Report for Calibration of G2 Laboratory HKO and SCL by NIM

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The report is divided by eight 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 verification for the final results by processing Rinex observation using dclrinex program. In part 6, it is shown how the calibration uncertainties are evaluated. Climate parameters during the calibration is involved in part 7.

From the verification, we can find the final calibration uncertainties for codes are evaluated both as 1.8 ns.

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-001 has been installed and operated at HKO since the end of January of 2018. NIM Cal-001 was sent to SCL from HKO and arrived at SCL in early March of 2018. From mid-February, NIM Cal-001 was sent to NMC A*STAR from SCL and arrived at NMC A*STAR in Mid-April of 2018. Finally, it came back to NIM in early November mainly due to waiting for the authorization of the equipment from NMC A*STAR and their paperwork for the customs.

2. Description of the equipments and the operation method

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

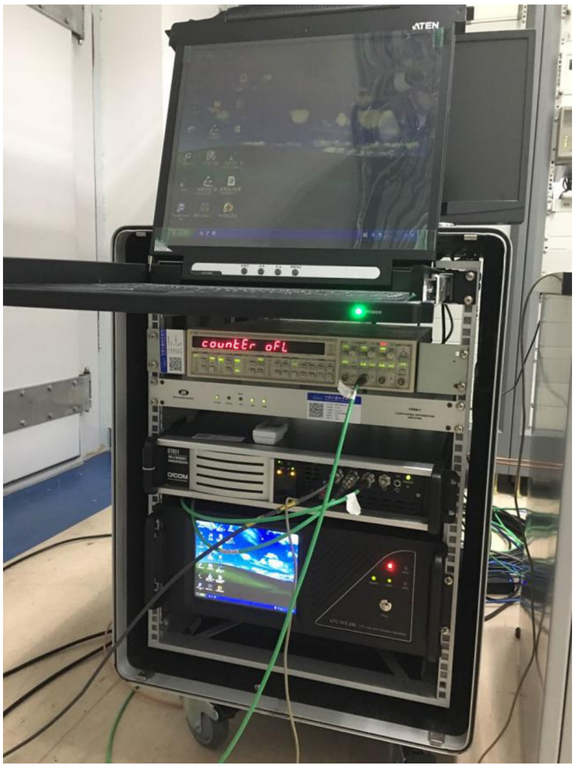


Figure 1. NIM calibrator(NIM Cal-001)

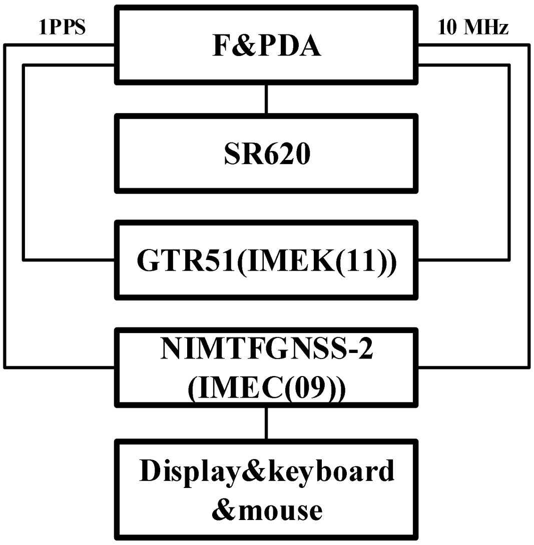


Figure 2. Schematic of NIM Cal-001

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

1. **NIMTFGNSS-2**: 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(site name for CGGTTS is IM09): NIM-TF-GNSS-2J(with antenna AT1675 AT-200)
IM11(site name for CGGTTS is IM11): 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. At SCL, the antenna cables for the calibrator cannot be installed since there is no specific path for the cables to be installed. There are only one spared antenna cable installed inside the wall in advance for calibration use, so only IMEC with this cable was used for the calibration measurements. At NMC A*STAR, there are the similar problems, however, there were two spared cables for the calibration use.

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	IM09	IM09	NIM-TF-GNSS-2	Traveling receiver	Traveling
NIM	IM11	IM11	GTR51	Traveling receiver	Traveling
HKO	HKO1	HKO1	TTS-4	Receiver to be calibrated	
HKO	HKO2	HKO2	TTS-4	Receiver to be calibrated	
SCL	SCL2	SCL2	PolaRx5TR	Receiver to be calibrated	Master, calibrated with IMEC

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	Place	Operation	Notes
MJD 58510-MJD 58119	NIM	Start CCD before calibration	Measurements used for computation from MJD 58510-MJD 58519
MJD 58159-MJD	HKO	Calibration on site	Measurements used for

58168			computation from MJD 58159-MJD 58168
MJD 58203-MJD 58210	SCL	Calibration on site	Measurements used for computation from MJD 58203-MJD 58210
MJD 58460 to 58466	NIM	Closure CCD after calibration	Measurements used for computation from MJD 58460-MJD 58466

The data from MJD 58159 to MJD 58168 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. IM06 (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 HKO and SCL was installed and the setups and the sub-delay information for start and closure experiments at NIM and calibration experiments on site at HKO and SCL were depicted in figure 4 and 5.

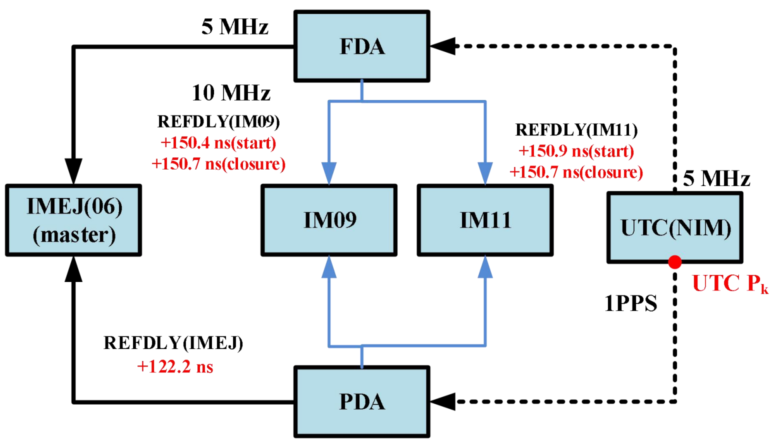


Figure 3. Experiment setup @NIM(for CCD experiments)

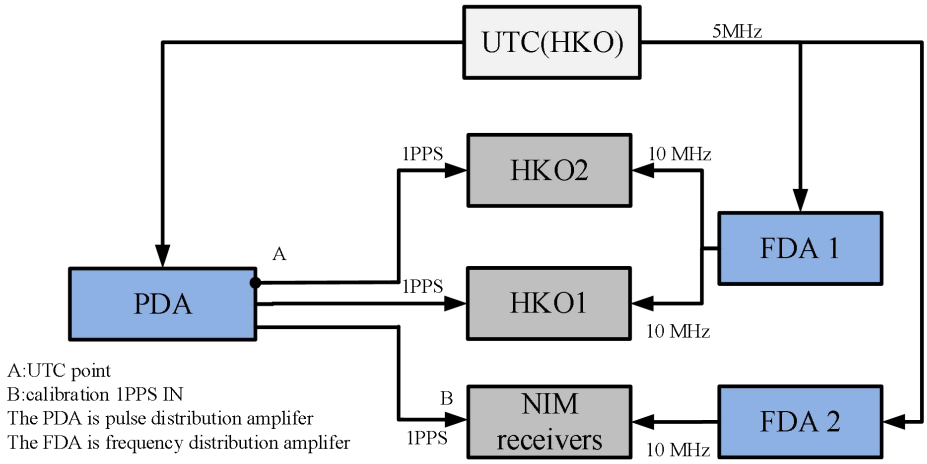


Figure 4. Experiment setup @HKO(for CCD experiments)

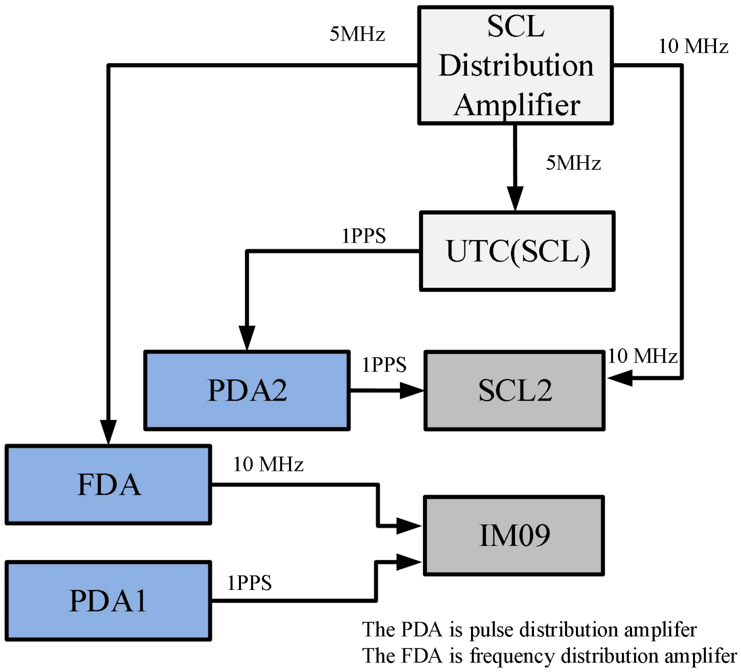


Figure 5. Experiment setup @SCL(for CCD experiments)

4. Data processing

The calibration tour is divided into three phases including start CCD before calibration, calibration on site and closure CCD after calibration. Thus, data processing results are divided into three sides.

4.1. HKO

4.1.1. Start CCD before calibration

Table 3. Real measurements of sub-delays for the sites in start experiment at NIM

Receiver	Ref-PPSin(XP) / ns	Meas 3.1(3.3)	Meas 3.2	Ant. Cable (XC+XD) / ns
		Int ref – 1PPSin(XO) / ns		
IM09	150.4	/		203.0
IM11	150.9	/		177.1
IM06	122.2	/		248.7

4.1.2. Calibration on site

Table 4. Real measurements of sub-delays for the sites in calibration experiment at HKO

Receiver	Ref-PPSin(XP) / ns	Meas 3.1(3.3)	Meas 3.2	Ant. Cable (XC+XD) / ns
		Int ref – 1PPSin(XO) / ns		
HKO1	1.49 ns (1PPS DLY: 7.92 ns, phase corr: -6.43 ns)	/		333.89
HKO2	12.70 ns (1PPS DLY: 7.92 ns, phase corr: 4.78 ns)	/		423.33
IM09	40.580	/		203
IM11	40.622	/		177.1

Note: The REFDLY values of HKO receivers have been measured in full accordance with the Annex 1 of the HKO calibration guidelines.

4.1.3. Closure CCD after calibration

Table 5. Real measurements of sub-delays for the sites in closure experiment at NIM

Receiver	Ref-PPSin(XP) / ns	Meas 3.1(3.3)	Meas 3.2	Ant. Cable (XC+XD) / ns
		Int ref – 1PPSin(XO) / ns		
IM09	150.7	/		203.0
IM11	150.7			177.1
IM06	122.2	/		248.7

4.2. SCL

4.2.1. Start CCD before calibration

Table 6. Real measurements of sub-delays for the sites in start experiment at NIM

Receiver	Ref-PPSin(XP) / ns	Meas 3.1(3.3)	Meas 3.2	Ant. Cable (XC+XD) / ns
		Int ref – 1PPSin(XO) / ns		
IMEC	150.4	/		203.0
IMEJ	122.2	/		248.7

4.2.2. Calibration on site

Table 7. Real measurements of sub-delays for the sites in calibration experiment at SCL

Receiver	Ref-PPSin(XP) / ns	Meas 3.1(3.3)	Meas 3.2	Ant. Cable (XC+XD) / ns
		Int ref – 1PPSin(XO) / ns		
SCL2	10.0	/		512.0
IMEC	10.0	/		526.6

4.2.3. Closure CCD after calibration

Table 8. Real measurements of sub-delays for the sites in closure experiment at NIM

Receiver	Ref-PPSin(XP) / ns	Meas 3.1(3.3)	Meas 3.2	Ant. Cable (XC+XD) / ns
		Int ref – 1PPSin(XO) / ns		
IM09	150.7	/		203.0
IMEJ	122.2	/		248.7

5. Calibration computation and calibration values

CGGTTS file headers
IM09
MJD 58110-58119
INT DLY = 0.0 ns (GPS P3)
CAB DLY = 203.0 ns (GPS)
REF DLY = 150.4 ns
MJD 58159-58168
INT DLY = 0.0 ns (GPS P3)
CAB DLY = 203.0 ns (GPS)
REF DLY = 0.2 ns
MJD 58203-58210
INT DLY = 0.0 ns (GPS P3)
CAB DLY = 526.6 ns
REF DLY = 10.0 ns
MJD 58460-58466
INT DLY = 0.0 ns (GPS P3)

CAB DLY = 203.0 ns
REF DLY = 150.7 ns
IM11
MJD 58110-58119
INT DLY = -29.2 ns (GPS C1), -35.0 ns (GPS P1), 0.0 ns (GPS C2), -37.5 ns (GPS P2), 0.0 ns (GPS L5)
CAB DLY = 177.1 ns
REF DLY = 150.9 ns
MJD 58159-58168
INT DLY = -29.2 ns (GPS C1), -35.0 ns (GPS P1), 0.0 ns (GPS C2), -37.5 ns (GPS P2), 0.0 ns (GPS L5)
CAB DLY = 177.1 ns
REF DLY = 0.2 ns
MJD 58460-58466
INT DLY = -29.2 ns (GPS C1), -35.0 ns (GPS P1), 0.0 ns (GPS C2), -37.5 ns (GPS P2), 0.0 ns (GPS L5)
CAB DLY = 177.1 ns
REF DLY = 150.7 ns

HKO1
MJD 58159-58168
INT DLY = [ns] GPS, L1C:-22.50 L2C:0.00 L1P:0.00 L2P:0.00 L5P:0.00,GLO: L1C:-228.06 L2C:0.00 L1P:0.00 L2P:0.00
CAB DLY = 333.89 ns (GPS)
REF DLY = 12.70 ns (1PPS DLY: 7.92 ns, phase corr: 4.78 ns)
HKO2
MJD 58159-58168
INT DLY = [ns] GPS: L1C:-19.66 L2C:0.00 L1P:0.00 L2P:0.00 L5P:0.00, GLO: L1C:-225.07 L2C:0.00 L1P:0.00 L2P:0.00
CAB DLY = 423.33 ns (GPS), 423.33 ns (GLONASS)
REF DLY = 1.49 ns (1PPS DLY: 7.92 ns, phase corr: -6.43 ns)

BM52
MJD 58203-58210
INT DLY = 0.0 ns (GPS P1) 0.0 ns (GPS P2) CAL_ID =
CAB DLY = 512.0 ns
REF DLY = 10.0 ns

Compensation for P1 and P2 results:
IM09
MJD 58110-58119 150.4-203.0 = -52.6 ns
MJD 58159-58168 0.2-203.0 = -202.8 ns
MJD 58203-58210 10-526.6 = -516.6 ns
MJD 58460-58466 150.7-203.0 = -52.3 ns

Note: P3 results are calculated by the formula P3=P1*2.54573-P2*1.54573. In the figures, the P1, P2 and P3 results are compensated by these corresponding values. IM06 has all the delays in CGGTTS header compensated in Rinex data.

5.1. Start CCD before Calibration

Table 9. Results for the sites by dclrinex in start experiment at NIM

Before calibration (ns)	P1		P2		P3	P1-P2
	Mean	Std	Mean	Std	Mean	Mean
IM09-IM06	-19.0	0.3	-14.1	0.4	-26.7	-5.0
IM11-IM06	-3.4	0.4	-1.0	0.5	-7.2	-2.4

5.2. Calibration on site

Table 10. Results for the sites by dclrinex in calibration experiment at HKO

On site(ns)	P1	P2	P3	P1-P2
	Mean	Mean	Mean	Mean
HKO1-IM09	42.7	36.3	52.7	6.4
HKO2-IM09	33.9	26.3	45.5	7.6
HKO1-IM11	26.6	22.9	33.4	3.8
HKO2-IM11	18.1	13.0	25.8	5.0
SCL2- IM09	70.3	65.0	78.4	5.3

5.3. Closure CCD after calibration

Table 11. Results for the sites by dclrinex in closure experiment at NIM

After Calibration(ns)	P1		P2		P3	P1-P2
	Mean	Std	Mean	Std	Mean	Mean
IM09-IM06	-18.3	0.4	-13.2	0.4	-26.1	-5.1
IM11-IM06	-3.2	0.5	-0.1	0.8	-6.6	-2.2

5.4. Calibration calculation

We can get the similar CCD values using dclrinex of HKO and SCL to the ones solved in section 8 by ourselves. The differences between them are smaller than 0.7 ns. So we can think the P3 calibration values from two processing methods should be agreed with each other. Anyway, we calculated the P1, P2 and P3 calibration values using CCD values using dclrinex as follows.

P1 and P2 calculation algorithm: $(XR+XS)_{RUC}$ = CCD(RUC-Calibrator)-compensation of IM20 for P1 and P2-$(XC+XD)_{RUC}$+$(XO+XP)_{RUC}$+ CCD(Calibrator-Ref)

RUC: Receiver under calibration

Ref: calibration reference receiver, NIM master GPS time and frequency

receiver IM06(IM06)
P3 calculation algorithm is the same to that of section 8.

Based on IM09

$(XR+XS)_{HKO1\_P1}$=42.72-(12.7-333.89-0)+(0.2-203-0)-(0.2+40.380-203-0)+7.92+4.78 -333.89+(-19.03) =-16.69 ns
$(XR+XS)_{HKO1\_P2}$=36.30-(12.7-333.89-0)+(0.2-203-0)-(0.2+40.380-203-0)+7.92+4.78 -333.89+(-14.07) =-18.15 ns
$(XR+XS)_{HKO1\_P3}$=52.65-(12.7-333.89-0)+(0.2-203-0)-(0.2+40.380-203-0)+7.92+4.78 -333.89+(-26.70) =-14.43 ns

$(XR+XS)_{HKO2\_P1}$=33.87-(1.49-423.33-0)+(0.2-203-0)-(0.2+40.380-203-0)+7.92-6.43-423.33+(-19.03) = -25.54 ns
$(XR+XS)_{HKO2\_P2}$=26.31-(1.49-423.33-0)+(0.2-203-0)-(0.2+40.380-203-0)+7.92-6.43-423.33+(-14.07) = -28.14 ns
$(XR+XS)_{HKO2\_P3}$=45.55-(1.49-423.33-0)+(0.2-203-0)-(0.2+40.380-203-0)+7.92-6.43-423.33+(-26.70) = -21.53 ns

$(XR+XS)_{SCL2\_P1}$=70.3-(10+40.380-526.6-0)+10-512+(-19.0)=25.5 ns
$(XR+XS)_{SCL2\_P2}$=65.0-(10+40.380-526.6-0)+10-512+(-14.1)=25.1 ns
$(XR+XS)_{SCL2\_P3}$=78.4-(10+40.380-526.6-0)+10-512+(-26.7)=25.9 ns

Based on IM11
$(XR+XS)_{HKO1\_P1}$=26.60-(12.7-333.89-0)+(0.2-177.1-(-35))-(0.2+40.422-177.1-(-35)) +7.92+4.78-333.89-3.42=-17.24 ns
$(XR+XS)_{HKO1\_P2}$=22.85-(12.7-333.89-0)+(0.2-177.1-(-37.5))-(0.2+40.422-177.1-(-37.5))+ 7.92+4.78-333.89-1.00=-18.57 ns
$(XR+XS)_{HKO1\_P3}$=33.40-(12.7-333.89-0)+(0.2-177.1-(2.54573*(-35)-1.54573*(-37.5)))- (0.2+40.422-177.1-(2.54573*(-35)-1.54573*(-37.5)))+ 7.92+4.78-333.89-7.17=-14.19 ns

$(XR+XS)_{HKO2\_P1}$=18.05-(1.49-423.33-0)+(0.2-177.1-(-35))-(0.2+40.422-177.1-(-35)) +7.92-6.43-423.33-3.42 = -25.79 ns
$(XR+XS)_{HKO2\_P2}$=13.04-(1.49-423.33-0)+(0.2-177.1-(-37.5))-(0.2+40.422-177.1-(-37.5))+7.92-6.43-423.33-1.00 = -28.38 ns
$(XR+XS)_{HKO2\_P3}$=25.79-(1.49-423.33-0)+(0.2-177.1-(2.54573*(-35)-1.54573*(-37.5)))- (0.2+40.422-177.1-(2.54573*(-35)-1.54573*(-37.5))) +7.92-6.43-423.33-7.17 = -21.80 ns

Averaged calibration values:

$(XR+XS)_{HKO1\_P1}$=(-16.69-17.24)/2=**-17.0 ns**
$(XR+XS)_{HKO1\_P2}$=(-18.15-18.57)/2=**-18.4 ns**

(XR+XS)$_{HKO1\_P3}$=(-14.43-14.19)/2=**-14.3 ns**

(XR+XS)$_{HKO2\_P1}$=(-25.54-25.79)/2=**-25.7 ns**
(XR+XS)$_{HKO2\_P2}$=(-28.14-28.38)/2=**-28.2 ns**
(XR+XS)$_{HKO2\_P3}$=(-21.53-21.80)/2=**-21.7 ns**

Based on IM09
(XR+XS)$_{SCL2\_P1}$=25.5 ns
(XR+XS)$_{SCL2\_P2}$=25.1 ns
(XR+XS)$_{SCL2\_P3}$=25.9 ns

6. Uncertainty Evaluation

Here we evaluated the uncertainty from the sources as follows and got the combined uncertainty as 1.8 ns conservatively for P3 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.

Table 12. Uncertainty contributions

Unc.	Value P1 (ns)	Value P2 (ns)	Value C1 (ns)	Value P3 (ns)	Description
u_a (T-V)	0.5	0.5	0.8	0.9	RAWDIF (traveling-visited)
u_a (T-R)	0.5	0.5	0.7	0.8	RAWDIF (traveling-reference)
u_a	0.7	0.7	1.1	1.2	
Misclosure					
$u_{b,1}$	0.1	0.1	0.3	0.1	observed mis-closure
Systematic components related to RAWDIF					
$u_{b,11}$	0.05	0.05	0.05	0.05	Position error at reference
$u_{b,12}$	0.05	0.05	0.05	0.05	Position error at visited
$u_{b,13}$	0.3	0.3	0.3	0.3	Multipaths at reference
$u_{b,14}$	0.3	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	0.5	$REFDLY_T$ (at ref lab)
$u_{b,22}$	0.5	0.5	0.5	0.5	$REFDLY_T$ (at visited lab)
$u_{b,TOT}$	0.8	0.8	0.8	0.8	
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)
$u_{b,SYS}$	1.1	1.1	1.1	1.1	Components of equation (2)
u_{CAL}	1.5	1.5	1.7	1.8	Composed of u_a and $u_{b,SYS}$
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	$CABDLY_V$
Combined Uncertainty: 1.8 ns					

7. Climate parameters

7.1. Temperature and humidity

22°C ±1°C

40% ±5%

7.2. Reference signal

Rise time of the local UTC pulse: < 5 ns

References:

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

Annex 1. CCD results for HKO

1. Start CCD before calibration

IM09-IM06

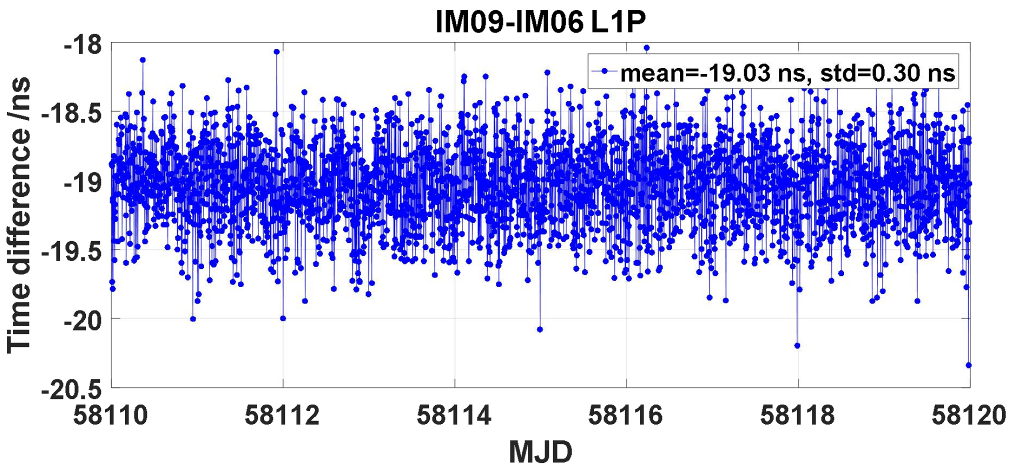


Figure 6. CCD between IM09 and IM06 at NIM(L1P)

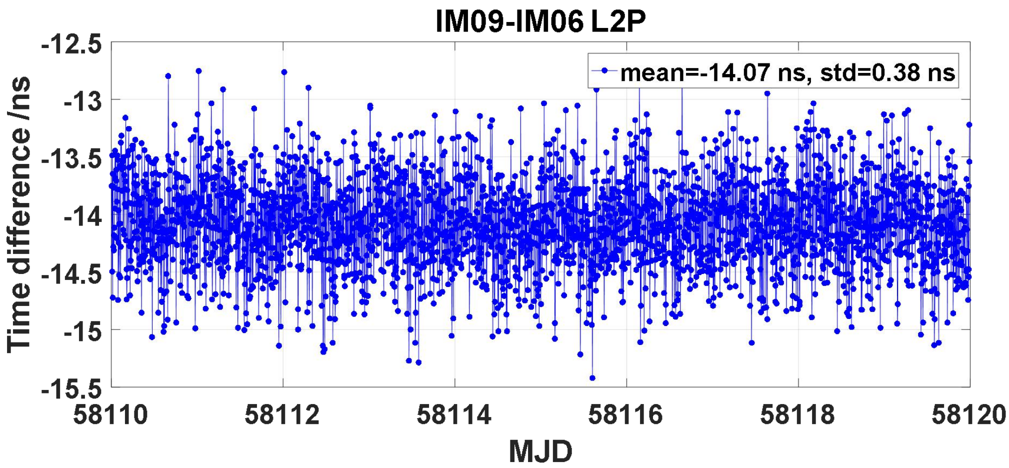


Figure 7. CCD between IM09 and IM06 at NIM(L2P)

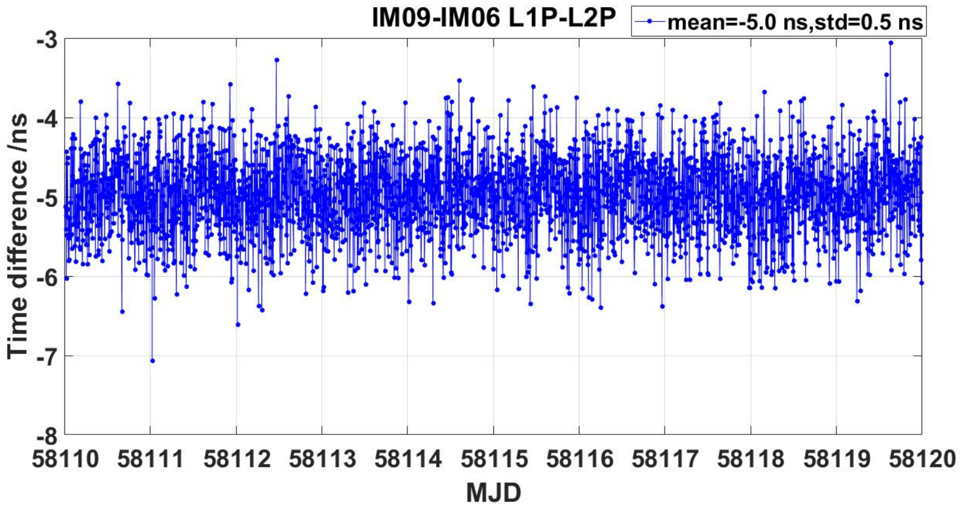


Figure 8. CCD between IM09 and IM06 at NIM(L1P-L2P)

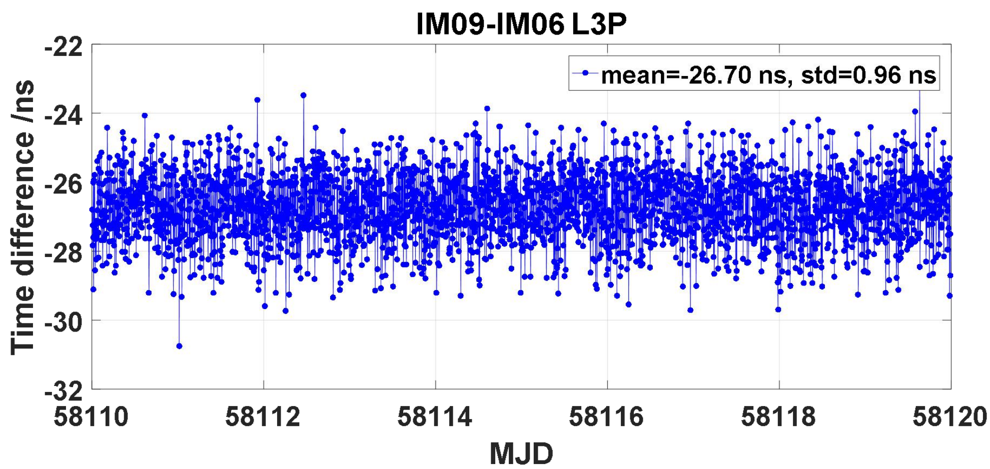


Figure 9. CCD between IM09 and IM06 at NIM(L3P)

IM11-IM06

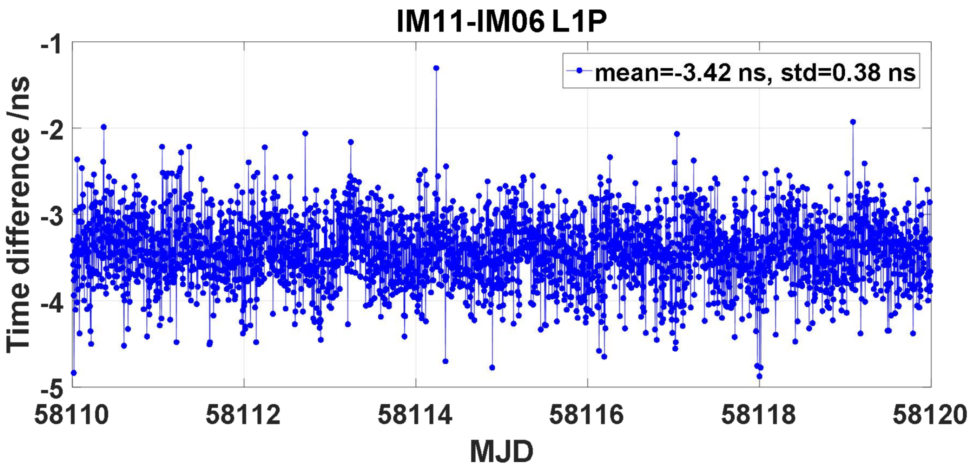


Figure 10. CCD between IM11 and IM06 at NIM(L1P)

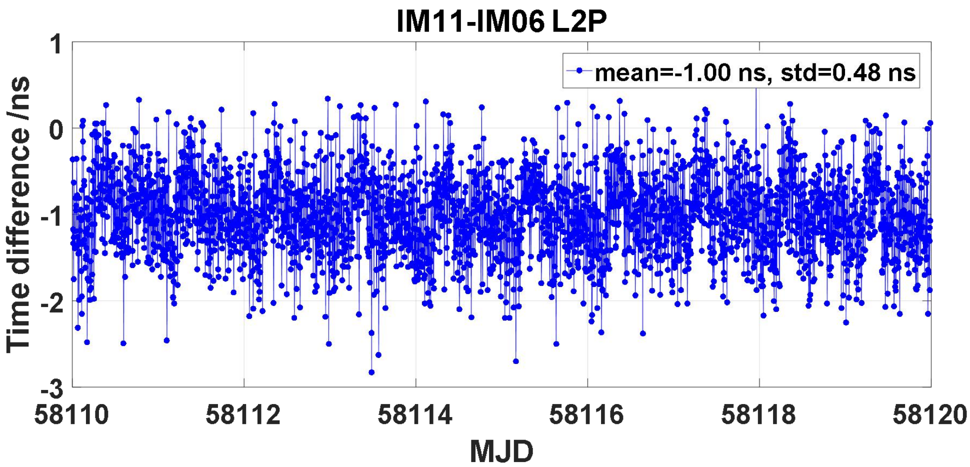


Figure 11. CCD between IM11 and IM06 at NIM(L2P)

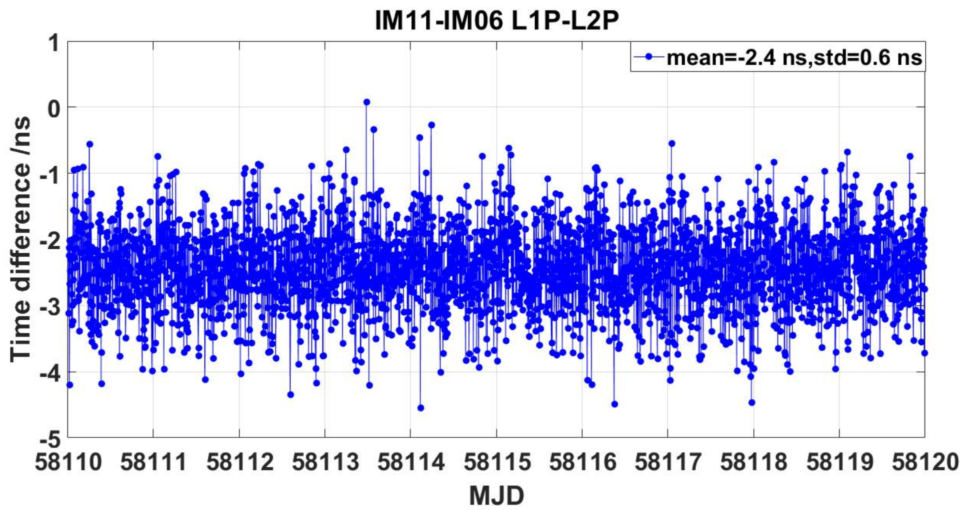


Figure 12. CCD between IM11 and IM06 at NIM(L1P-L2P)

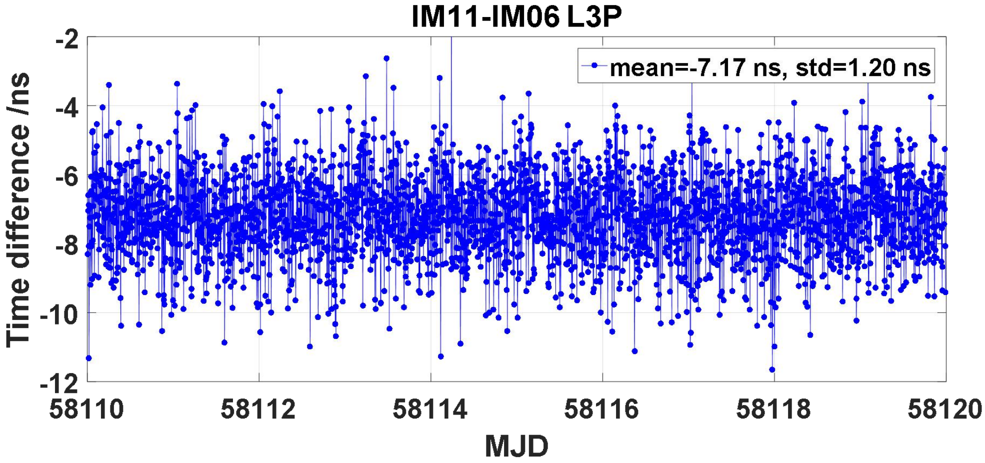


Figure 13. CCD between IM11 and IM06 at NIM(L3P)

2. Calibration on site

HKO1-IM09

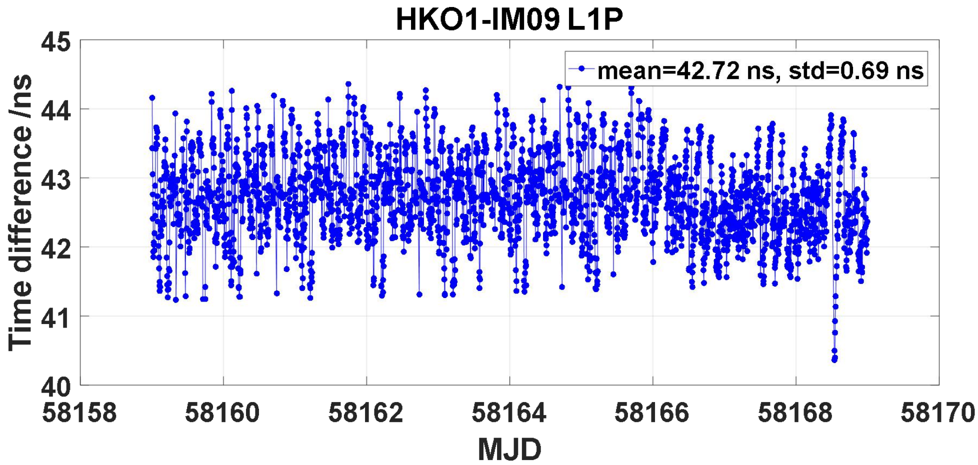


Figure 14. CCD between IM09 and HKO1 at HKO (L1P)

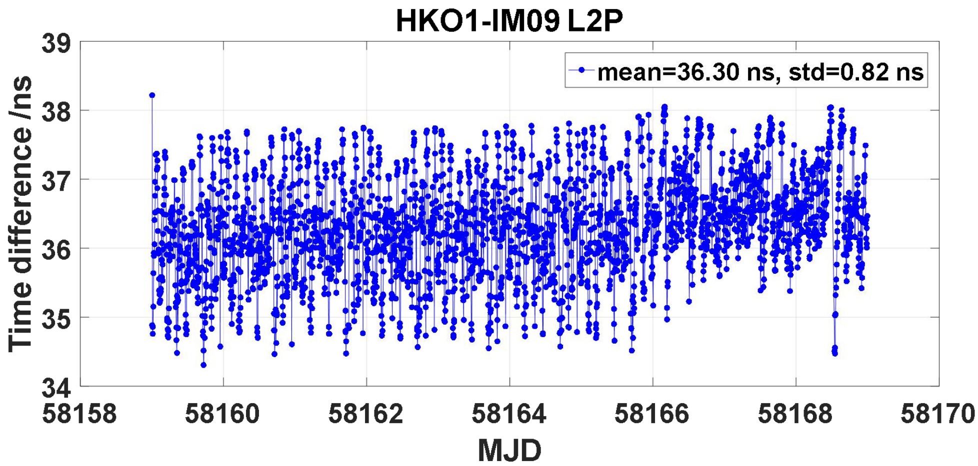


Figure 15. CCD between IM09 and HKO1 at HKO(L2P)

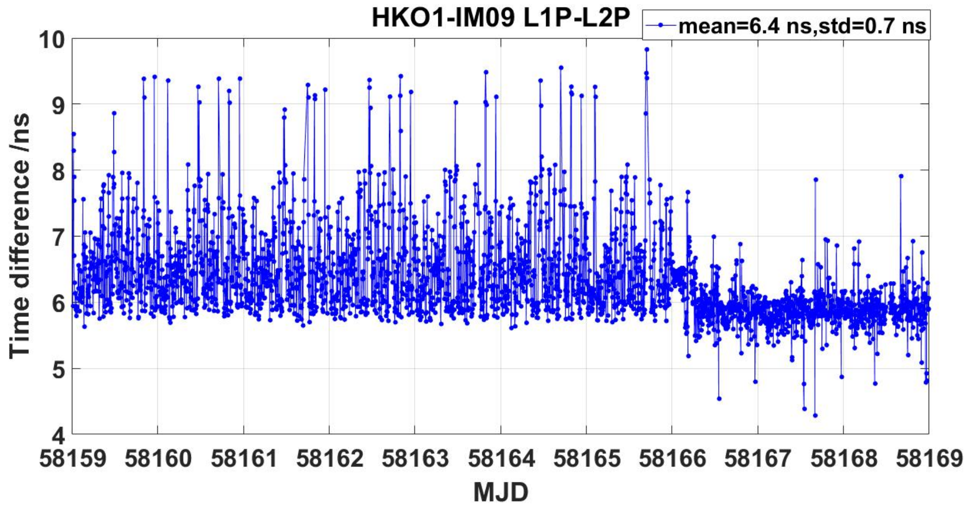


Figure 16. CCD between IM09 and HKO1 at HKO(L1P-L2P)

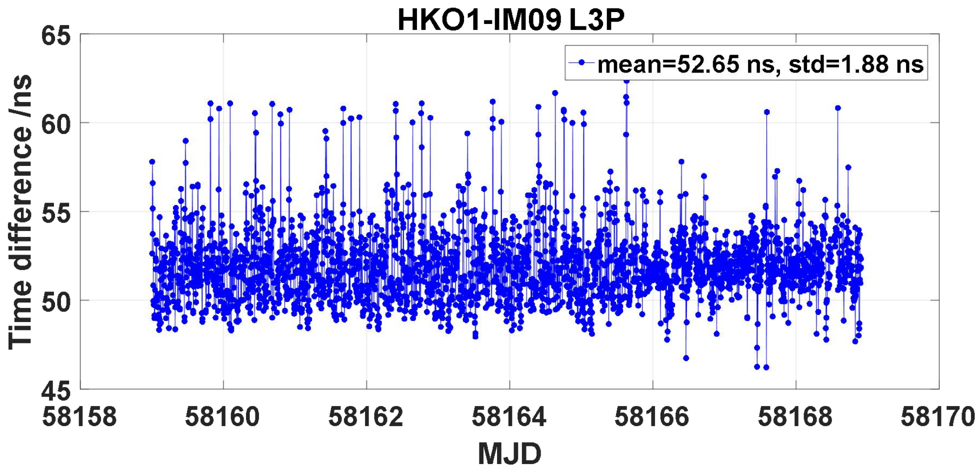


Figure 17. CCD between IM09 and HKO1 at HKO(L3P)

HKO1-IM11

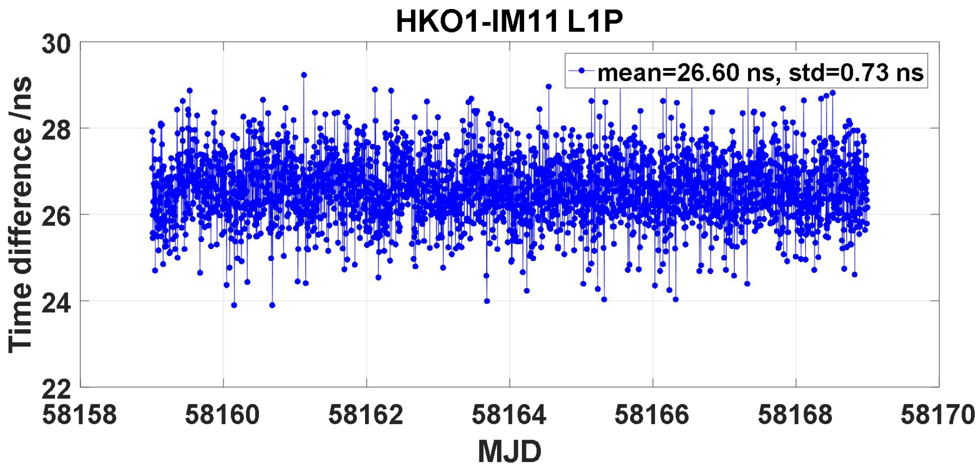


Figure 18. CCD between IM11 and HKO1 at HKO(L1P)

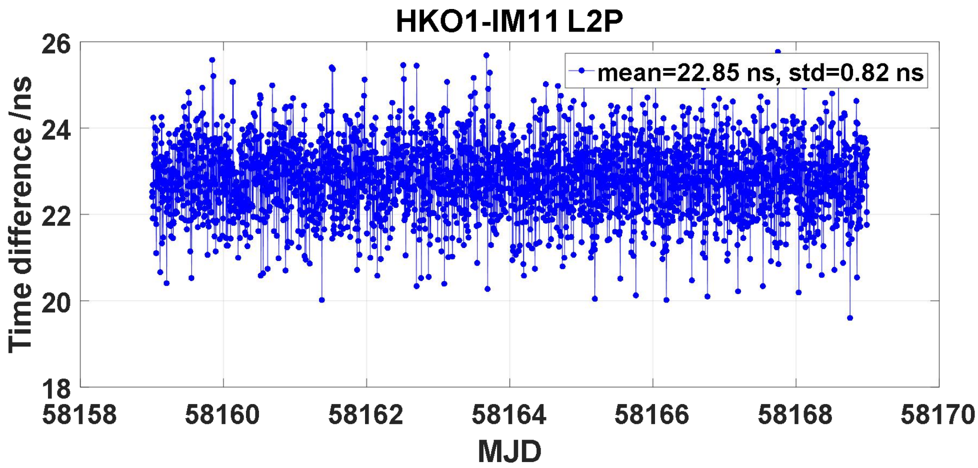


Figure 19. CCD between IM11 and HKO1 at HKO(L2P)

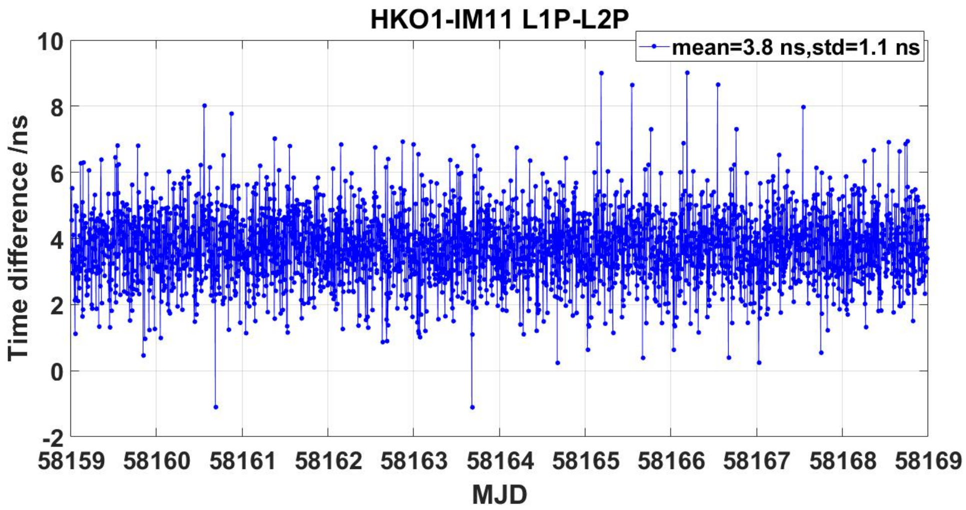


Figure 20. CCD between IM11 and HKO1 at HKO(L1P-L2P)

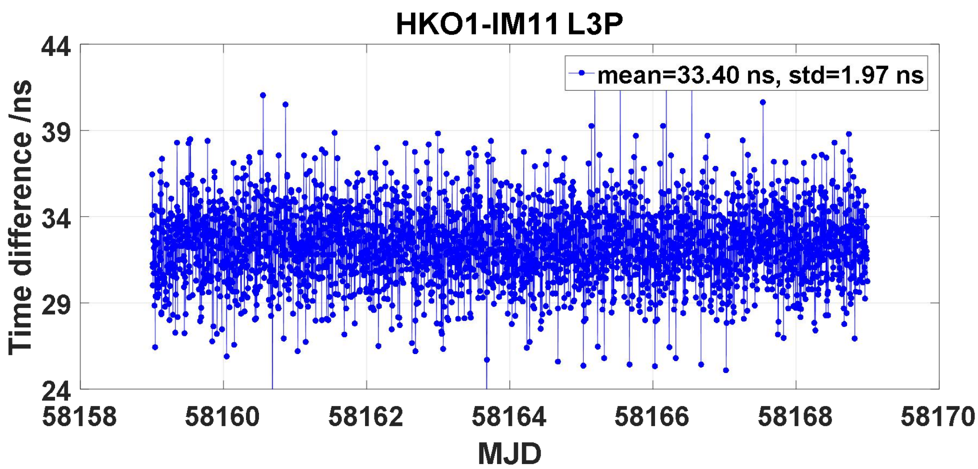


Figure 21. CCD between IM11 and HKO1 at HKO(L3P)

HKO2-IM09

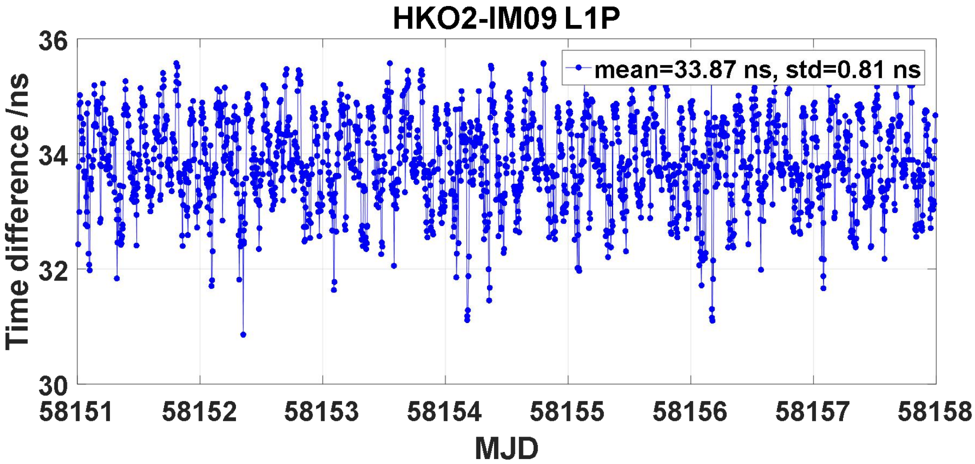


Figure 22. CCD between IM09 and HKO2 at HKO(L1P)

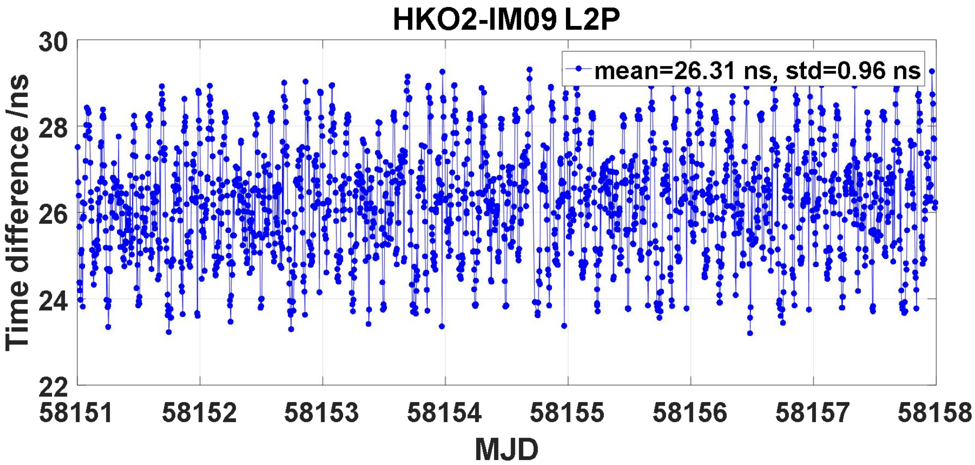


Figure 23. CCD between IM09 and HKO2 at HKO(L2P)

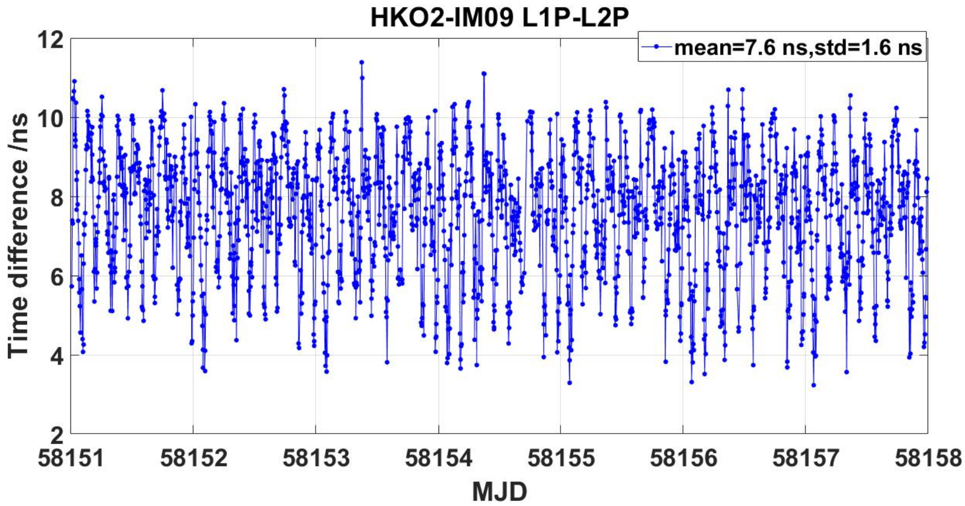


Figure 24. CCD between IM09 and HKO2 at HKO(L1P-L2P)

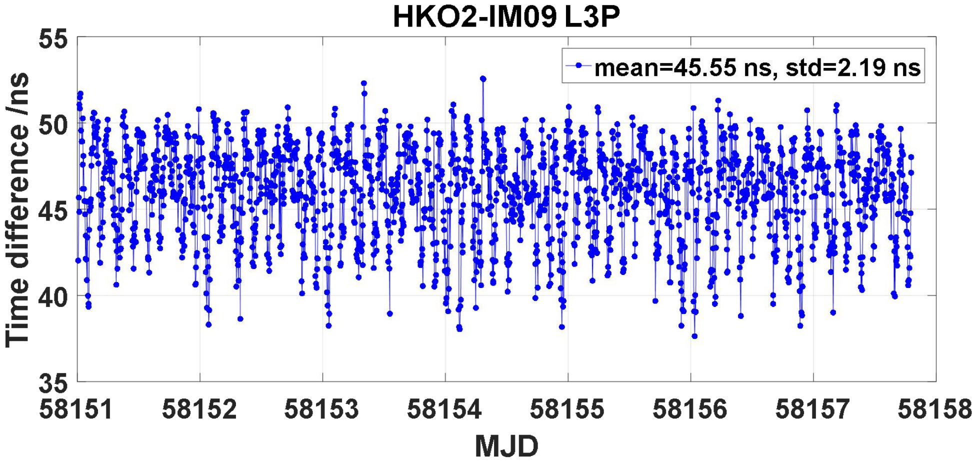


Figure 25. CCD between IM09 and HKO2 at HKO(L3P)

HKO2-IM11

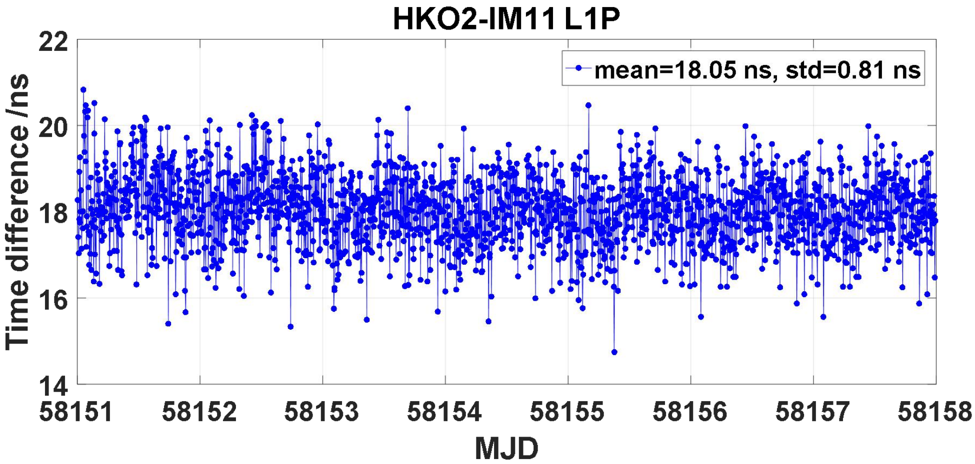


Figure 26. CCD between IM11 and HKO2 at HKO(L1P)

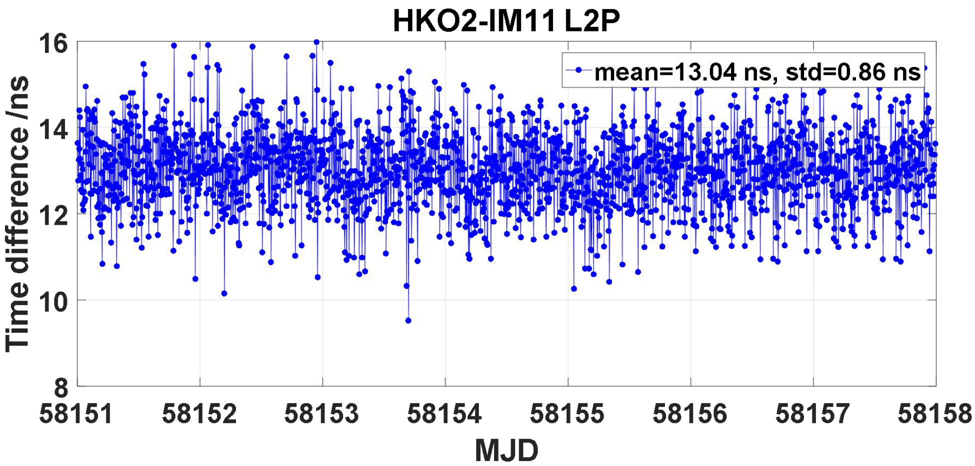


Figure 27. CCD between IM11 and HKO2 at HKO(L2P)

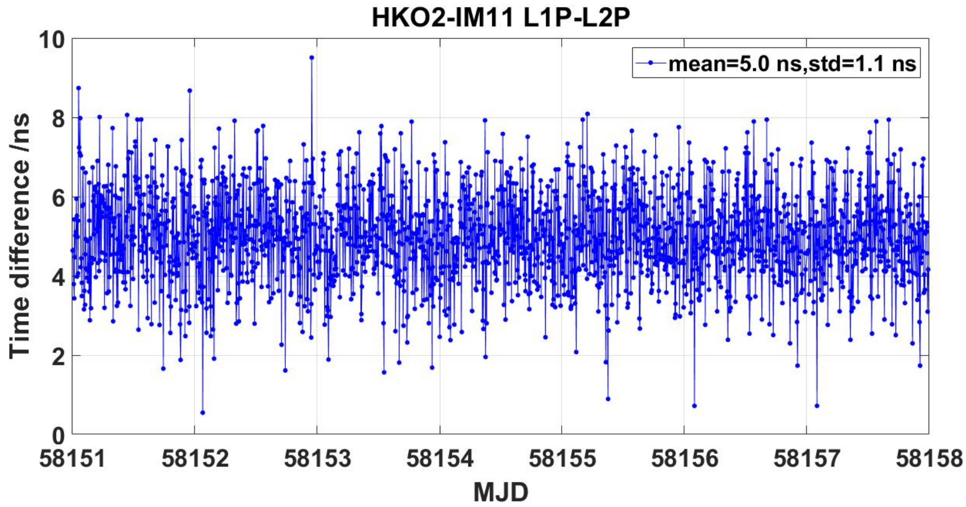


Figure 28. CCD between IM11 and HKO2 at HKO(L1P-L2P)

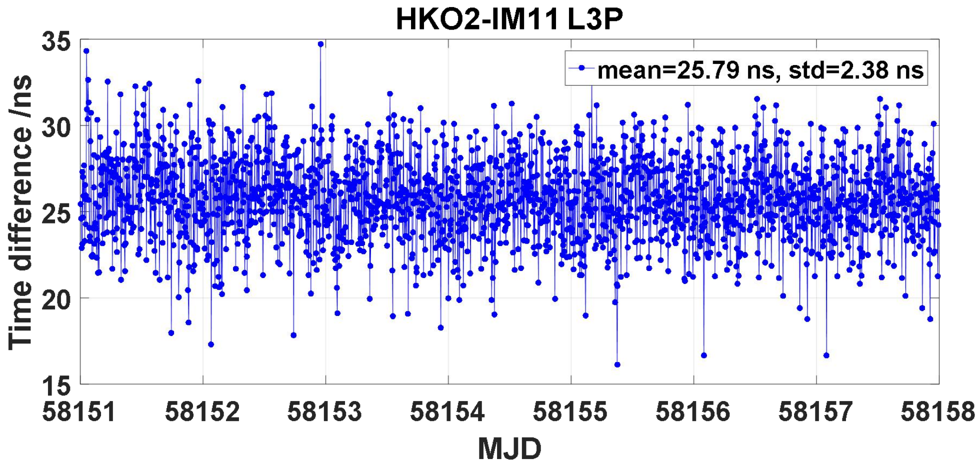


Figure 29. CCD between IM11 and HKO2 at HKO(L3P)

3. Closure CCD after calibration

IM09-IM06

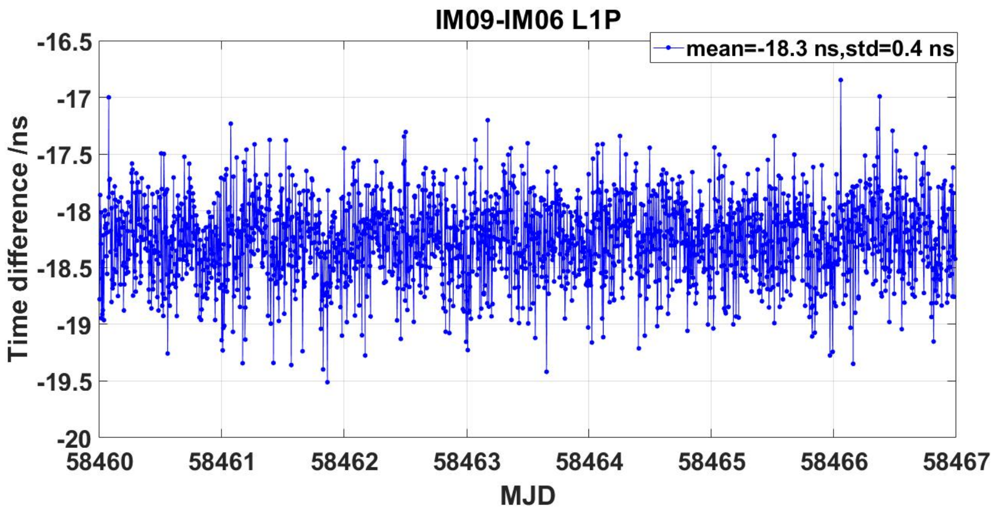


Figure 30. CCD between IM09 and IM06 at NIM(L1P)

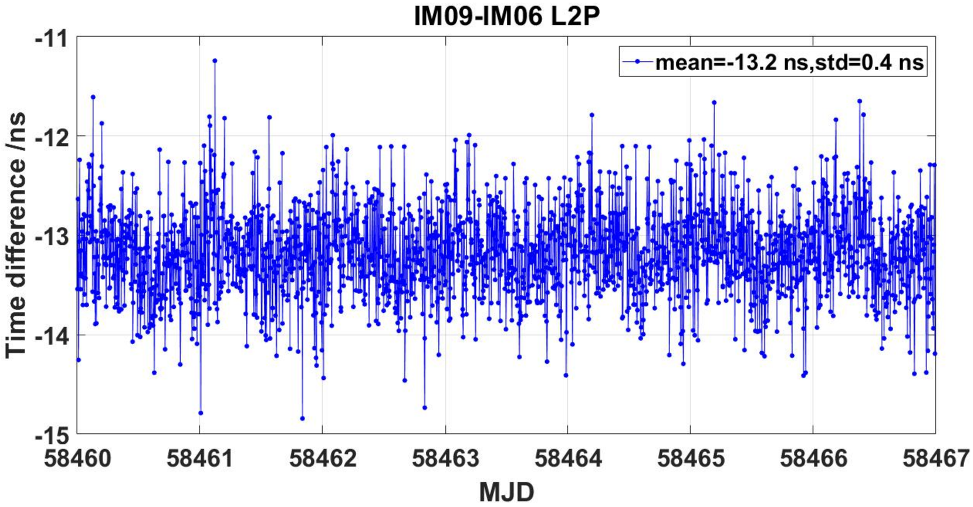


Figure 31. CCD between IM09 and IM06 at NIM(L2P)

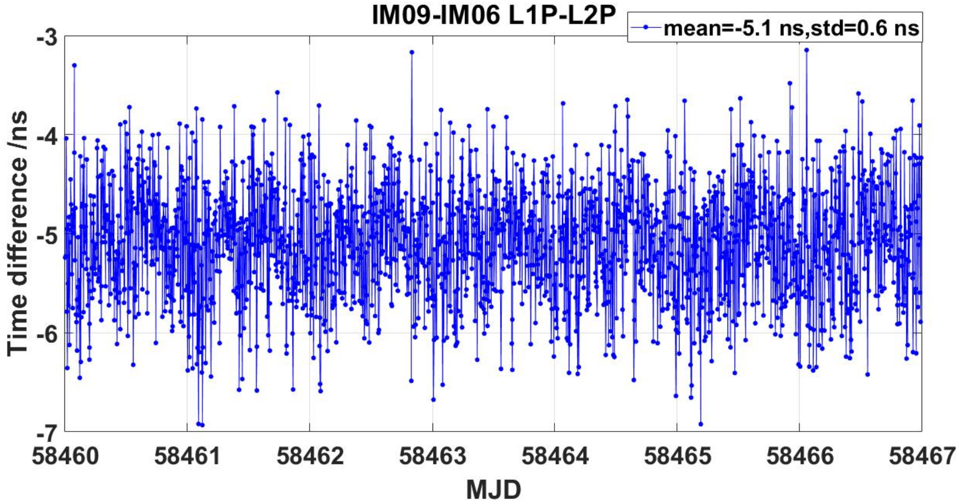


Figure 32. CCD between IM09 and IM06 at NIM(L1P-L2P)

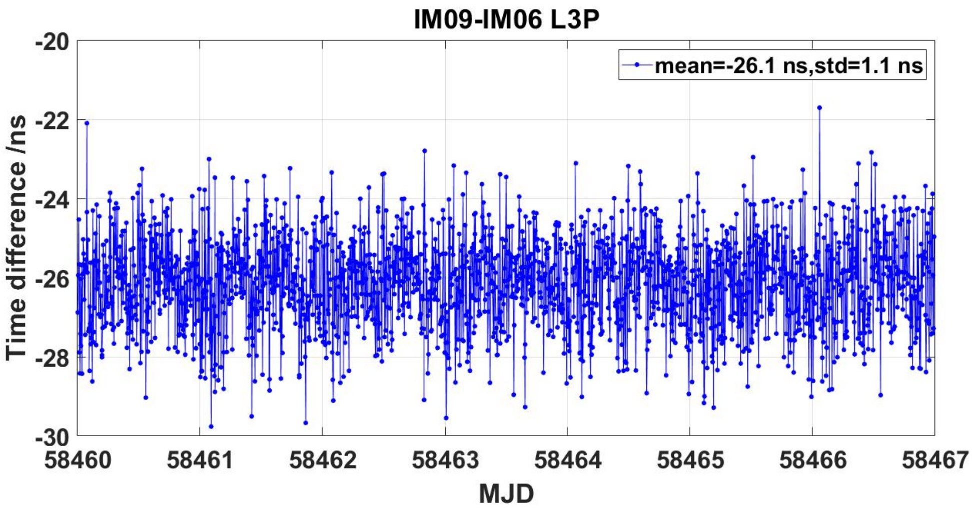


Figure 33. CCD between IM09 and IM06 at NIM(L3P)

IM11-IM06

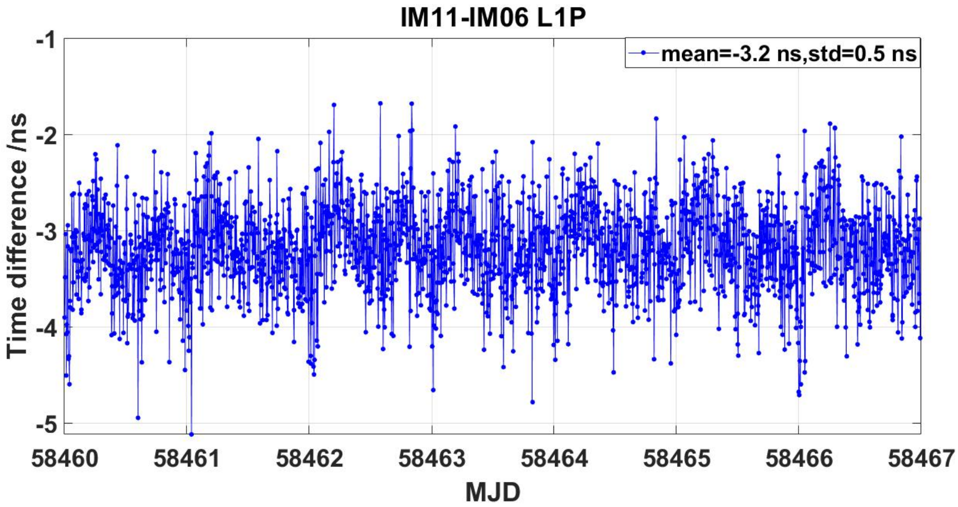


Figure 34. CCD between IM11 and IM06 at NIM(L1P)

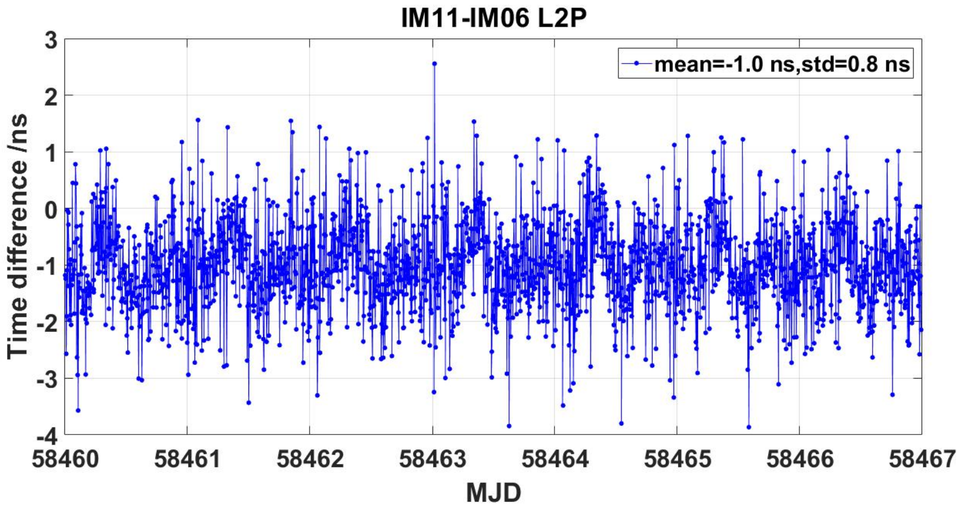


Figure 35. CCD between IM11 and IM06 at NIM(L2P)

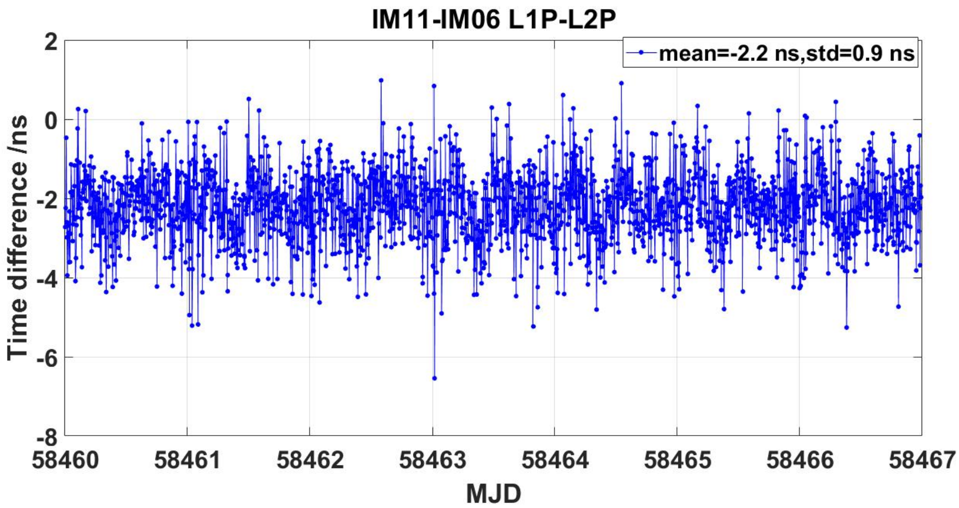


Figure 36. CCD between IM11 and IM06 at NIM(L1P-L2P)

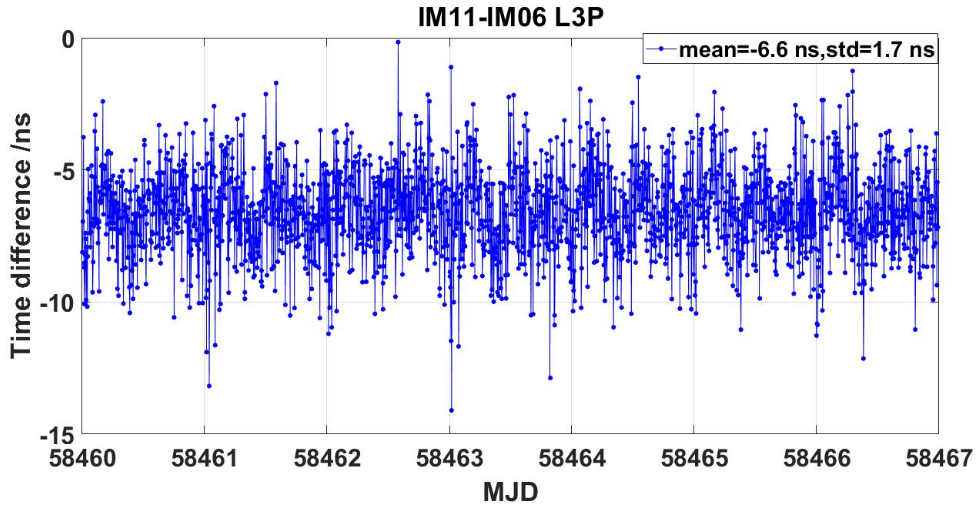


Figure 37. CCD between IM11 and IM06 at NIM(L3P)

Annex 2. CCD results for SCL

1. Start CCD before calibration

IM09-IM06

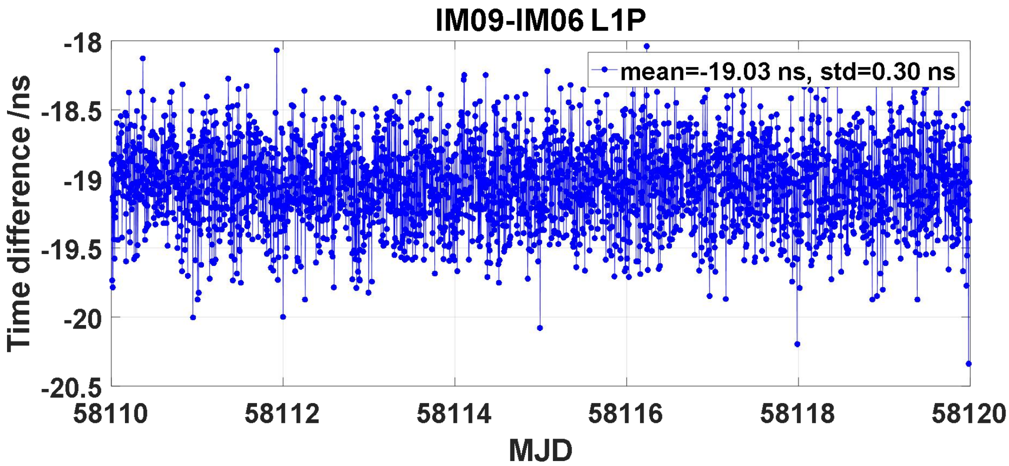


Figure 38. CCD between IM20 and IM06 at NIM(L1P)

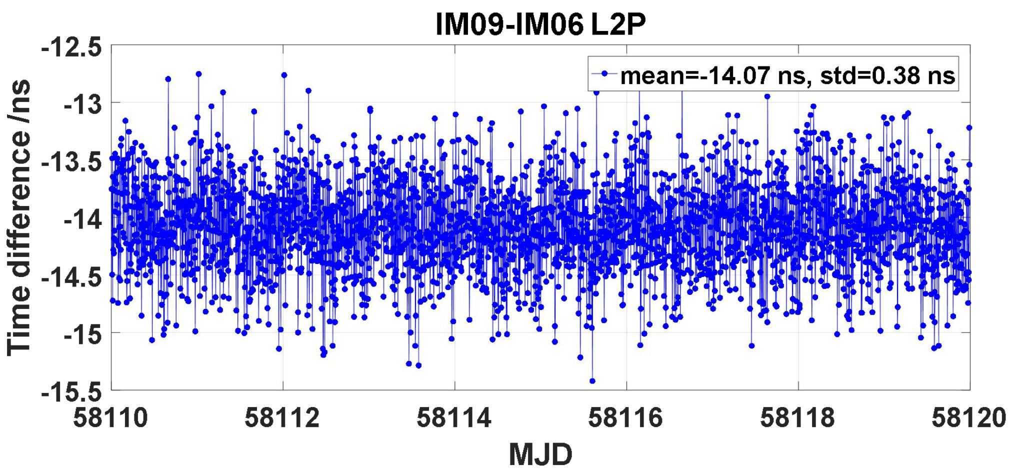


Figure 39. CCD between IM09 and IM06 at NIM(L2P)

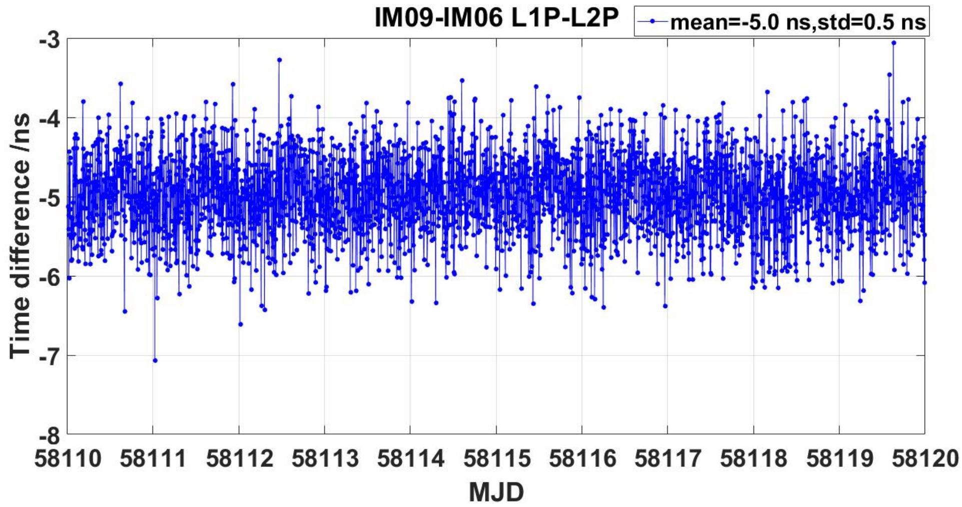


Figure 40. CCD between IM09 and IM06 at NIM(L1P-L2P)

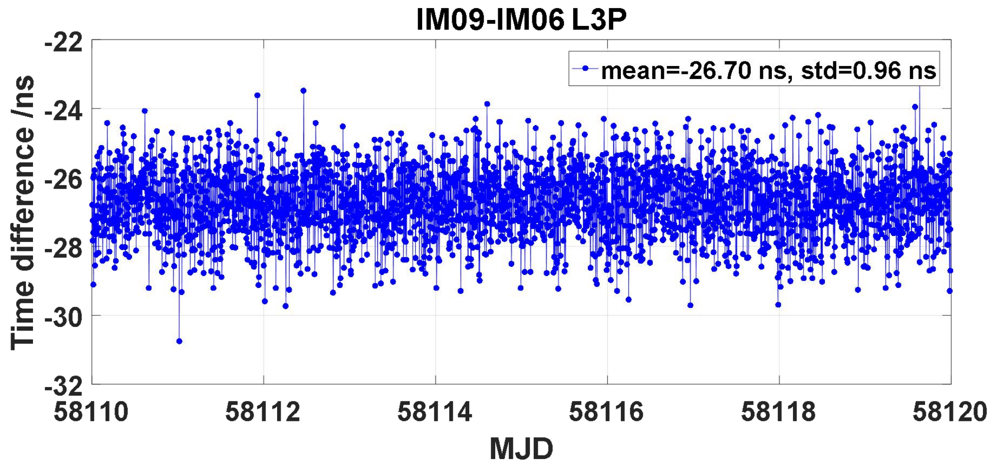


Figure 41. CCD between IM09 and IM06 at NIM(L3P)

2. Calibration on site

SCL2-IM09

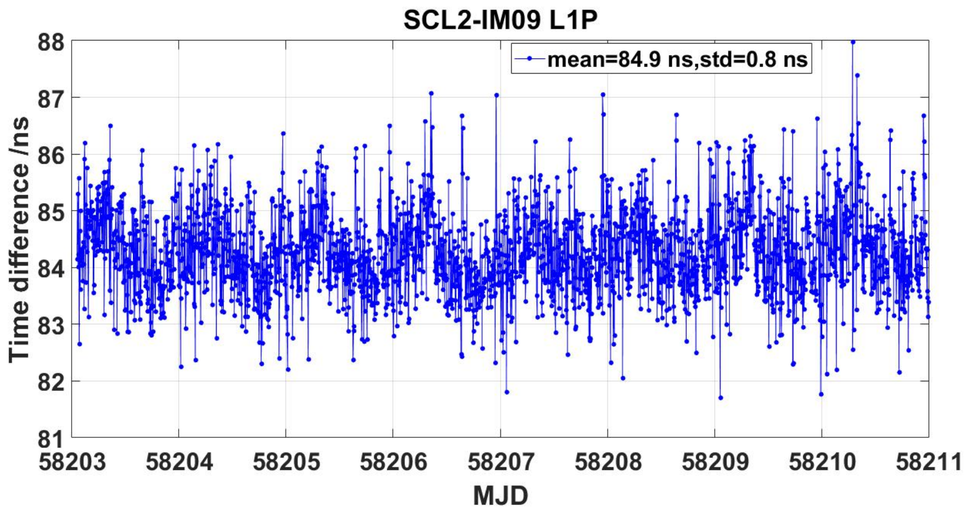


Figure 42. CCD between SCL2 and IM09 at SCL (L1P)

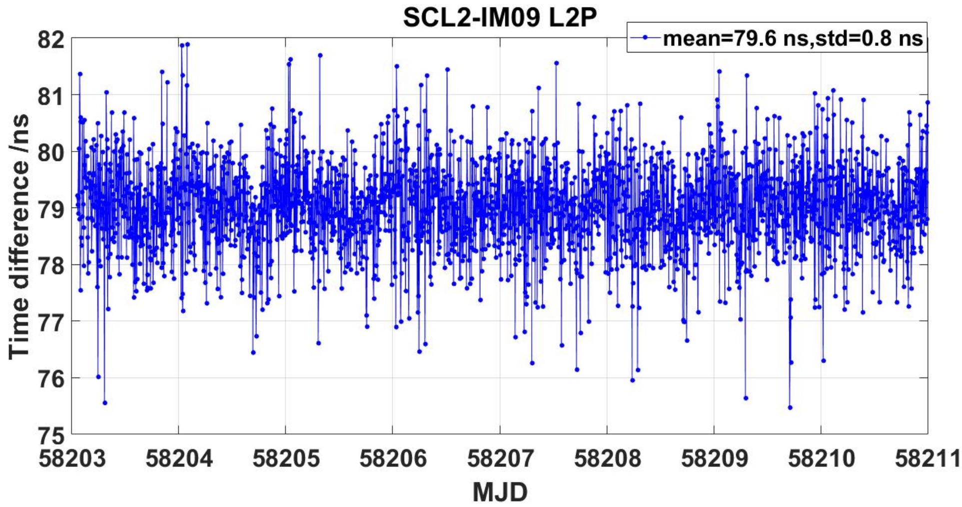


Figure 43. CCD between SCL2 and IM09 at SCL (L2P)

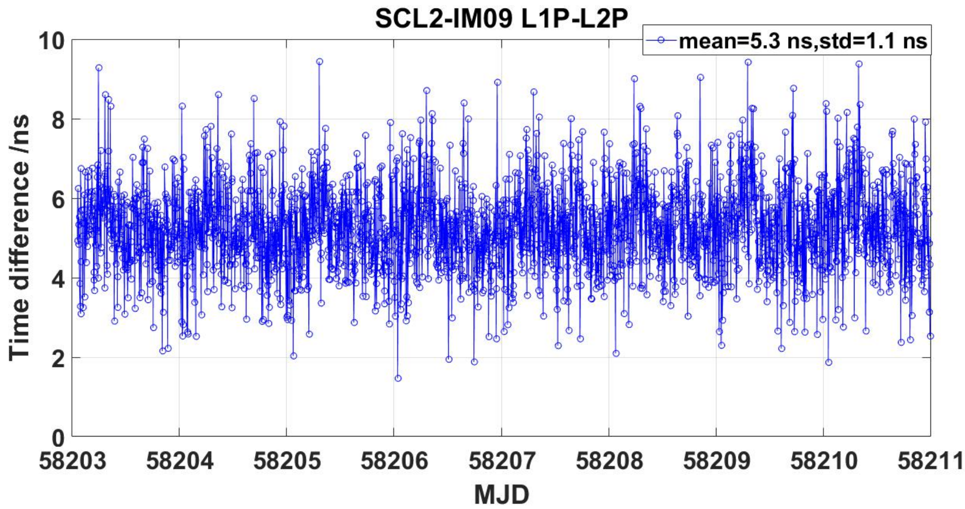


Figure 44. CCD between SCL2 and IM09 at SCL (L1P-L2P)

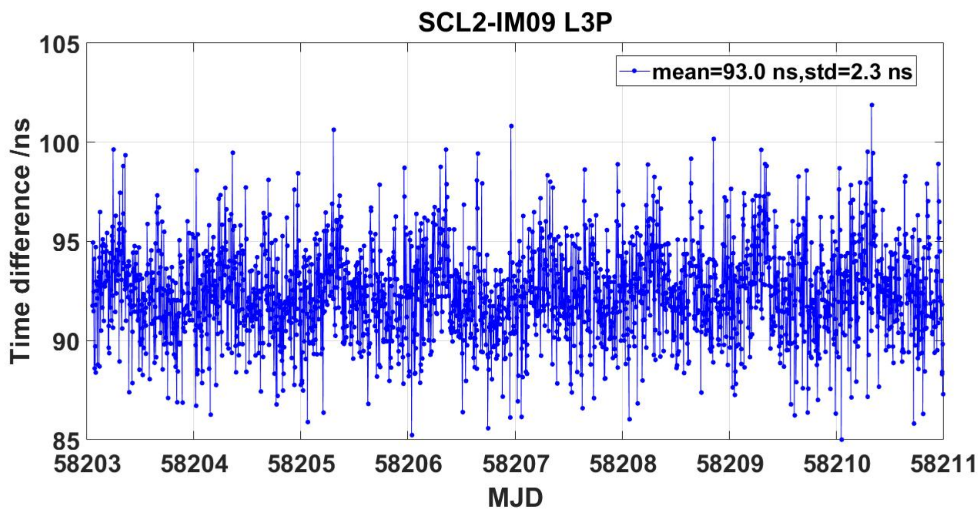


Figure 45. CCD between SCL2 and IM09 at SCL (L3P)

3. Closure CCD after calibration

IM09-IM06

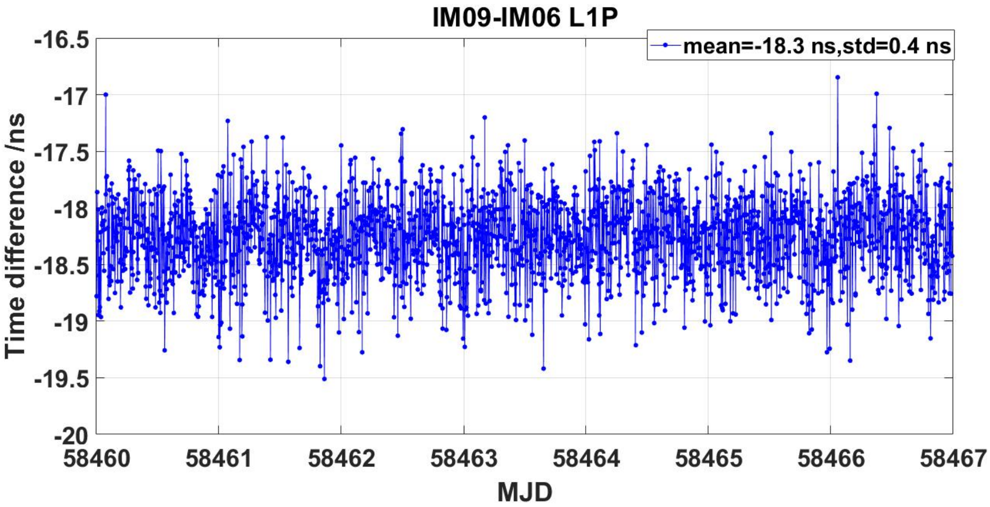


Figure 46. CCD between IM09 and IM06 at NIM(L1P)

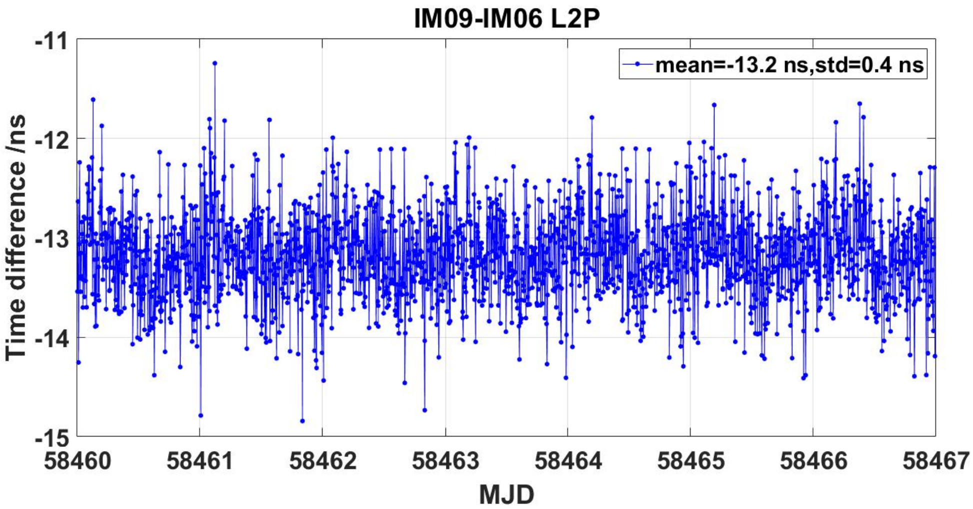


Figure 47. CCD between IM09 and IM06 at NIM(L2P)

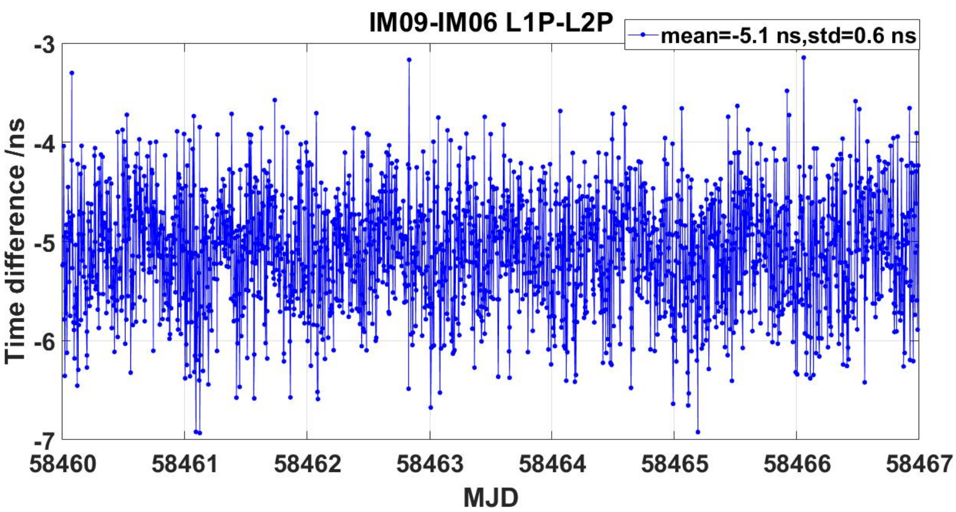


Figure 48. CCD between IM09 and IM06 at NIM(L1P-L2P)

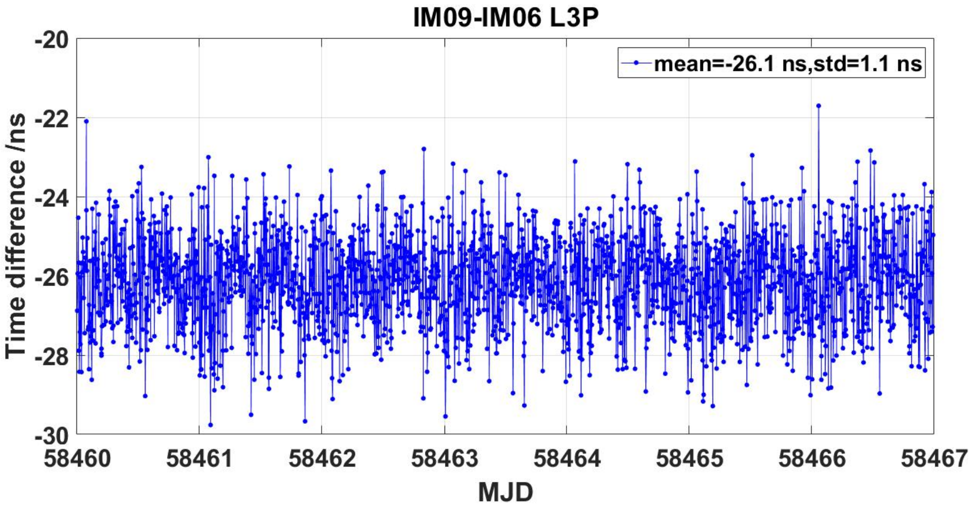


Figure 49. CCD between IM09 and IM06 at NIM(L3P)

Annex 3 - Information Sheet

(to be repeated for each calibrated system)

Laboratory：	HKO
Date and hour of the beginning of measurements:	2018-02-10 00:00 UTC
Date and hour of the end of measurements:	2018-02-26 00:00 UTC

Information on the system

	Local:	**Travelling:**
4-character BIPM code	hko1	
Receiver maker and type: Receiver serial number：	Piktime TTS-4, SN: 126	
1 PPS trigger level /V:	0.5	
Antenna cable maker and type: Phase stabilised cable (Y/N):	CNT, CNT-400 N	
Length outside the building /m:	5 (estimated)	
Antenna maker and type: Antenna serial number:	JAVAD RingAnt-G3T SN: 00577	
Temperature (if stabilised) /°C	36	

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	7.92ns	
Delay from 1 PPS-in to internal Reference (if different):	--	
Antenna cable delay:	333.89	

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

Data used for the generation of CGGTTS files

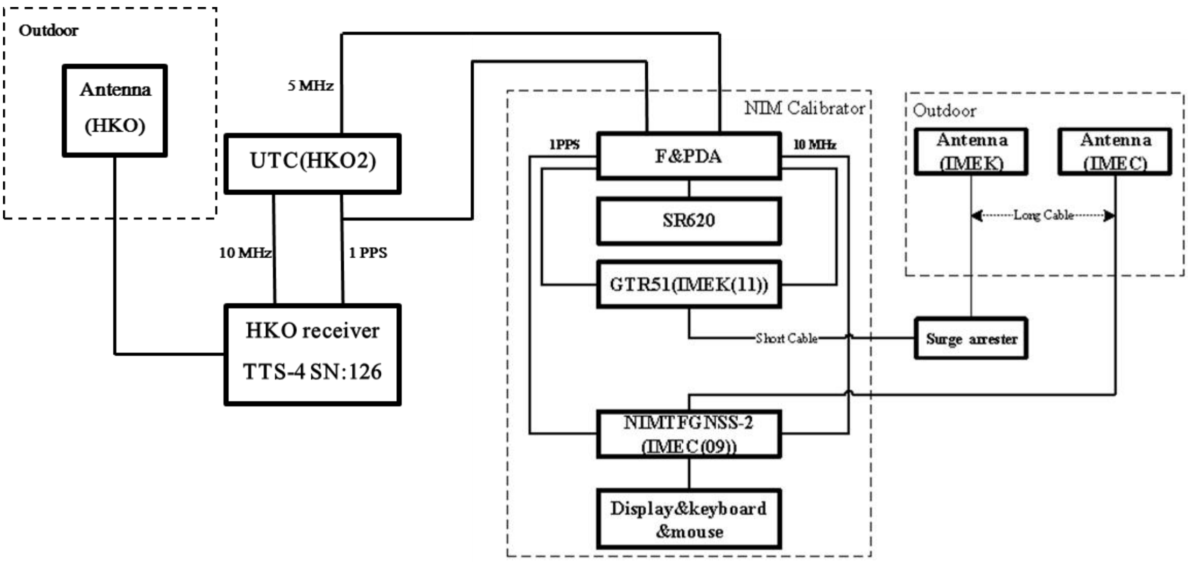
INT DLY (GPS) /ns:	-22.50 (L1C)
INT DLY (GLONASS) /ns:	-228.06 (L1C)
CAB DLY /ns:	333.89
REF DLY /ns:	7.92
Coordinates reference frame:	ITRF
Latitude or X /m:	-2417749.20
Longitude or Y /m:	+5386168.63
Height or Z /m:	+2405440.42

General information

Rise time of the local UTC pulse	<5ns
Is the laboratory air conditioned	Y
Set temperature value and uncertainty:	22℃±1
Set humidity value and uncertainty:	40%±5

(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:	HKO
Date and hour of the beginning of measurements:	2018-02-02 00:00 UTC
Date and hour of the end of measurements:	2018-02-09 00:00 UTC

Information on the system

	Local:	Travelling:
4-character BIPM code	hko2	
Receiver maker and type: Receiver serial number：	Piktime TTS-4, SN: 133	
1 PPS trigger level /V:	0.5	
Antenna cable maker and type: Phase stabilised cable (Y/N):	HELIAX FSJ4-50B N	
Length outside the building /m:	20 (estimated)	
Antenna maker and type: Antenna serial number:	JAVAD RingAnt-G3T SN: 00587	
Temperature (if stabilised) /°C	44	

Measured delays /ns

	Local:	Travelling:
Delay from local UTC to receiver 1 PPS-in:	7.92ns	
Delay from 1 PPS-in to internal Reference (if different):	--	
Antenna cable delay:	423.33	
Splitter delay (if any):	--	
Additional cable delay (if any):	--	

Data used for the generation of CGGTTS files

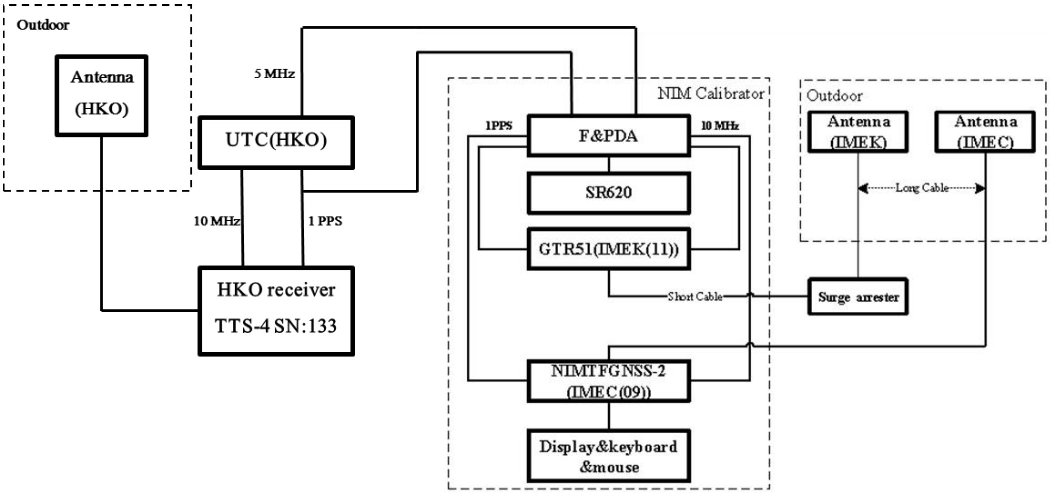
INT DLY (GPS) /ns:	-19.66
INT DLY (GLONASS) /ns:	-225.07 (L1C)
CAB DLY /ns:	423.33 (L1C)
REF DLY /ns:	7.92
Coordinates reference frame:	ITRF
Latitude or X /m:	-2417748.93
Longitude or Y /m:	+5386168.70
Height or Z /m:	+2405440.68

General information

Rise time of the local UTC pulse	<5ns
Is the laboratory air conditioned	Y
Set temperature value and uncertainty:	22℃±1
Set humidity value and uncertainty:	40%±5

(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：	SCL
Date and hour of the beginning of measurements:	
Date and hour of the end of measurements:	

Information on the system

	Local:	Travelling:
4-character BIPM code	SCL	NIM
Receiver maker and type: Receiver serial number：	Septentrio PolaRx5TR-3022579 s/n: 4701243	Navcompass NIMTFGNSS-2 s/n: 201401
1 PPS trigger level /V:	N/A	N/A
Antenna cable maker and type: Phase stabilised cable (Y/N):	RFS LCF78-50JA and Suhner Sucoflex 104 cables N	RFS LCF78-50JA and Suhner Sucoflex 104 cables N
Length outside the building /m:	39 m	39 m
Antenna maker and type: Antenna serial number:	Septentrio Polant-X MF AT1675-540S s/n: 12220	AERAT1675-200 s/n: 5098
Temperature (if stabilised) /°C	N/A	N/A

Measured delays /ns

	Local:	Travelling:
Delay from local UTC to receiver 1 PPS-in:	10 ns	10 ns

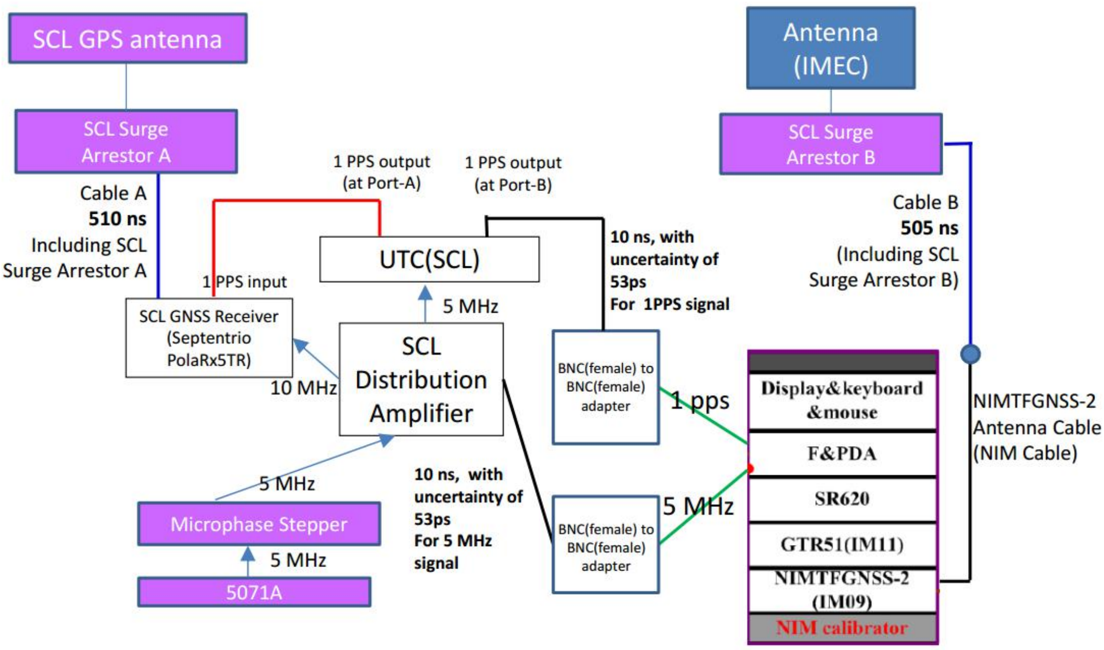
Delay from 1 PPS-in to internal Reference (if different):	N/A	N/A
Antenna cable delay:	512 ns	526.6 ns
Splitter delay (if any):	N/A	N/A
Additional cable delay (if any):	N/A	N/A

Data used for the generation of CGGTTS files	
INT DLY (GPS) /ns:	0 ns
INT DLY (GLONASS) /ns:	N/A
CAB DLY /ns:	512 ns
REF DLY /ns:	10 ns
Coordinates reference frame:	WGS84
Latitude or X /m:	22° 16′ 47.4780″ N
Longitude or Y /m:	114° 10′ 22.7533″ E
Height or Z /m:	185.4 m

General information	
Rise time of the local UTC pulse	5.8 ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	(23±1) °C
Set humidity value and uncertainty:	(45±8) %

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

Measurement scheme



Annex 4 – TDEV for CCD results at HKO

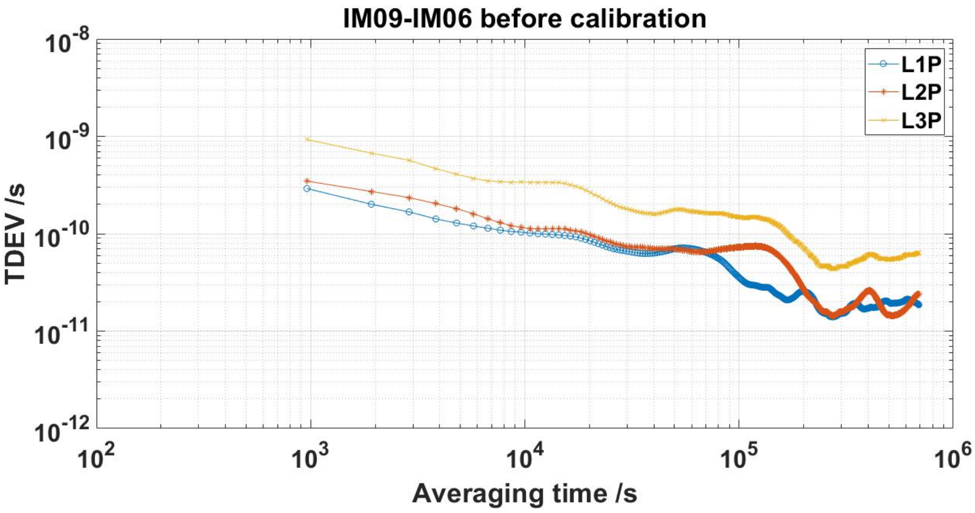


Figure 50. TDEV between IM09 and IM06 receivers at NIM before calibration

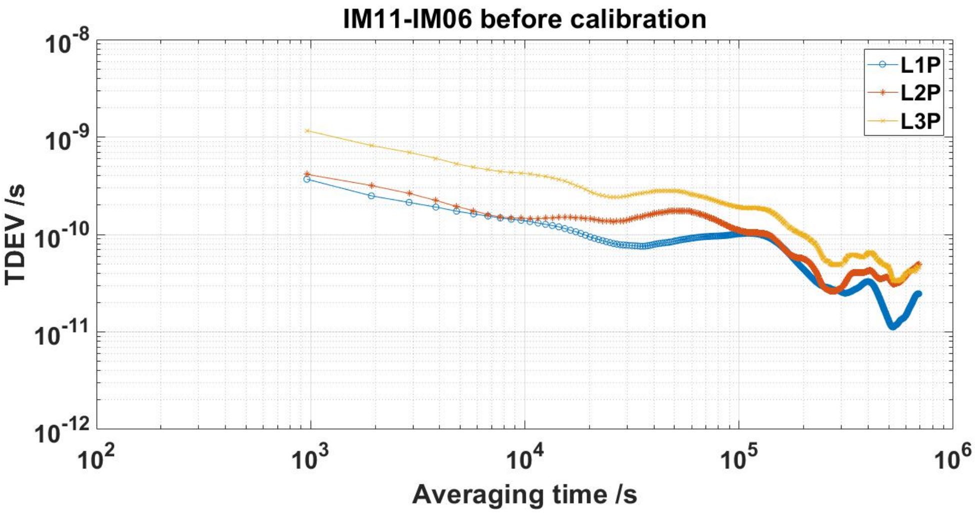


Figure 51. TDEV between IM11 and IM06 receivers at NIM before calibration

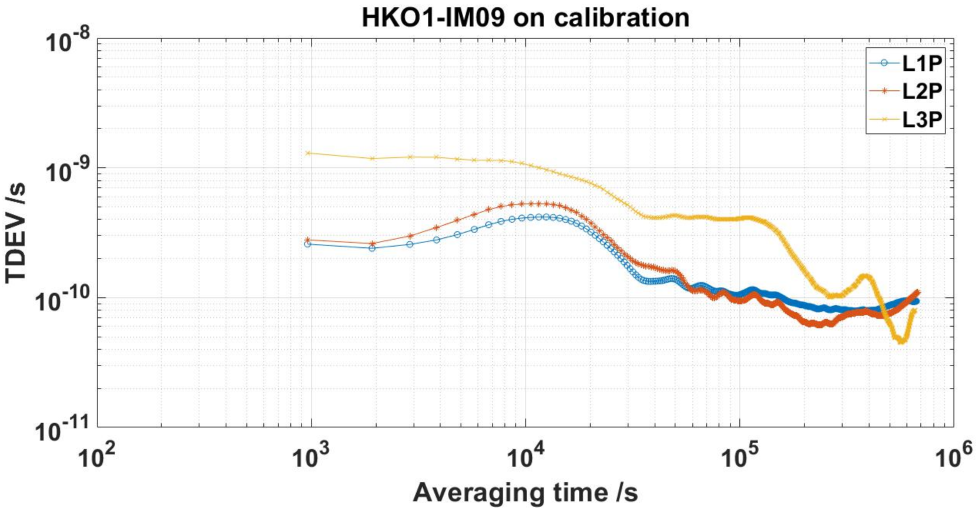


Figure 52. TDEV between HKO1 and IM09 receivers at HKO on calibration

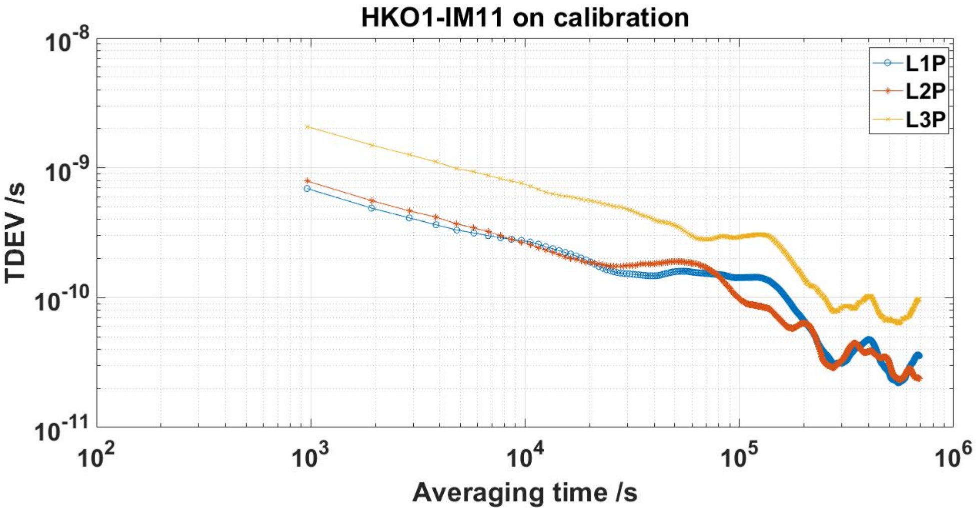


Figure 53. TDEV between HKO1 and IM011 receivers at HKO on calibration

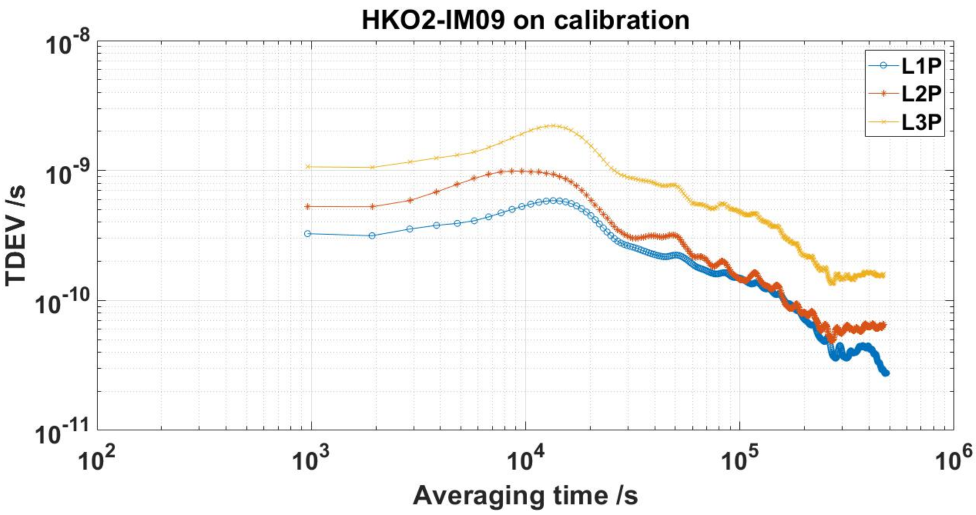


Figure 54. TDEV between HKO2 and IM09 receivers at HKO on calibration

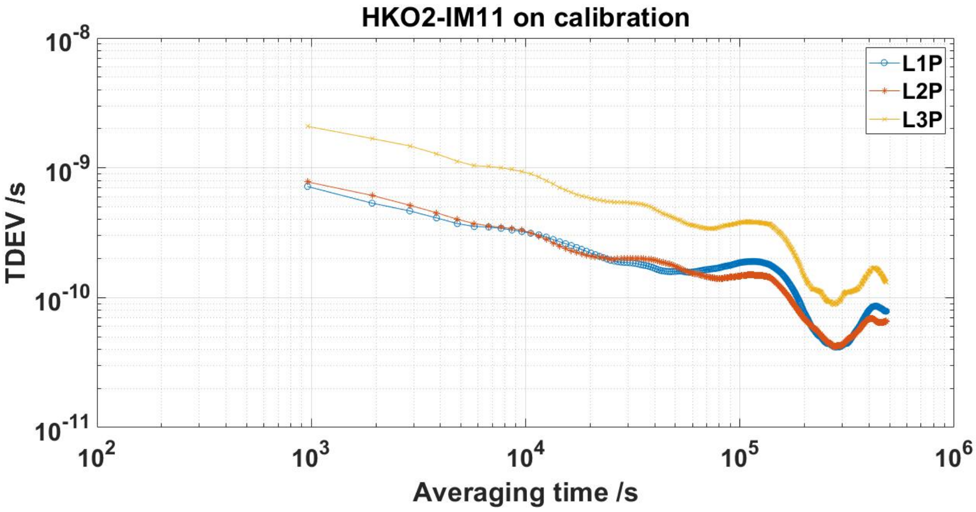


Figure 55. TDEV between HKO2 and IM11 receivers at HKO on calibration

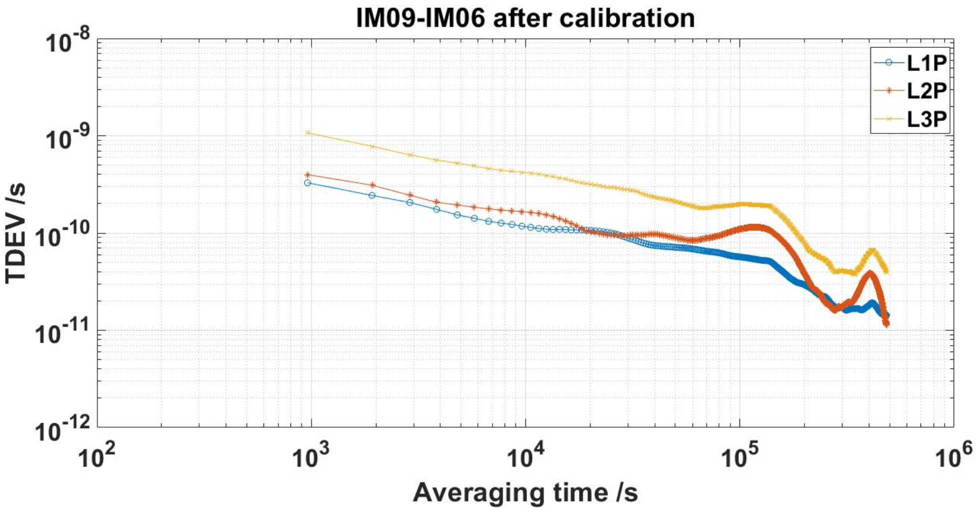


Figure 56. TDEV between IM09 and IM06 receivers at NIM after calibration

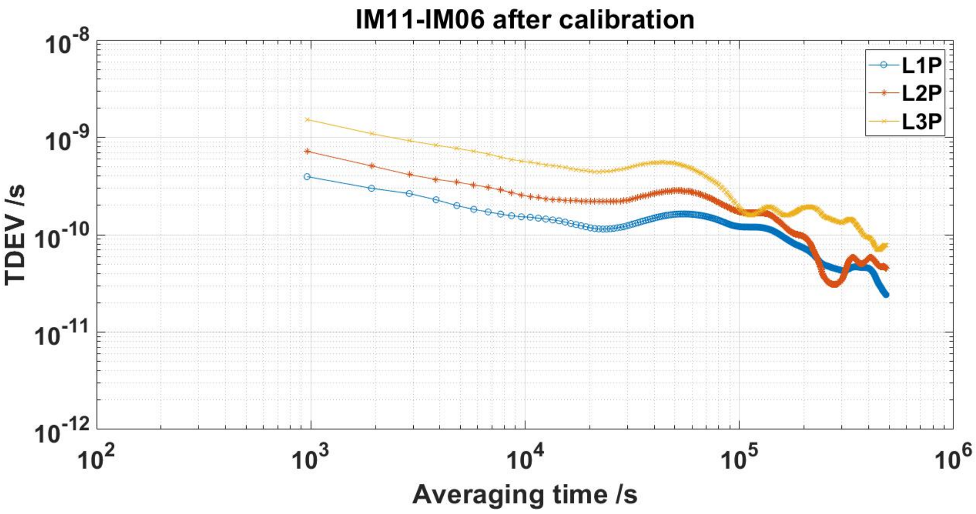


Figure 57. TDEV between IM11 and IM06 receivers at NIM after calibration

Annex 5 – TDEV for CCD results at SCL

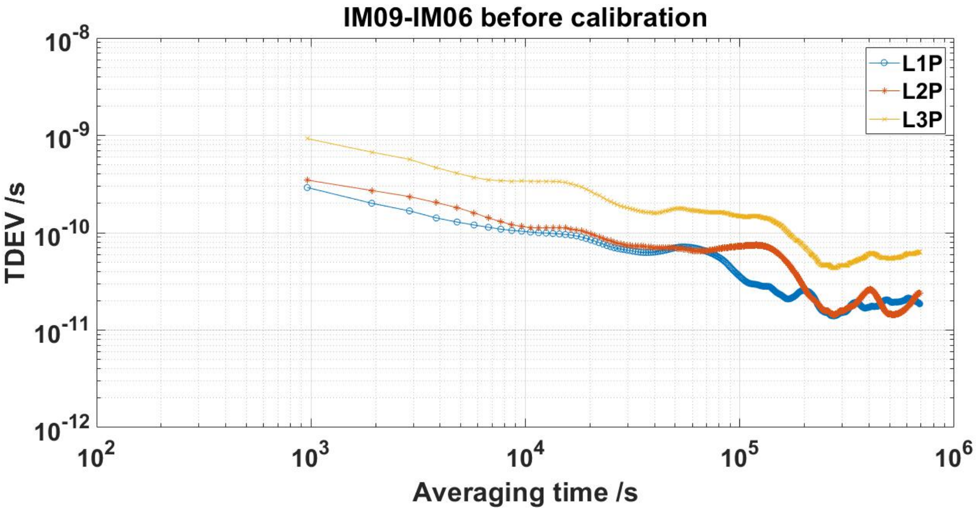


Figure 58. TDEV between IM09 and IM06 receivers at NIM before calibration

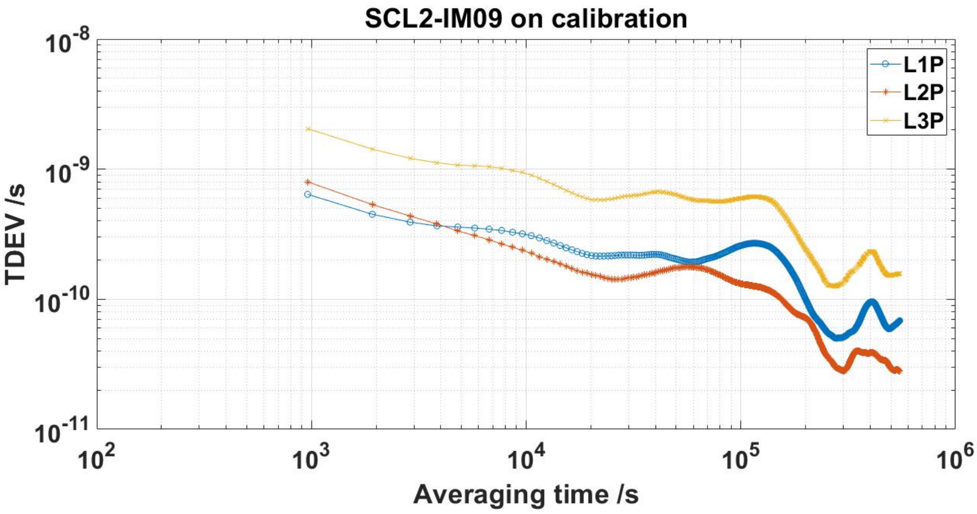


Figure 59. TDEV between SCL2 and IM09 receivers at SCL during calibration

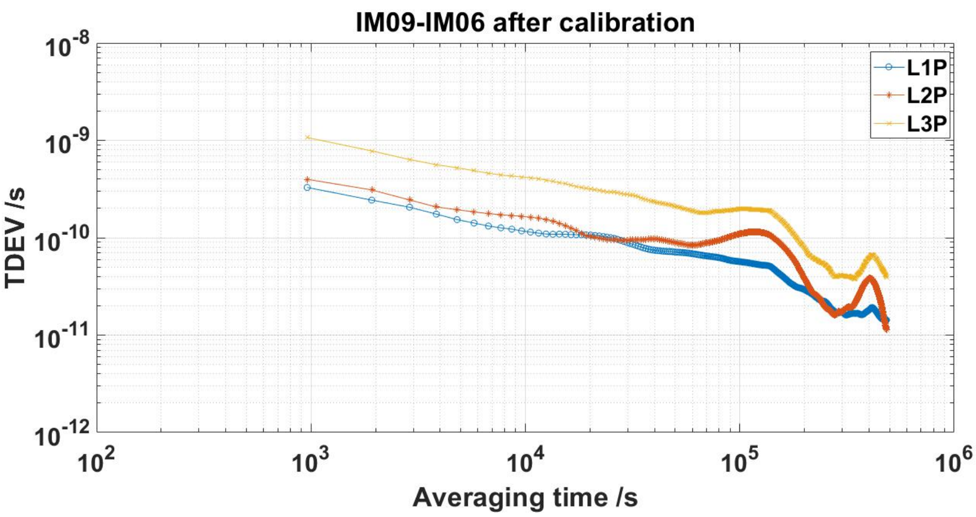


Figure 60. TDEV between IM09 and IM06 receivers at NIM after calibration