CCD between IM20 and IM06 at NIM(P2)

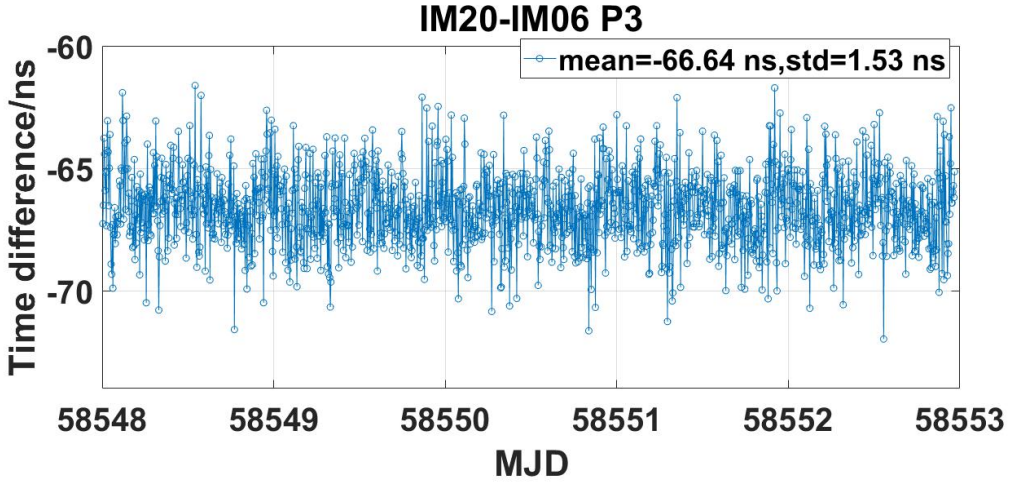


Figure 29. CCD between IM20 and IM06 at NIM(P3)

IM20-IM12

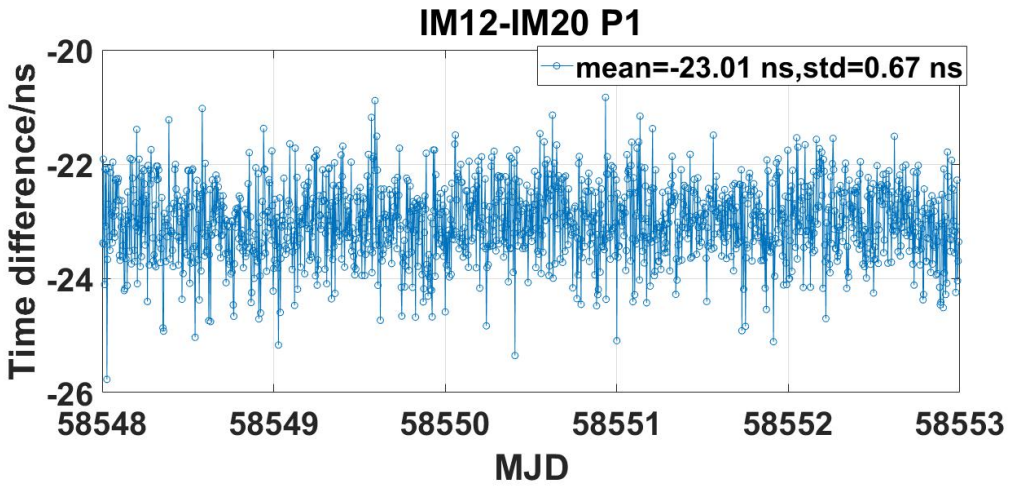


Figure 30. CCD between IM20 and IM12 at NIM(P1)

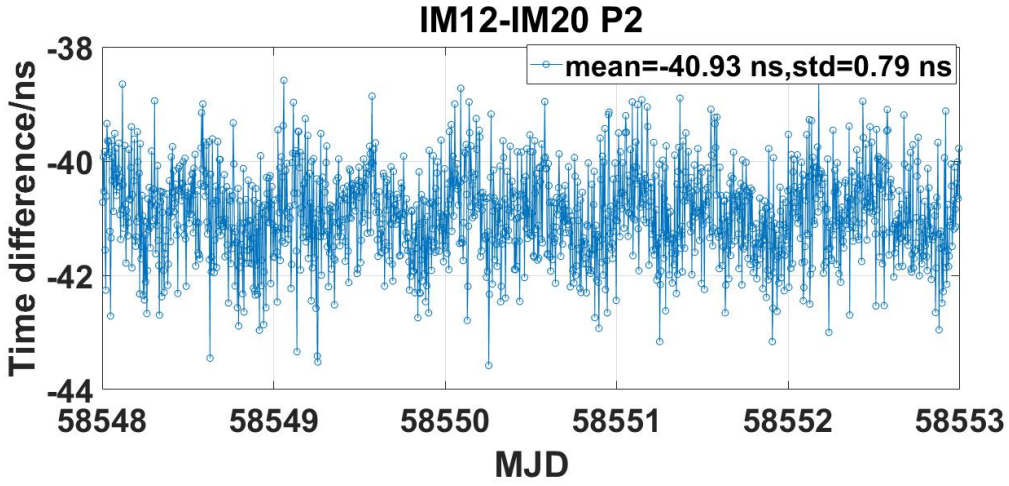


Figure 31. CCD between IM20 and IM12 at NIM(P2)

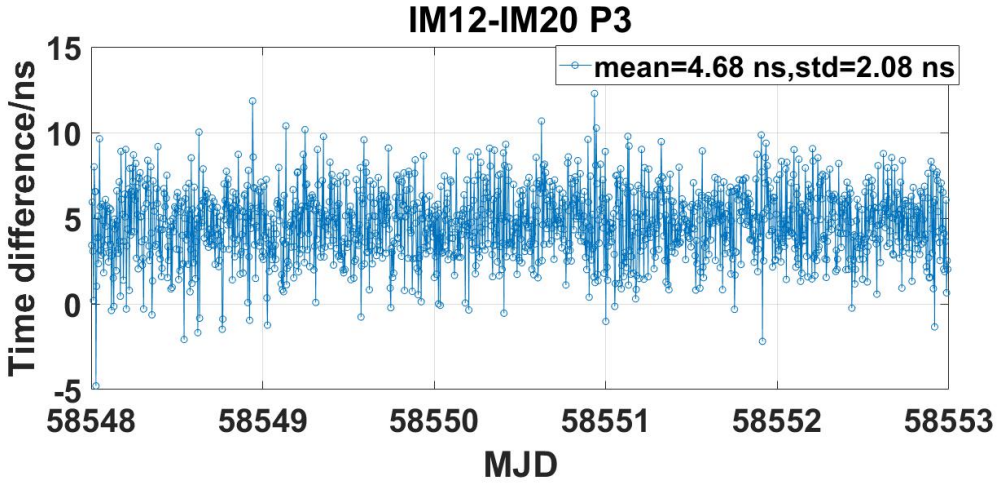


Figure 32. CCD between IM20 and IM12 at NIM(P3)

Annex 2. CCD results for NMC

1. Start CCD before calibration

IM12-IM06

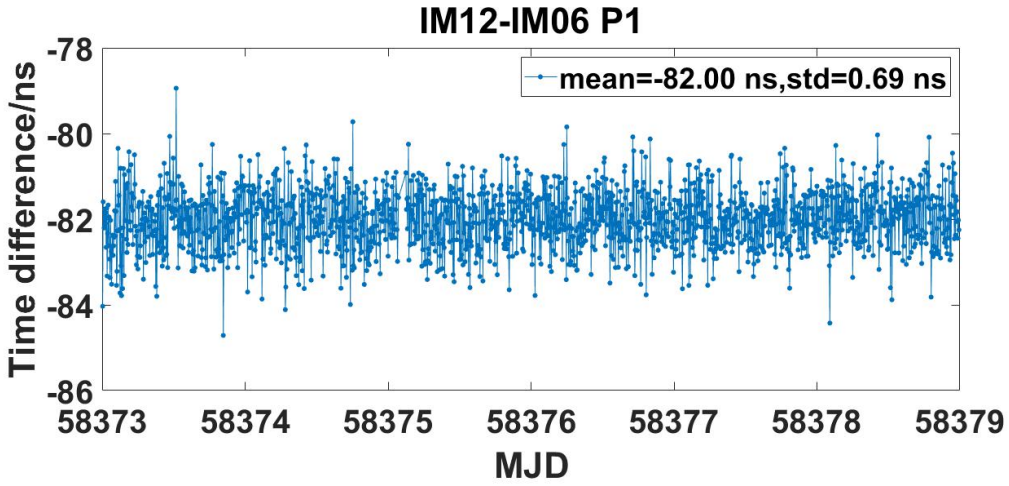


Figure 33. CCD between IM12 and IM06 at NIM(P1)

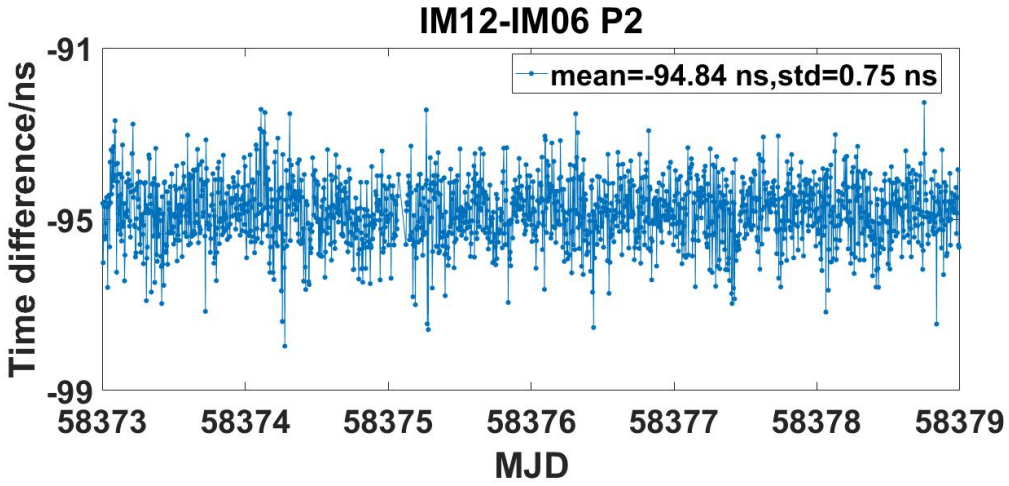


Figure 34. CCD between IM12 and IM06 at NIM(P2)

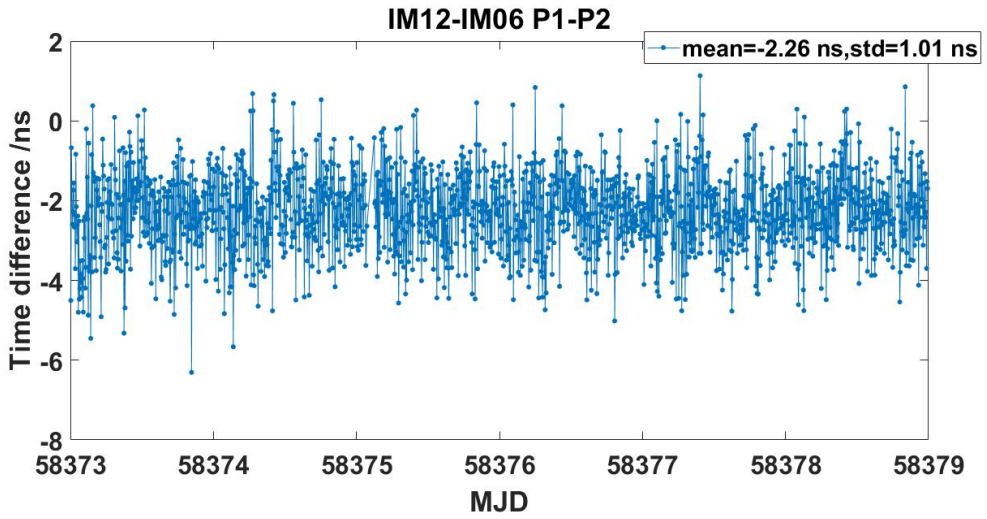


Figure 35. CCD between IM12 and IM06 at NIM(P1-P2)

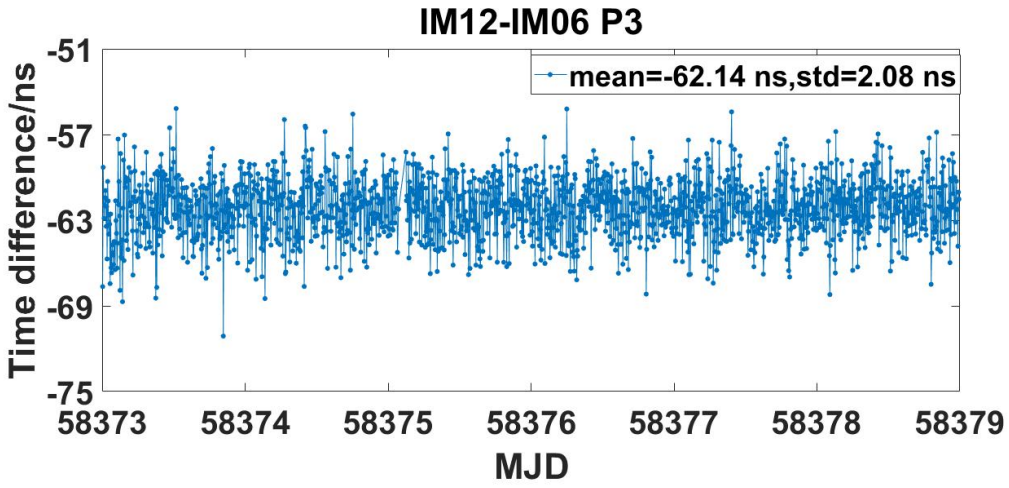


Figure 36. CCD between IM012 and IM06 at NIM(P3)

IM20-IM06

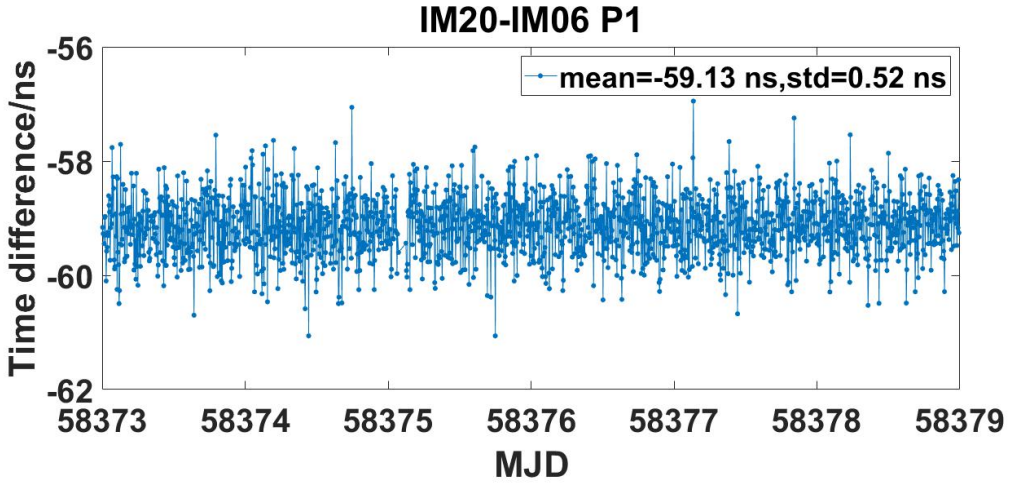


Figure 37. CCD between IM20 and IM06 at NIM(P1)

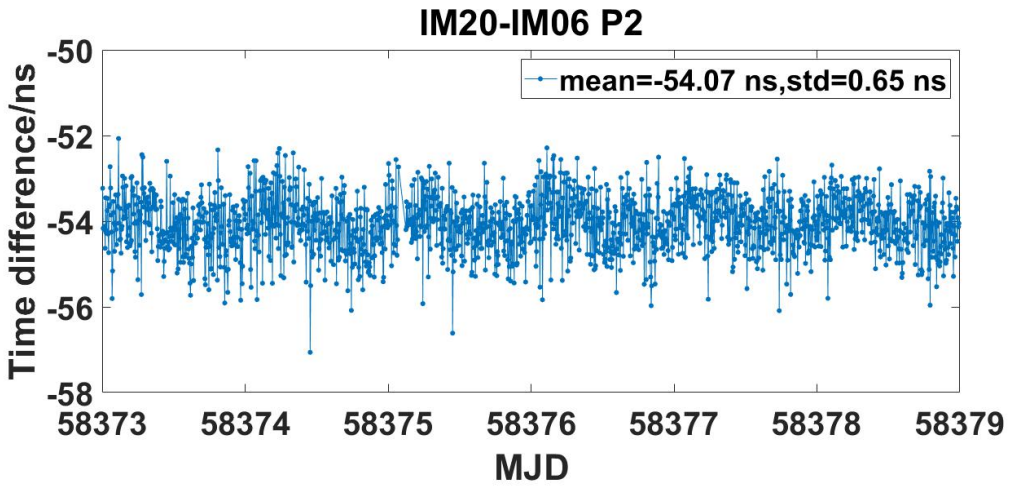


Figure 38. CCD between IM20 and IM06 at NIM(P2)

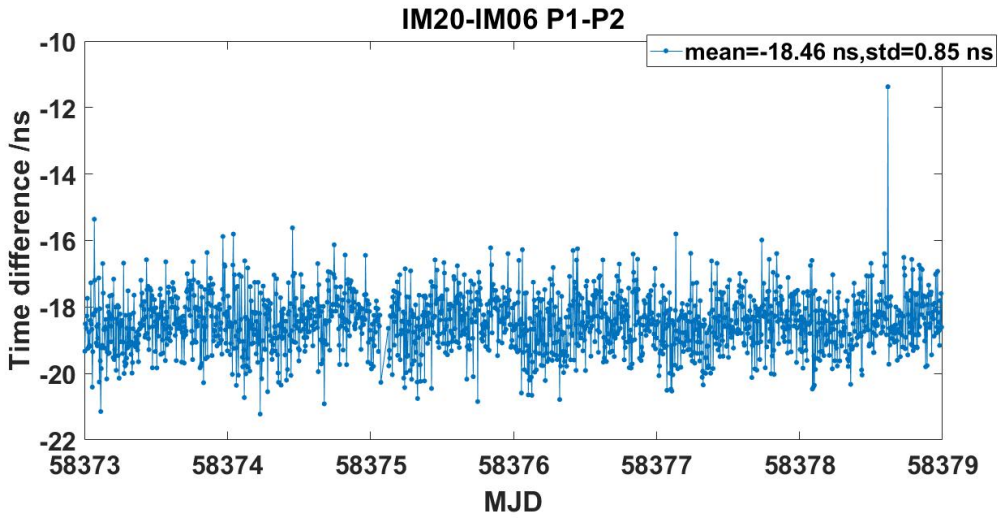


Figure 39. CCD between IM20 and IM06 at NIM(P1-P2)

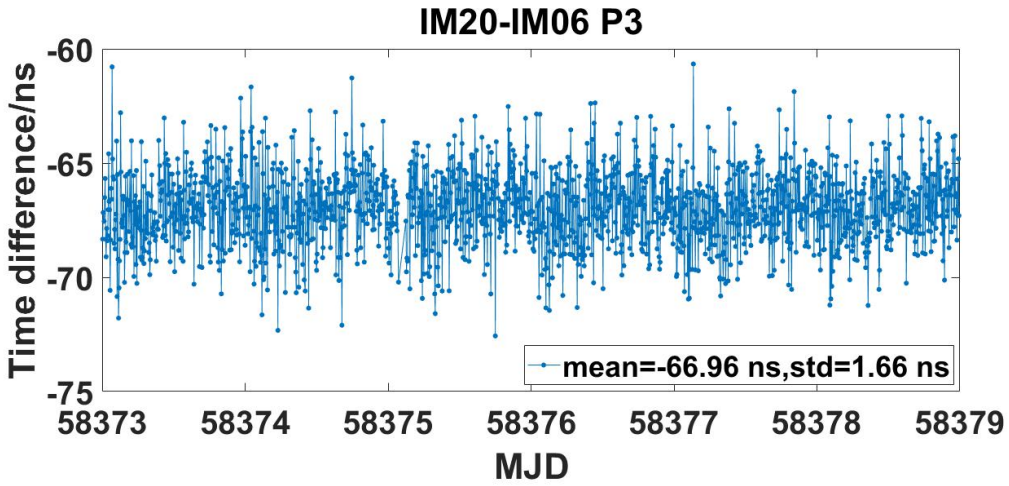


Figure 40. CCD between IM20 and IM06 at NIM(P3)

IM12-IM20

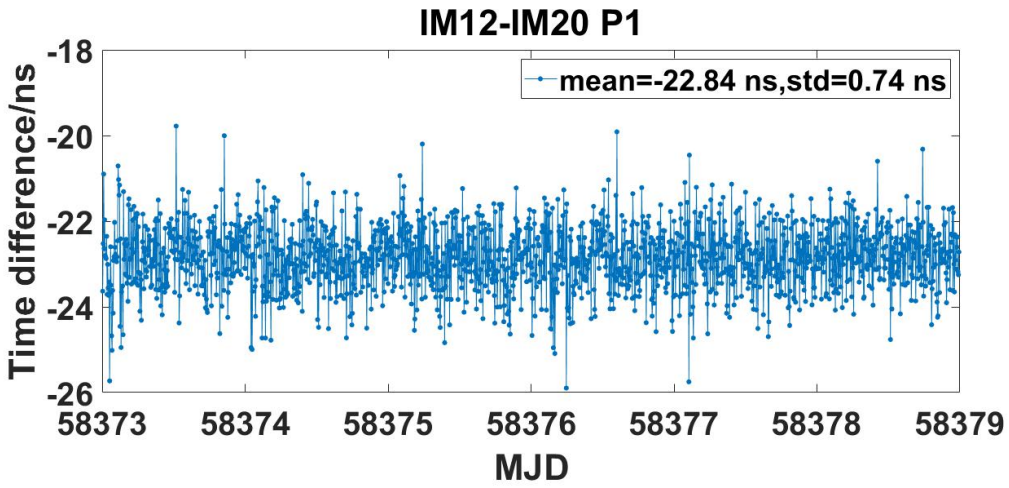


Figure 41. CCD between IM12 and IM20 at NIM(P1)

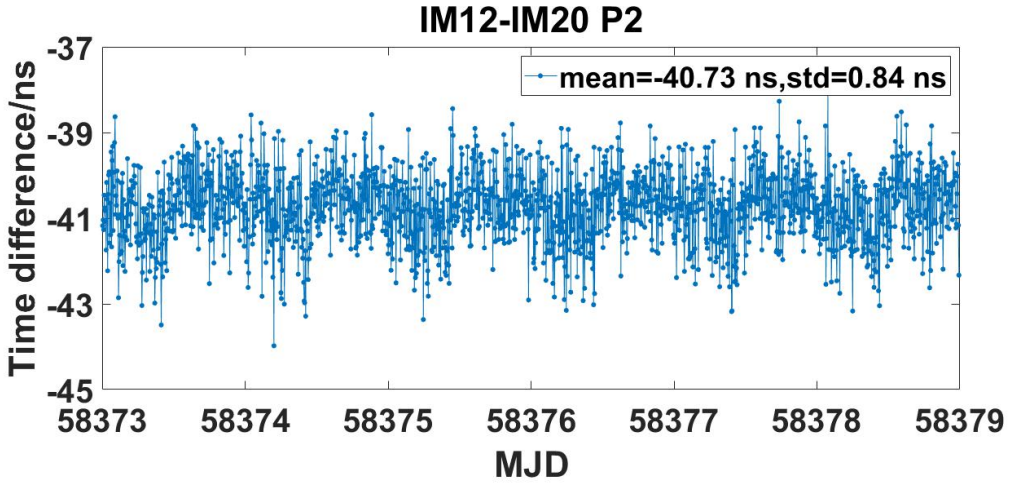


Figure 42. CCD between IM12 and IM20 at NIM(P2)

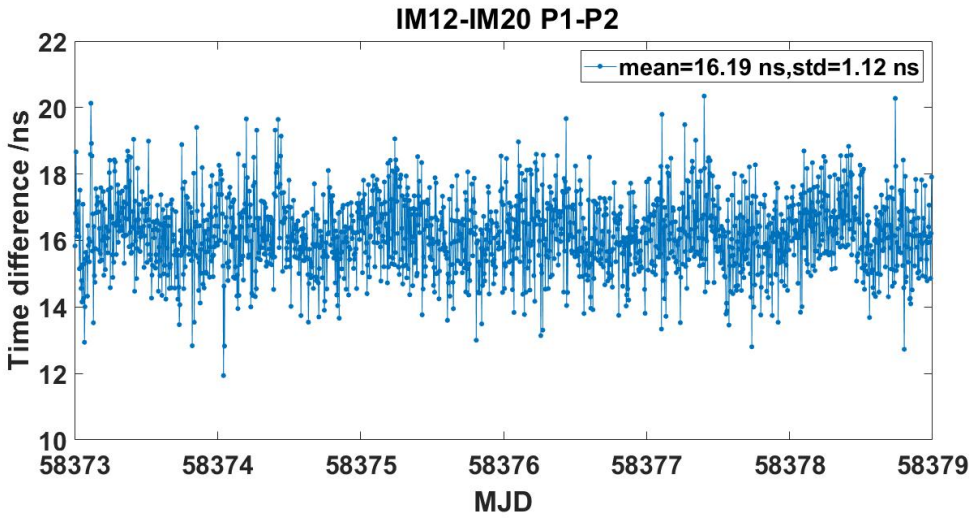


Figure 43. CCD between IM12 and IM20 at NIM(P1-P2)

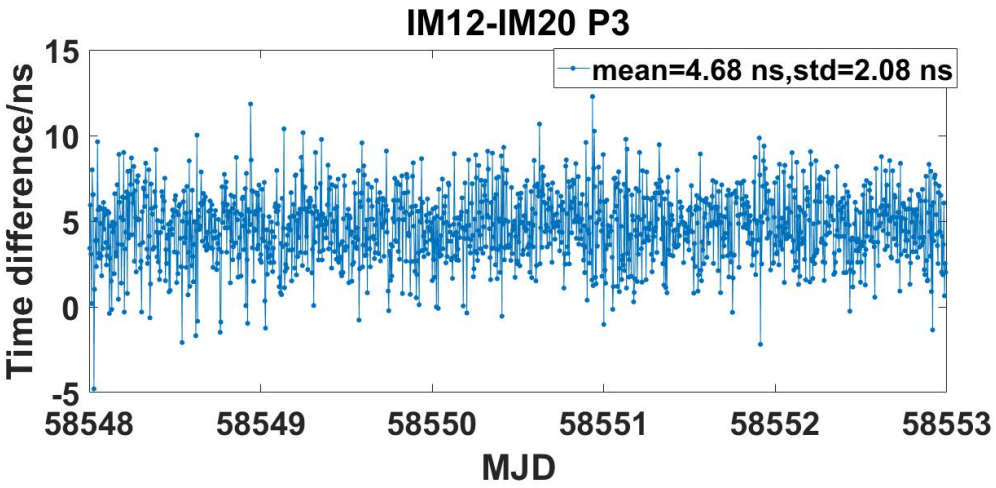


Figure 44. CCD between IM12 and IM20 at NIM(P3)

2. Calibration on site

SG01-IM12

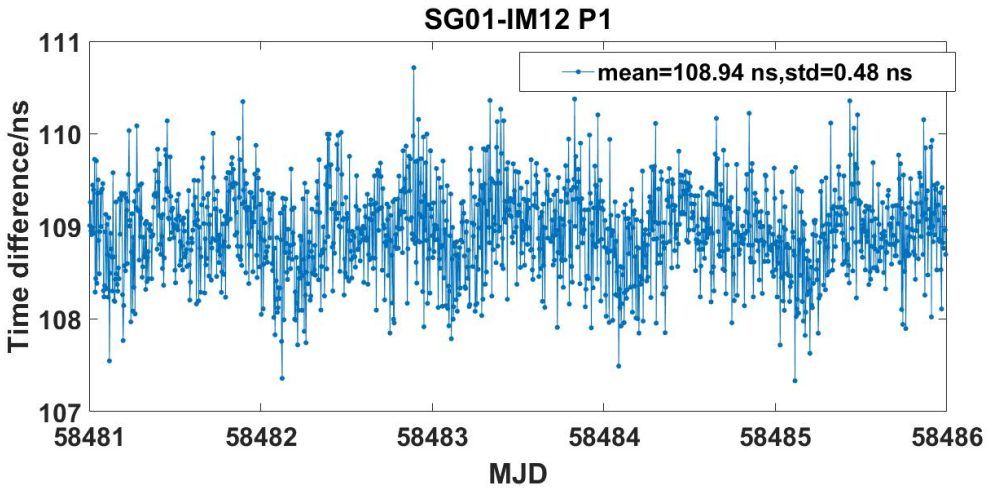


Figure 45. CCD between IM12 and SG01 at NMC(P1)

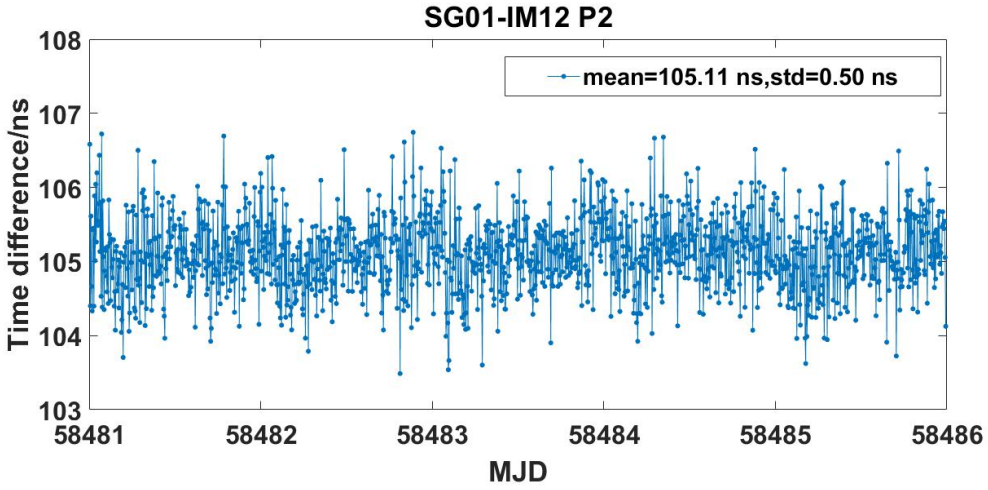


Figure 46. CCD between IM12 and SG01 at NMC(P2)

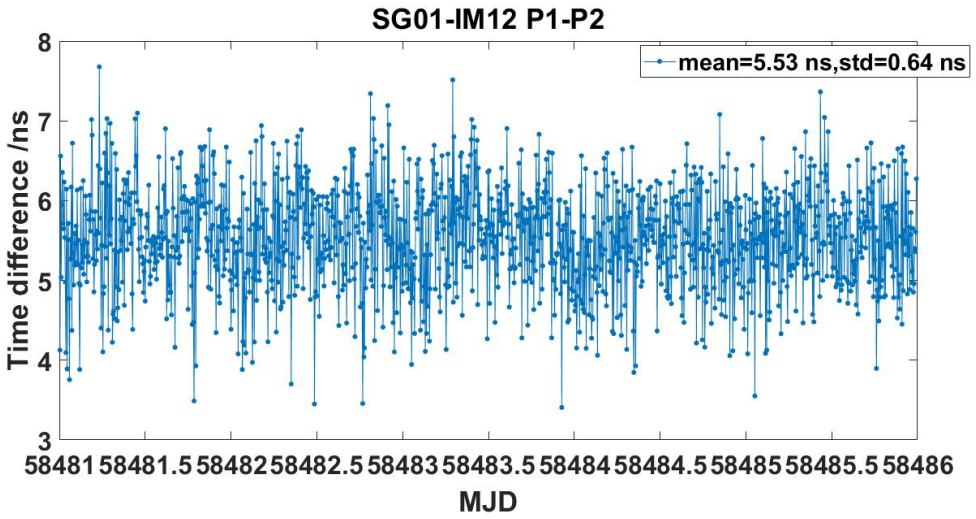


Figure 47. CCD between IM12 and SG01 at NMC(P1-P2)

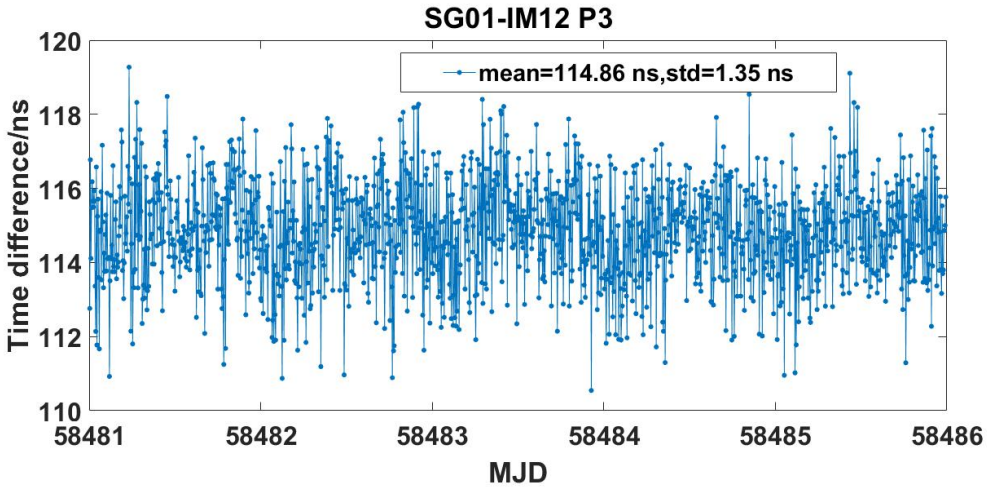


Figure 48. CCD between IM12 and SG01 at NMC(P3)

SG01-IM20

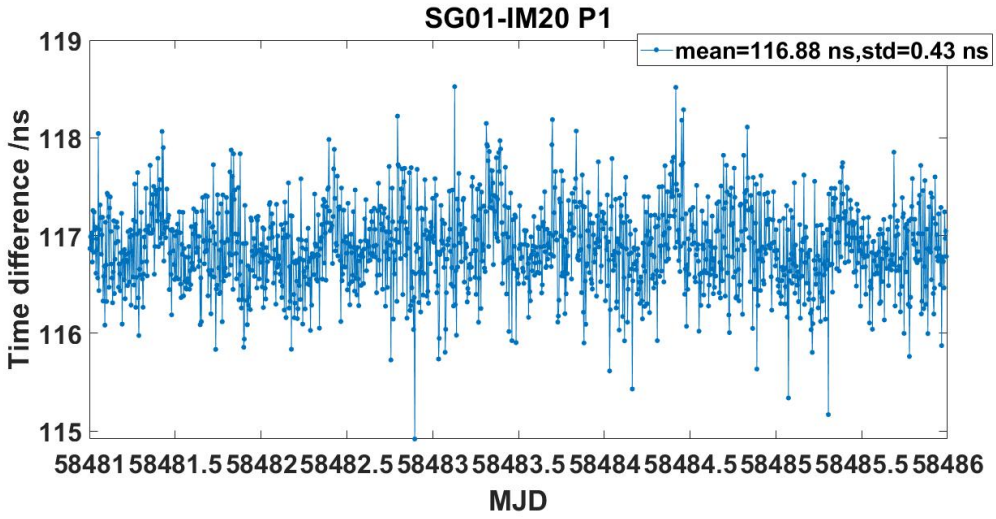


Figure 49. CCD between IM20 and SG01 at NMC(P1)

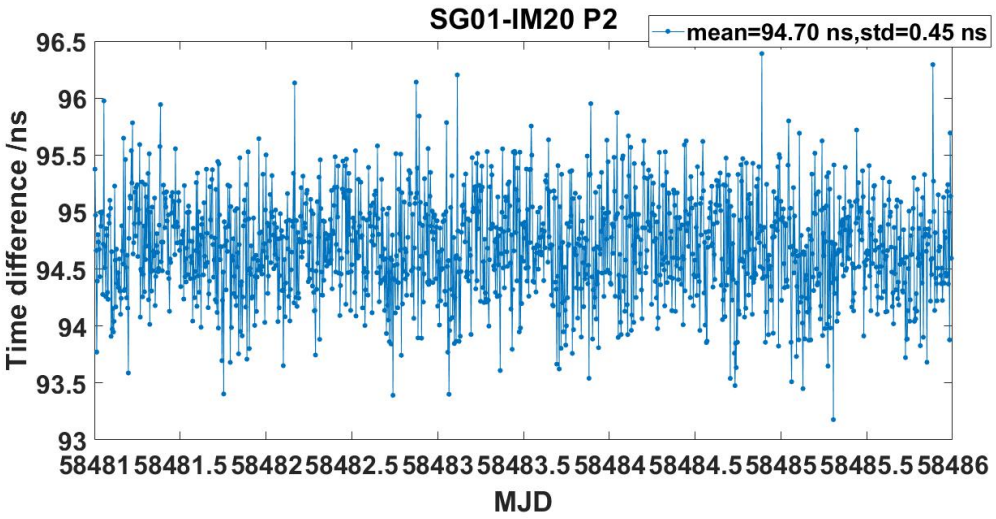


Figure 50. CCD between IM20 and SG01 at NMC(P2)

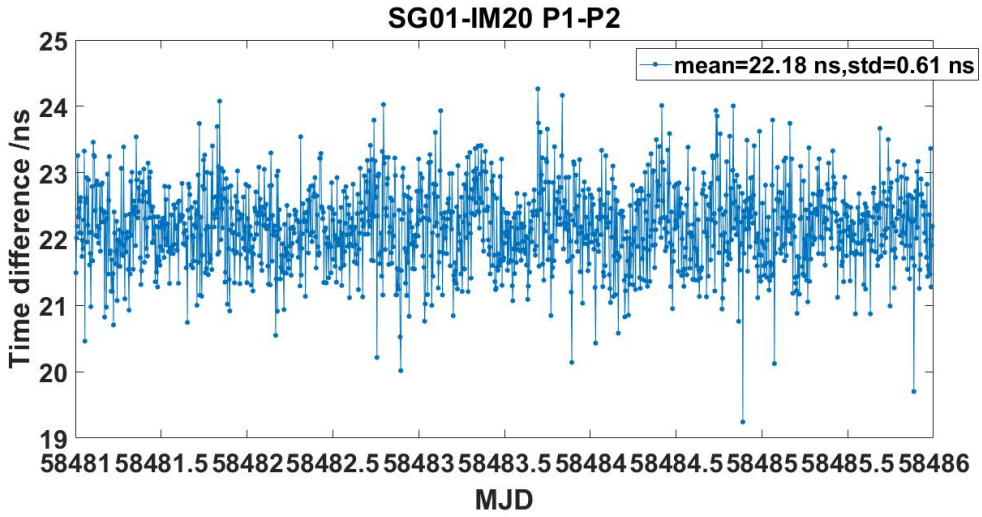


Figure 51. CCD between IM20 and SG01 at NMC(P1-P2)

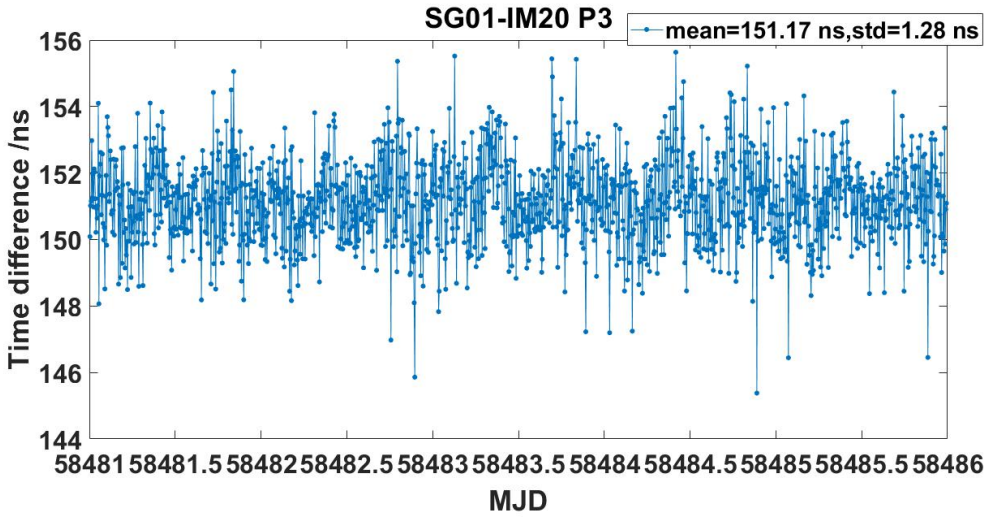


Figure 52. CCD between IM20 and SG01 at NMC(P3)

SG02-IM12

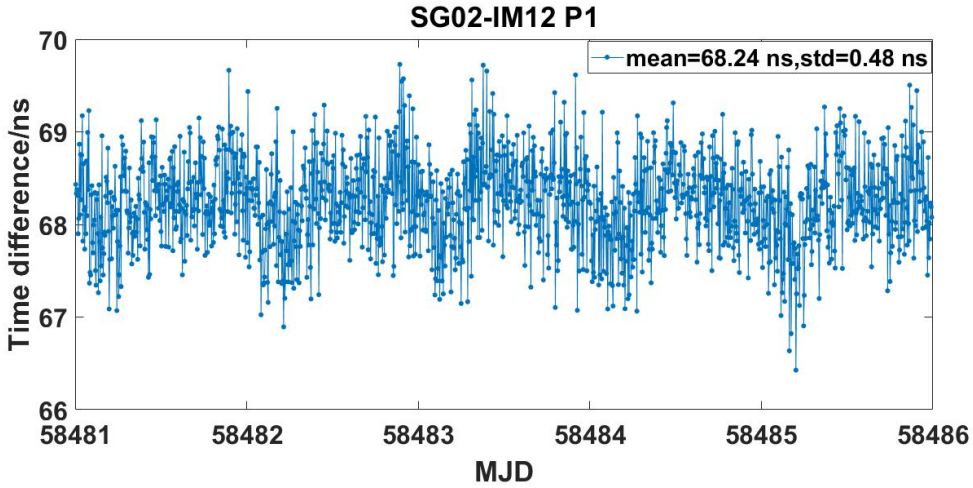


Figure 53. CCD between IM12 and SG02 at NMC(P1)

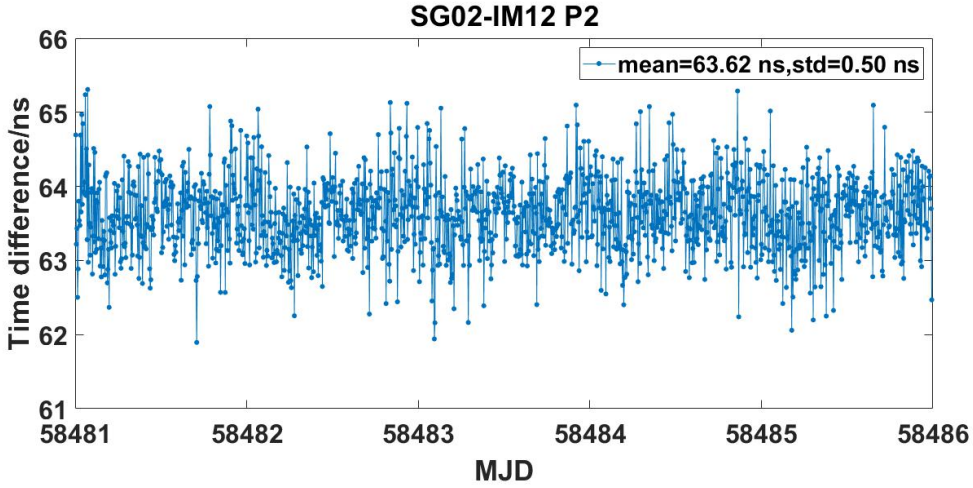


Figure 54. CCD between IM12 and SG02 at NMC(P2)

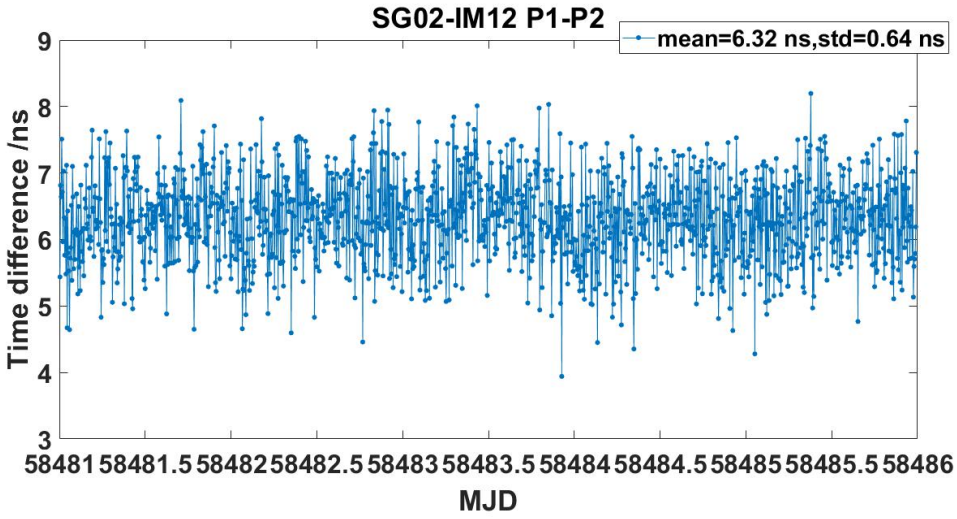


Figure 55. CCD between IM12 and SG02 at NMC(P1-P2)

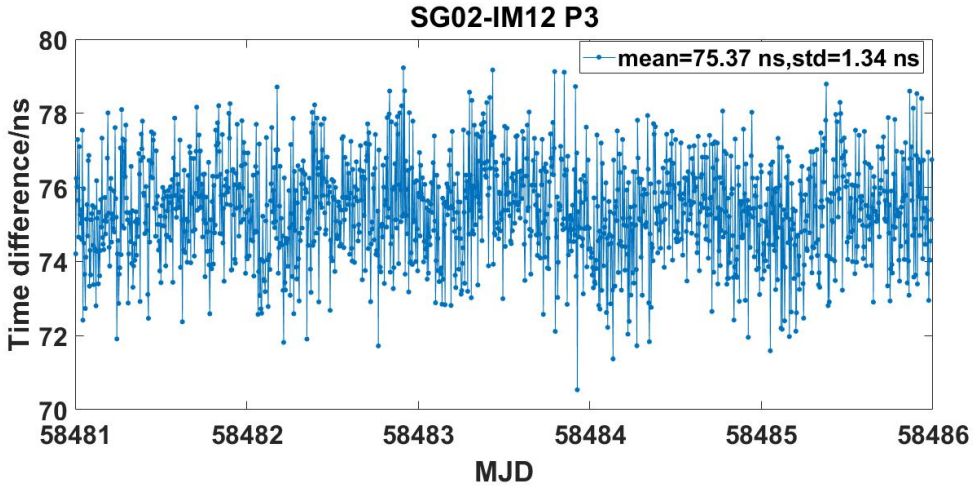


Figure 56. CCD between IM12 and SG02 at NMC(P3)

SG02-IM20

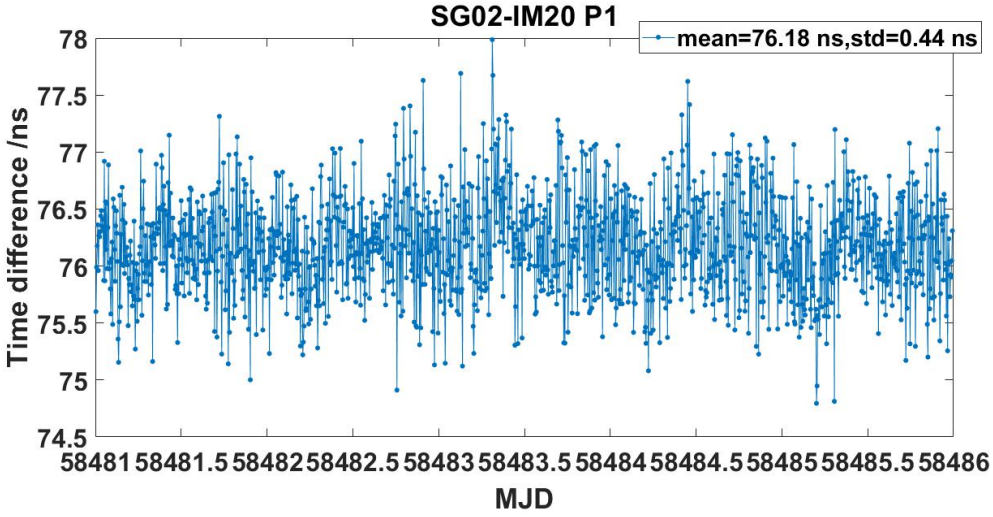


Figure 57. CCD between IM20 and SG02 at NMC(P1)

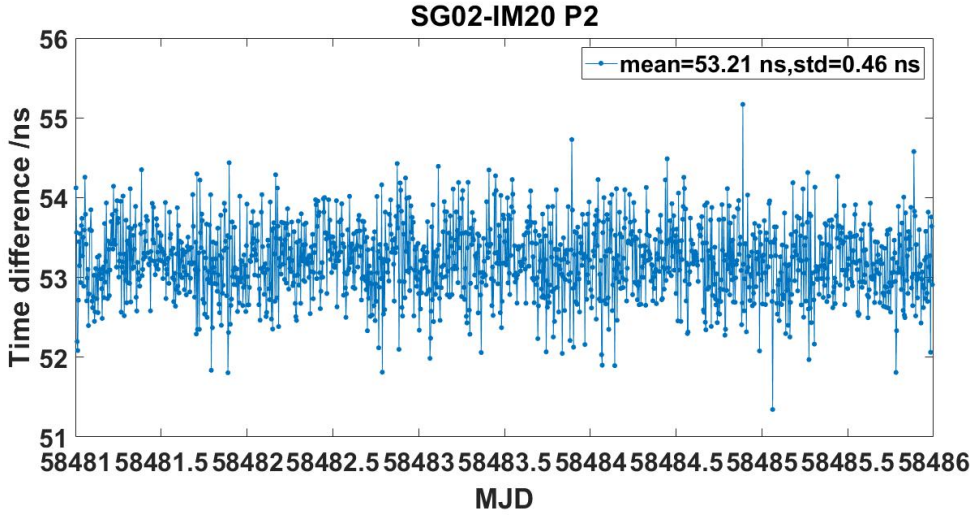


Figure 58. CCD between IM20 and SG02 at NMC(P2)

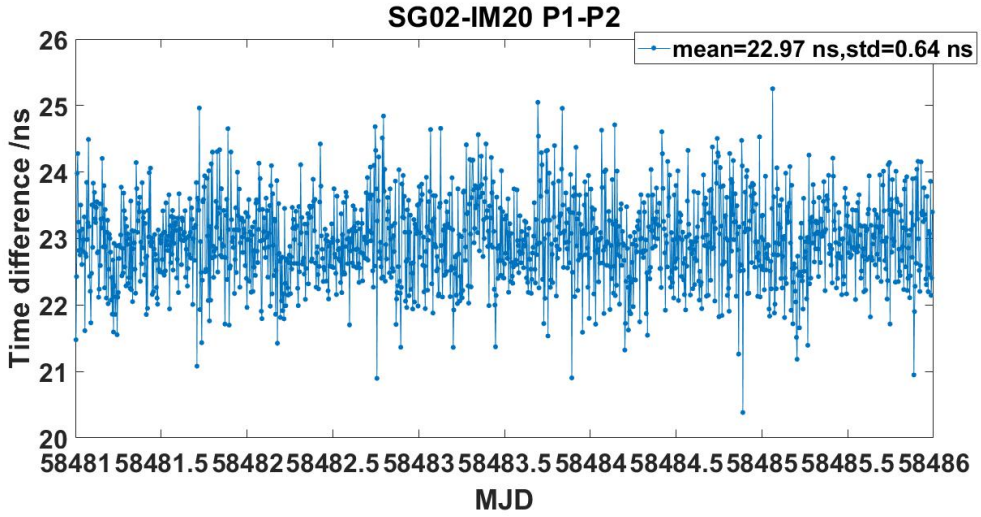


Figure 59. CCD between IM20 and SG02 at NMC(P1-P2)

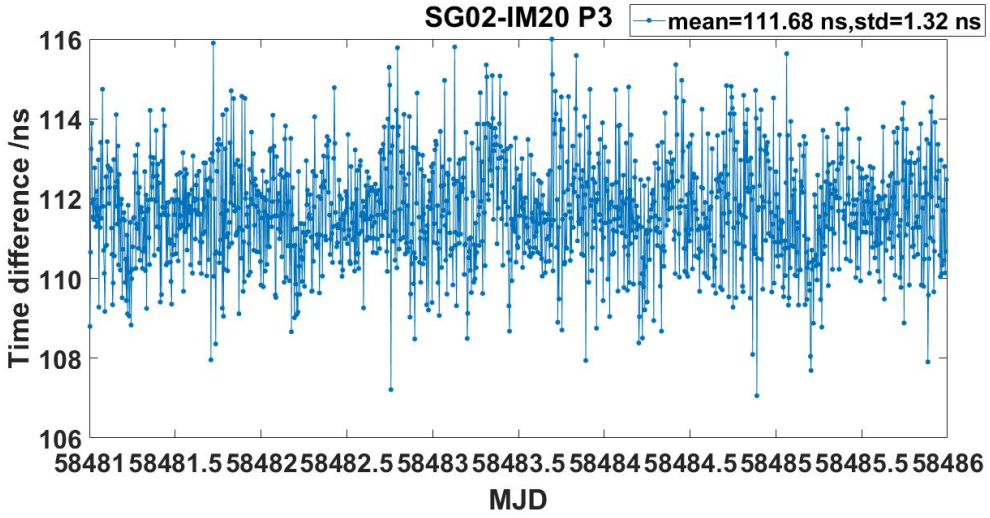


Figure 60. CCD between IM20 and SG02 at NMC(P3)

SG2P-IM12

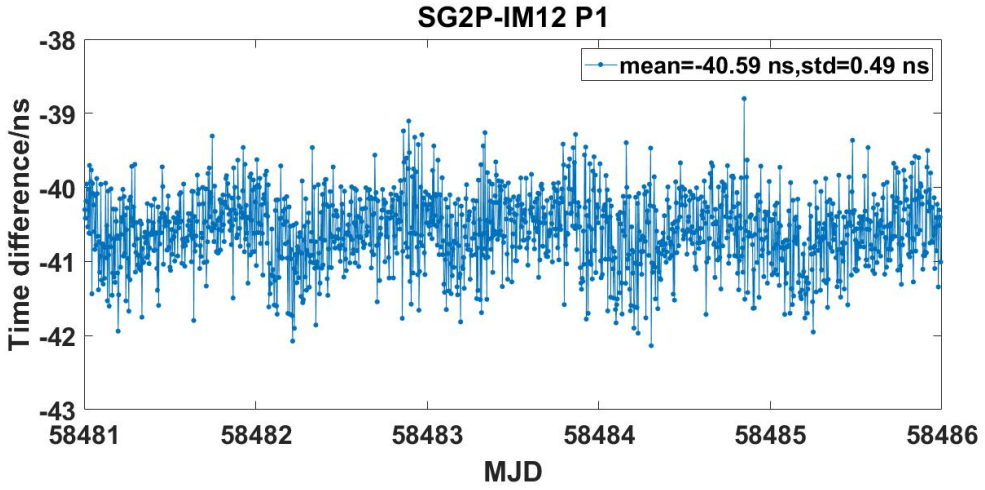


Figure 61. CCD between IM12 and SG2P at NMC(P1)

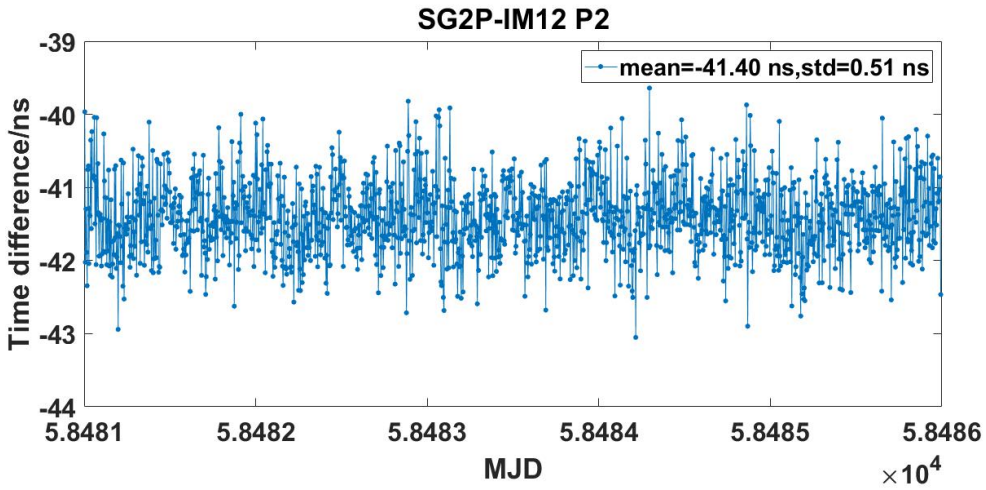


Figure 62. CCD between IM12 and SG2P at NMC(P2)

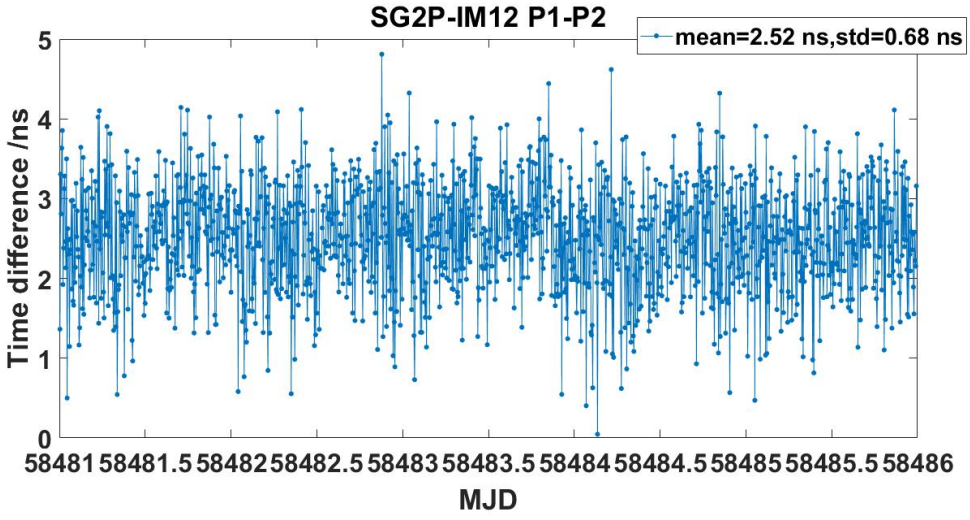


Figure 63. CCD between IM12 and SG2P at NMC(P1-P2)

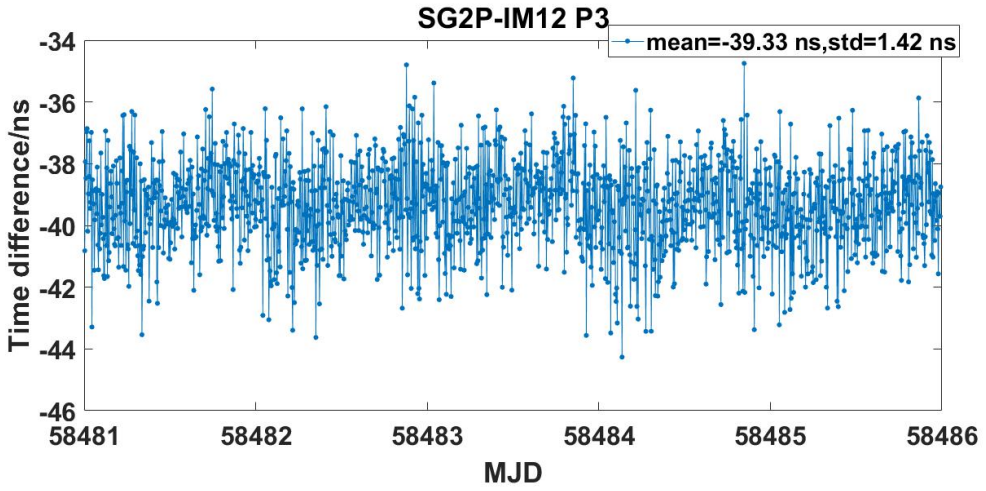


Figure 64. CCD between IM12 and SG2P at NMC(P3)

SG2P-IM20

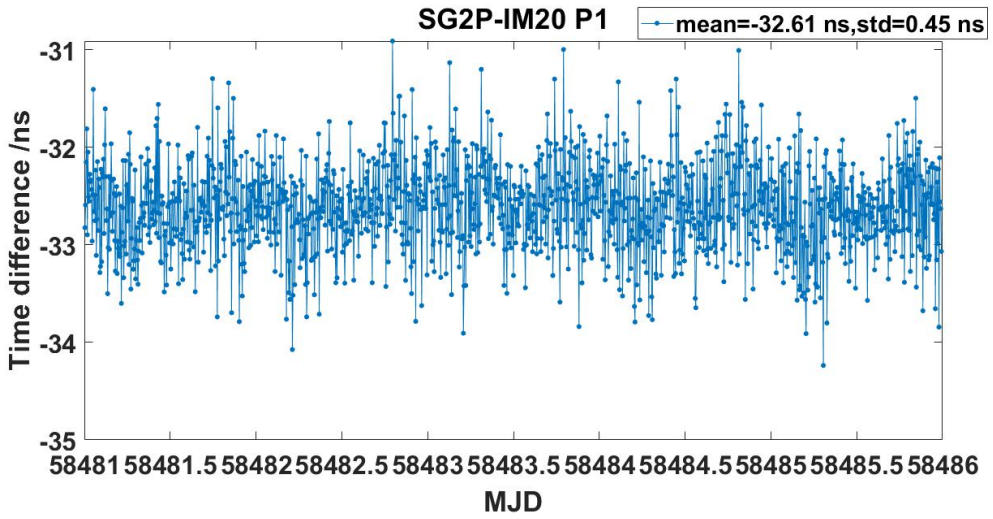


Figure 65. CCD between IM20 and SG2P at NMC(P1)

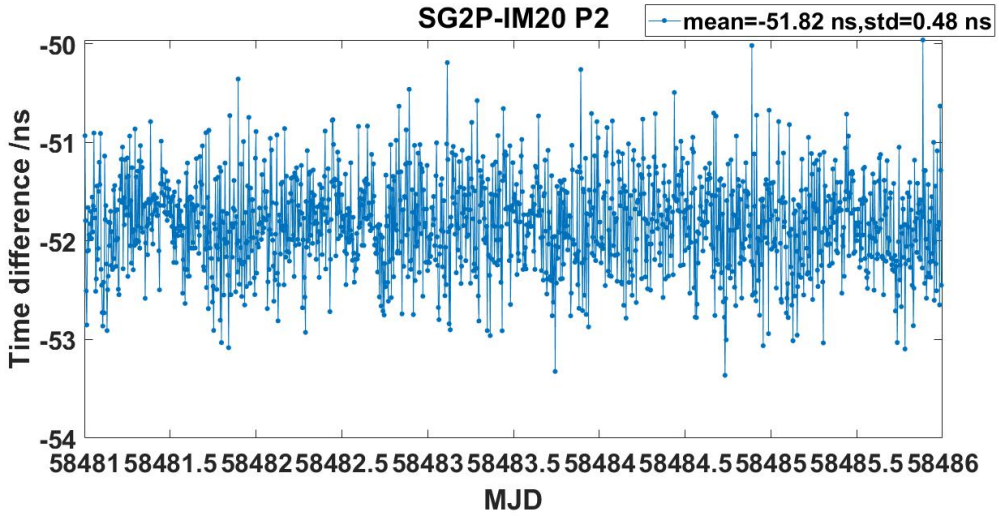


Figure 66. CCD between IM20 and SG2P at NMC(P2)

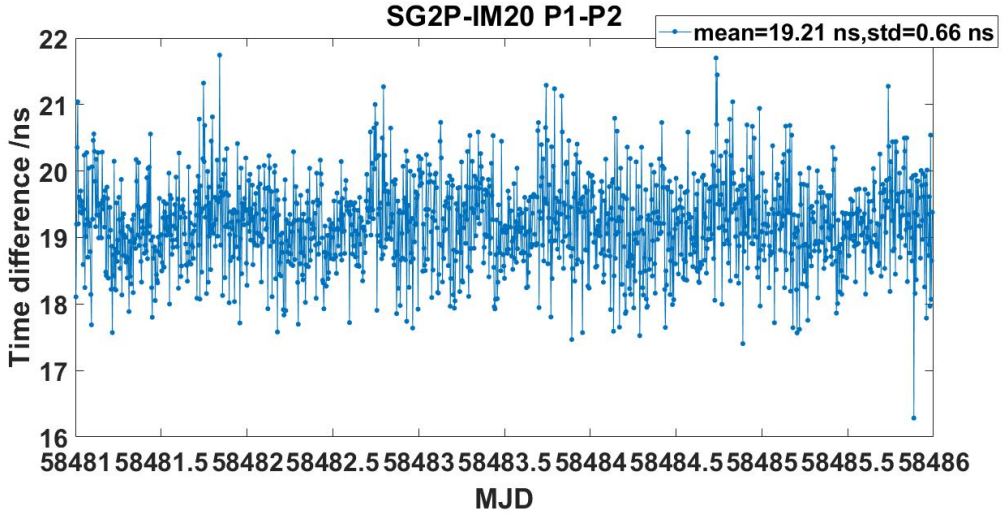


Figure 67. CCD between IM20 and SG2P at NMC(P1-P2)

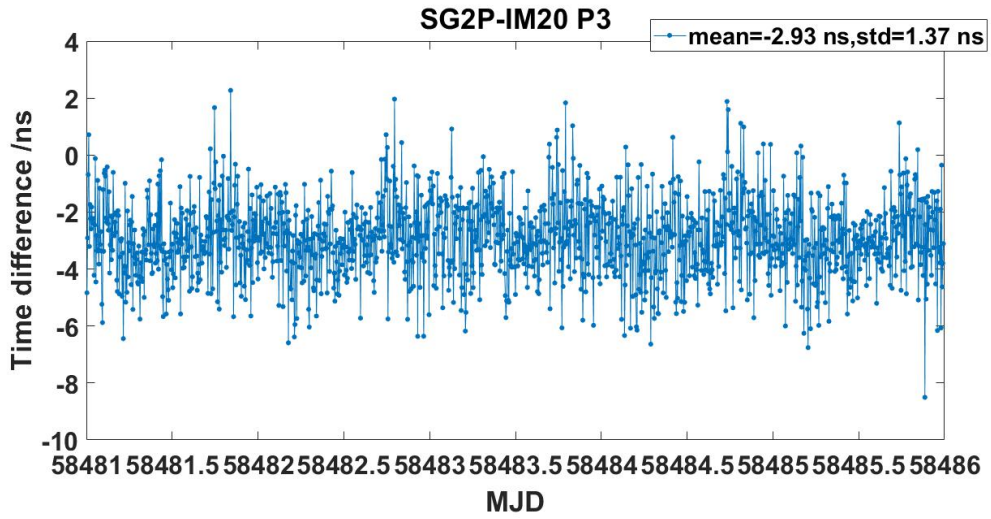


Figure 68. CCD between IM20 and SG2P at NMC(P3)

SGBK-IM12

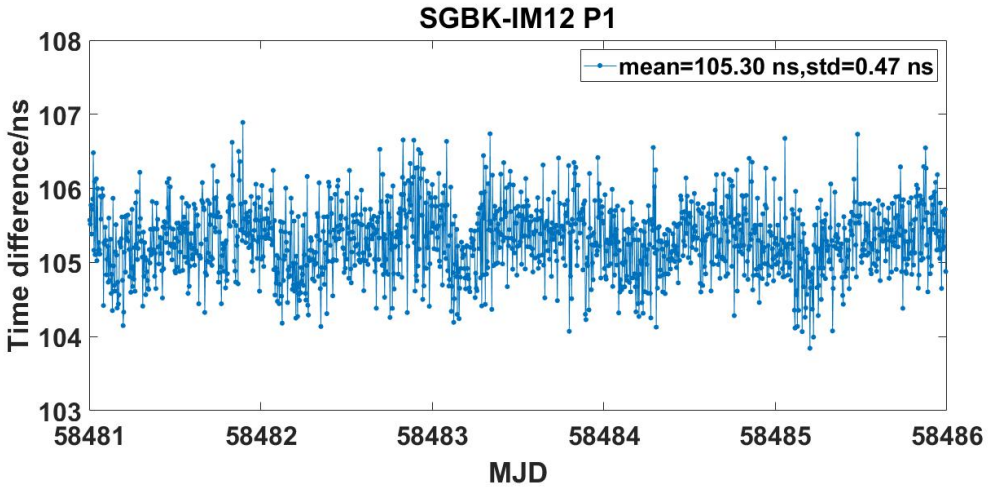


Figure 69. CCD between IM12 and SGBK at NMC(P1)

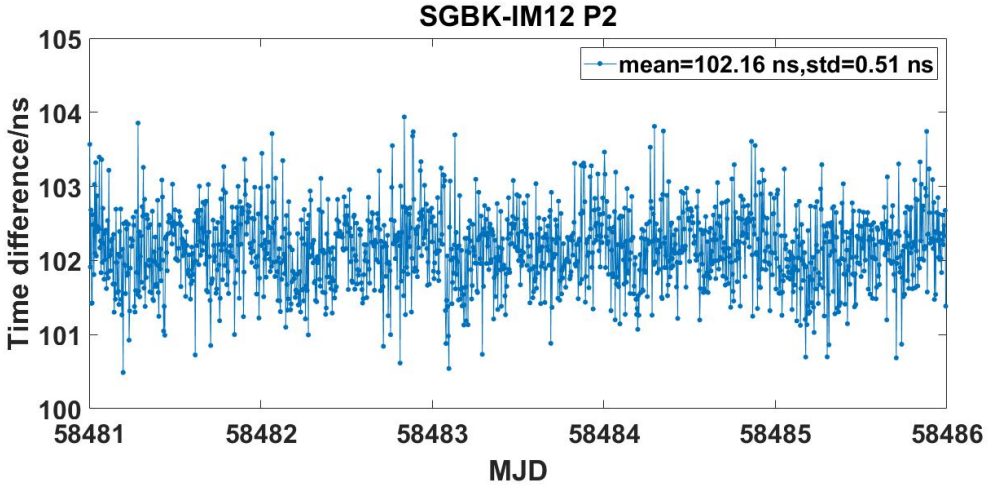


Figure 70. CCD between IM12 and SGBK at NMC(P2)

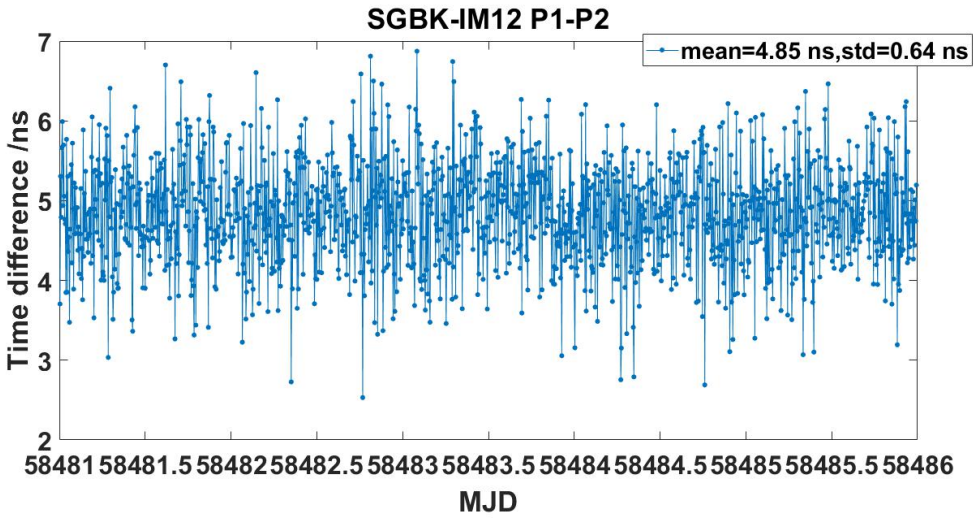


Figure 71. CCD between IM12 and SGBK at NMC(P1-P2)

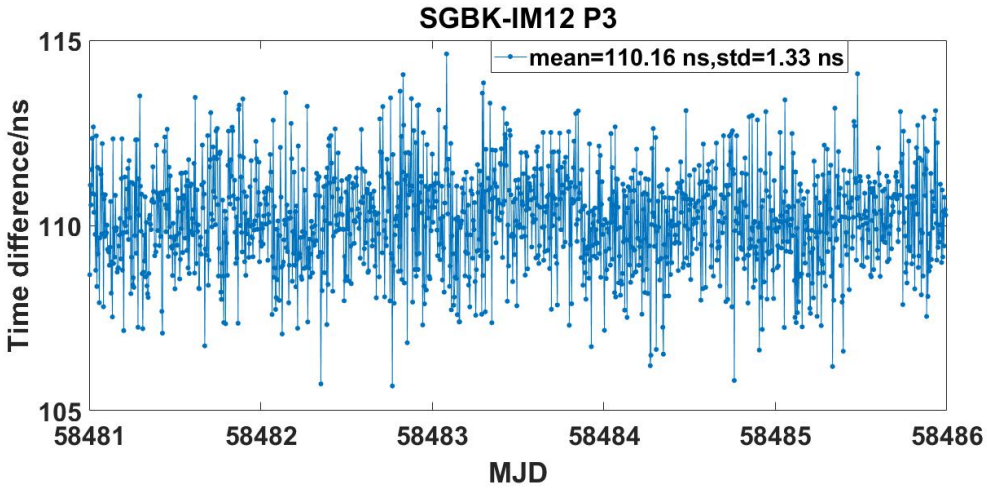


Figure 72. CCD between IM12 and SGBK at NMC(P3)

SGBK-IM20

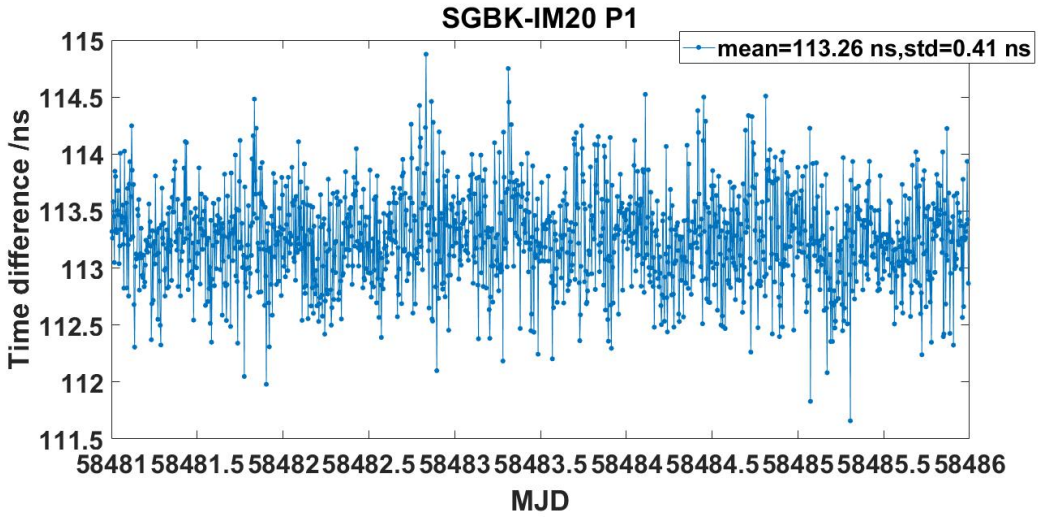


Figure 73. CCD between IM20 and SGBK at NMC(P1)

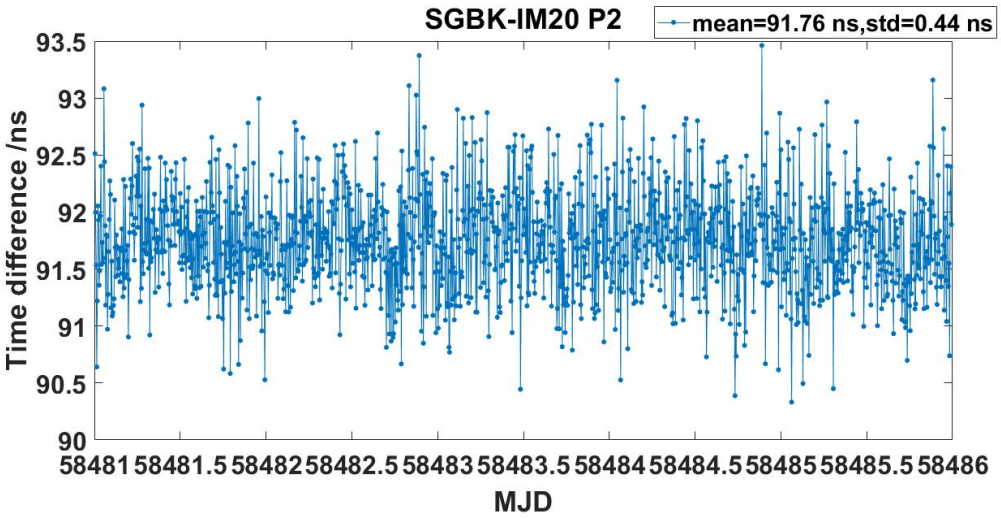


Figure 74. CCD between IM20 and SGBK at NMC(P2)

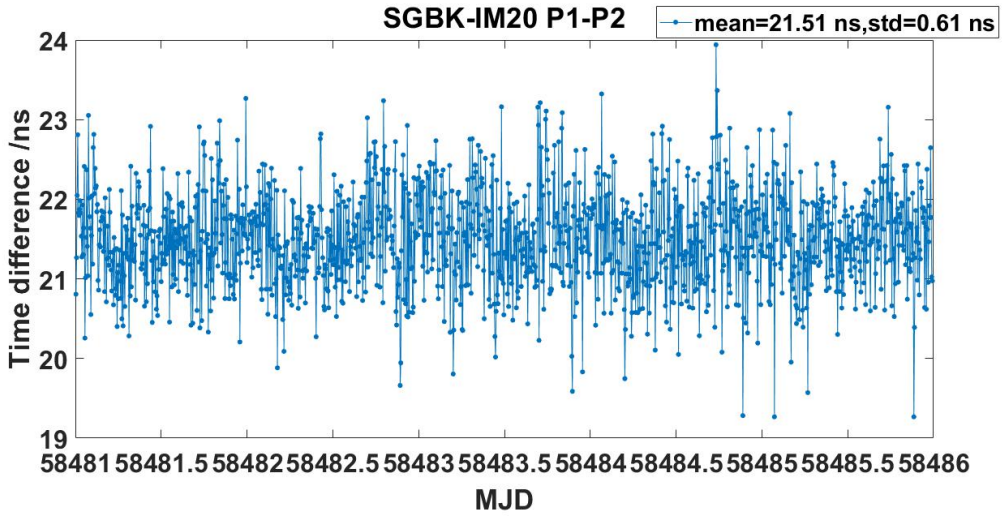


Figure 75. CCD between IM20 and SGBK at NMC(P1-P2)

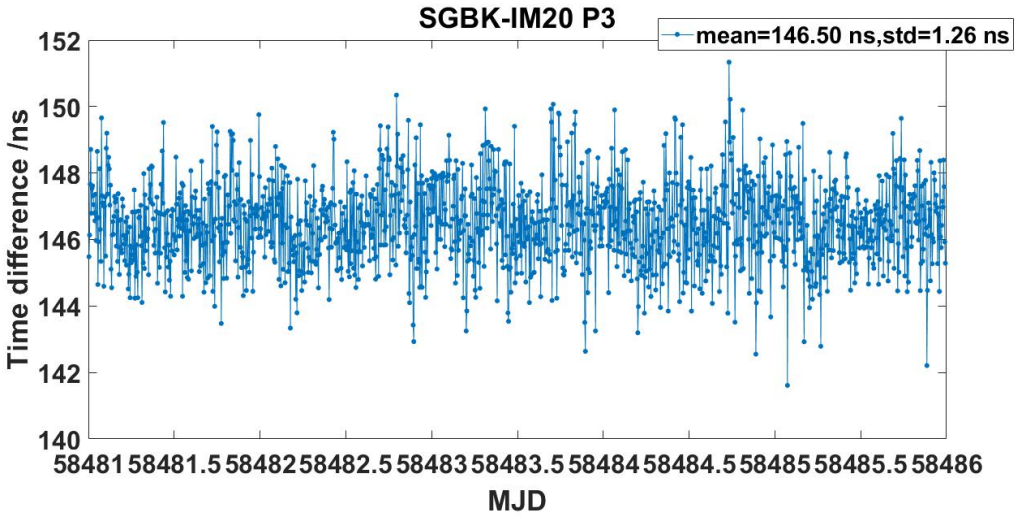


Figure 76. CCD between IM20 and SGBK at NMC(P3)

4. Closure CCD after calibration

IM06-IM12

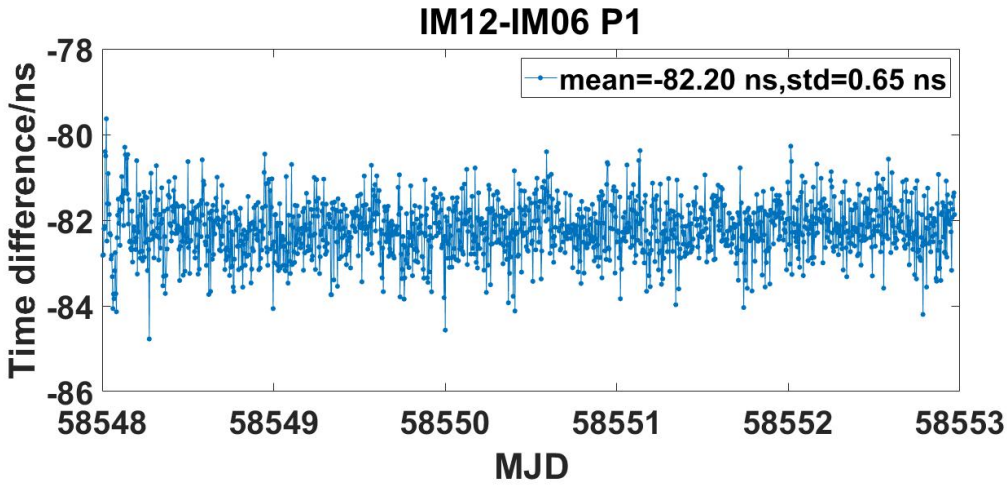


Figure 77. CCD between IM12 and IM06 at NIM(P1)

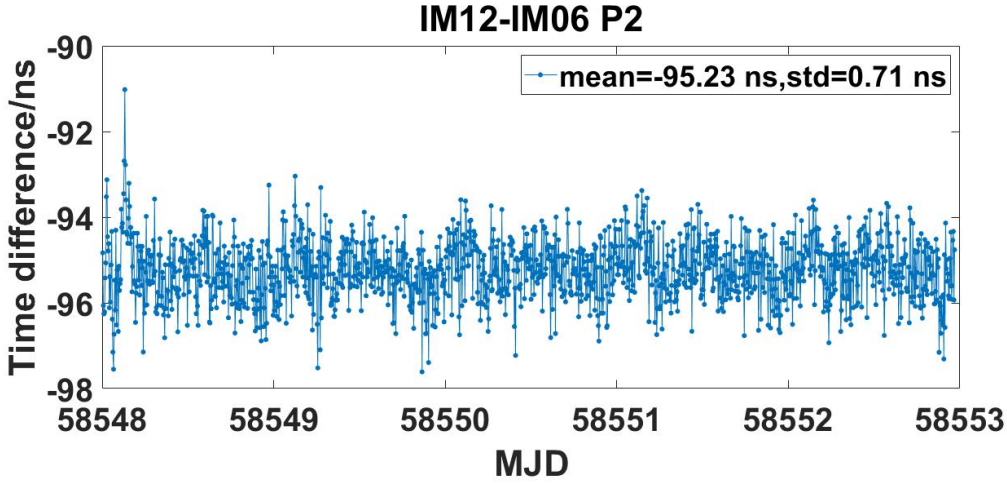


Figure 78. CCD between IM12 and IM06 at NIM(P2)

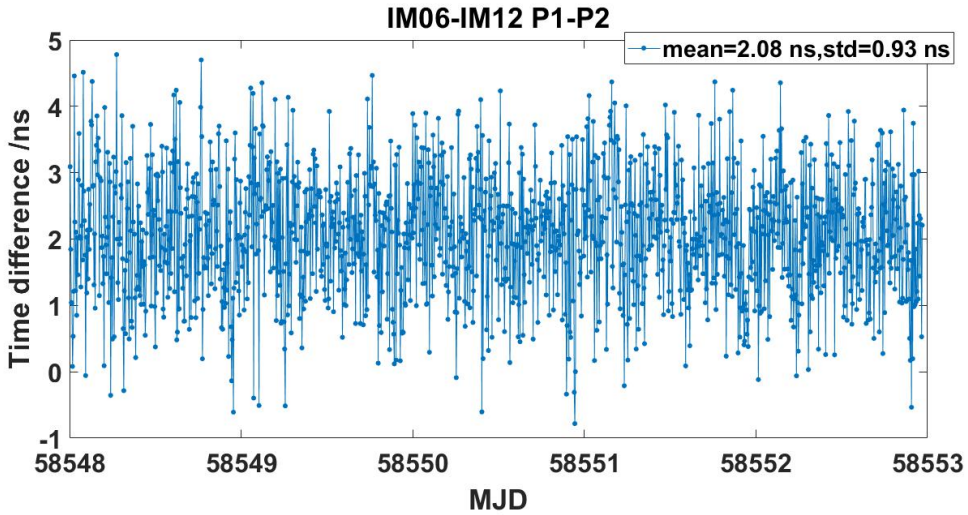


Figure 79. CCD between IM12 and IM06 at NIM(P1-P2)

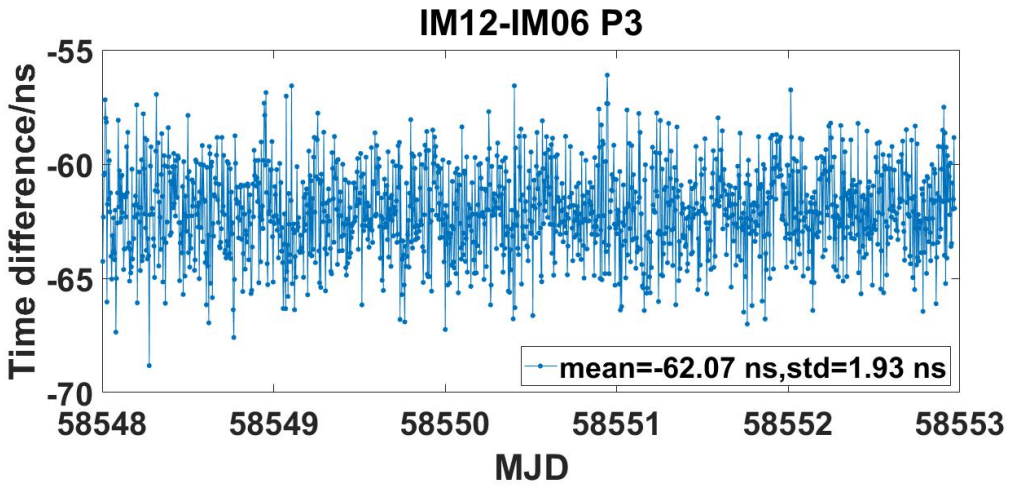


Figure 80. CCD between IM12 and IM06 at NIM(P3)

IM20-IM06

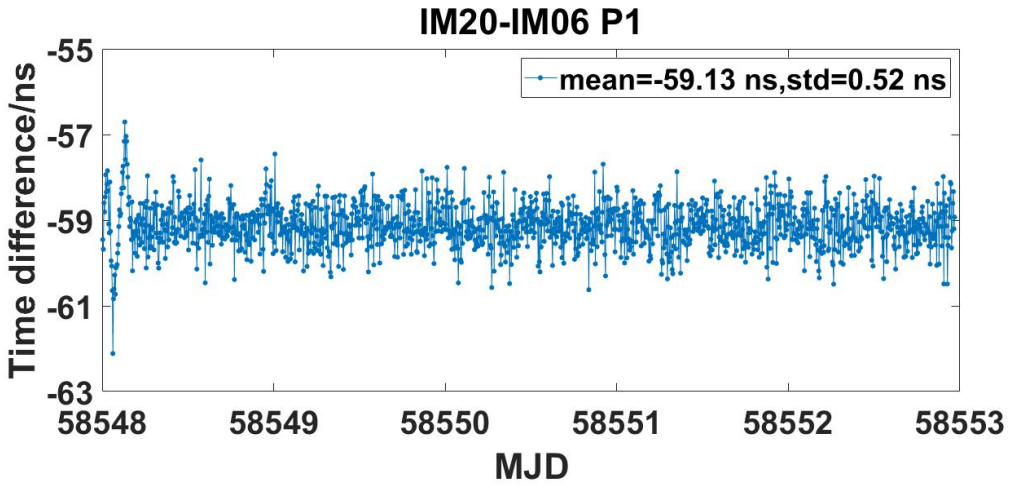


Figure 81. CCD between IM20 and IM06 at NIM(P1)

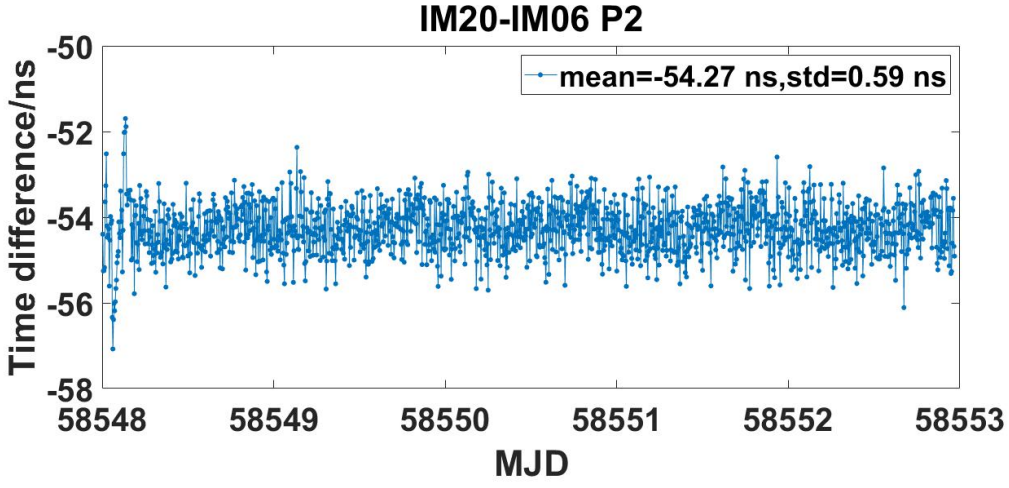


Figure 82. CCD between IM20 and IM06 at NIM(P2)

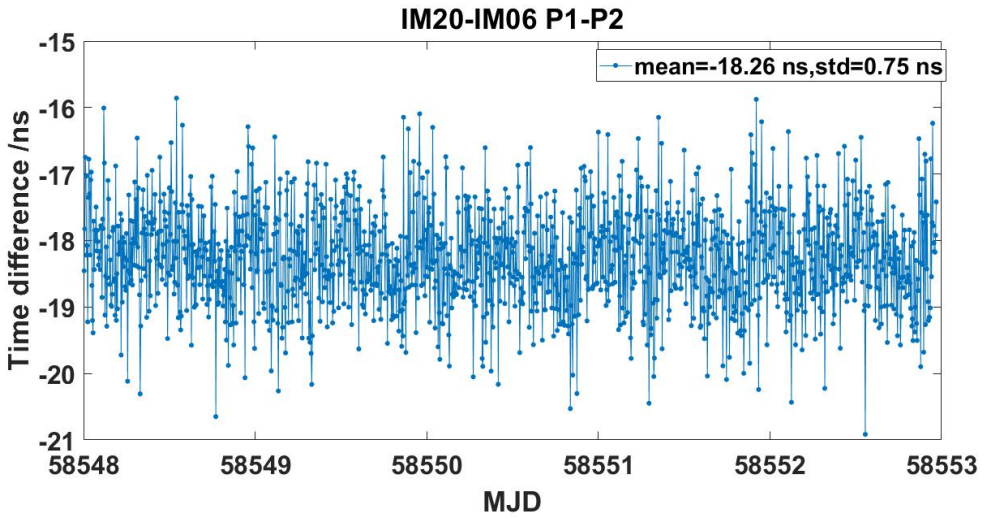


Figure 83. CCD between IM20 and IM06 at NIM(P1-P2)

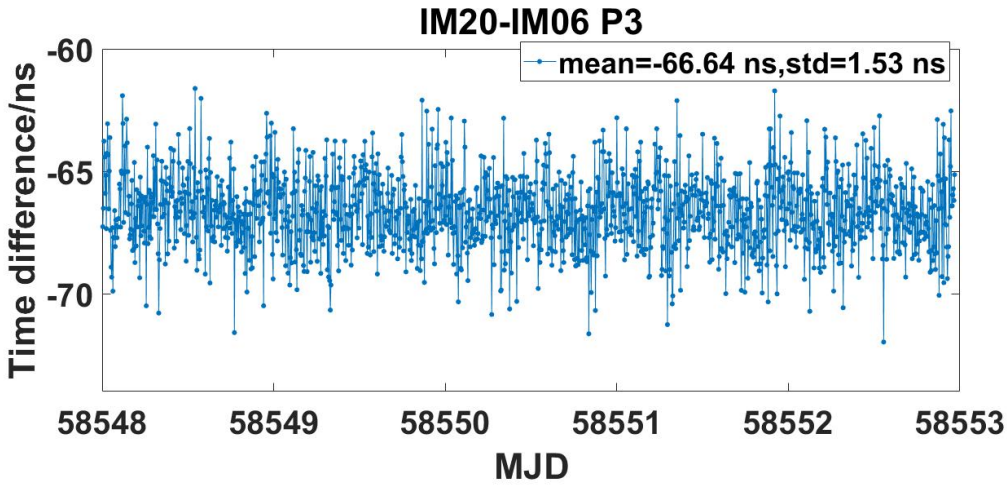


Figure 84. CCD between IM20 and IM06 at NIM(P3)

IM20-IM12

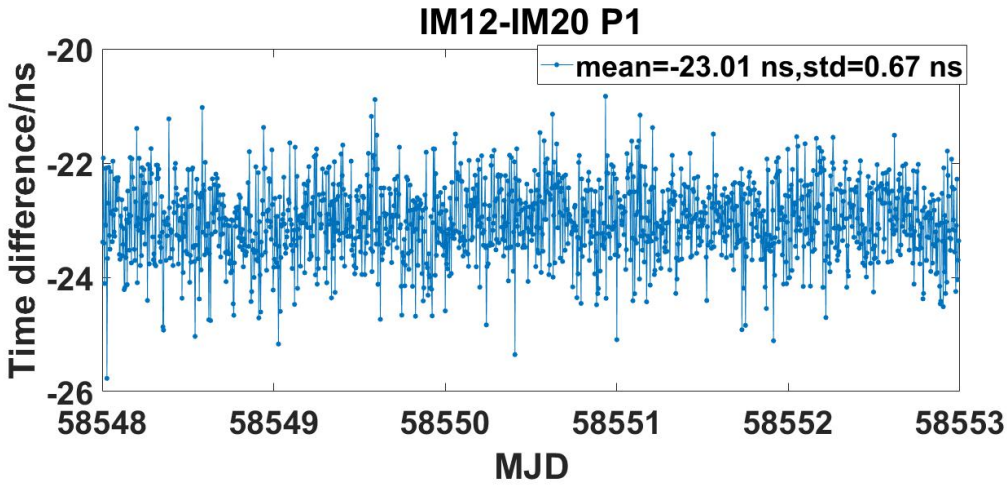


Figure 85. CCD between IM20 and IM12 at NIM(P1)

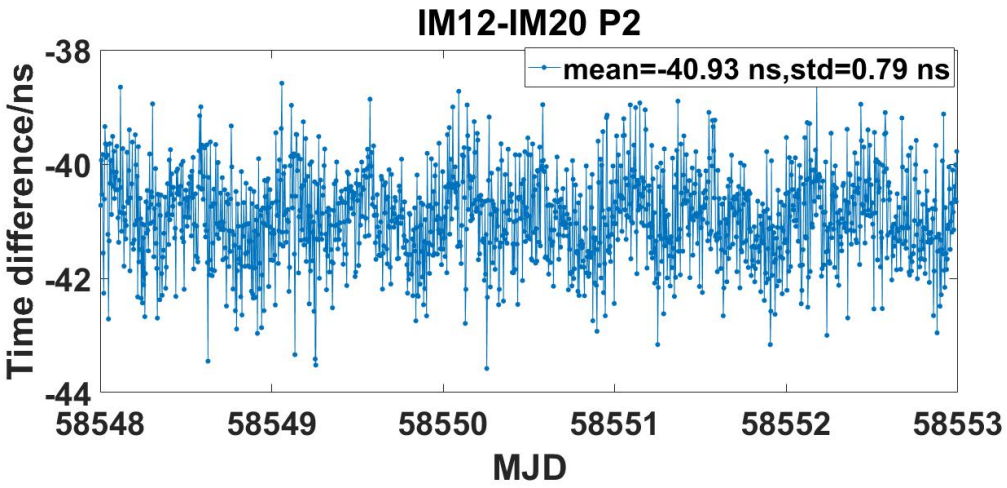


Figure 86. CCD between IM20 and IM12 at NIM(P2)

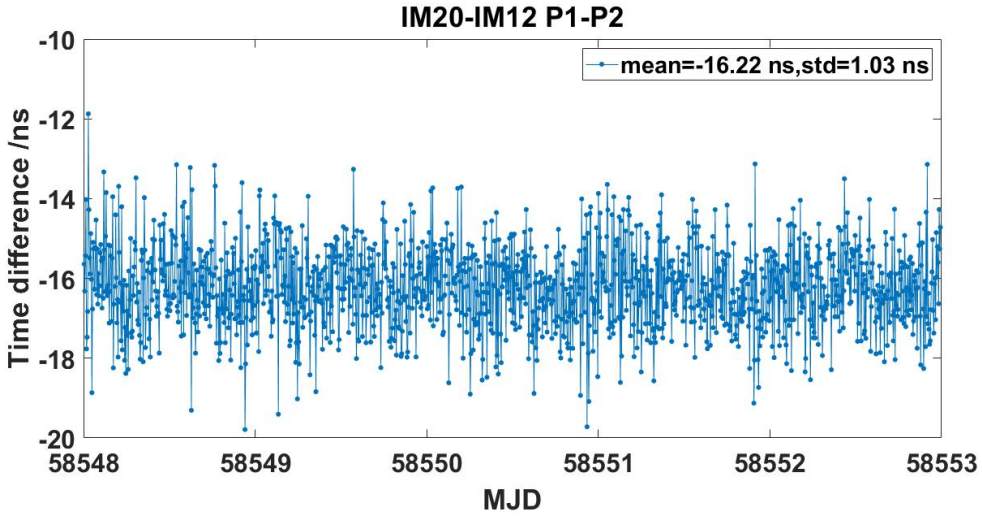


Figure 87. CCD between IM20 and IM12 at NIM(P1-P2)

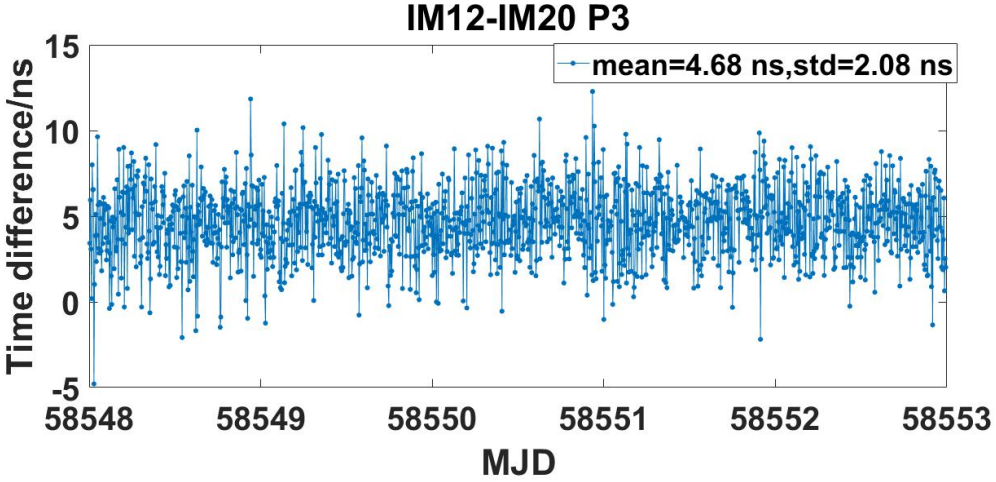


Figure 88. CCD between IM20 and IM12 at NIM(P3)

Annex 3 - Information Sheets

Information Sheet

Laboratory:	NIM
Date and hour of the beginning of measurements:	UTC time 0:00 am Sep. 12,2018
Date and hour of the end of measurements:	UTC time 0:00 am Sep.19,2018

Information on the system

	Local:	**Travelling:**
4-character BIPM code	IM06	(1) IM12 (2) IM20
Receiver maker and type: Receiver serial number：	maker:Dicom type: GTR50 serial number:1007011	(1)maker:Dicom type: GTR51 serial number:11506132 (2)maker:NIM type: NIM-TF-GNSS-2J serial number:2016005
1 PPS trigger level /V:	0~2	0~2
Antenna cable maker and type: Phase stabilised cable (Y/N):	maker: type: Phase stabilised cable:N	(1)NOV-703-GGG P/N: 01018146 (2) NOV-702-GG P/N: 01017577
Length outside the building /m:	5.0	5.0
Antenna maker and type: Antenna serial number:	maker:Novatel type: GPS-702-GGG Serial number: NAE10220060	(1)NOV-703-GGG NEG15210020 (2)NOV-702-GG NAE 16270022
Temperature (if stabilised) /°C		

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	121.7	(1)148.5 (2)146.9
Delay from 1 PPS-in to internal Reference (if different):		
Antenna cable delay:	248.7	(1)201.4 (2)205.1

Splitter delay (if any):		
Additional cable delay (if any):		

Data used for the generation of CGGTTS files (IM06)

INT DLY (GPS) /ns:	-31.3 ns (GPS P1), -17.9 ns (GPS P2)
INT DLY (GLONASS) /ns:	0.0
CAB DLY /ns:	248.7
REF DLY /ns:	122.2
Coordinates reference frame:	ITRF
Latitude or X /m:	-2154288.06
Longitude or Y /m:	+4373440.56
Height or Z /m:	+4098884.94

Data used for the generation of CGGTTS files (IM12)

INT DLY (GPS) /ns:	-27.4 ns (GPS C1), -33.5 ns (GPS P1), 0.0 ns (GPS C2), -35.2 ns (GPS P2), 0.0 ns (GPS L5)
INT DLY (GLONASS) /ns:	0
CAB DLY /ns:	201.4 ns
REF DLY /ns:	148.5ns
Coordinates reference frame:	ITRF Dx = 0.0 m, Dy = 0.0 m, Dz = 0.0 m, ds = 0.0, Rx = 0.0, Ry = 0.0, Rz = 0.000000
Latitude or X /m:	-2154283.45
Longitude or Y /m:	+4373442.66
Height or Z /m:	+4098885.13

Data used for the generation of CGGTTS files (IM20)

INT DLY (GPS) /ns:	L1C/A : 0.0 ns L1P: 0.0 ns L2P: 0.0 ns
INT DLY (GLONASS) /ns:	L1C/A : 0.0 ns L1P: 0.0 ns L2P: 0.0 ns
CAB DLY /ns:	205.1 ns
REF DLY /ns:	146.9 ns
Coordinates reference frame:	ITRF Dx = 0.0 m, Dy = 0.0 m, Dz = 0.0 m, ds = 0.0, Rx = 0.0, Ry = 0.0, Rz = 0.000000
Latitude or X /m:	-2154283.452
Longitude or Y /m:	+4373442.660
Height or Z /m:	+4098885.129

General information

Rise time of the local UTC pulse	unknown
Is the laboratory air conditioned	No
Set temperature value and uncertainty:	26.0ºC ±0.2 ºC
Set humidity value and uncertainty:	21% ± 1%

(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

Please see the report.

Log of Events / Additional Information

(to be repeated for each calibrated system)

Laboratory：MASM – TF- Lab	MN
Date and hour of the beginning of measurements:	MJD 58401 UTC 04:24:51
Date and hour of the end of measurements:	MJD 58410 UTC 07:02:10

Information on the system

	Local:	**Travelling:**
4-character BIPM code	(1) MN_	(1)IM20 (2)IM12
Receiver maker and type: Receiver serial number：	(1) Dicom ,GTR51 SN:1311002	(1) NIM ,NIM-TF-GNSS-2J; SN:2016005 (2) Dicom ,GTR51; SN:1506132
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	(1) NOV-703-GGG NEG 13360009	(1) NOV702GG P/N: 01017577 (2) NOV-703-GGG P/N: 01018146
Length outside the building /m:	(1) 37 m	(1) 37 m (2) 37 m
Antenna maker and type: Antenna serial number:	(1) NOV-703-GGG NEG 13360009	(1) NOV702GG NAE 16270022 (2) NOV-703-GGG NEG15210020
Temperature (if stabilised) /°C		

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	(1) 0.0 ns	1) 47.32129 ns / 47.4 ns 2) 47.31039 ns / 47.9 ns
Delay from 1 PPS-in to internal Reference (if different):	(1) 0.0 ns	

Antenna cable delay:	(1) 131.4 ns	1) 201.4 ns 2) 205.1 ns
Splitter delay (if any):		
Additional cable delay (if any):		

Data used for the generation of CGGTTS files (MASM)

INT DLY (GPS) /ns:	L1C/A : 0.0 ns L1P: 0.0 ns L2C: 0.0 ns L2P: 0.0 ns L5: 0.0 ns
INT DLY (GLONASS) /ns:	L1OF: 0.0 L1SF: 0.0 ns L2OF: 0.0 ns L2SF: 0.0 ns
CAB DLY /ns:	131.4 ns
REF DLY /ns:	0.0 ns
Coordinates reference frame:	FRAME
Latitude or X /m:	-1248821.2
Longitude or Y /m:	4097255.60
Height or Z /m:	4711728.68

Data used for the generation of CGGTTS files (IM12)

INT DLY (GPS) /ns:	L1C/A : -27.4 ns L1P: -33.5 ns L2C: 0.0 ns L2P: -35.2 ns L5: 0.0 ns
INT DLY (GLONASS) /ns:	L1OF: 0.0 L1SF: 0.0 ns L2OF: 0.0 ns L2SF: 0.0 ns
CAB DLY /ns:	201.4 ns
REF DLY /ns:	47.3 ns UTC(MASM)
Coordinates reference frame:	ITRF Dx = 0.0 m, Dy = 0.0 m, Dz = 0.0 m, ds = 0.0, Rx = 0.0, Ry = 0.0, Rz = 0.000000
Latitude or X /m:	-1248821.121
Longitude or Y /m:	+4097254.832
Height or Z /m:	+4711728.385

Data used for the generation of CGGTTS files (IM20)

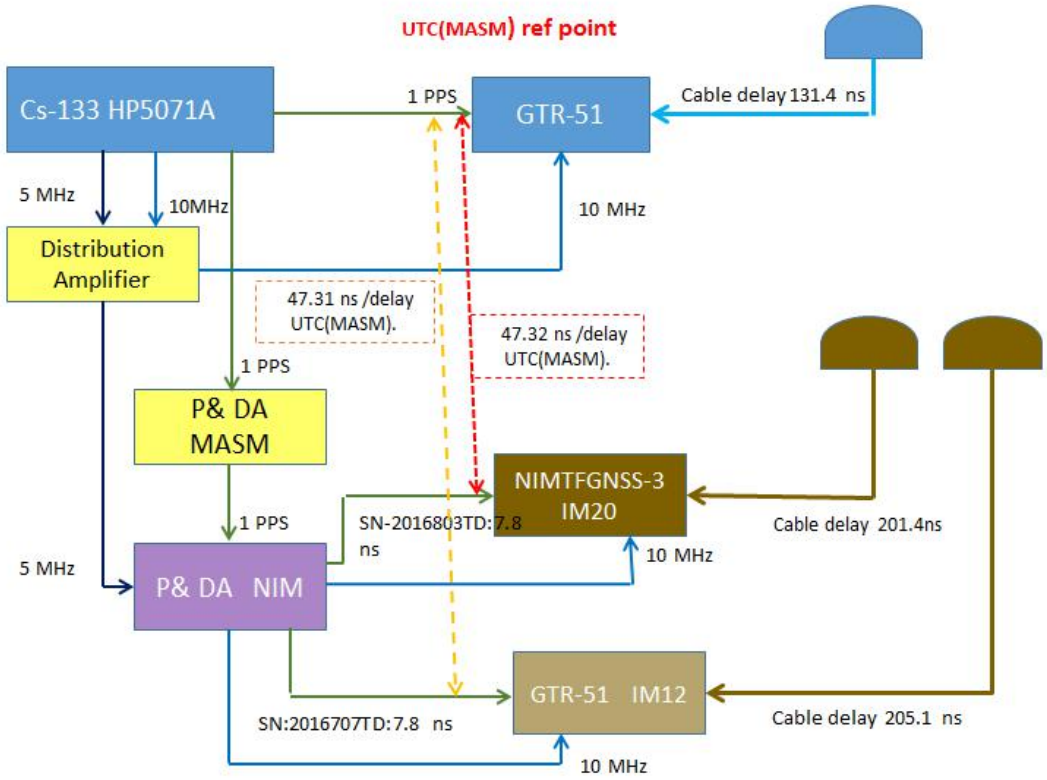
INT DLY (GPS) /ns:	L1C/A : 0.0 ns L1P: 0.0 ns L2P: 0.0 ns
INT DLY (GLONASS) /ns:	L1C/A : 0.0 ns L1P: 0.0 ns L2P: 0.0 ns
CAB DLY /ns:	205.1 ns
REF DLY /ns:	47.3 ns
Coordinates reference frame:	ITRF Dx = 0.0 m, Dy = 0.0 m, Dz = 0.0 m, ds = 0.0, Rx = 0.0, Ry = 0.0, Rz = 0.000000
Latitude or X /m:	-1248820.999
Longitude or Y /m:	+4097255.264
Height or Z /m:	+4711728.359

General information

Rise time of the local UTC pulse	unknown
Is the laboratory air conditioned	No
Set temperature value and uncertainty:	26.0ºC ±0.2 ºC
Set humidity value and uncertainty:	21% ± 1%

(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



Log of Events / Additional Information

(to be repeated for each calibrated system)

Laboratory:	SG
Date and hour of the beginning of measurements:	MJD 58479, 00:00:00
Date and hour of the end of measurements:	

Information on the system

	Local:	**Travelling:**
4-character BIPM code	SG01	IM20 IM12

Receiver maker and type: Receiver serial number:	Septentrio PolaRx5TR S/N: 4701189	NIM-TF-GNSS-2J GTR51
1 PPS trigger level /V:		
Antenna cable maker and type: Phase stabilised cable (Y/N):	Huber+Suhner Sucofeed ½ inch	HUBER+SUHNER SUCOFEED (for both) 3/8 Inch 1/2 Inch
Length outside the building /m:	98 m	80 m 92 m
Antenna maker and type: Antenna serial number:	Leica AR25 S/N: 726808	NOV-GPS-702-GG NOV-GPS-703-GGG
Temperature (if stabilised) /° C	–	–

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	38.24 ns	37.16 ns 37.10 ns
Delay from 1 PPS-in to internal Reference (if different):	–	–
Antenna cable delay:	376.0 ns	341.8 ns 366.5 ns
Splitter delay (if any):	–	–
Additional cable delay (if any):	–	–

Data used for the generation of CGGTTS files

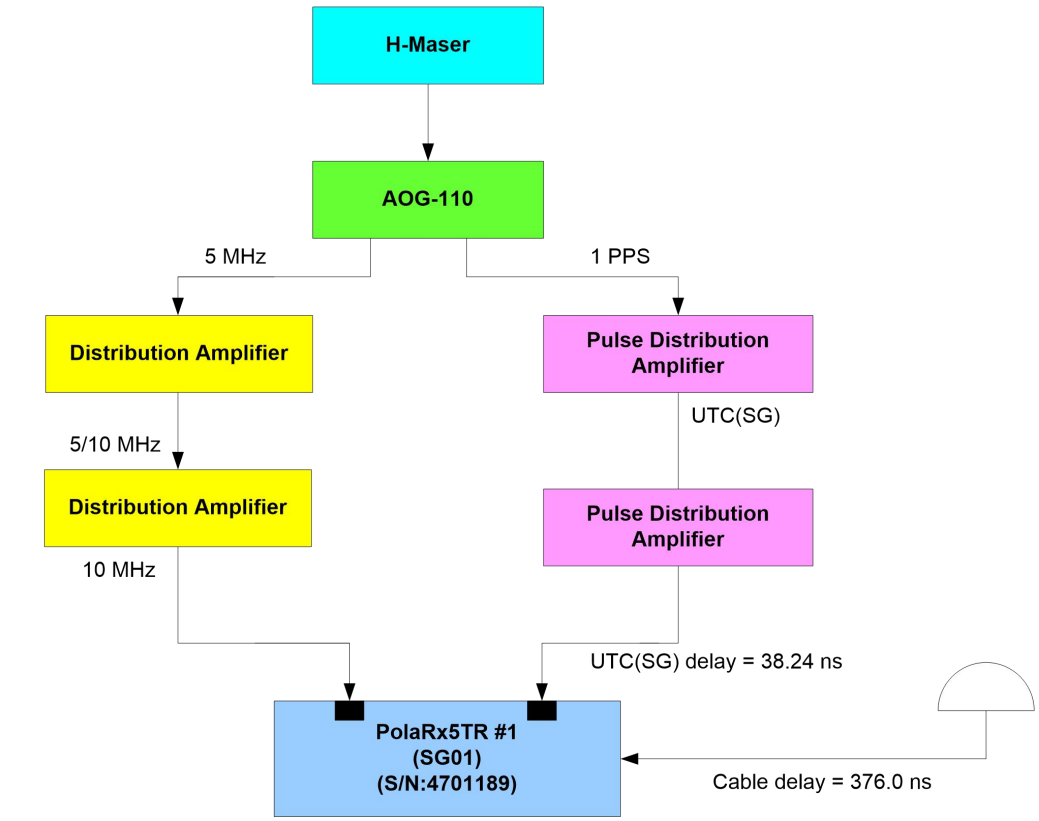
INT DLY (GPS) /ns:	–
INT DLY (GLONASS) /ns:	–
CAB DLY /ns:	376.0 ns
REF DLY /ns:	40.4 ns
Coordinates reference frame:	ITRF
Latitude or X /m:	-1519470.700 m
Longitude or Y /m:	+6192911.180 m
Height or Z /m:	+142840.120 m

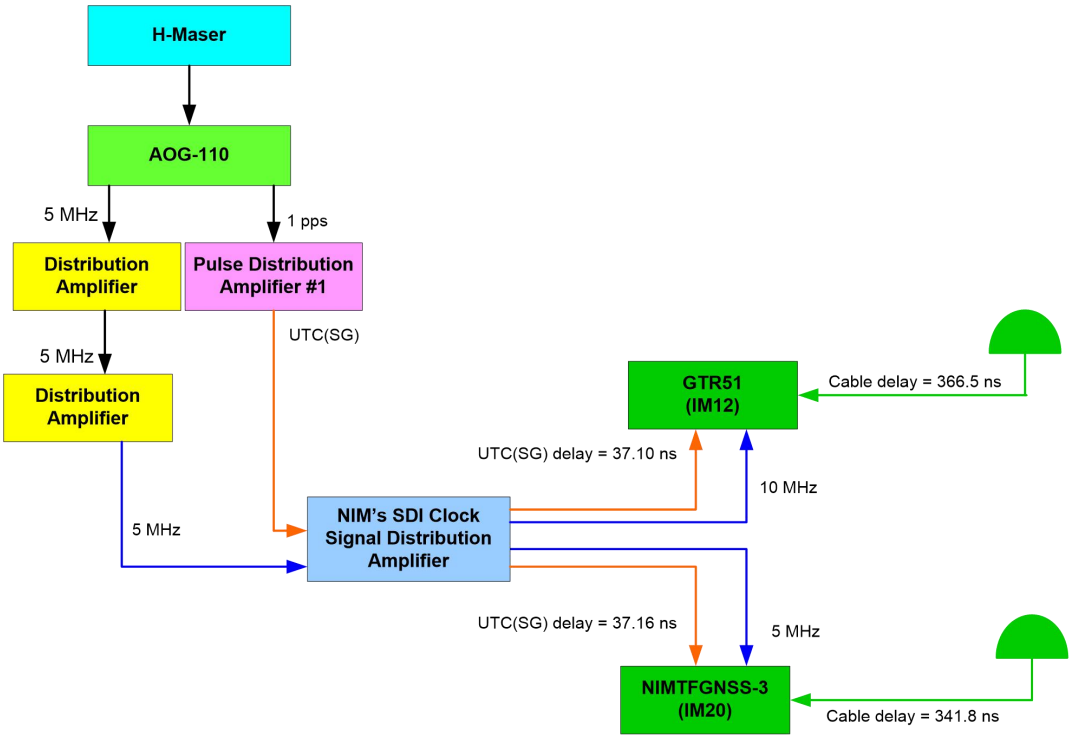
General information

Rise time of the local UTC pulse	807.7 ps
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	(23±2)0C
Set humidity value and uncertainty:	(55±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





Log of Events / Additional Information

(to be repeated for each calibrated system)

Laboratory：	SG
Date and hour of the beginning of measurements:	MJD 58479, 00:00:00
Date and hour of the end of measurements:	

Information on the system

	Local:	**Travelling:**
4-character BIPM code	SG02	IM20 IM12
Receiver maker and type: Receiver serial number：	Septentrio PolaRx5TR S/N: 4701190	NIM-TF-GNSS-2J GTR51
1 PPS trigger level /V:		
Antenna cable maker and type: Phase stabilised cable (Y/N):	Huber+Suhner Sucofeed 7/8 Inch	HUBER+SUHNER SUCOFEED (for both) 3/8 Inch 1/2 Inch
Length outside the building /m:	84 m	80 m 92 m
Antenna maker and type: Antenna serial number:	Leica AR25 S/N: 726809	NOV-GPS-702-GG NOV-GPS-703-GGG
Temperature (if stabilised) /° C	–	–

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	38.25 ns	37.16 ns 37.10 ns
Delay from 1 PPS-in to internal Reference (if different):	0.0 ns	–
Antenna cable delay:	328.0 ns	341.8 ns 366.5 ns
Splitter delay (if any):	–	–
Additional cable delay (if any):	–	–

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	–
INT DLY (GLONASS) /ns:	–
CAB DLY /ns:	328.0 ns
REF DLY /ns:	40.4 ns
Coordinates reference frame:	ITRF

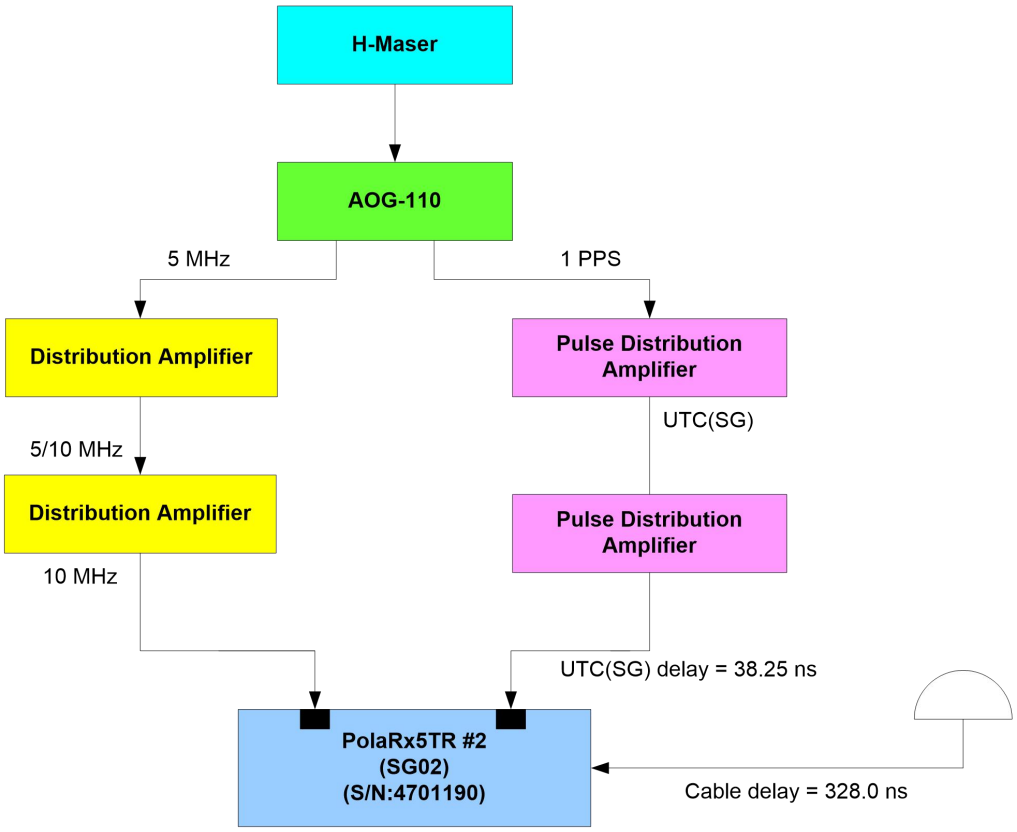
Latitude or X /m:	-1519464.790 m
Longitude or Y /m:	+6192912.490 m
Height or Z /m:	+142845.940 m

General information

Rise time of the local UTC pulse	807.7 ps
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	(23±2)0C
Set humidity value and uncertainty:	(55±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



Log of Events / Additional Information

(to be repeated for each calibrated system)

Laboratory:	SG
Date and hour of the beginning of measurements:	MJD 58479, 00:00:00
Date and hour of the end of measurements:	

Information on the system

	Local:	Travelling:

4-character BIPM code	SG2P	IM20 IM12
Receiver maker and type: Receiver serial number：	Septentrio PolaRx2eTR S/N: 3364	NIM-TF-GNSS-2J GTR51
1 PPS trigger level /V:		
Antenna cable maker and type: Phase stabilised cable (Y/N):	Huber+Suhner Sucofeed ½ inch	HUBER+SUHNER SUCOFEED (for both) 3/8 Inch 1/2 Inch
Length outside the building /m:	70m	80 m 92 m
Antenna maker and type: Antenna serial number:	Novatel GNSS 750 S/N: 01018874	NOV-GPS-702-GG NOV-GPS-703-GGG
Temperature (if stabilised) /° C	–	–

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	10.39 ns	37.16 ns 37.10 ns
Delay from 1 PPS-in to internal Reference (if different):	224.7 ns (using with 8.7 ns)	–
Antenna cable delay:	272.0 ns	341.8 ns 366.5 ns
Splitter delay (if any):	–	–
Additional cable delay (if any):	–	–

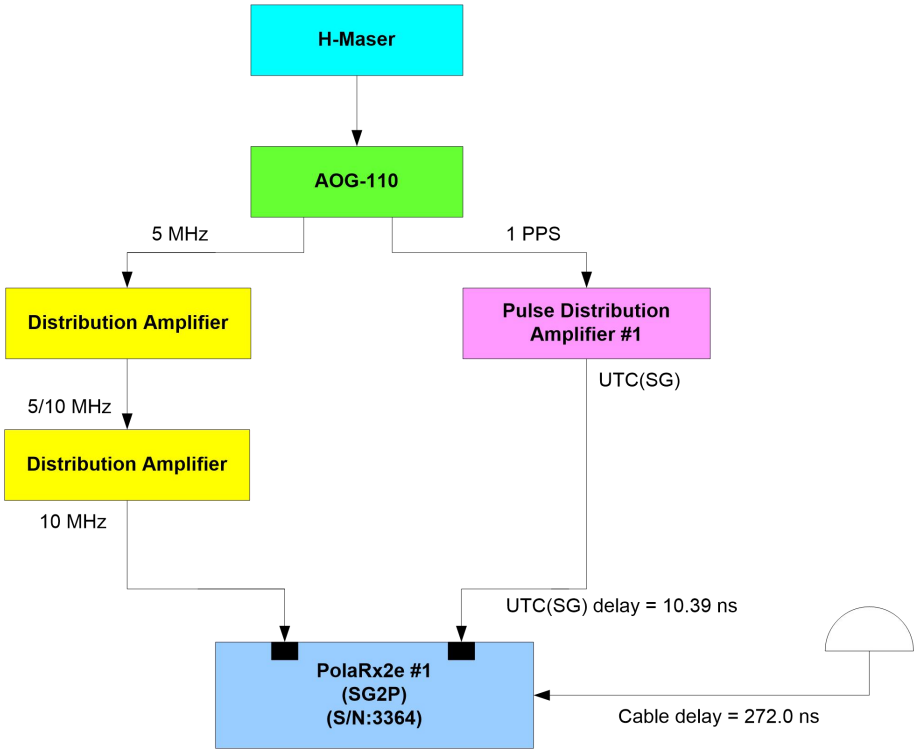
Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	224.6 ns (P1); 222.3 ns (P2)
INT DLY (GLONASS) /ns:	–
CAB DLY /ns:	272.0 ns
REF DLY /ns:	205.6 ns
Coordinates reference frame:	ITRF
Latitude or X /m:	-1519459.05 m
Longitude or Y /m:	+6192913.72 m
Height or Z /m:	+142851.46 m

General information

Rise time of the local UTC pulse	807.7 ps
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	(23±2)0C
Set humidity value and uncertainty:	(55±10)% rh

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



Log of Events / Additional Information

Laboratory:	SG
Date and hour of the beginning of measurements:	MJD 58479, 00:00:00
Date and hour of the end of measurements:	

Information on the system

	Local:	**Travelling:**
4-character BIPM code	SGBK	IM20 IM12
Receiver maker and type: Receiver serial number:	Septentrio PolaRx2eTR S/N: 3613	NIM-TF-GNSS-2J GTR51
1 PPS trigger level /V:		
Antenna cable maker and type: Phase stabilised cable (Y/N):	Huber+Suhner Sucofeed ½ inch	HUBER+SUHNER SUCOFEED (for both) 3/8 Inch 1/2 Inch
Length outside the building /m:	105 m	80 m 92 m

Antenna maker and type: Antenna serial number:	Leica AR25 S/N: 765733	NOV-GPS-702-GG NOV-GPS-703-GGG
Temperature (if stabilised) /° C	–	–

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	7.68 ns	37.16 ns 37.10 ns
Delay from 1 PPS-in to internal Reference (if different):	220.2 ns (using with 8.7 ns)	–
Antenna cable delay:	413.0 ns	341.8 ns 366.5 ns
Splitter delay (if any):	–	–
Additional cable delay (if any):	–	–

Data used for the generation of CGGTTS files

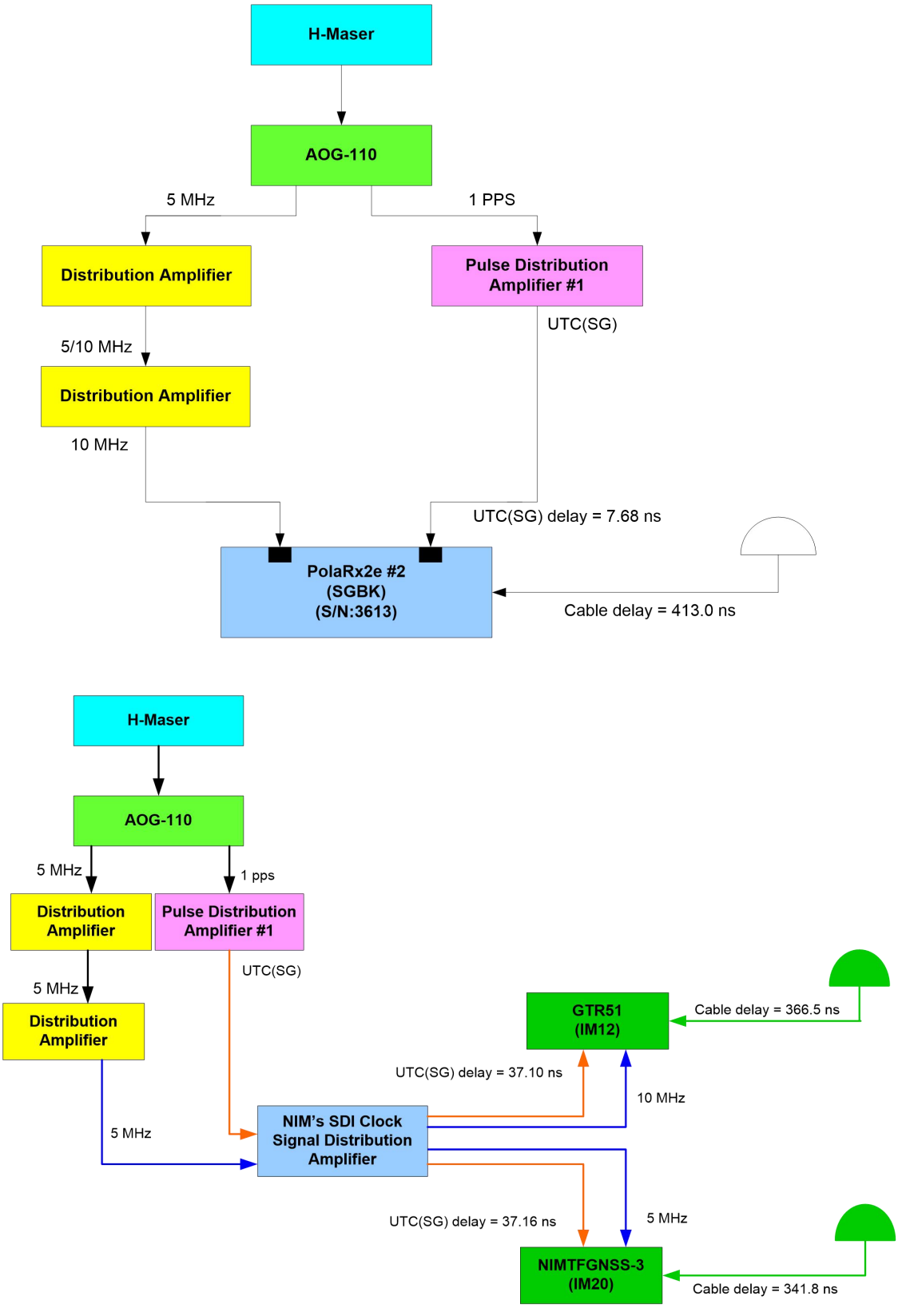
INT DLY (GPS) /ns:	222.3 ns (P1); 217.5 ns (P2)
INT DLY (GLONASS) /ns:	–
CAB DLY /ns:	413.0 ns
REF DLY /ns:	198.7 ns
Coordinates reference frame:	ITRF
Latitude or X /m:	-1519473.55m
Longitude or Y /m:	+6192910.47 m
Height or Z /m:	+142837.24 m

General information

Rise time of the local UTC pulse	807.7 ps
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	(23±2)0C
Set humidity value and uncertainty:	(55±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



Log of Events / Additional Information

Annex 4 –TDEV for CCD results at MASM

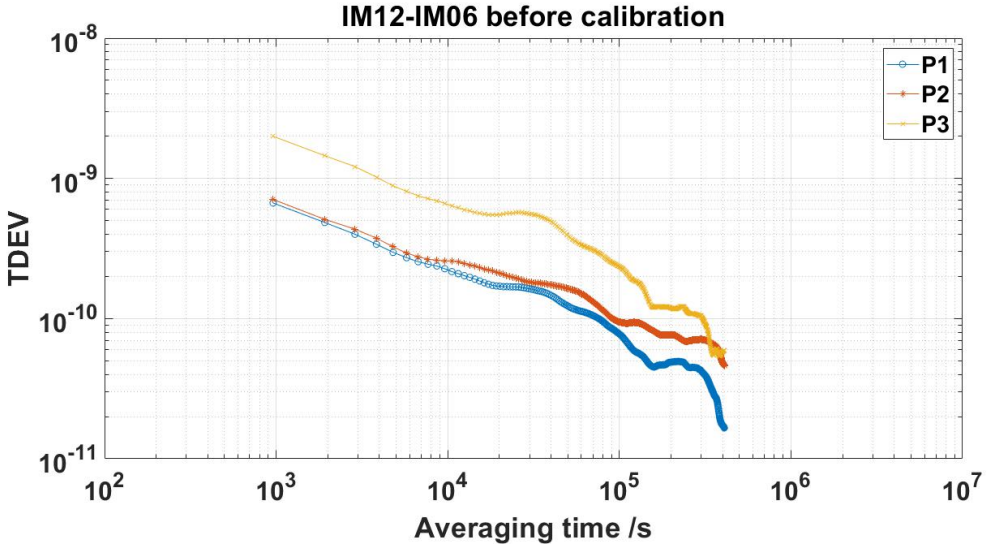


Figure 89. TDEV between IM12 and IM06 receivers at NIM before calibration

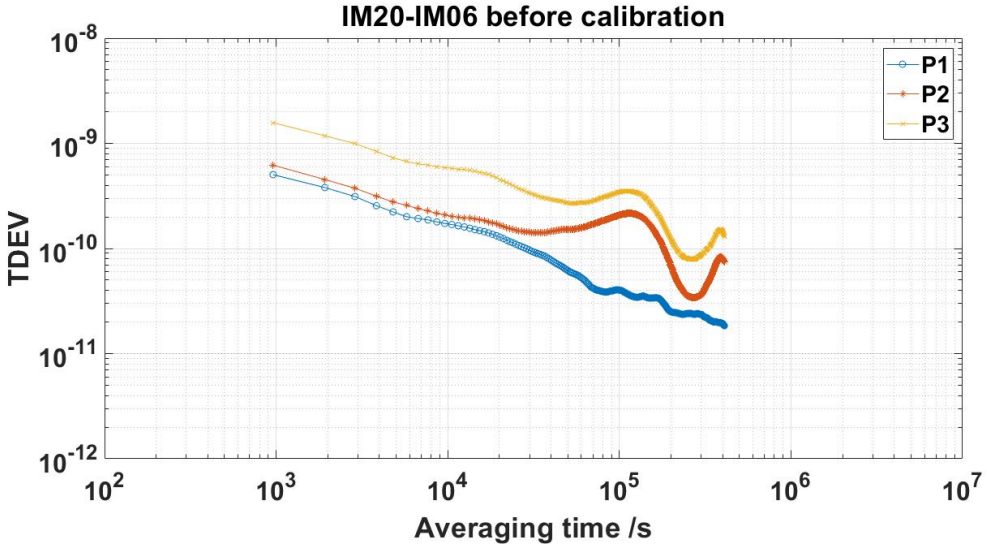


Figure 90. TDEV between IM20 and IM06 receivers at NIM before calibration

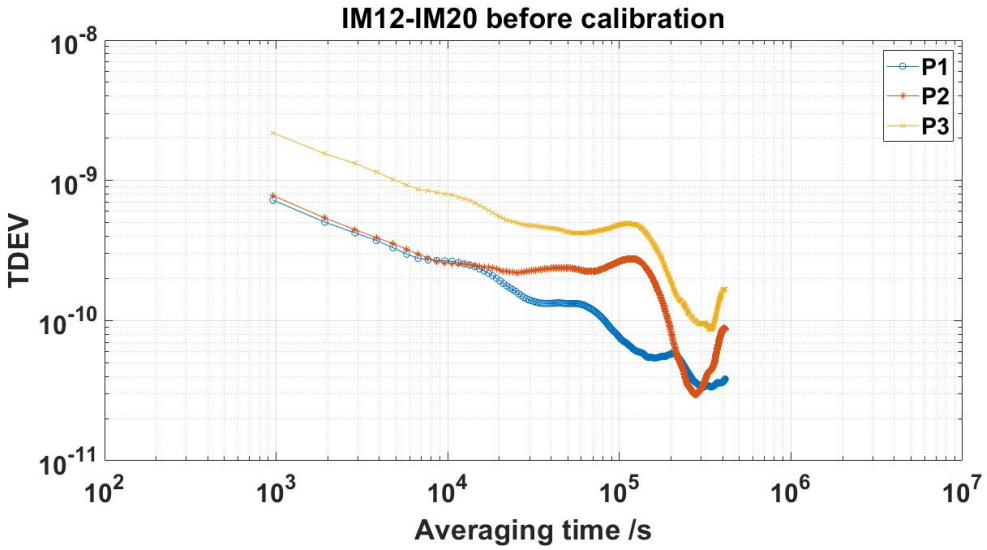


Figure 91. TDEV between IM12 and IM20 receivers at NIM before calibration

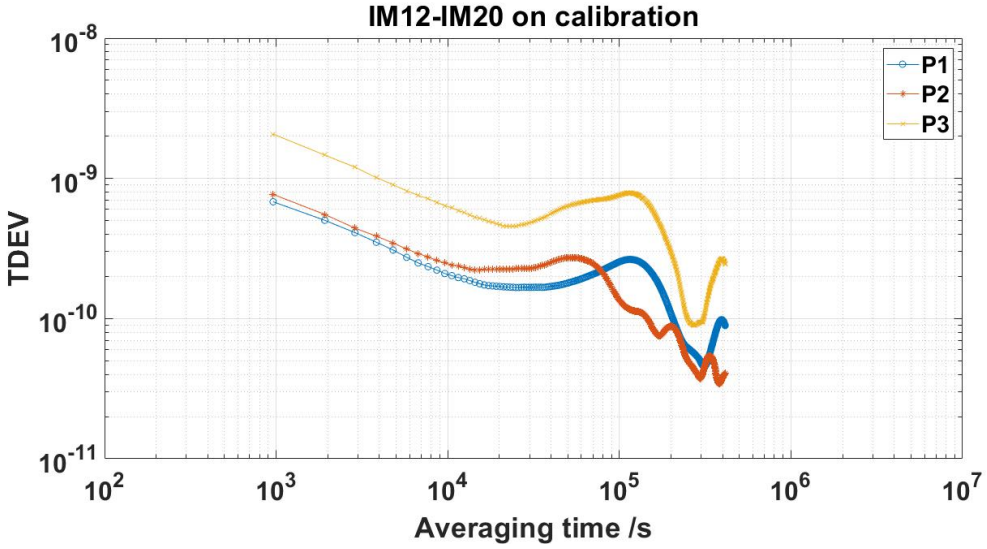


Figure 92. TDEV between IM12 and IM20 receivers at MASM during calibration

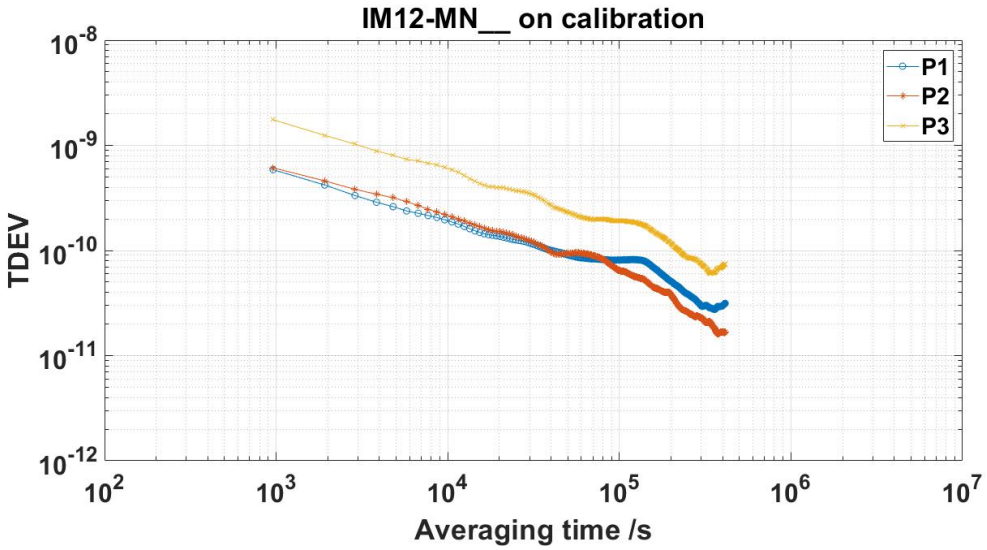


Figure 93. TDEV between IM12 and MN_ receivers at MASM during calibration

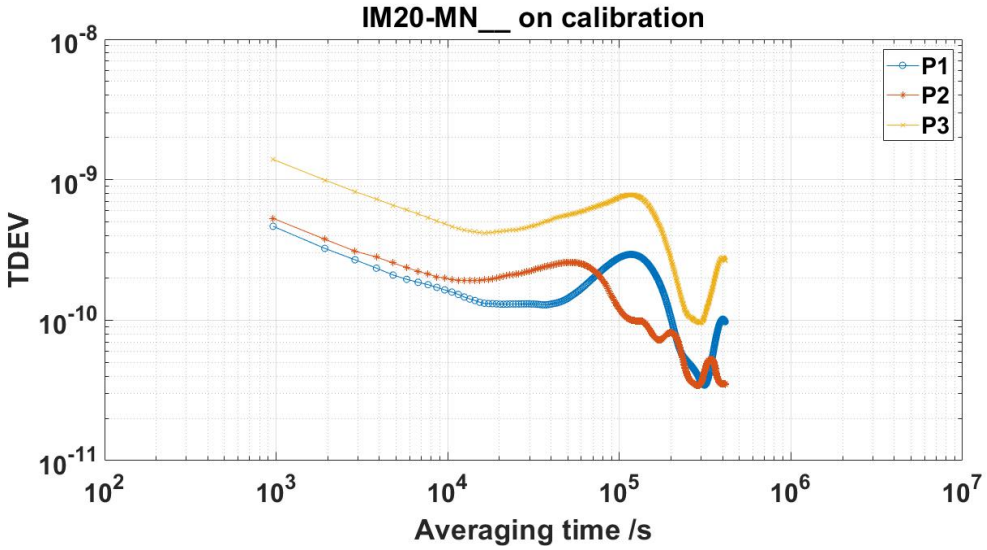


Figure 94. TDEV between IM20 and MN_ receivers at MASM during calibration

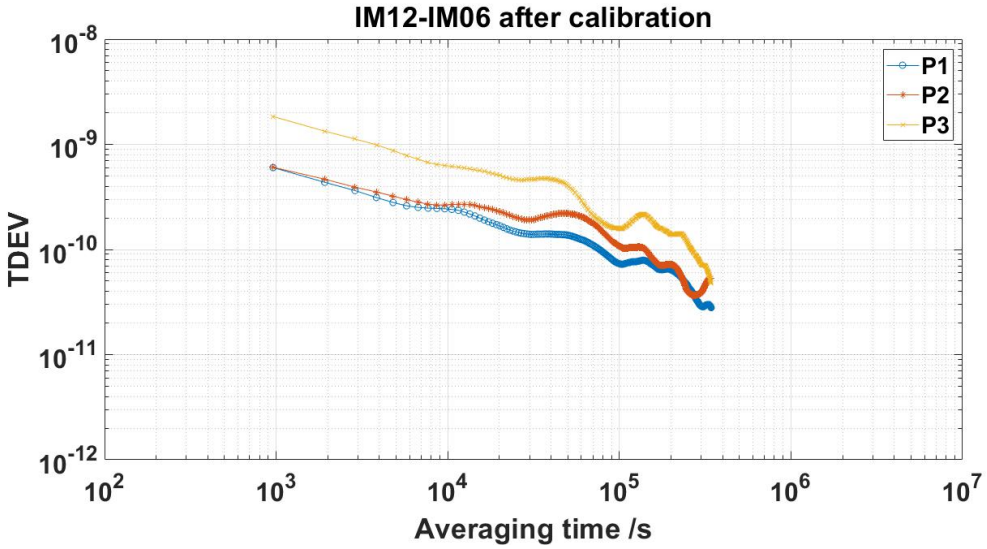


Figure 95. TDEV between IM12 and IM06 receivers at NIM after calibration

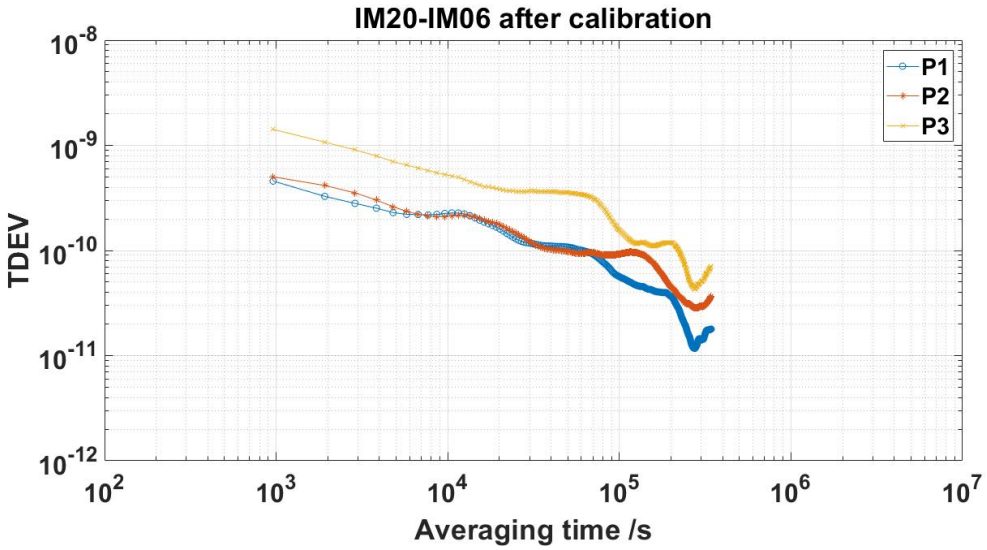


Figure 96. TDEV between IM20 and IM06 receivers at NIM after calibration

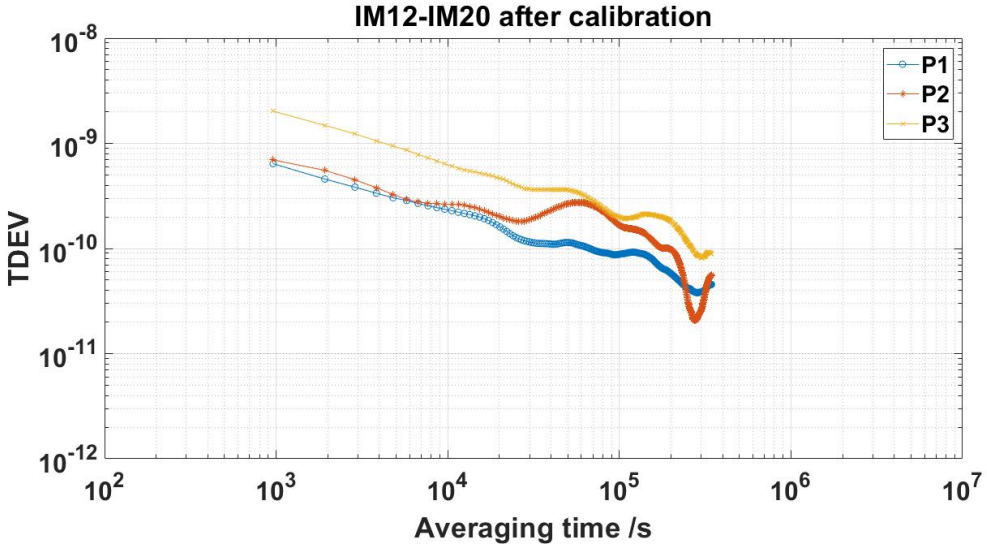


Figure 97. TDEV between IM12 and IM20 receivers at NIM after calibration

Annex 5 –TDEV for CCD results at NMC

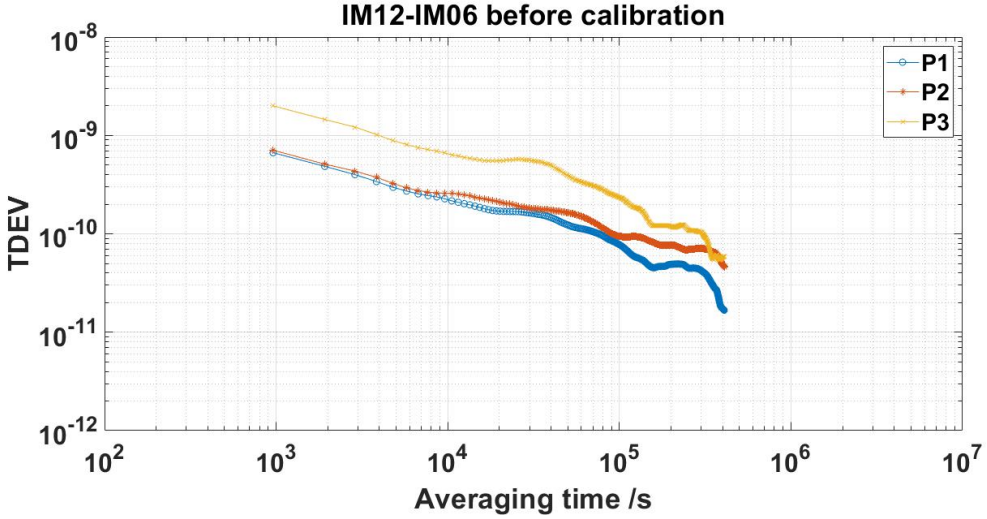


Figure 98. TDEV between IM12 and IM06 receivers at NIM before calibration

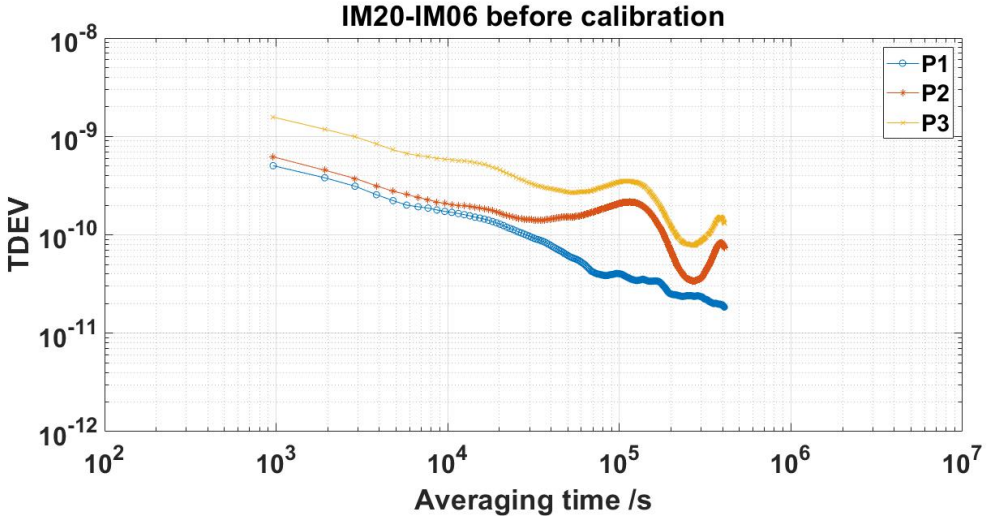


Figure 99. TDEV between IM20 and IM06 receivers at NIM before calibration

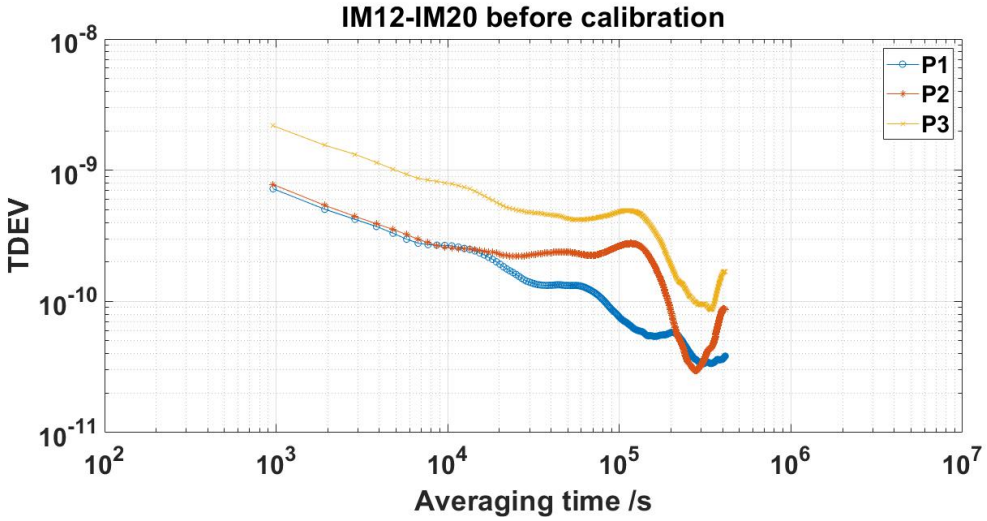


Figure 100. TDEV between IM12 and IM20 receivers at NIM before calibration

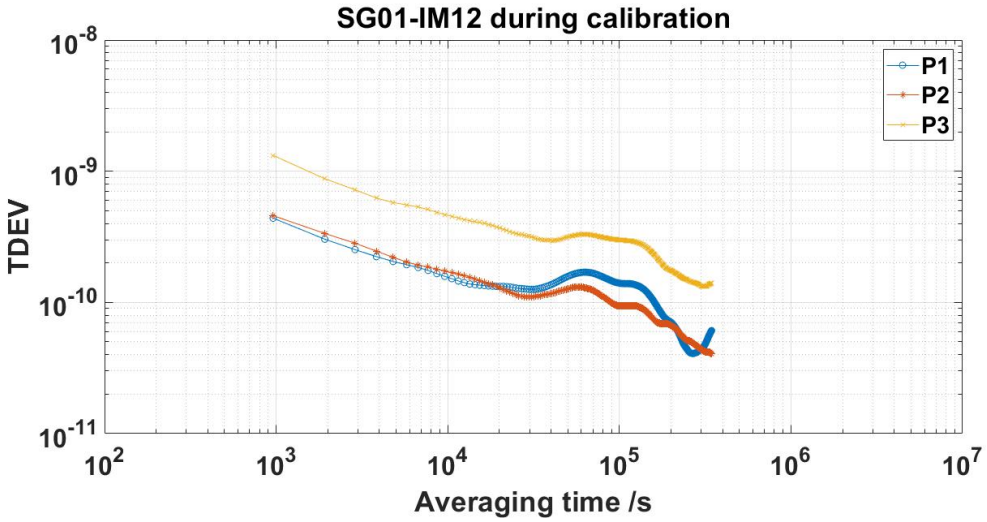


Figure 101. TDEV between SG01 and IM12 receivers at NMC on calibration

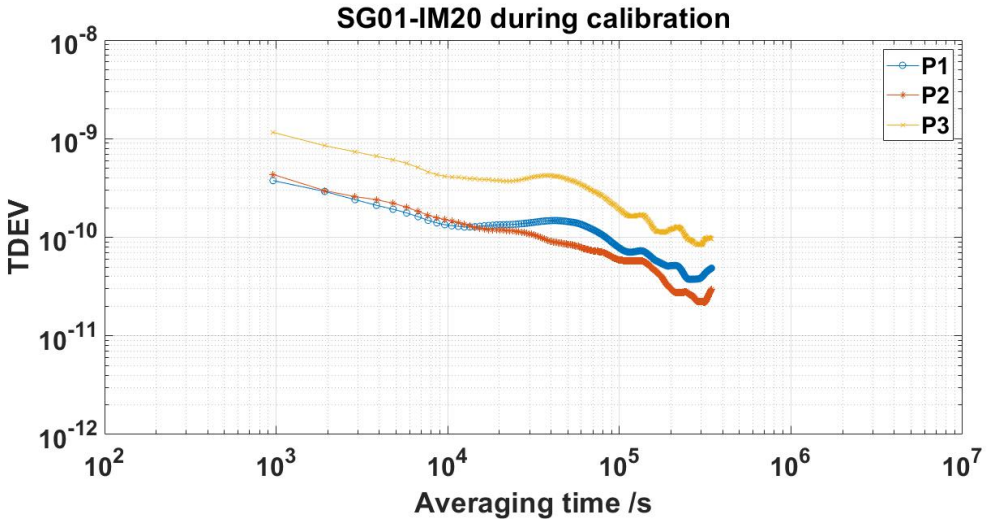


Figure 102. TDEV between SG01 and IM20 receivers at NMC on calibration

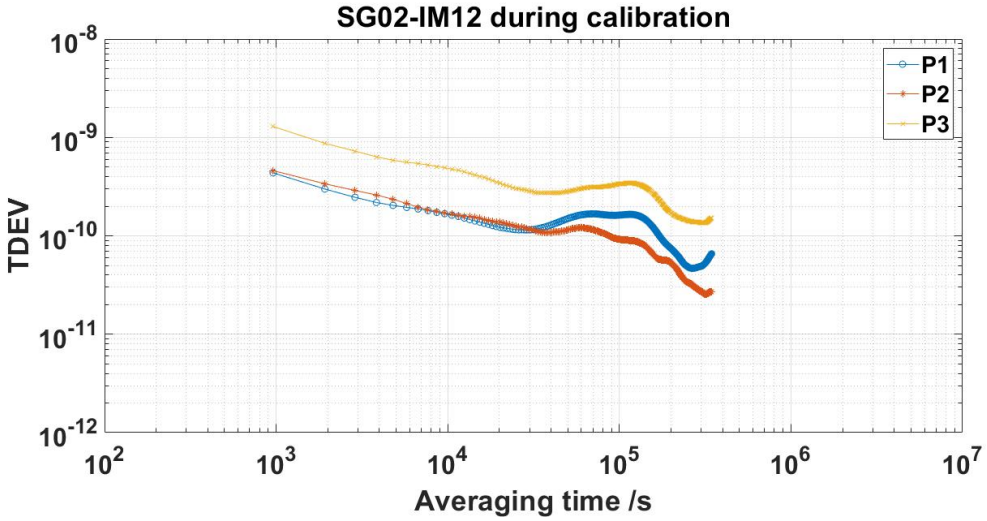


Figure 103. TDEV between SG02 and IM12 receivers at NMC on calibration

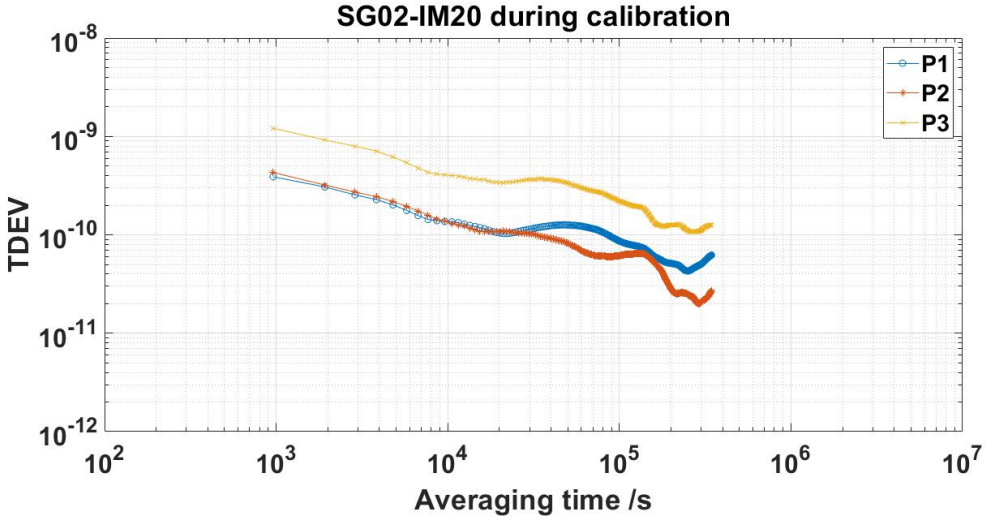


Figure 104. TDEV between SG02 and IM20 receivers at NMC on calibration

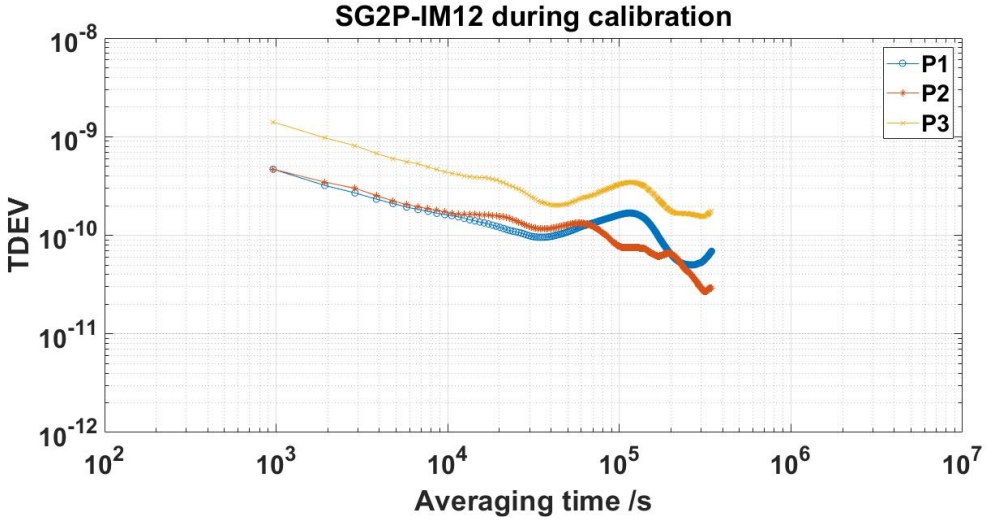


Figure 105. TDEV between SG2P and IM12 receivers at NMC on calibration

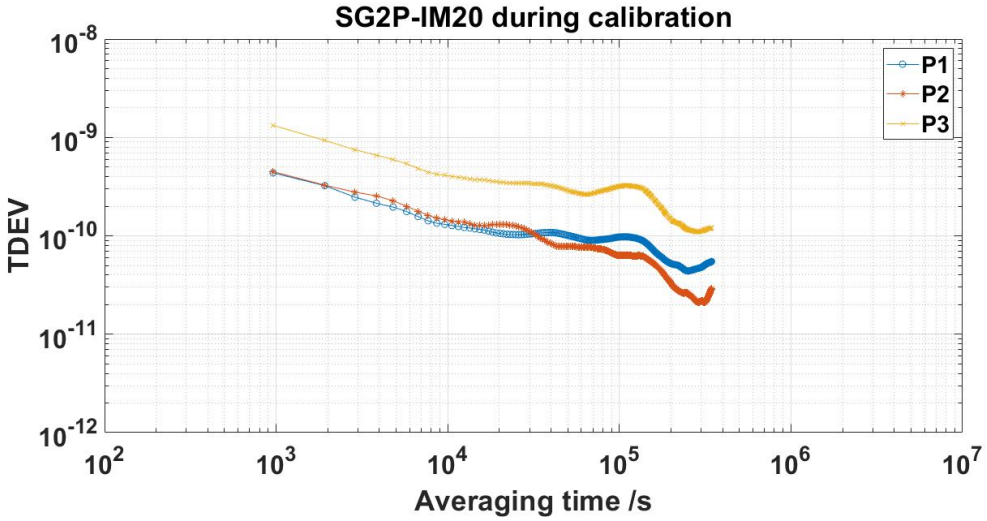


Figure 106. TDEV between SG2P and IM20 receivers at NMC on calibration

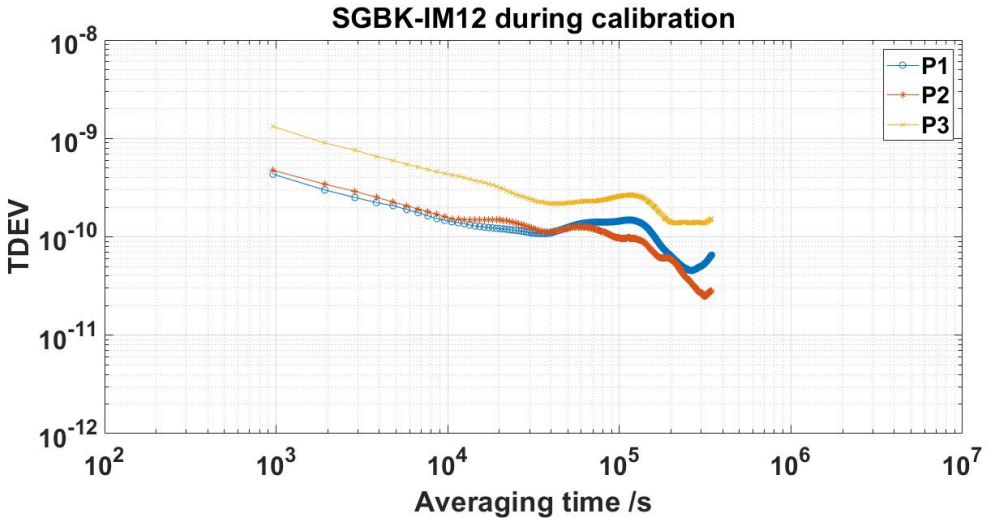


Figure 107. TDEV between SGBK and IM12 receivers at NMC on calibration

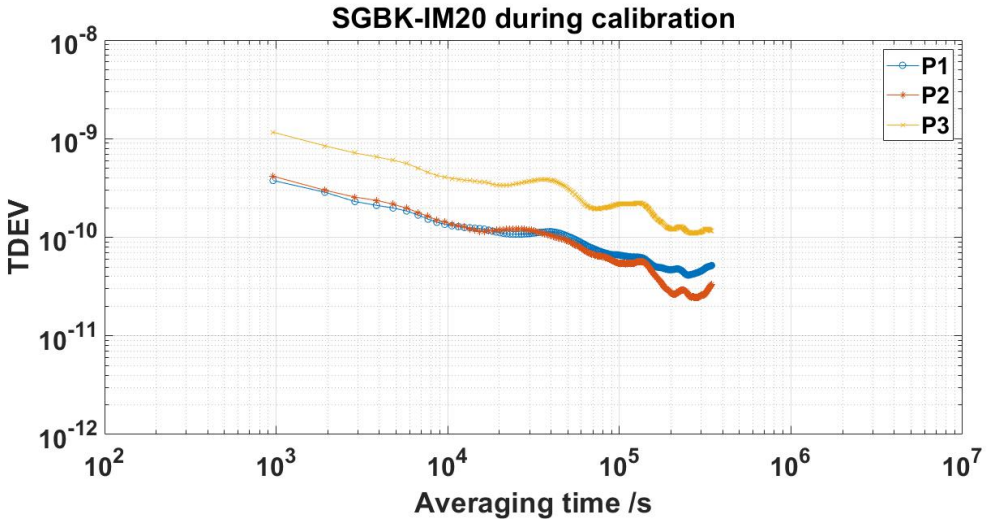


Figure 108. TDEV between SGBK and IM20 receivers at NMC on calibration

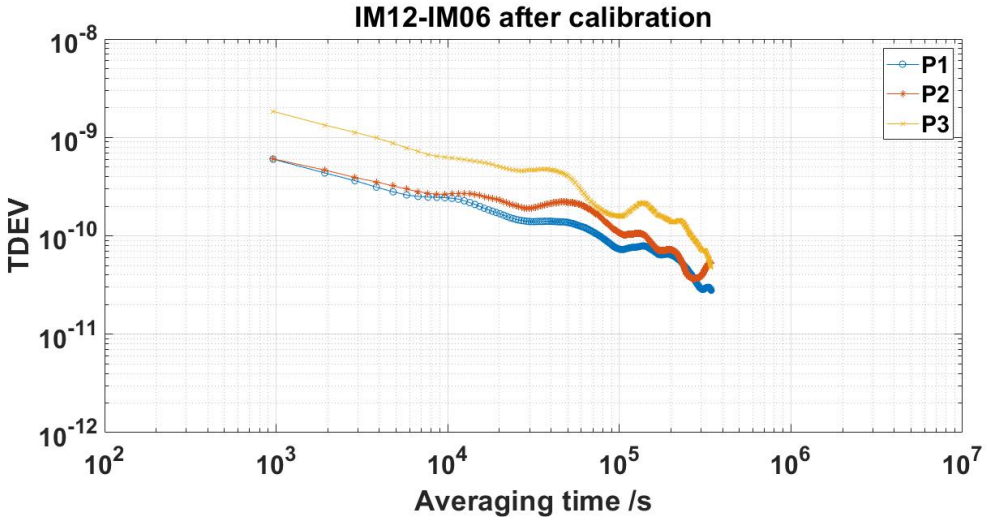


Figure 109. TDEV between IM12 and IM06 receivers at NIM after calibration

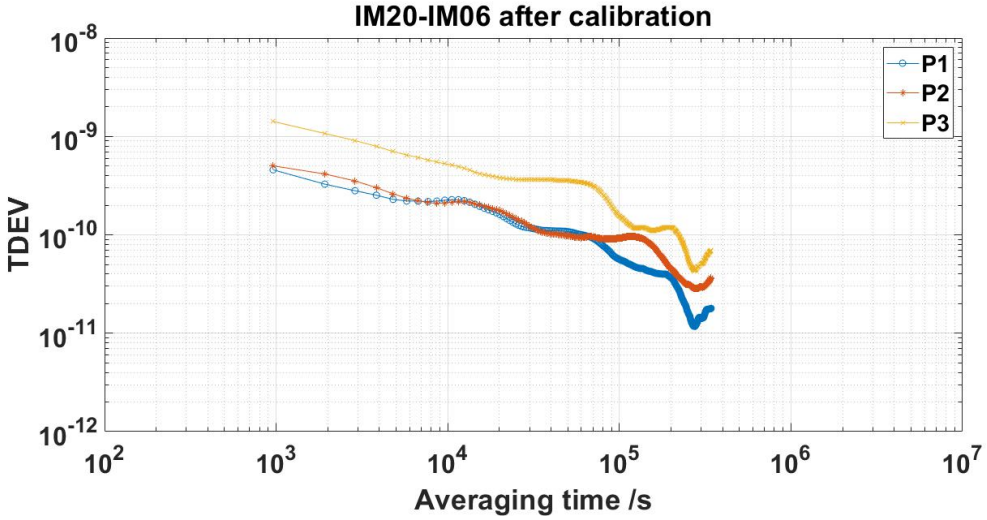


Figure 110. TDEV between IM20 and IM06 receivers at NIM after calibration

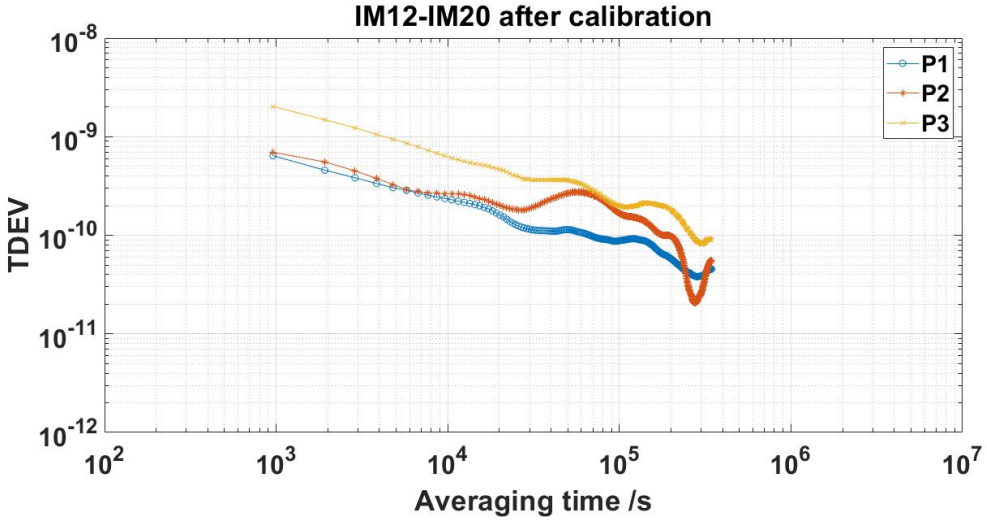


Figure 111. TDEV between IM12 and IM20 receivers at NIM after calibration