Report for Calibration of G2 Laboratory NTSC by NIM

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The report is divided by eight parts. The first part introduces the calibration process 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 and 5 separately introduce the data processing of the calibration, and the final calibration results by the computation. Then the sixth part describe the verification for the final results by processing Rinex observation using dclrinex program. In part 7, it is shown how the calibration uncertainties are evaluated. Climate parameters during the calibration is involved in part 8. In part 9, the comparison to the NTSC results of 1001-2016 campaign is introduced and the agreement has been shown.

From the verification, we can find the discrepancy of less than 0.1 ns between the results by the two methods as shown in part 5 and 6 separately. And the final calibration uncertainties for P3 codes are evaluated both as 1.8 ns.

1. Introduction

Time link calibration is the premise of time transfer. At present, there are two kinds of time links in TAI (Temps Atomique International): GNSS (Global Navigation Satellite System) based links and TWSTFT (Two Way Satellite Time and Frequency Transfer) based links. GNSS-based links can be calibrated using the method of differential calibration (golden receiver method) with an uncertainty of about 5 ns and using the whole link calibration method, with an uncertainty of less than 2 ns, perhaps even 1 ns. Since 2001, BIPM has conducted many GNSS time link calibration campaigns around the world using the golden receiver method, mostly because it is easier to operate. TWSTFT links can be calibrated using a mobile station with an uncertainty of about 1 ns, however the mobile station is hard to get for use of the calibration and the calibrated GNSS links can be used for the alignment and calibration of TWSTFT links and calibration for GNSS links could be transferred to TWSTFT based links.

In late February, we received the calibration request from NTSC(in Xi'an, China). Because this should be one calibration of G2 lab and NTSC is not one member of APMP and APMP are not responsible for this determination and after some communication with NTSC, we determined to accept this request in the end of February. Due to their very urgent request, we planned that the calibration tour would happen in this two weeks and we are sending the NIM calibration system(NIM calibrator including one NIMTFGNSS-2 receiver and one GTR51 receiver). Finally we will provide the calibration data and report to BIPM. As well

BIRM(in Beijing, China) sent us the calibration request recently and it should be the similar case and we want to plan it after October.

2. Description of the equipments and the operation method

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

Figure 1. NIM calibrator

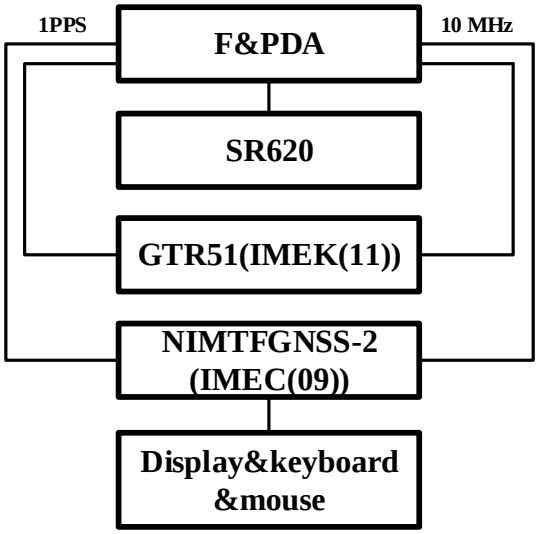


Figure 2. Schematic of NIM calibrator

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:
IMEC(site name for CGGTTS is IM09): NIMTFGNSS-2(with antenna AT1675 AT-200)
IMEK(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.

Table 1. Sites used for the calibration

Timing lab	Site name	BIPM code	Model	Role	Notes
NIM	IMEJ	IM06	Dicom GTR50	Reference receiver	Master
NIM	IMEC	IM09	NIMTFGNSS-2	Traveling receiver	Traveling
NIM	IMEK	IM11	Dicom GTR51	Traveling receiver	Traveling
NTSC	NTP1	NTP1	Septentrio PolaRx4TR_PRO	Receiver to be calibrated	Master
NTSC	NTP2	NTP2	Septentrio PolaRx4TR_PRO	Receiver to be calibrated	Backup
NTSC	NTP4	NTP4	Septentrio PolaRx4TR_PRO	Receiver to be calibrated	Backup

Note: NTP1 and NTP2 are operated in one antenna with a splitter. Specially, the site names of the three NTSC receivers for CGGTTS data are all the same, which is NT2P.

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

Table 2. Sites used for the calibration

Time period	Place	Operation	Notes
MJD57457-MJD57462	NIM	Start CCD before calibration	
MJD57472-MJD57477	NTSC	Calibration on site	
MJD57501-MJD57506	NIM	Closure CCD after calibration	

The calibration method, the differential calibration with closure of GPS (Global Positioning System) time and frequency transfer receiver, is used. Its principle concept of is addressed in [1],. Here we don't repeat the description of the differential calibration by BIPM.

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 and has been calibrated in 2012 by NIM and 2014 by BIPM. The calibrator sites at NTSC were installed as figure 3 and 4 shows. And the setup and the sub-delay information for start and closure experiments at NIM were depicted in figure 5 and 6.

Figure 3. Calibrator installed in NTSC

Figure 4. Calibrator installed in NTSC

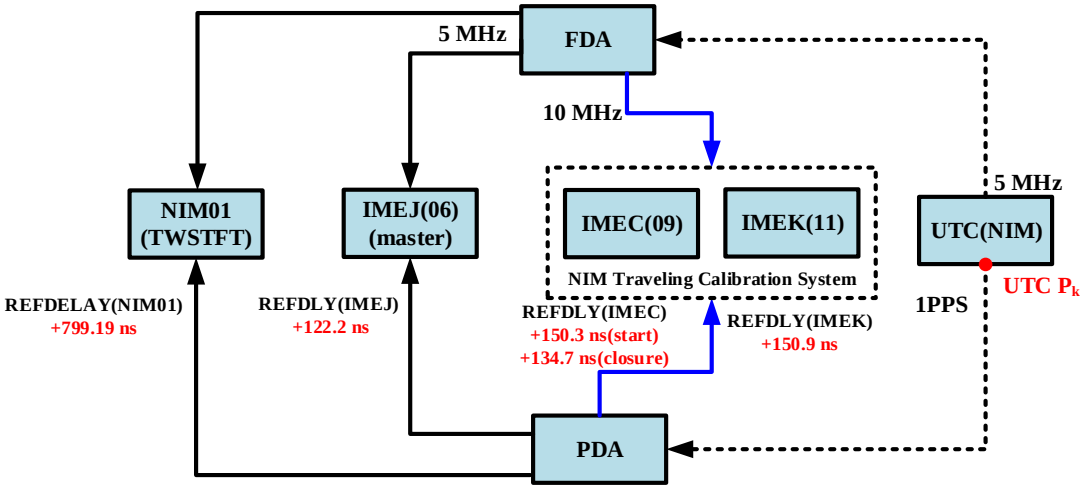


Figure 5. Experiment setup @NIM(for CCD experiments)

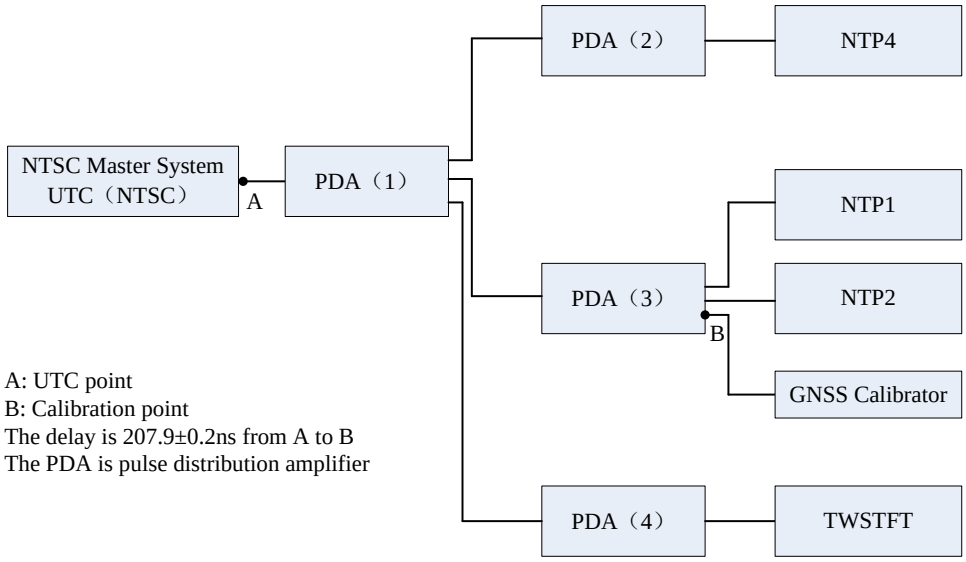


Figure 6. Experiment setup @NTSC(for calibration experiment)

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 using P3 CGGTTS data of the receivers.

4.1. 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		
IMEC	150.3	/		203.0
IMEK	150.9	/		177.1
IMEJ	122.2	/		248.7

4.2. Calibration on site

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

Receiver	Ref-PPSin(XP) / ns	Meas 3.1(3.3)	Meas 3.2	Ant. Cable (XC+XD) / ns
		Int ref – 1PPSin(XO) / ns		
NTP1	222.8	149.6/149.6		209.0
NTP2	232.9	143.7/143.9		221.0
NTP4	191.1	139.8/139.8		208.0
IMEC	226.1	/		203.0
IMEK	247.5	/		177.1

4.3. 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		
IMEC	134.7	/		203.0
IMEK	150.9	/		177.1
IMEJ	122.2	/		248.7

Closure values(the difference between the mean values before calibration and after calibration shown in the figures in the Annex 1.)
IM09: 3.31-3.06=0.25 ns
IM11:-8.25+7.89=-0.36 ns

5. P3 Calibration computation

Algorithm: $(XR+XS)_{RUC}$=CCD(RUC- Calibrator)-original compensation for (RUC- Calibrator) from CGGTTS header-$(XC+XD)_{RUC}$+$(XO+XP)_{RUC}$+$(XC+XD)_{Cal}$+ CCD(Calibrator-Ref)
RUC: Receiver under calibration
Ref: calibration reference receiver, NIM master GPS time and frequency receiver IM06(IMEJ)

Base on IM09
GZ data

$(XR+XS)_{NTP1}$=58.5200 ns
Total_delay=-104.8800 ns

$(XR+XS)_{NTP2}$=59.3100 ns
Total_delay=-96.2900 ns

$(XR+XS)_{NTP4}$=58.4500 ns
Total_delay=-64.4500 ns

Based on IM11
GZ data

$(XR+XS)_{NTP1}$=57.9900 ns
Total_delay=-105.4100 ns

$(XR+XS)_{NTP2}$=58.7500 ns
Total_delay=-96.8500 ns

$(XR+XS)_{NTP4}$=57.9300 ns
Total_delay=-64.9700 ns

Calibration values are as follows in terms of the computation according to the formulas (red parts) using the corresponding CCD mean values shown in the figures in Annex 1. IM06 receiver has been calibrated by BIPM in 2014 during the first G1 calibration campaign and afterwards the calibration values are compensated in the Rinex and CGGTTS measurements, thus the internal delay could be regarded as 0 ns.

NTP1(P3)：(58.52+57.99)/2=58.3 ns
NTP2(P3)：(59.31+58.75)/2=59.0 ns
NTP4(P3)：(58.45+57.93)/2=58.2 ns

6. Verification using dclrinex

IM09
MJD 57457-57462
INT DLY = -38.7 ns (GPS P1), -38.7 ns (GPS P2)
CAB DLY = 203.0 ns (GPS)
REF DLY = 150.3 ns
MJD 57472-57477
INT DLY = -38.7 ns (GPS P1), -38.7 ns (GPS P2)
CAB DLY = 203.0 ns (GPS)
REF DLY = 226.1 ns
MJD 57501-57506
INT DLY = -38.7 ns (GPS P1), -38.7 ns (GPS P2)
CAB DLY = 203.0 ns (GPS)
REF DLY = 134.7 ns

NT1P
MJD 57472-57477
INT DLY = -132.9 ns (GPS P1), -132.9 ns (GPS P2)
CAB DLY = 209.4 ns (GPS)
REF DLY = 208.5 ns

NT2P
MJD 57472-57477
INT DLY = -123.2 ns (GPS P1), -123.2 ns (GPS P2)
CAB DLY = 217.0 ns (GPS)
REF DLY = 207.8 ns

NT4P
MJD 57472-57477
INT DLY = 30.2 ns (GPS P1), 30.2 ns (GPS P2)
CAB DLY = 208.0 ns (GPS)
REF DLY = 330.0 ns

Compensation for P1 and P2 results:
IM09
MJD 57457-57462 -203+150.3 =-52.7 ns
MJD 57472-57477 -203+226.1 =+23.1 ns
MJD 57501-57506 -203+134.7 =-68.3 ns

Note: P3 results are calculated by the formula P3=P1*2.54573-P2*1.54573. In the figures, only the P3 results are compensated by these corresponding values, and P1, P2 and P1-P2 results are not compensated. IM11 and IM06 have all the delay compensation in CGGTTS header in Rinex data.

6.1. Start CCD before Calibration

Table 6. 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	Std
IMEC-IMEJ	24.87	0.34	29.75	0.44	3.32	-4.88	0.55
IMEK-IMEJ	-4.38	0.43	-2.01	0.55	-8.05	-2.37	0.65
IMEC-IMEK	29.23	0.41	31.74	0.50	11.36	-2.51	0.59

6.2. Calibration on site

Table 7. Results for the sites by dclrinex in calibration experiment at NTSC

On site(ns)	P1		P2		P3	P1-P2	
	Mean	Std	Mean	Std	Mean	Mean	Std
IMEC-NT1P	56.42	0.38	62.76	0.44	-23.58	-6.34	0.57
IMEC-NT2P	48.85	0.38	55.86	0.44	-14.18	-7.00	0.57
IMEC-NT4P	17.11	0.39	24.27	0.47	-23.95	-7.16	0.60
IMEK-NT1P	102.85	0.51	106.42	0.50	-34.67	-3.57	0.67
IMEK-NT2P	95.27	0.52	99.52	0.49	-25.29	-4.25	0.67
IMEK-NT4P	63.53	0.51	67.97	0.51	-35.13	-4.44	0.70
IMEC-IMEK	-46.43	0.53	-43.68	0.59	11.11	-2.75	0.74

6.3. Closure CCD after calibration

Table 8. Results for the sites by dclrinex in closure experiment at NIM

After	P1	P2	P3	P1-P2

Calibration(ns)	Mean	Std	Mean	Std	Mean	Mean	Std
IMEC-IMEJ	40.25	0.31	45.17	0.41	3.03	-4.93	0.52
IMEK-IMEJ	-4.19	0.42	-1.93	0.54	-7.70	-2.27	0.61
IMEC-IMEK	44.42	0.44	47.10	0.51	10.68	-2.68	0.57

6.4. Calibration calculation

We can get the similar all CCD values using dclrinex of BIPM compared to the ones solved in section 5 by ourselves. The differences between them are smaller than 0.1 ns. So We can think the P3 calibration values from two processing methods should be agreed with each other. Anyway, we calculate 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 IM09 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(IMEJ)

P3 calculation algorithm is the same to that of section 8.

Base on IM09

$(XR+XS)_{NTP1\_P1}$=56.0500 ns
$(XR+XS)_{NTP1\_P2}$=54.5900 ns
$(XR+XS)_{NTP1\_P3}$=-58.3000 ns

$(XR+XS)_{NTP2\_P1}$=55.8200 ns
$(XR+XS)_{NTP2\_P2}$=53.6900 ns
$(XR+XS)_{NTP2\_P3}$=59.1000 ns

$(XR+XS)_{NTP4\_P1}$=54.8600 ns
$(XR+XS)_{NTP4\_P2}$=52.5800 ns
$(XR+XS)_{NTP4\_P3}$=58.3700 ns

Based on IM11

$(XR+XS)_{NTP1\_P1}$=56.1700 ns
$(XR+XS)_{NTP1\_P2}$=54.9700 ns
$(XR+XS)_{NTP1\_P3}$=58.0200 ns

$(XR+XS)_{NTP2\_P1}$=55.9500 ns
$(XR+XS)_{NTP2\_P2}$=54.0700 ns
$(XR+XS)_{NTP2\_P3}$=58.8400 ns

$(XR+XS)_{NTP4\_P1}$=54.9900 ns

$(XR+XS)_{NTP4\_P2}$=52.9200 ns
$(XR+XS)_{NTP4\_P3}$=58.1800 ns

Averaged calibration values:

$(XR+XS)_{NTP1\_P1}$=(56.0500+56.1700)/2=**56.1 ns**
$(XR+XS)_{NTP1\_P2}$=(54.5900+54.9700)/2=**54.8 ns**
$(XR+XS)_{NTP1\_P3}$=(58.3000+58.0200)/2=**58.2 ns**

$(XR+XS)_{NTP2\_P1}$=(55.8200+55.9500)/2=**55.9 ns**
$(XR+XS)_{NTP2\_P2}$=(53.6900+54.0700)/2=**53.9 ns**
$(XR+XS)_{NTP2\_P3}$=(59.1000+58.8400)/2=**59.0 ns**

$(XR+XS)_{NTP4\_P1}$=(54.8600+54.9900)/2=**54.9 ns**
$(XR+XS)_{NTP4\_P2}$=(52.5800+52.9200)/2=**52.8 ns**
$(XR+XS)_{NTP4\_P3}$=(58.3700+58.1800)/2=**58.3 ns**

Calibration values are as follows in terms of the computation according to the formulas in section 5 using the corresponding CCD mean values shown in the figures in Annex 2. For convenience of P1 and P2 code calibration value settings, we can use directly these results as the calibration values.

7. Uncertainty Evaluation

Table 9. Uncertainty contributions.
Values P3 are computed as P1 + 1.54573*(P1-P2)

Unc.	Value P1 (ns)	Value P2 (ns)	Value P1-P2 (ns)	Value P3 (ns)	Description
u_a (T-V)	0.3	0.3	0.6		RAWDIF (traveling-visited)
u_a (T-R)	0.3	0.3	0.6		RAWDIF (traveling-reference)
u_a	0.4	0.4	0.8	1.0	
Misclosure					
$u_{b,1}$	0.2	0.2	0.1		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	0.4		Multipaths at reference
$u_{b,14}$	0.3	0.3	0.4		Multipaths at visited
Link of the Traveling system to the local UTC(k)					
$u_{b,21}$	0.5	0.5	0		$REFDLY_T$ (at ref lab)
$u_{b,22}$	0.5	0.5	0		$REFDLY_T$ (at visited lab)
$u_{b,TOT}$	0.9	0.9	0.6	1.3	
Link of the Reference system to its local UTC(k)					
$u_{b,31}$	0.5	0.5	0		$REFDLY_R$ (at ref lab)
Link of the Visited system to its local UTC(k)					

$u_{b,32}$	0.5	0.5	0		$REFDLY_V$ (at visited lab)
$u_{b,SYS}$	1.1	1.1	0.6	1.4	Components of equation (2)
u_{CAL0}				1.8	Composed of u_a and $u_{b,SYS}$
Antenna cable delays					
$u_{b,41}$	0.5	0.5	0	0.5	$CABDLY_R$
$u_{b,42}$	0.5	0.5	0	0.5	$CABDLY_V$
Combined Uncertainty: 1.8 ns					

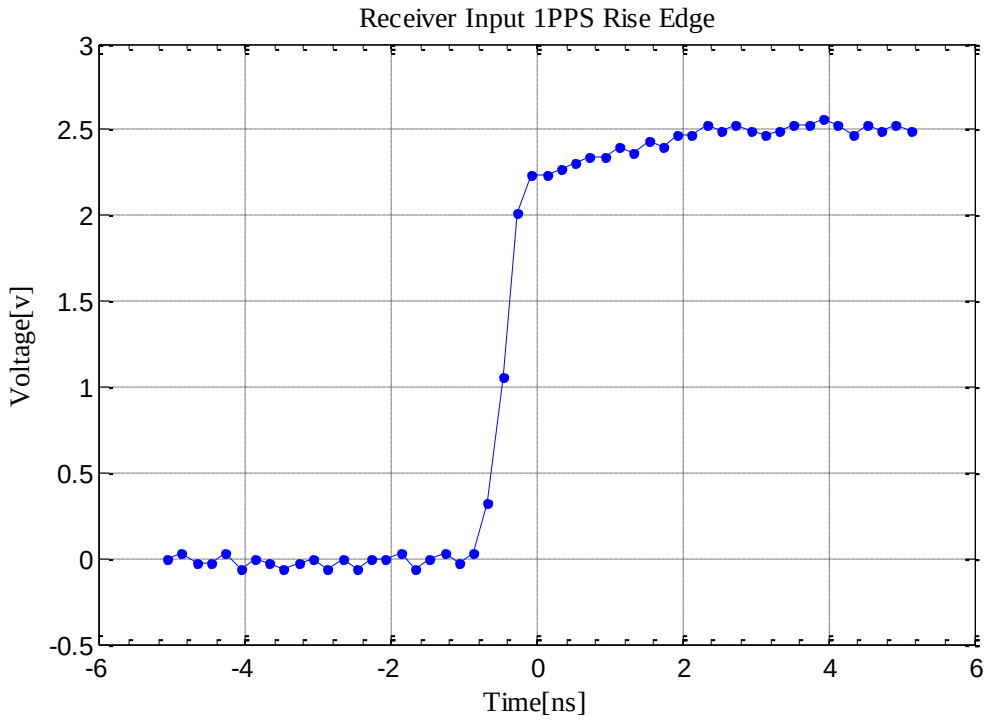
The u_a uncertainties of P1, P2 and P1-P2 codes are evaluated from the TDEV of CCD experiments shown in the figures in Annex 2 at the corresponding site.

8. Climate parameters

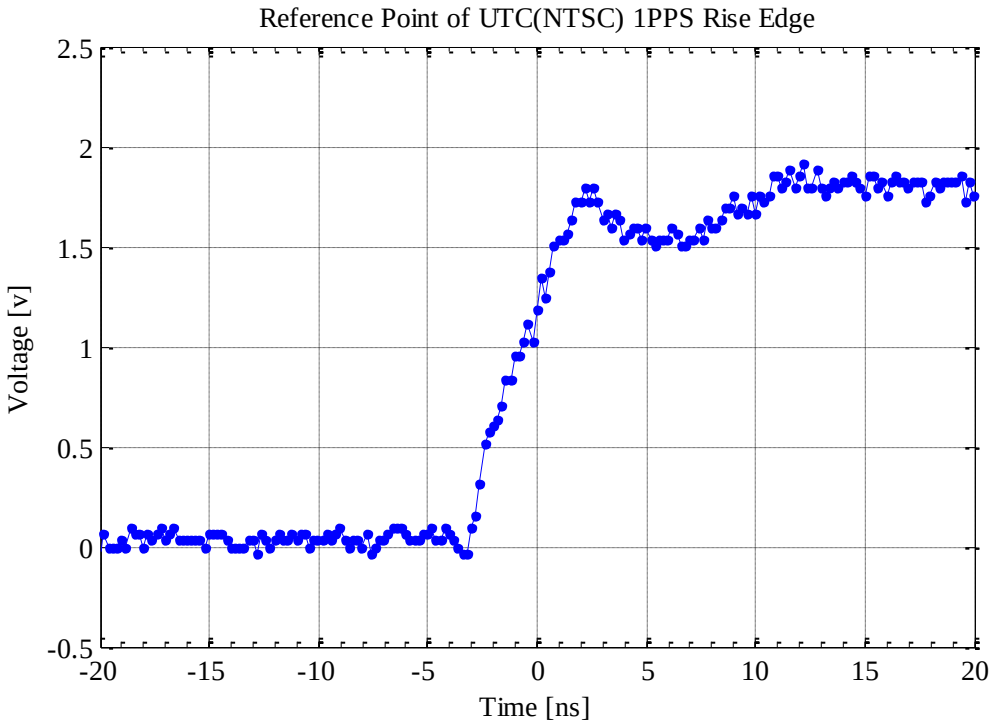
8.1. Temperature and humidity

NTP1 and NTP2 inside the same room: 21.4 degrees Celsius and 46%
NTP4 inside another room: 21.9 degrees Celsius and 44%

8.2. Reference signal



374.93 ps（20%~80%）（std =23.39 ps）



3.209 ns（20%~80%）（std =115.27 ps）

9. Comparison to NTSC results of 1001-2016 campaign

We finished the calibration and made the early version of the calibration report of 1014-2016 and submitted to BIPM, and it happened that BIPM sent its calibrator to NIM for G1 calibration, and then BIPM also sent its calibrator for the verification of NIM calibration results during the late period of July. During the first calibration by NIM, we found the raw observation of NTP4 are nosier than those of NTP1 or NTP2, and thus NTSC decided to use NTP3 receiver instead of NTP4. So BIPM has acquired the calibration values of P1 and P2 codes for NTP1, NTP2 and NTP3(please check the summary file for 1001-2016 calibration campaign).

Finally, BIPM has approved the NIM calibration results by getting the differences of P1 and P2 codes for NTP1 and NTP2 receivers between two calibrations separately by NIM and BIPM as follows. The differences are within the combined uncertainty.

Difference of $(XR+XS)_{NTP1\_P1}$ = 56.1-55.7 = 0.4 ns
Difference of $(XR+XS)_{NTP1\_P2}$ = 54.8-55.1 = -0.3 ns
Difference of $(XR+XS)_{NTP1\_P3}$ = 58.2-56.6 = 1.6 ns

Difference of $(XR+XS)_{NTP2\_P1}$ = 55.9-55.5 = 0.4 ns
Difference of $(XR+XS)_{NTP2\_P2}$ = 53.9-54.2 = -0.3 ns
Difference of $(XR+XS)_{NTP2\_P3}$ = 59.0 -57.5 = 1.7 ns

References:

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

Annex 1. CCD results(P3 code) for calculation

1. Start CCD before calibration

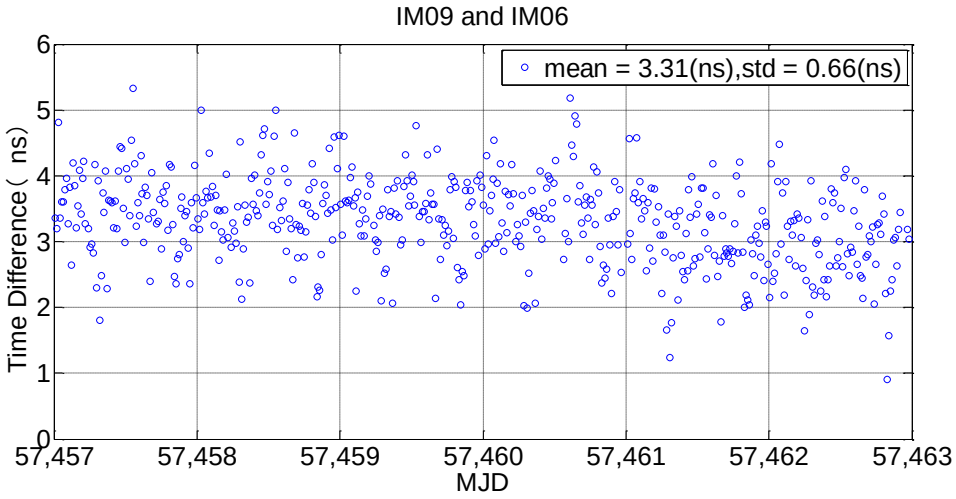


Figure 8. CCD between IM09 and IM06 at NIM

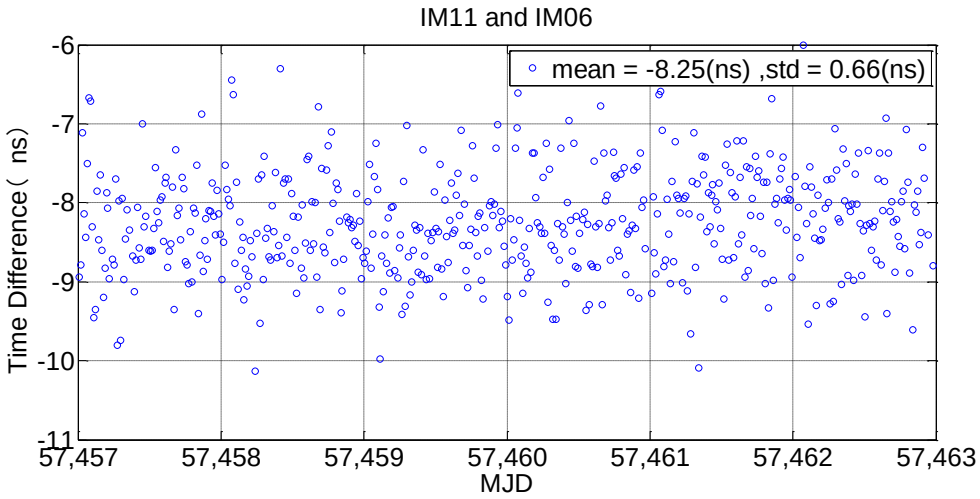


Figure 9. CCD between IM11 and IM06 at NIM

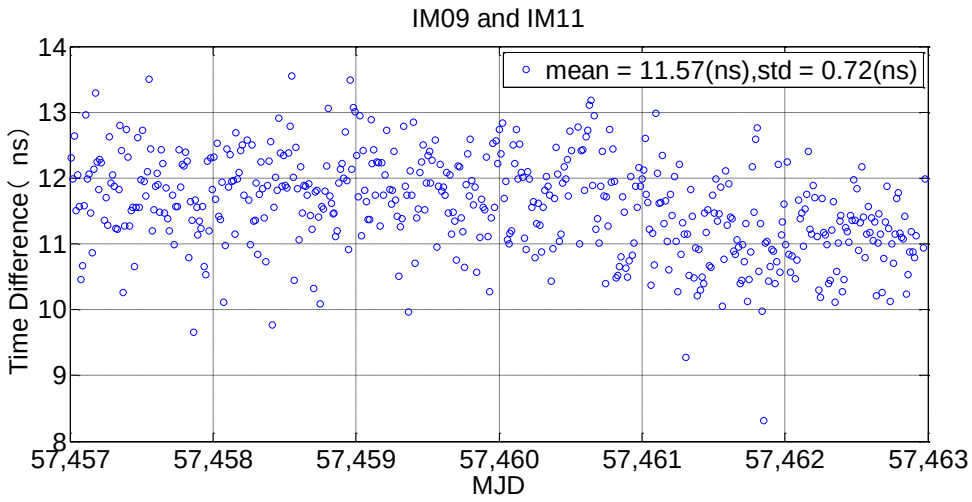


Figure 10. CCD between IM09 and IM11 at NIM

2. Calibration on site

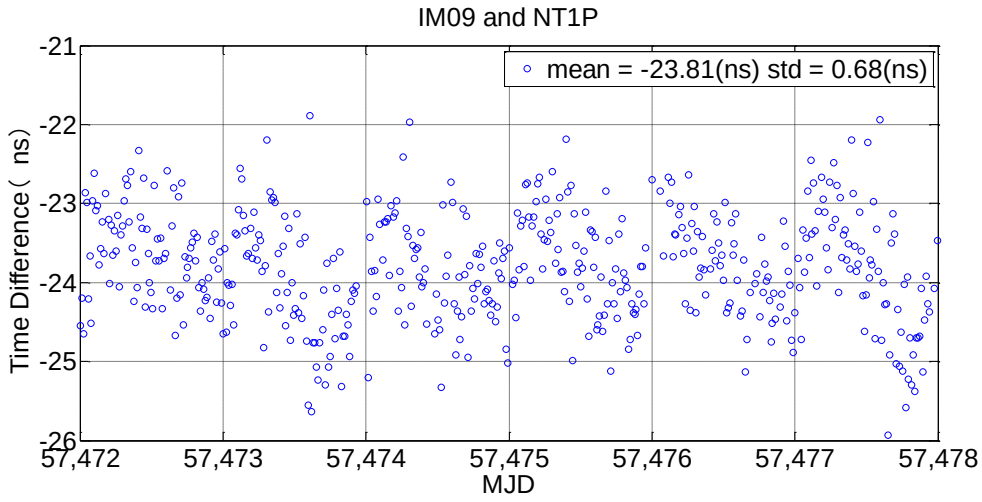


Figure 12. CCD between IM09 and NTP1 at NTSC

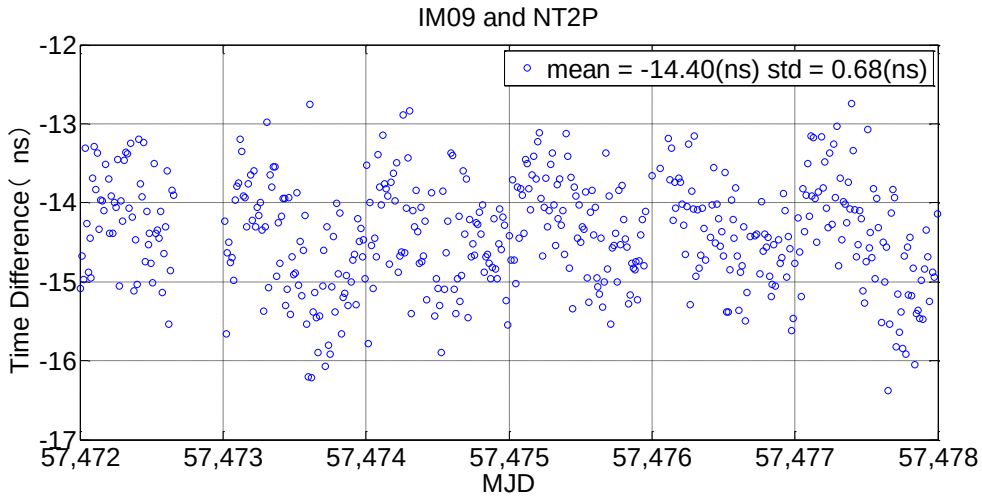


Figure 13. CCD between IM09 and NTP2 at NTSC

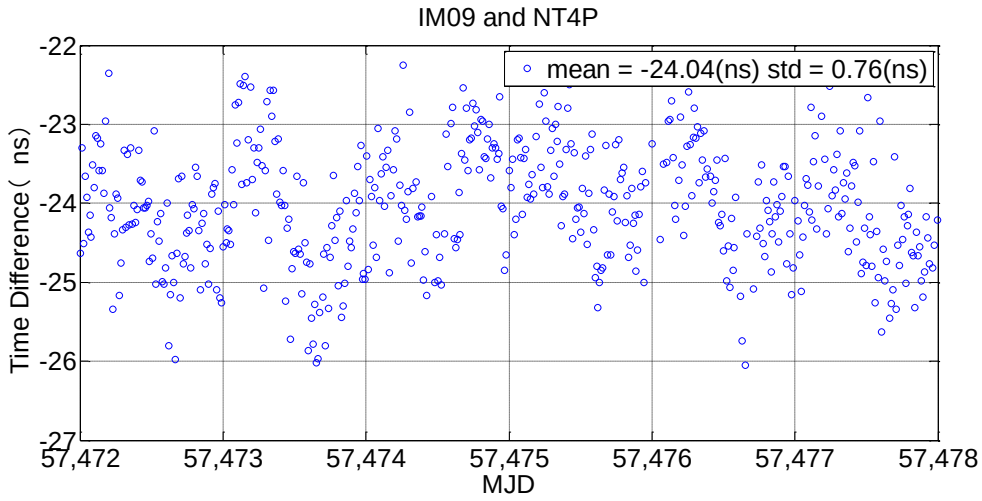


Figure 14. CCD between IM09 and NTP4 at NTSC

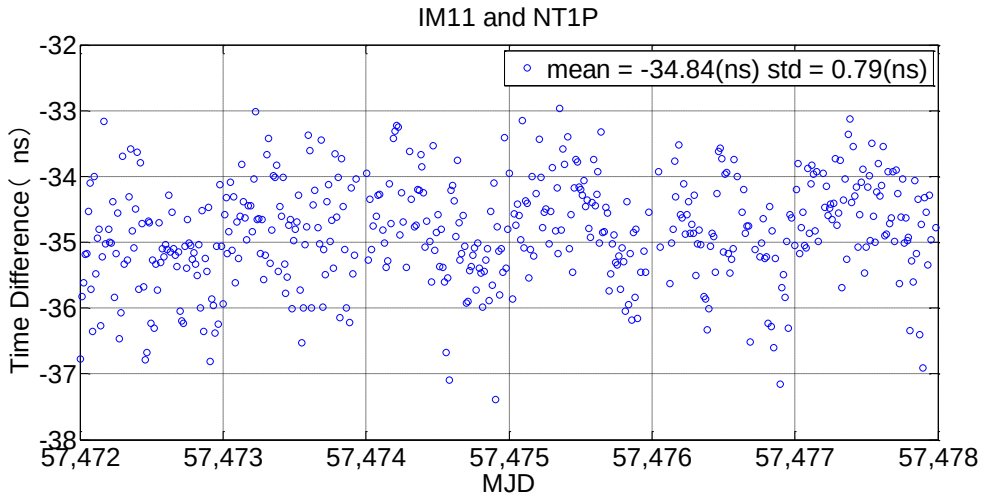


Figure 15. CCD between IM11 and NTP1 at NTSC

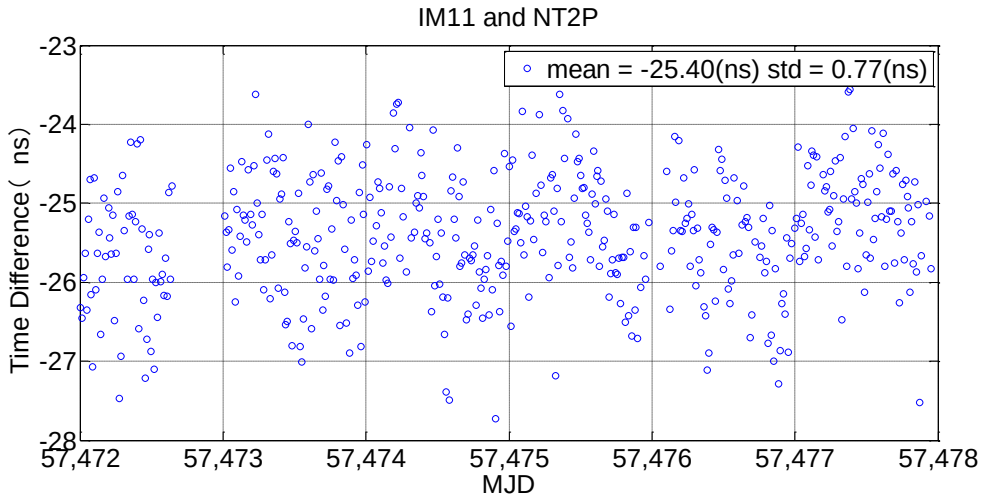


Figure 16. CCD between IM11 and NTP2 at NTSC

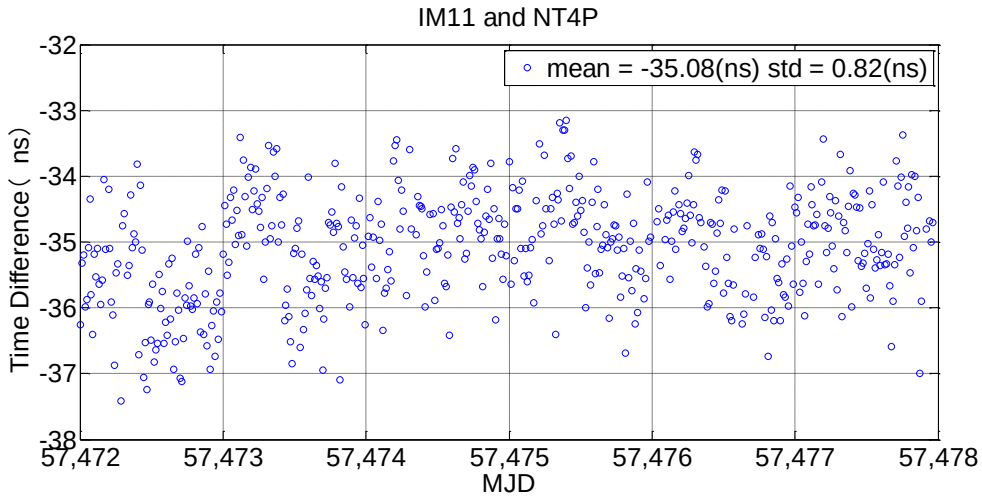


Figure 17. CCD between IM11 and NTP4 at NTSC

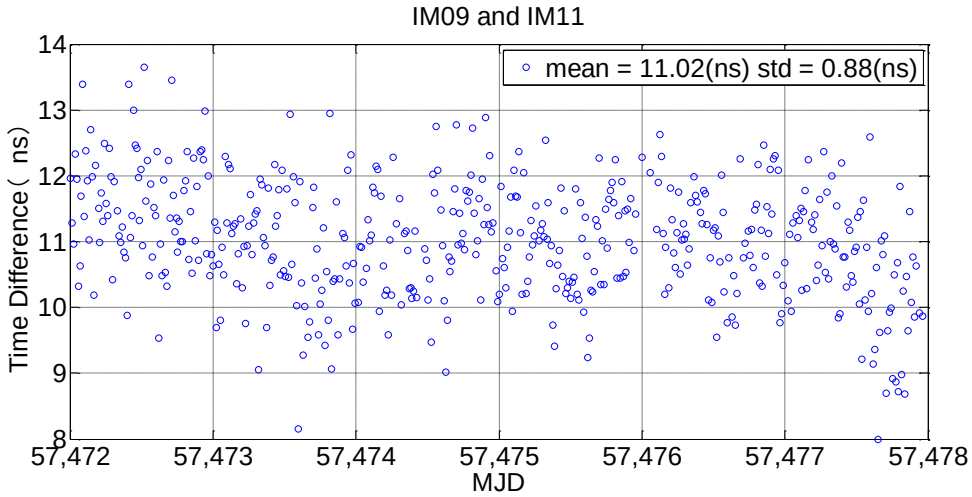


Figure 18. CCD between IM09 and IM11 at NTSC

3. Closure CCD after calibration

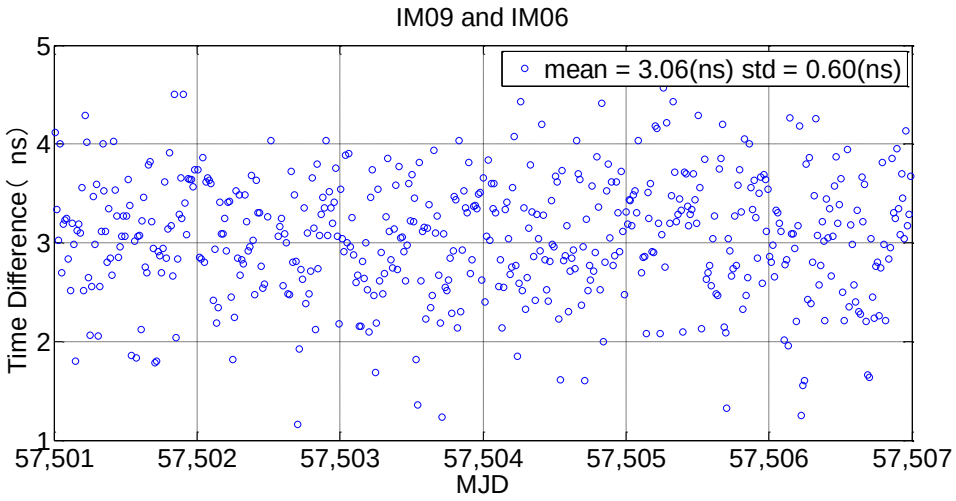


Figure 20. CCD between IM09 and IM06 at NIM

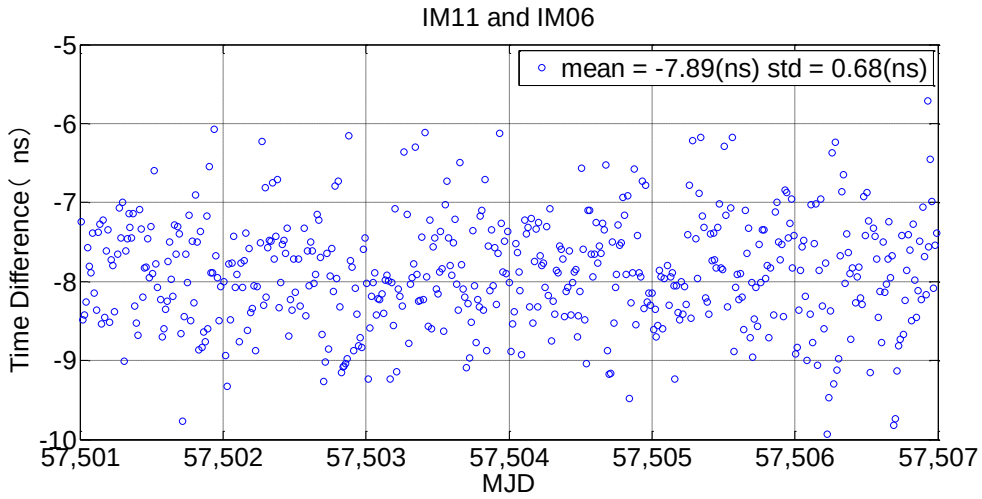


Figure 21. CCD between IM11 and IM06 at NIM

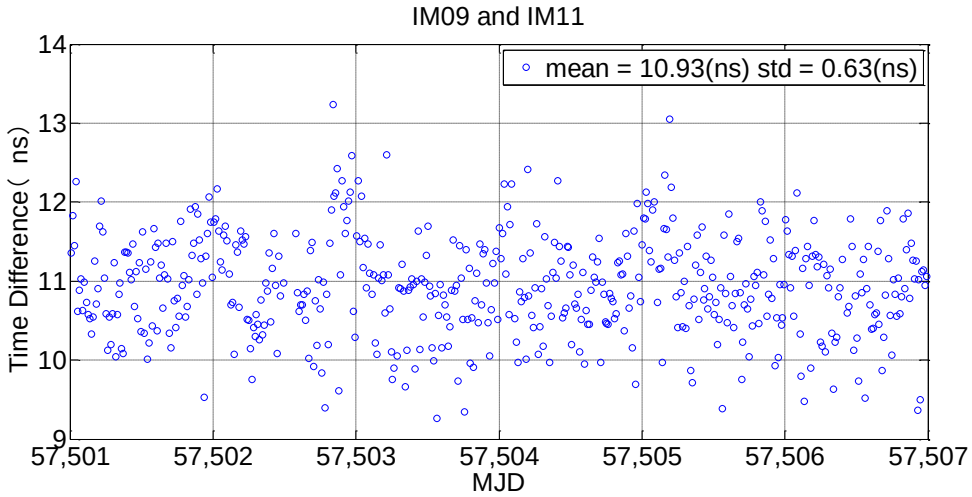
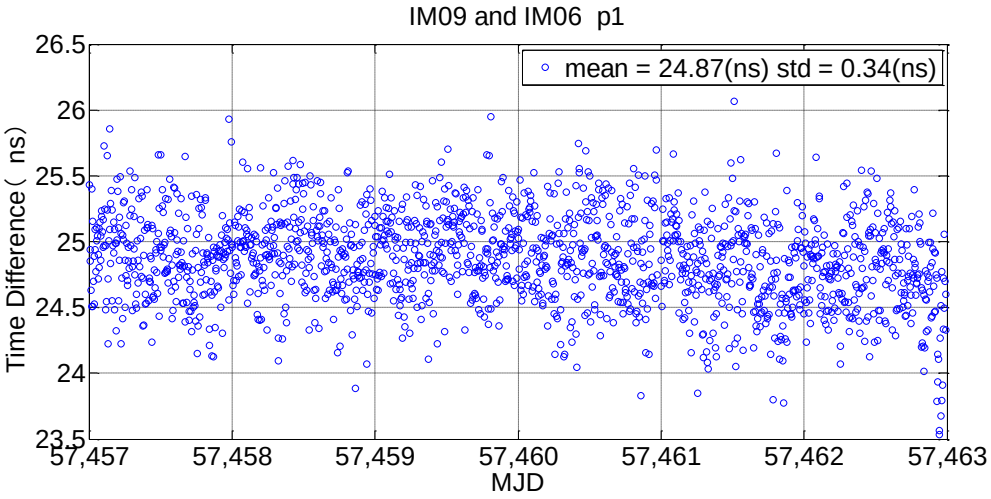


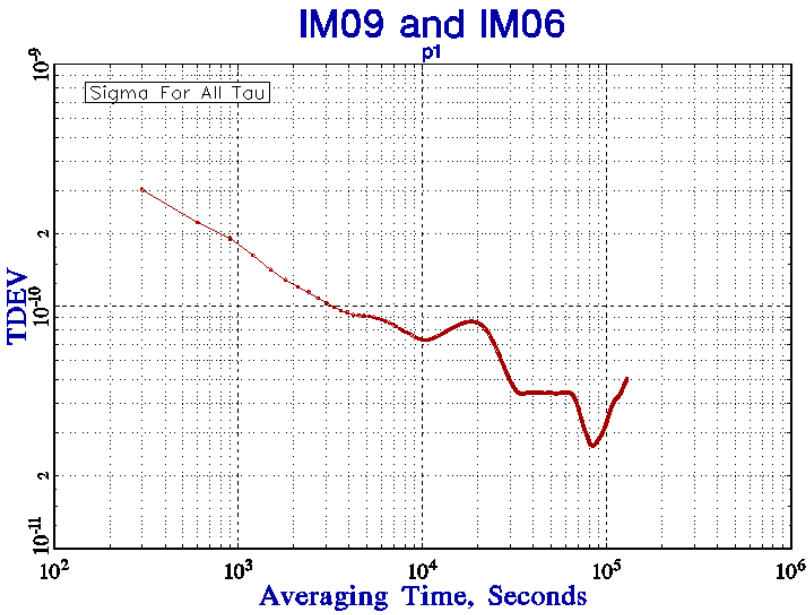
Figure 22. CCD between IM09 and IM11 at NIM

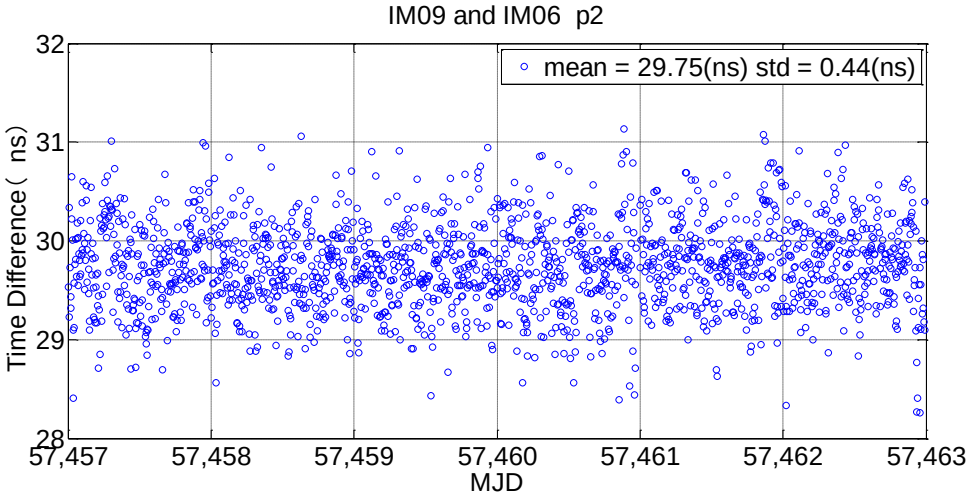
Annex 2. CCD results using dclrinex

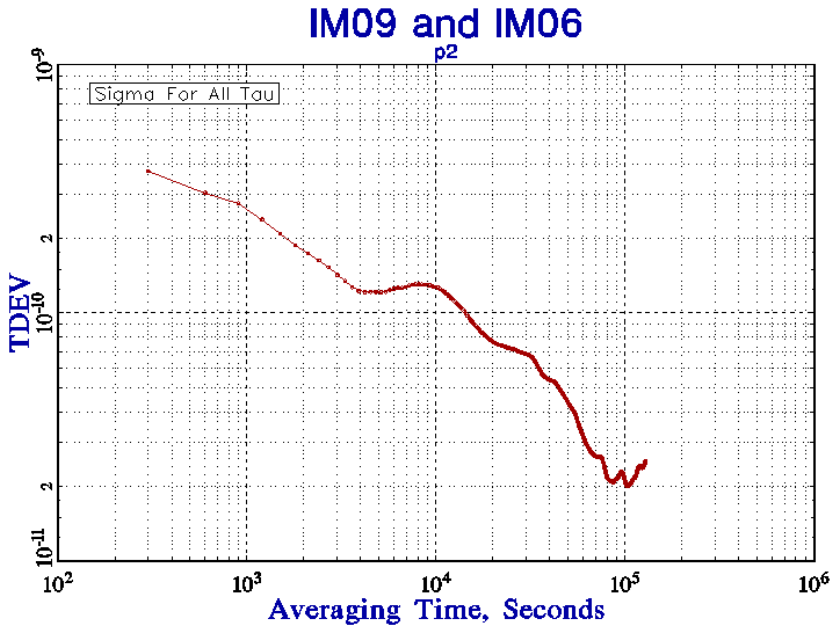
1. Start CCD before calibration

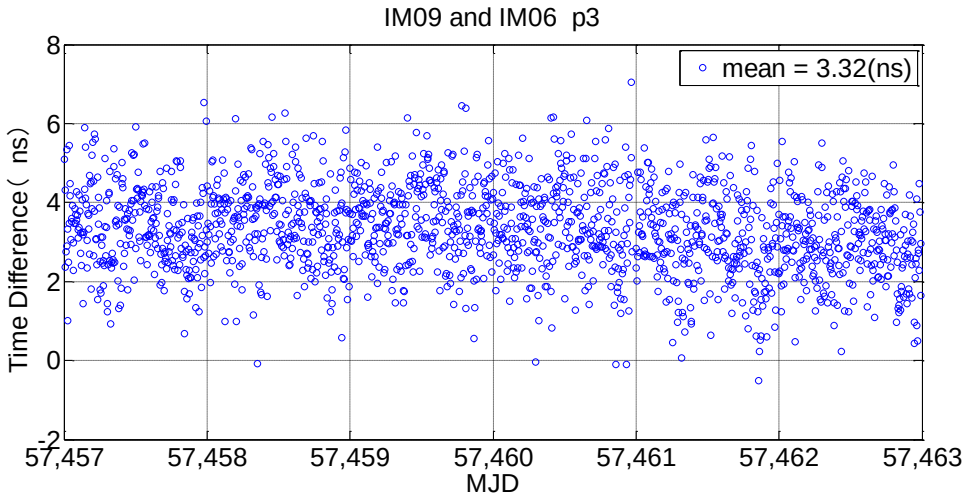
IMEC-IMEJ

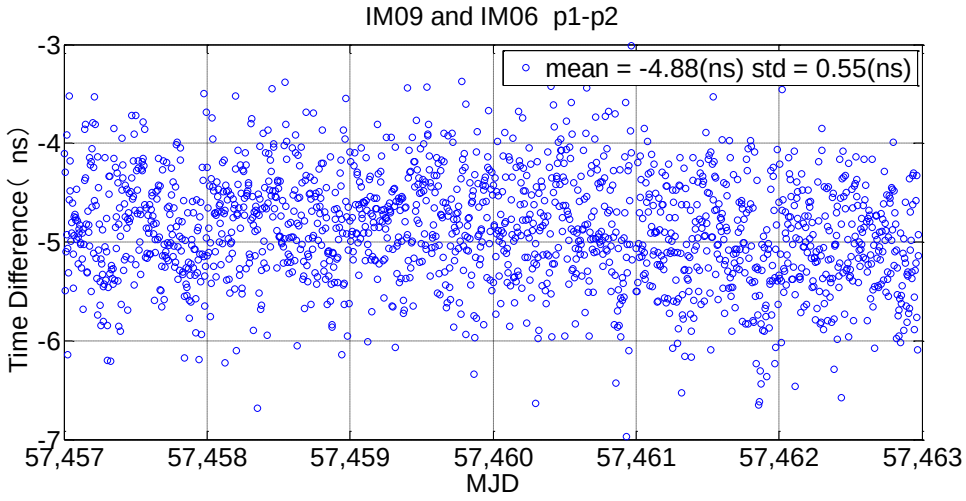


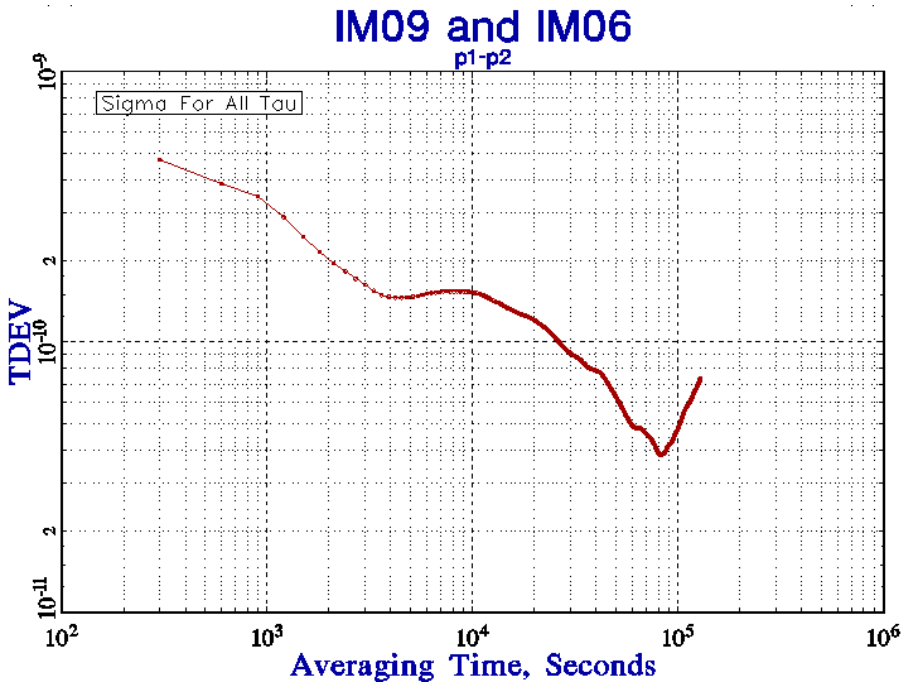




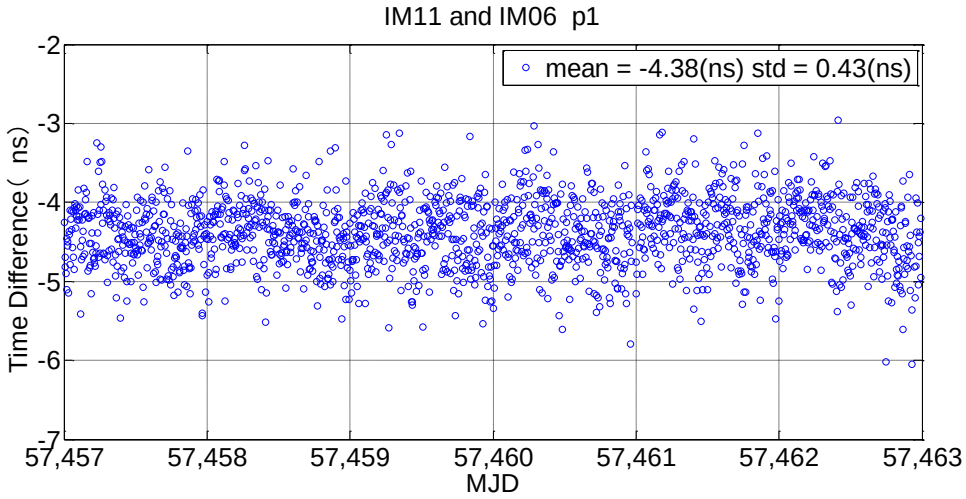

IM09 and IM06
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

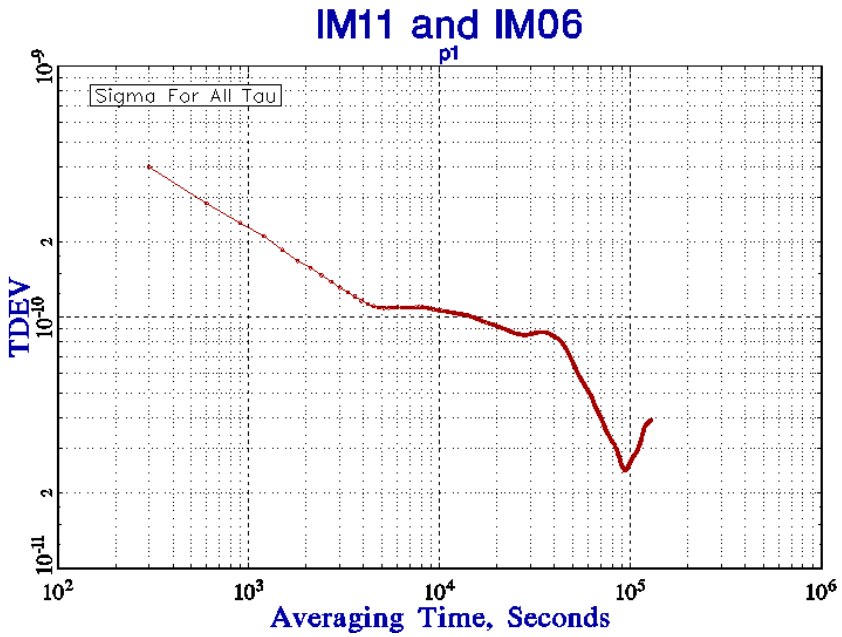

IM09 and IM06 p3
mean = 3.32(ns)
Time Difference (ns)
MJD

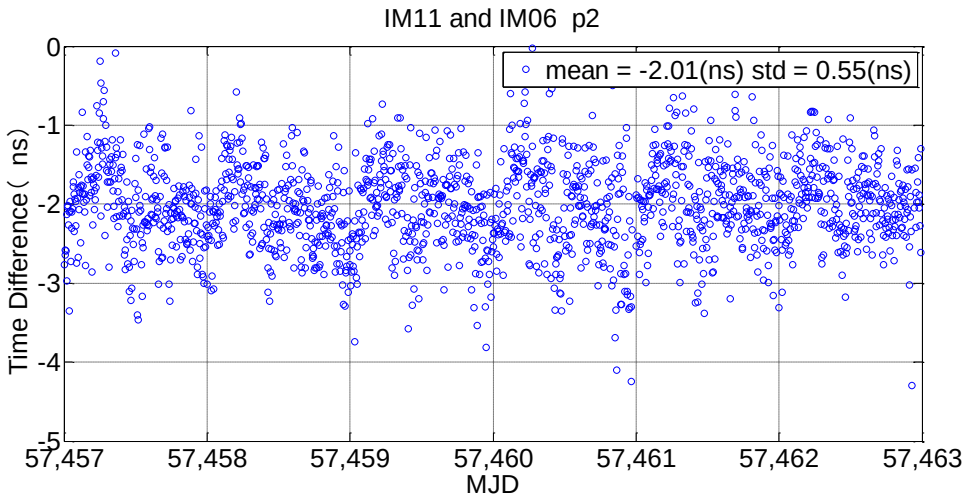

IM09 and IM06 p1-p2
mean = -4.88(ns) std = 0.55(ns)
Time Difference (ns)
MJD

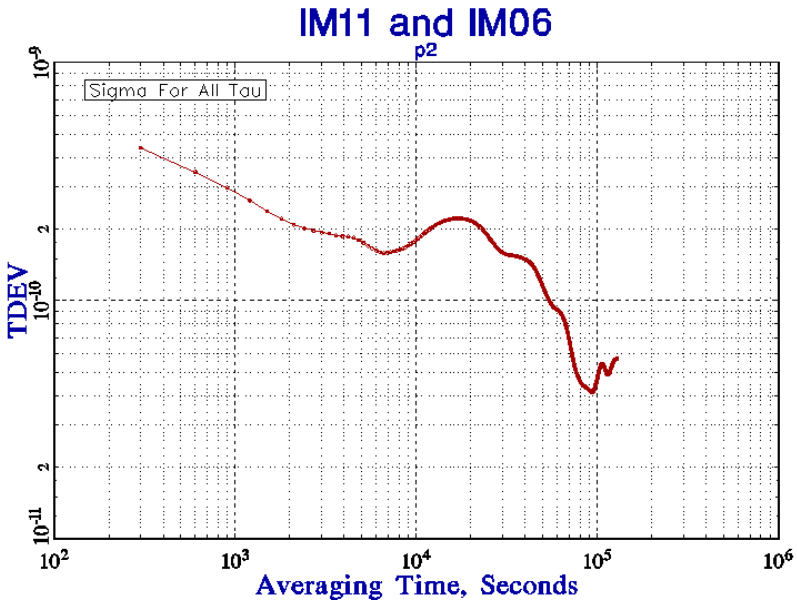

IM09 and IM06
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

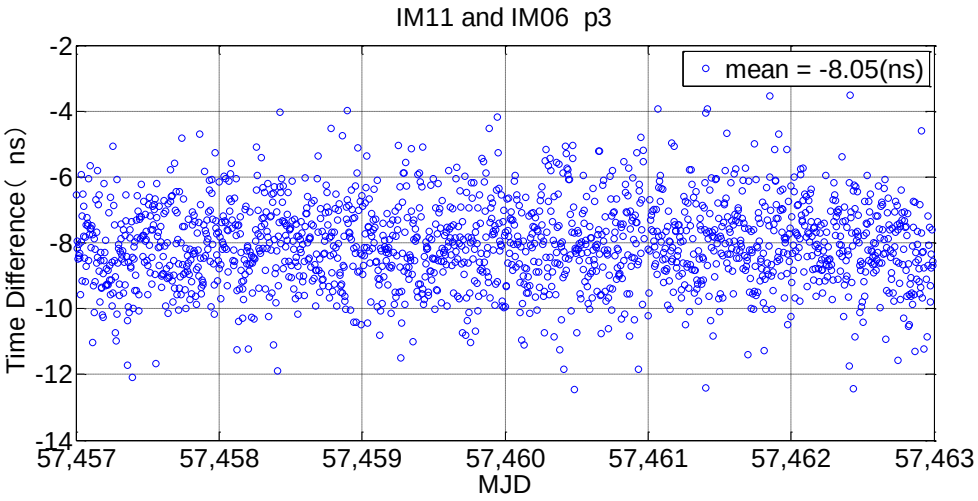
IMEK-IMEJ

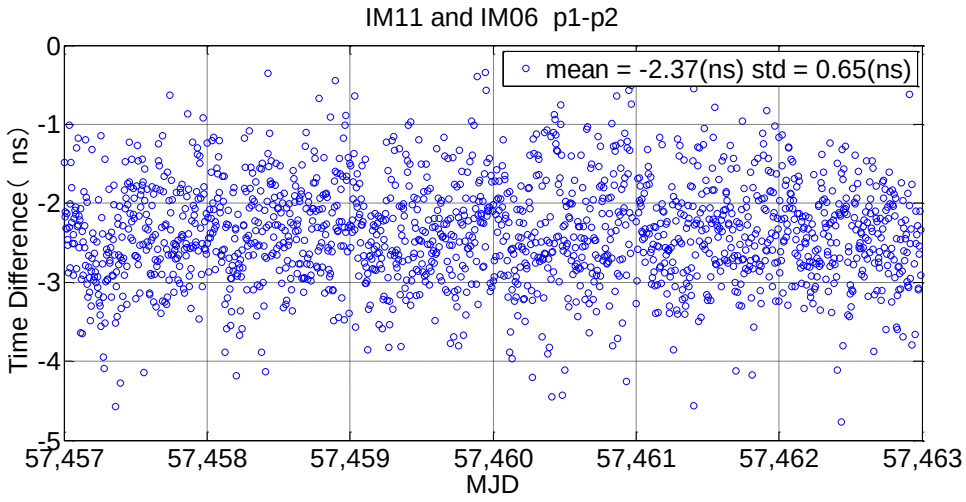

IM11 and IM06 p1
mean = -4.38(ns) std = 0.43(ns)
Time Difference (ns)
MJD

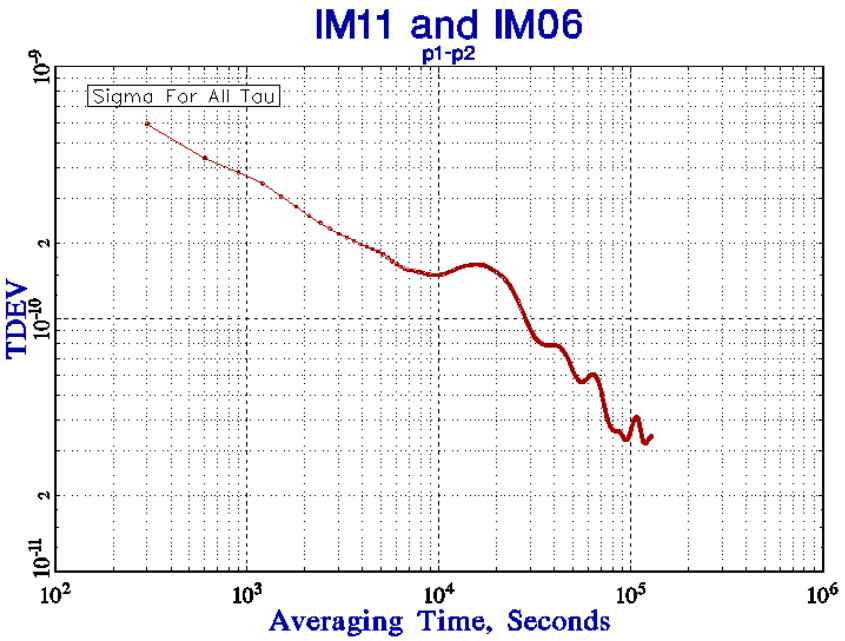

IM11 and IM06
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM11 and IM06 p2
mean = -2.01(ns) std = 0.55(ns)
Time Difference (ns)
MJD

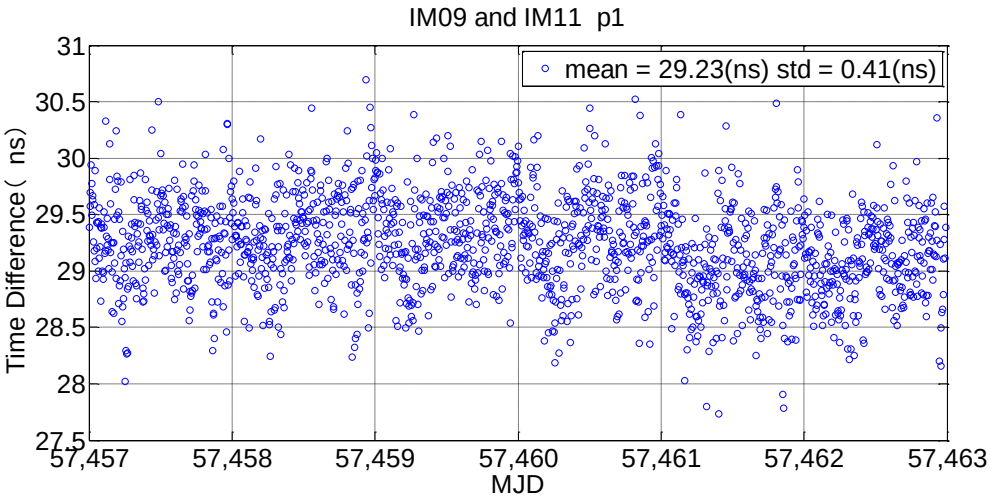

IM11 and IM06
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

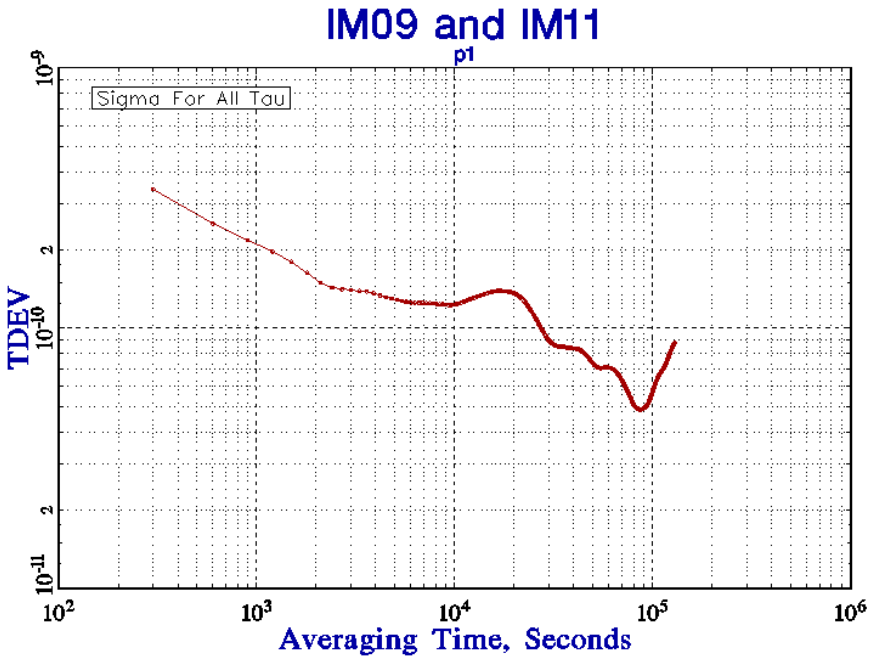

IM11 and IM06 p3
mean = -8.05(ns)
Time Difference (ns)
-2
-4
-6
-8
-10
-12
-14
57,457
57,458
57,459
57,460
57,461
57,462
57,463
MJD

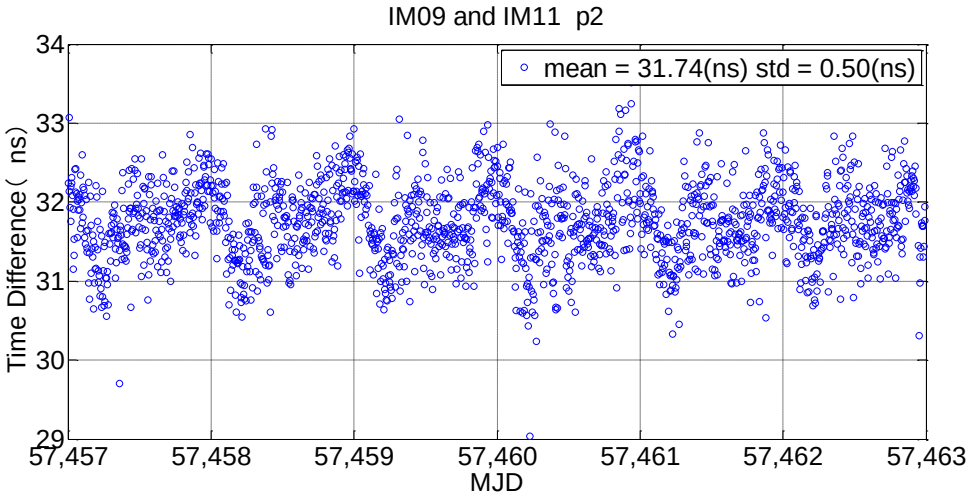

IM11 and IM06 p1-p2
mean = -2.37(ns) std = 0.65(ns)
Time Difference (ns)
0
-1
-2
-3
-4
-5
57,457
57,458
57,459
57,460
57,461
57,462
57,463
MJD

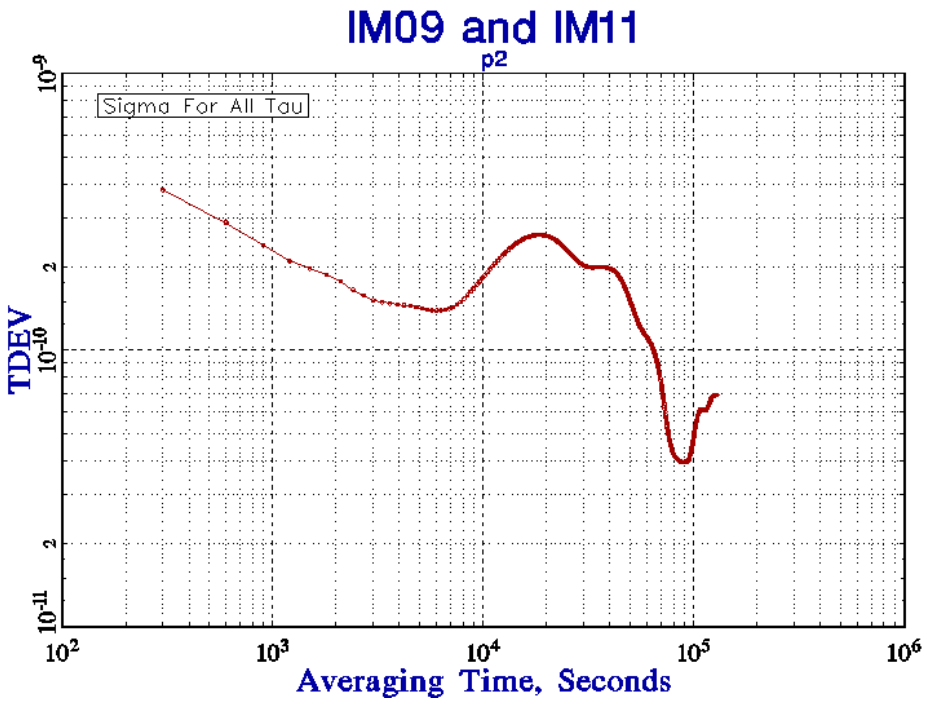

IM11 and IM06
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

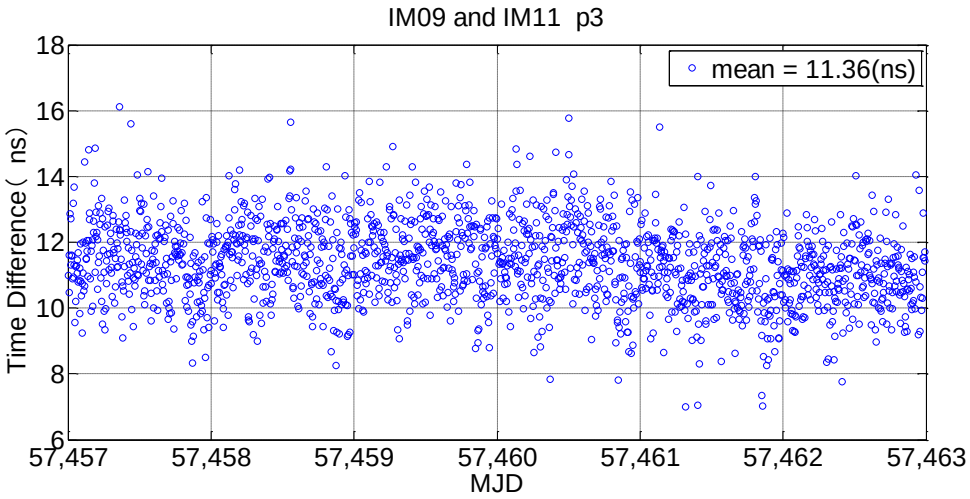
IMEC-IMEK

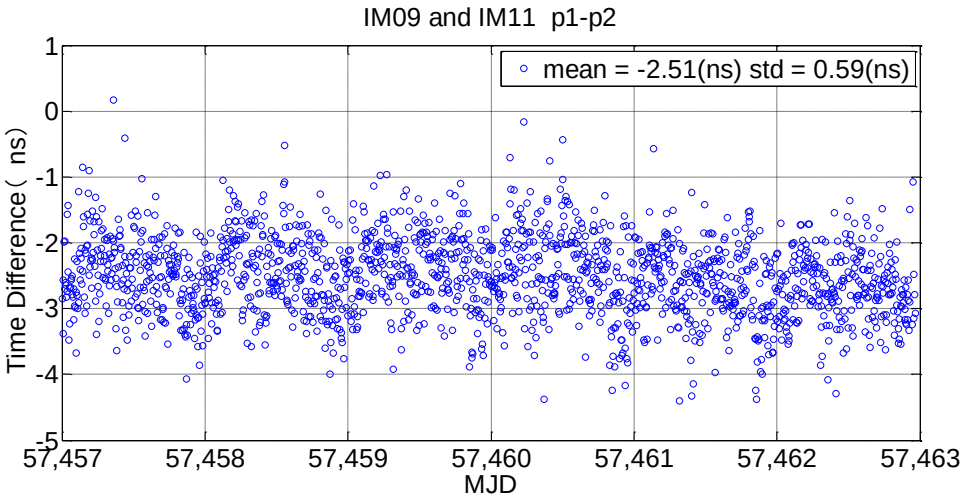

IM09 and IM11 p1
mean = 29.23(ns) std = 0.41(ns)
Time Difference (ns)
MJD

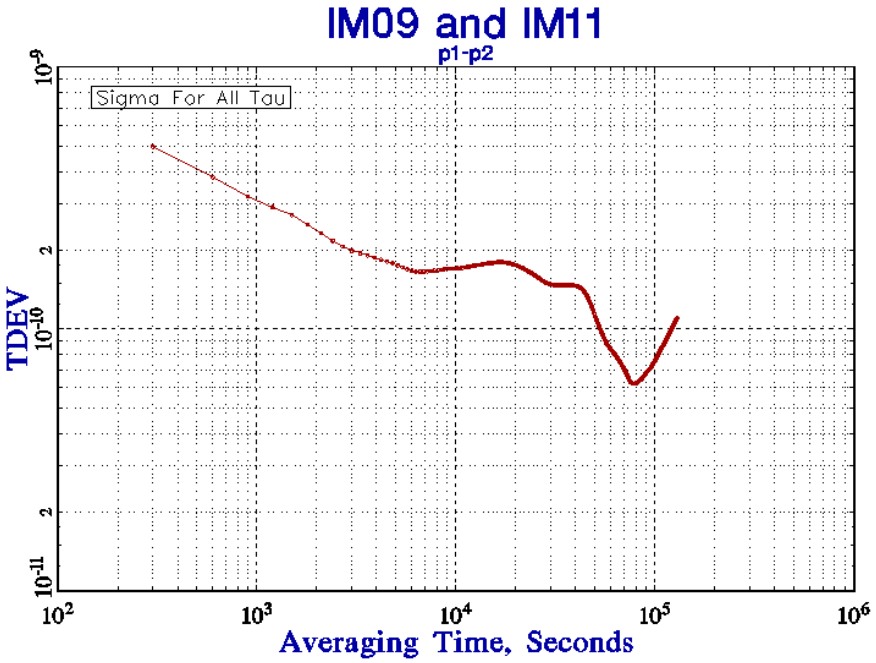

IM09 and IM11
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM09 and IM11 p2
mean = 31.74(ns) std = 0.50(ns)
Time Difference (ns)
MJD


IM09 and IM11
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

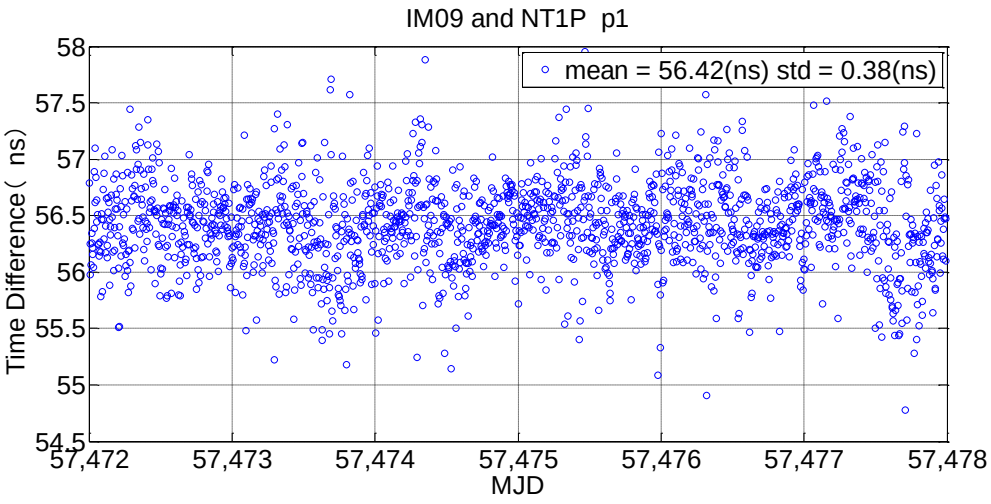

IM09 and IM11 p3
mean = 11.36(ns)
Time Difference (ns)
MJD

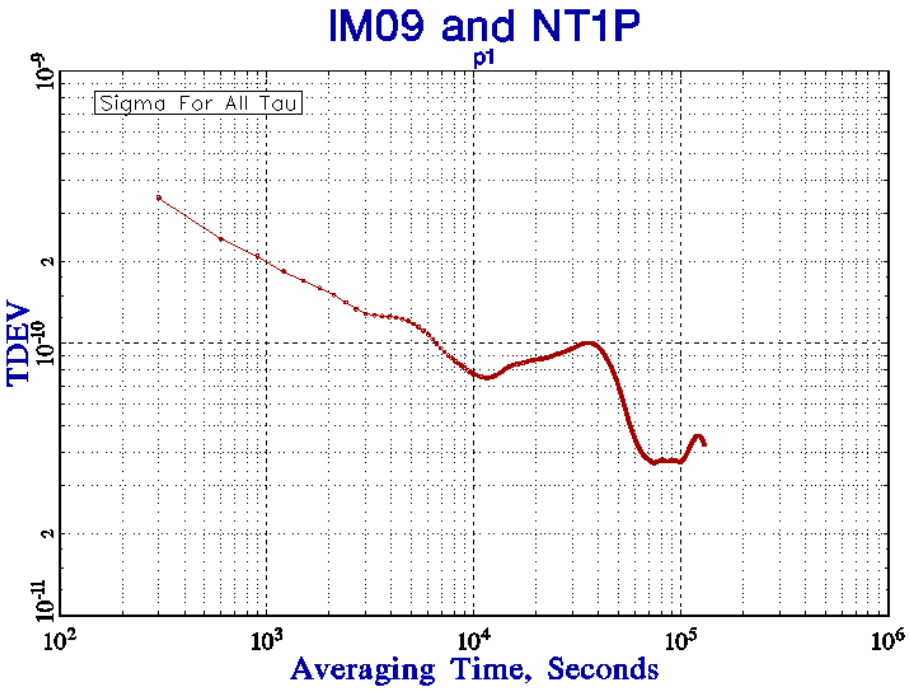


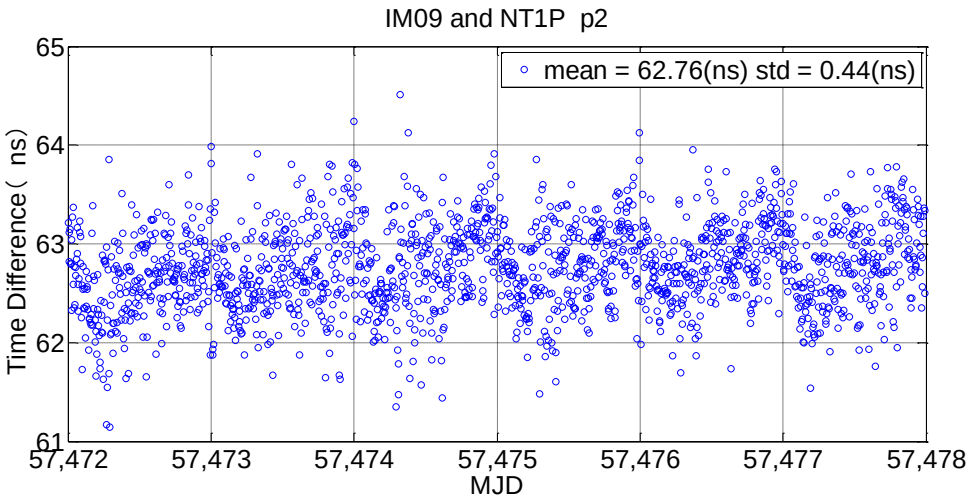


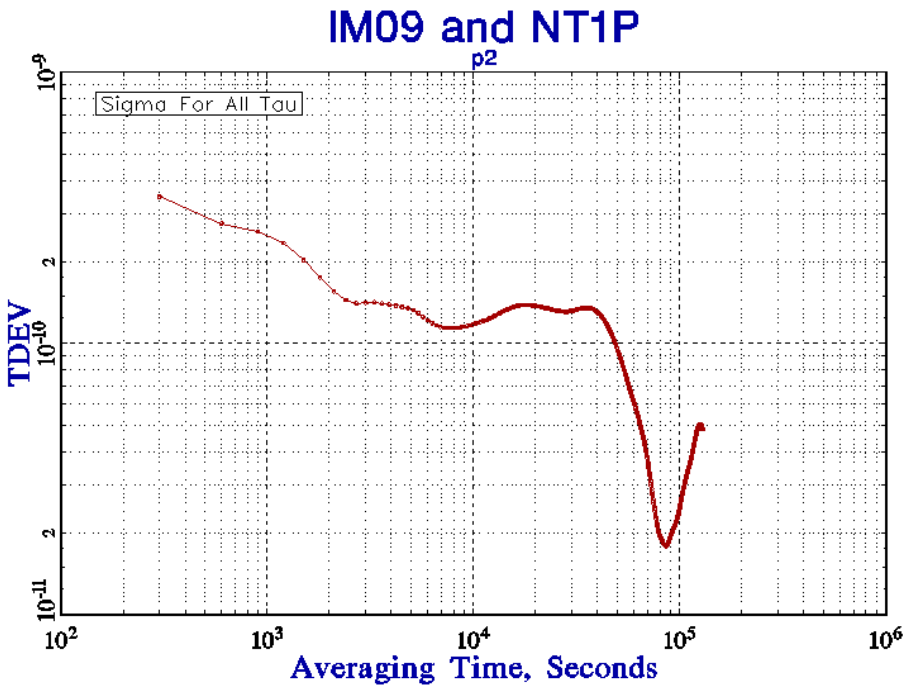
2. Calibration on site

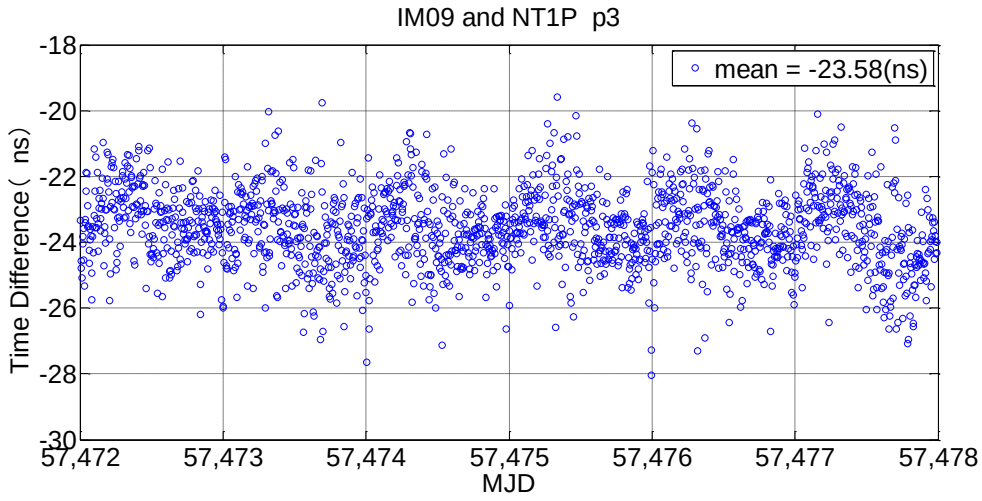
IMEC-NTP1

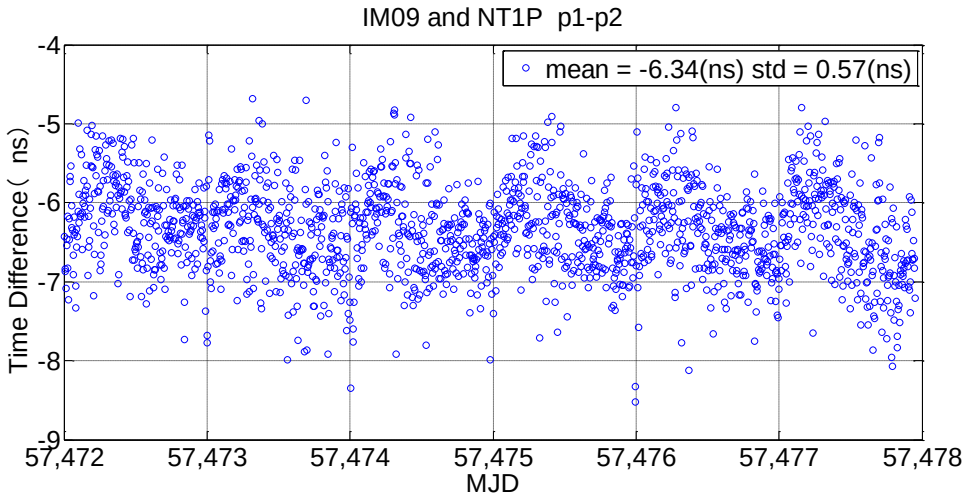


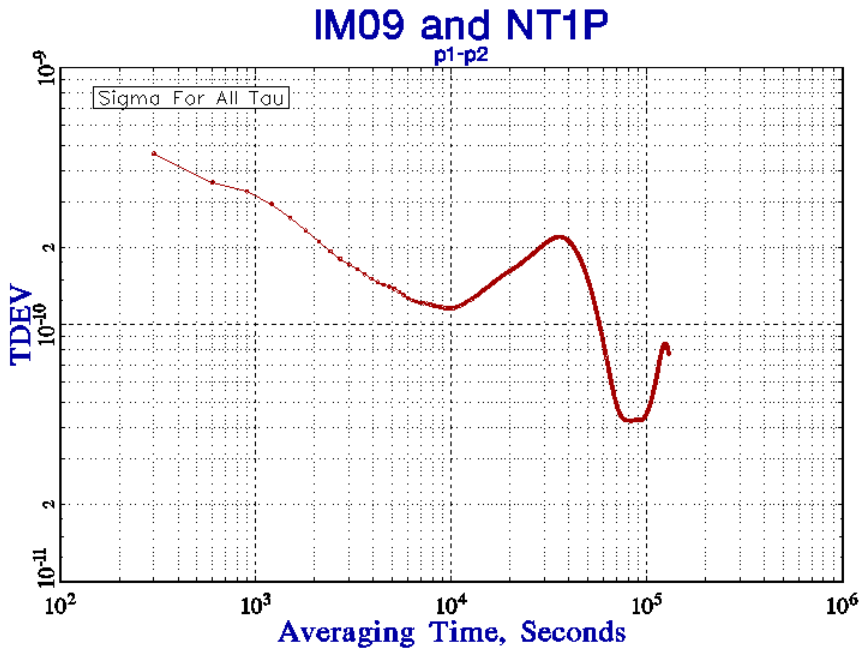

IM09 and NT1P
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM09 and NT1P p2
mean = 62.76(ns) std = 0.44(ns)
Time Difference (ns)
MJD

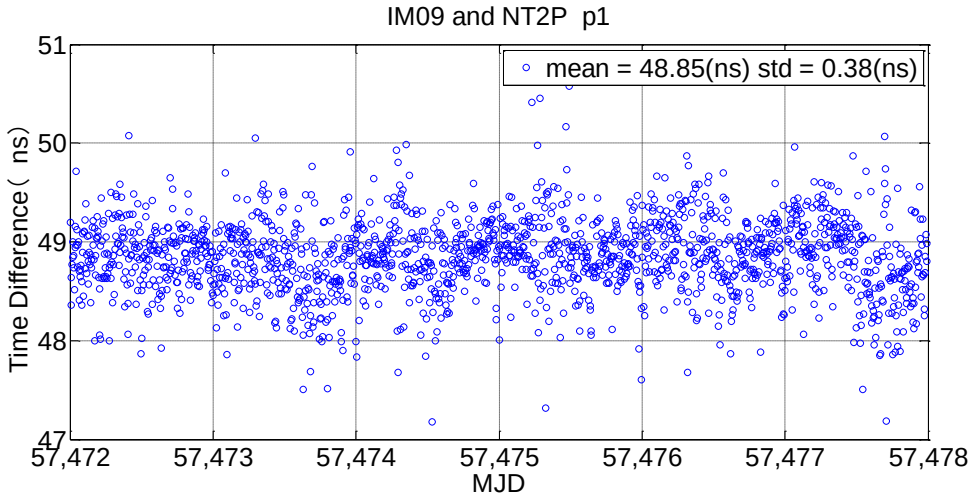

IM09 and NT1P
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

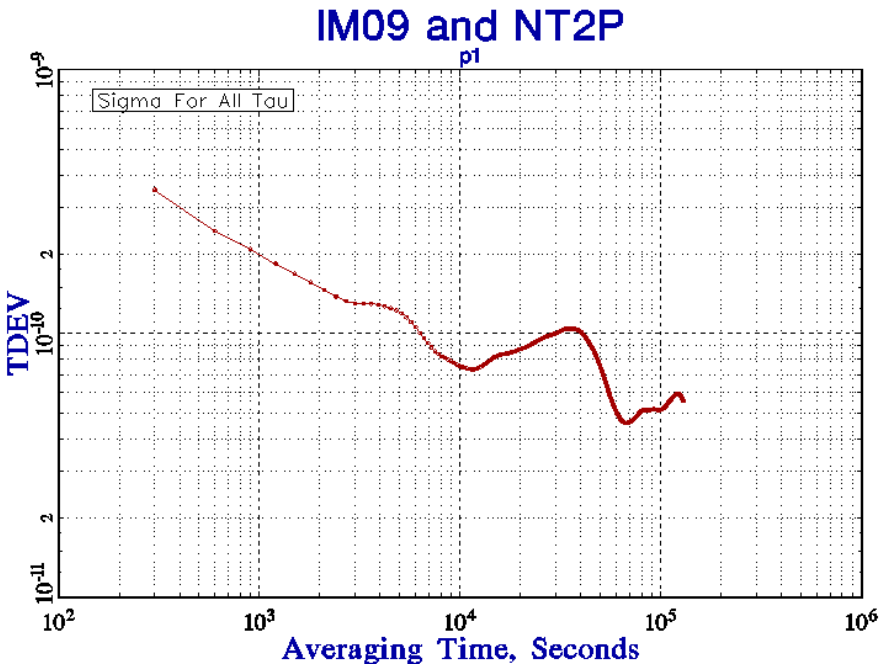

IM09 and NT1P p3
mean = -23.58(ns)
Time Difference (ns)
MJD

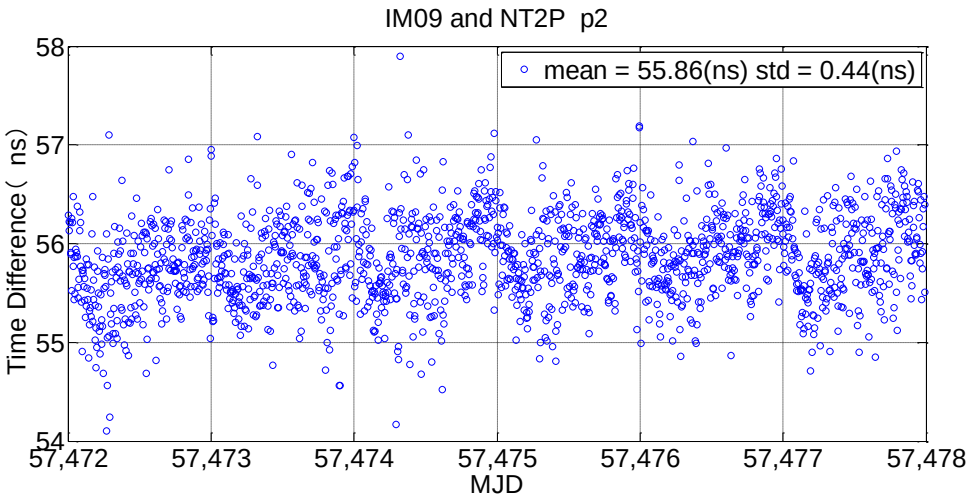

IM09 and NT1P p1-p2
mean = -6.34(ns) std = 0.57(ns)
Time Difference (ns)
MJD

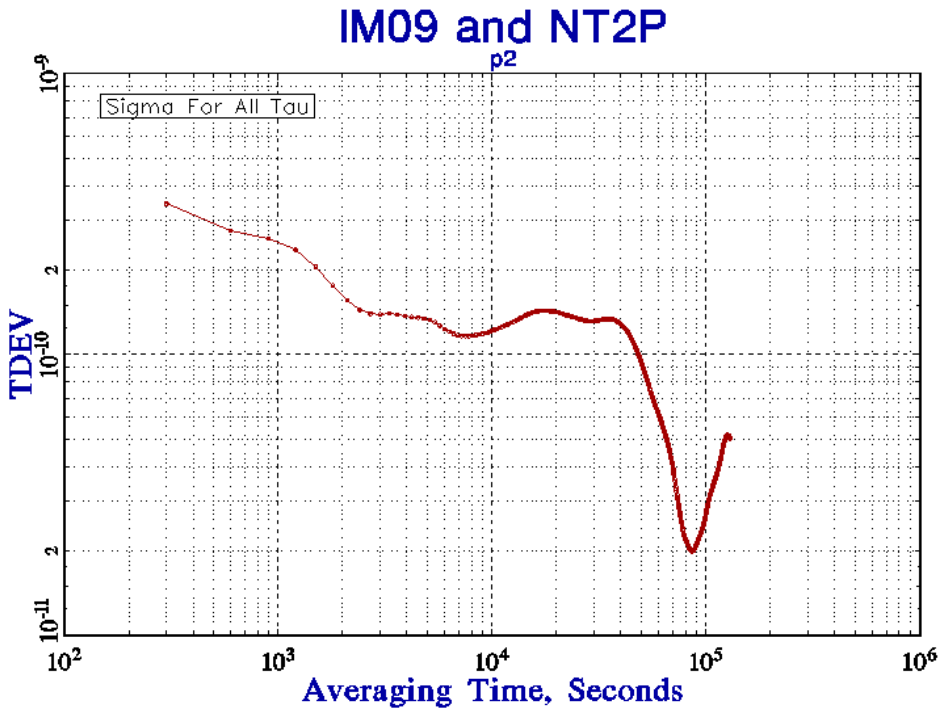

IM09 and NT1P
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

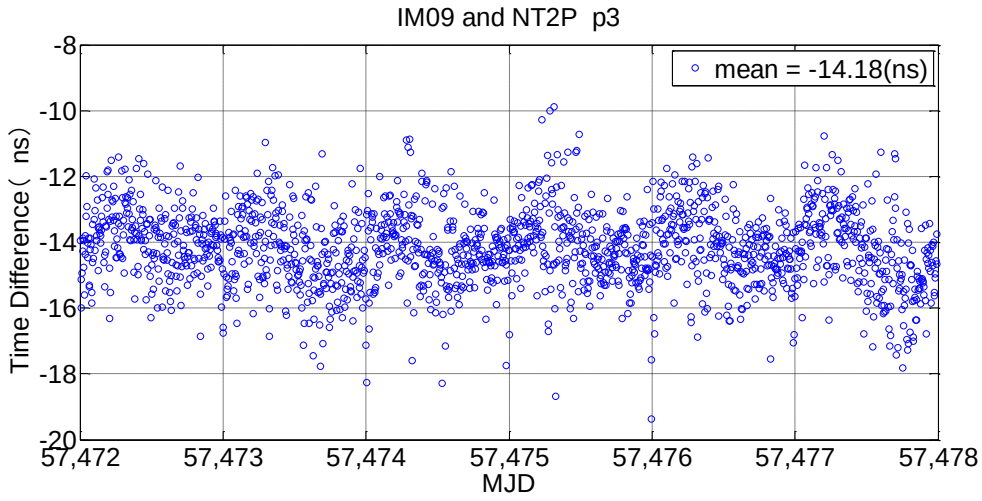
IMEC-NTP2

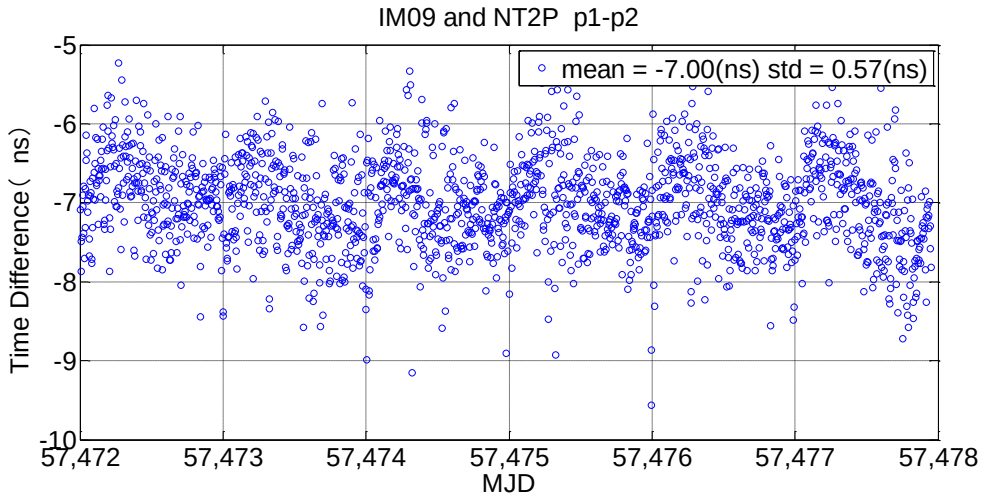

IM09 and NT2P p1
mean = 48.85(ns) std = 0.38(ns)
Time Difference (ns)
MJD

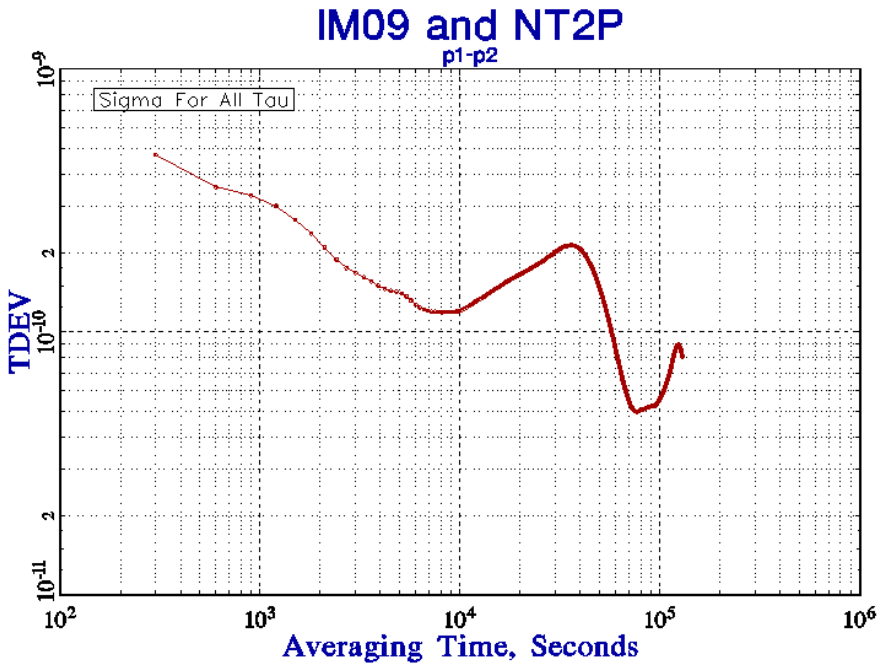

IM09 and NT2P
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM09 and NT2P p2
mean = 55.86(ns) std = 0.44(ns)
Time Difference (ns)
MJD

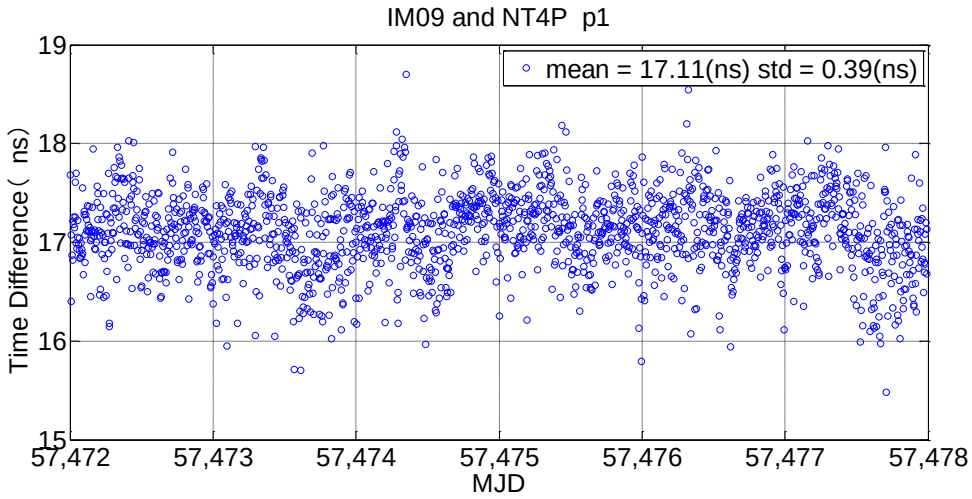

IM09 and NT2P
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

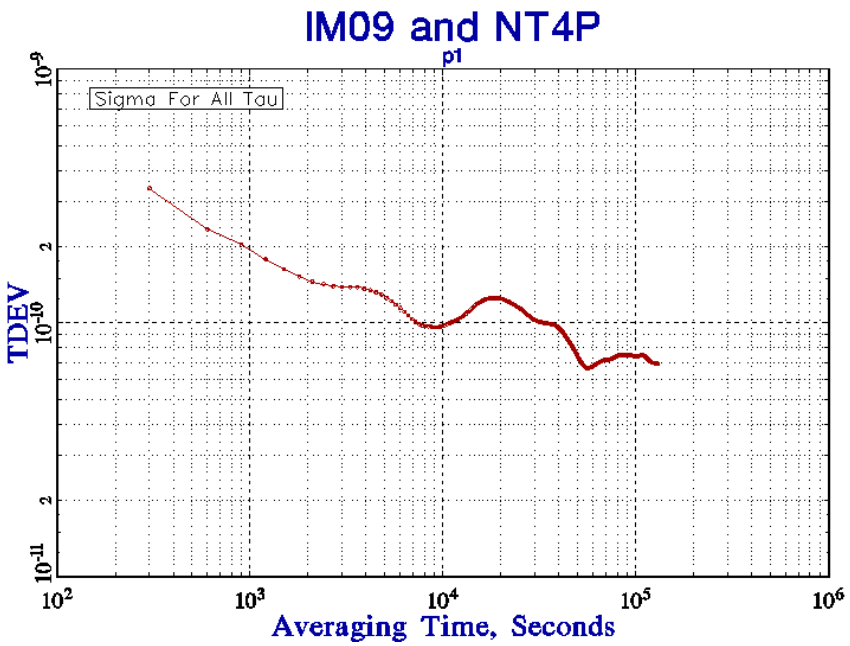

IM09 and NT2P p3
mean = -14.18(ns)
Time Difference (ns)
MJD

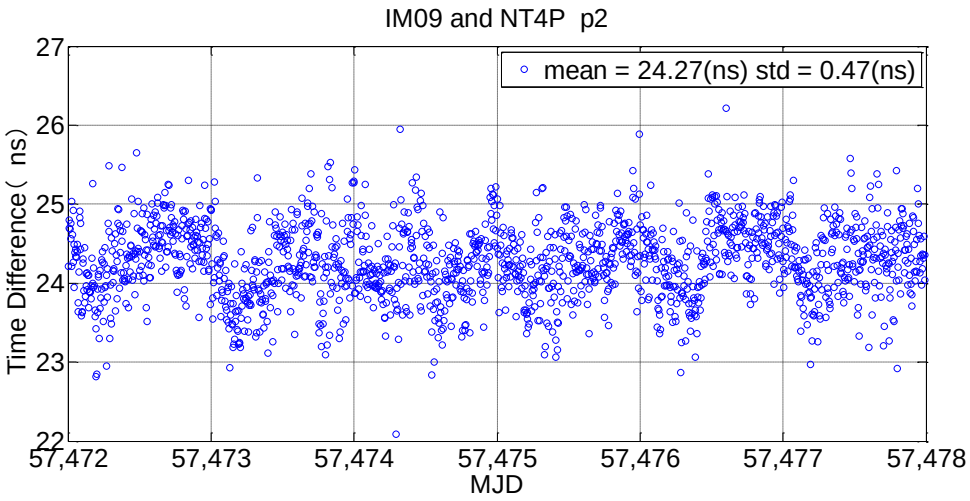

IM09 and NT2P p1-p2
mean = -7.00(ns) std = 0.57(ns)
Time Difference (ns)
MJD

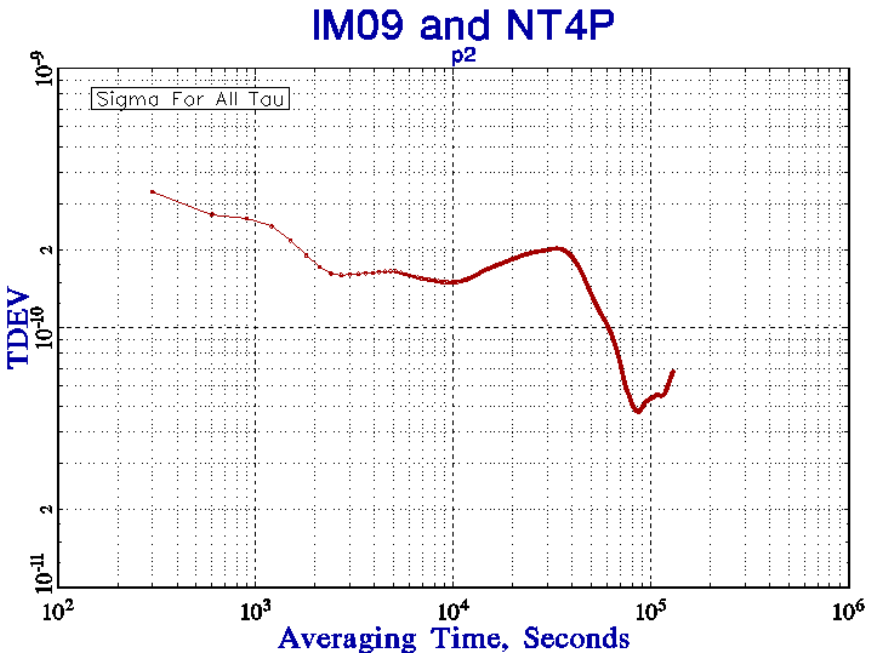

IM09 and NT2P
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

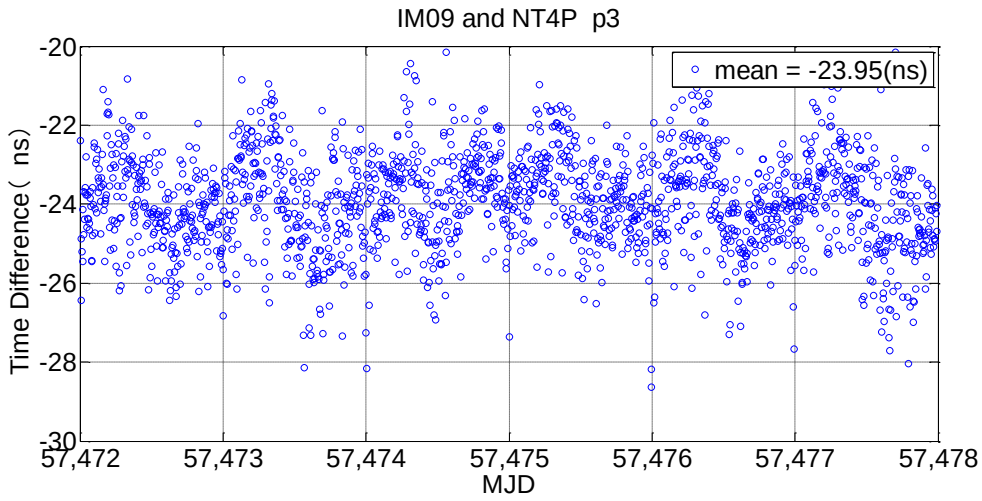
IMEC-NTP4

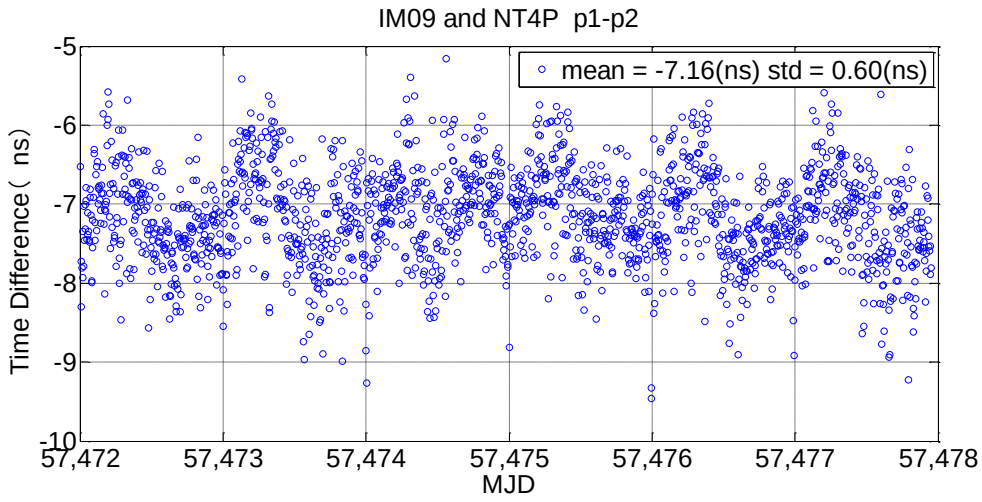

IM09 and NT4P p1
mean = 17.11(ns) std = 0.39(ns)
Time Difference (ns)
MJD

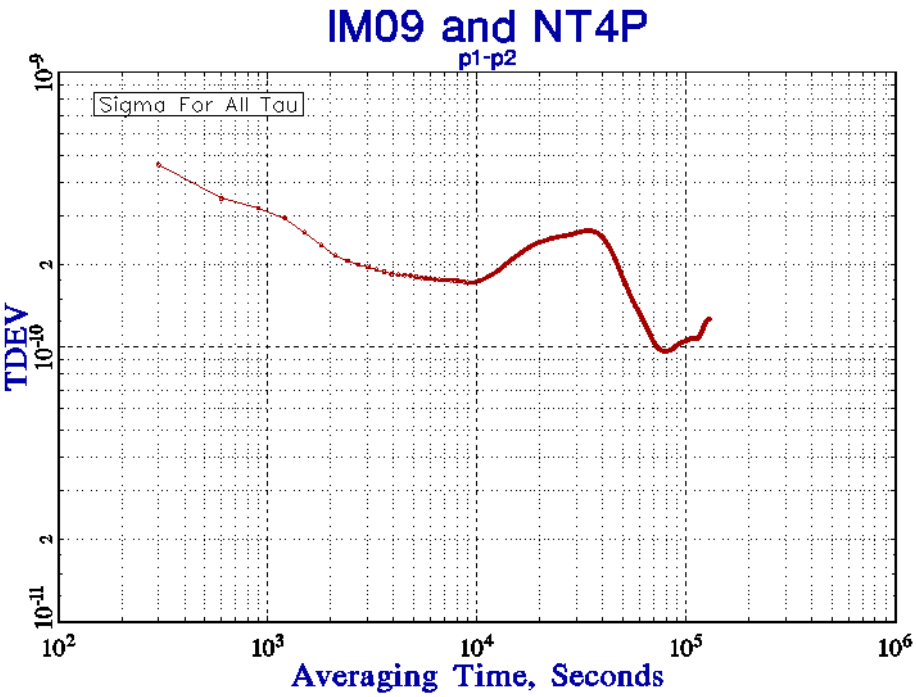

IM09 and NT4P
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM09 and NT4P p2
mean = 24.27(ns) std = 0.47(ns)
Time Difference (ns)
MJD

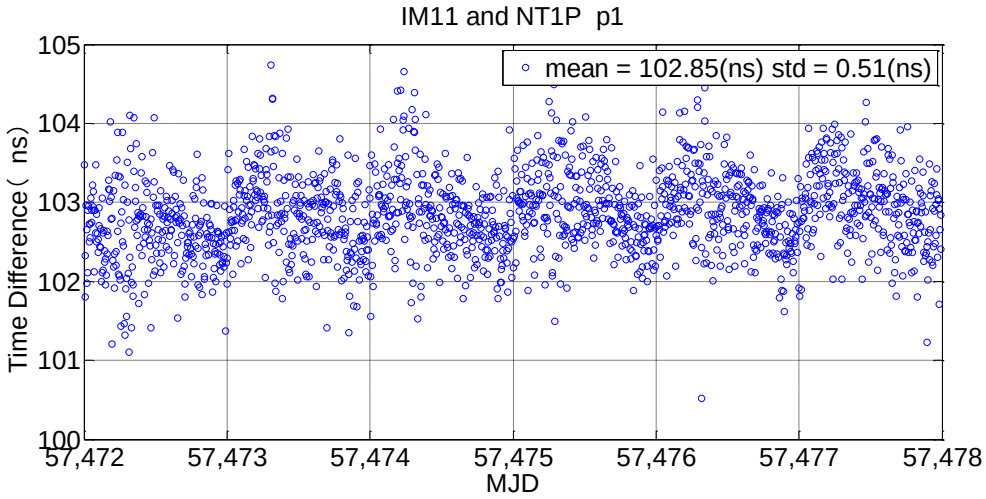

IM09 and NT4P
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

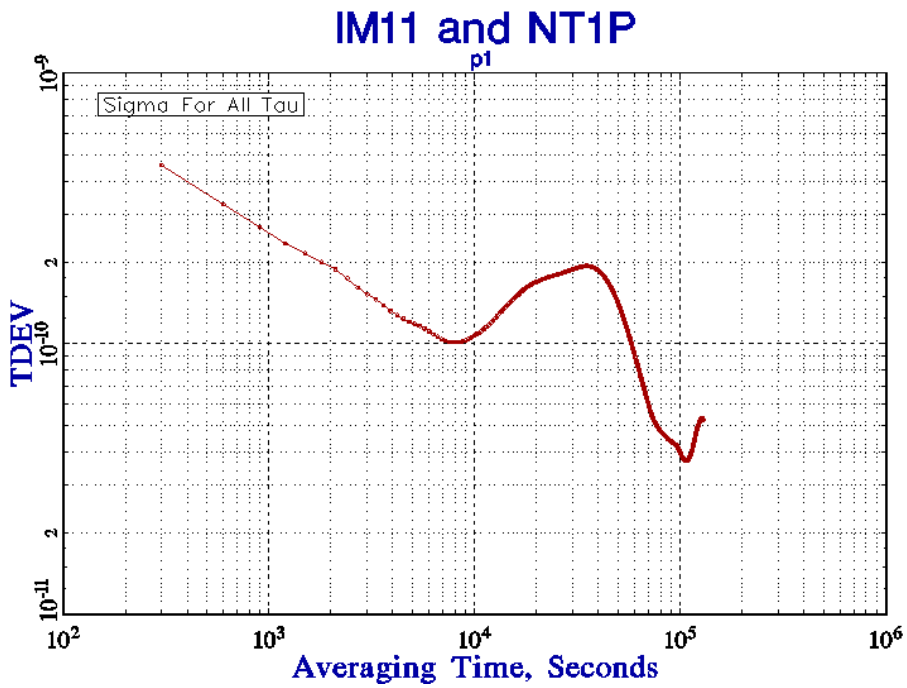

IM09 and NT4P p3
mean = -23.95(ns)
Time Difference (ns)
MJD

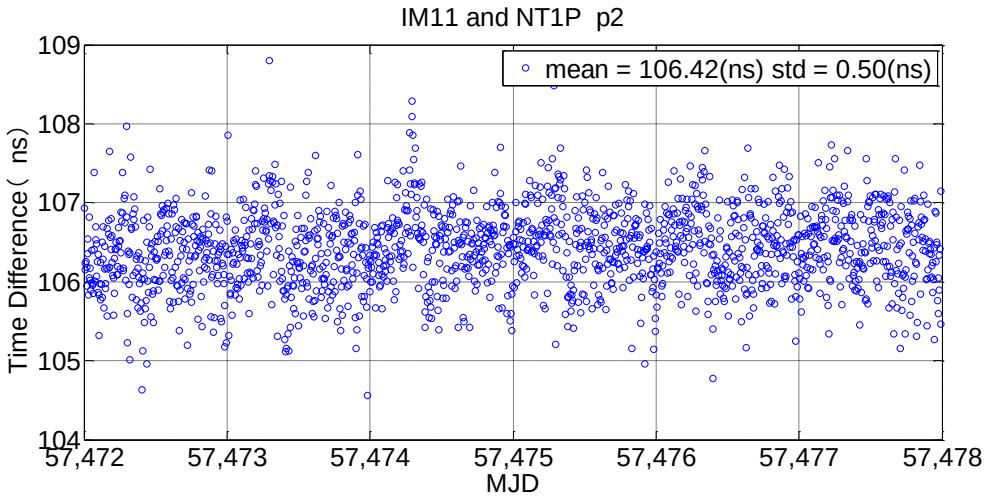

IM09 and NT4P p1-p2
mean = -7.16(ns) std = 0.60(ns)
Time Difference (ns)
MJD

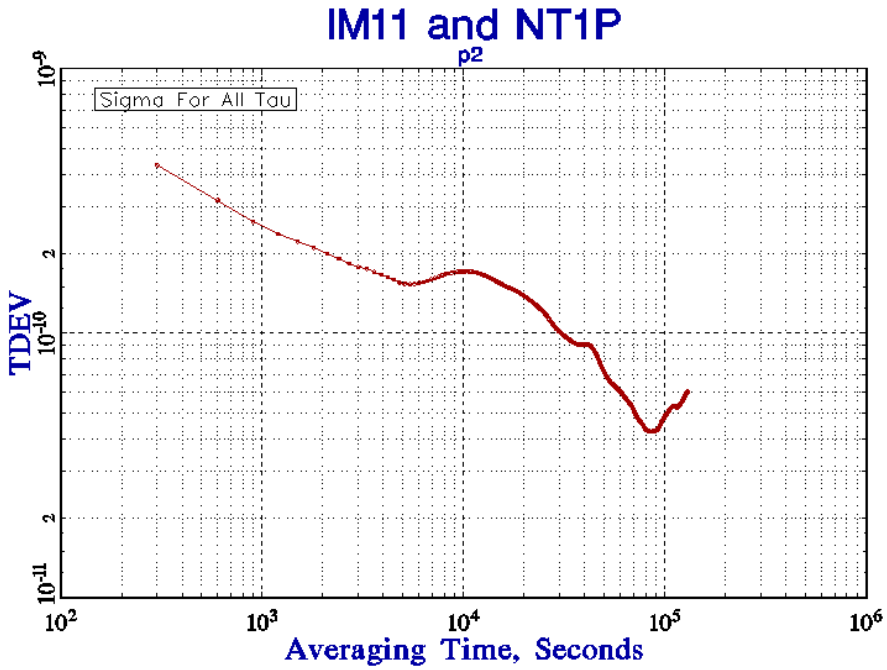

IM09 and NT4P
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

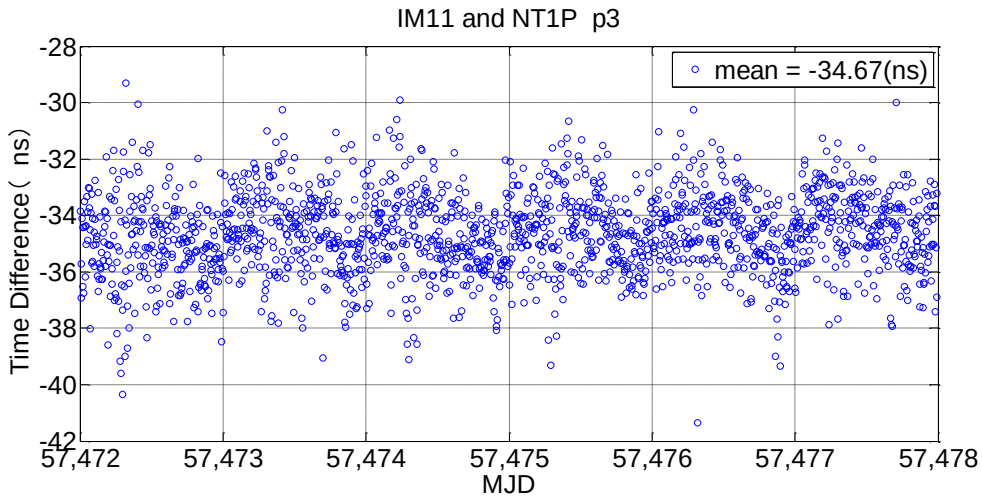
IMEK-NTP1

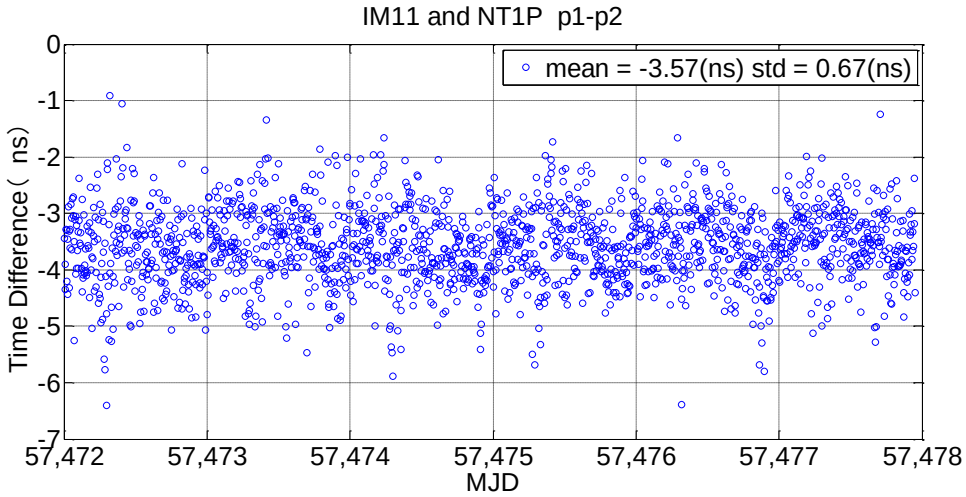

IM11 and NT1P p1
mean = 102.85(ns) std = 0.51(ns)
Time Difference (ns)
MJD

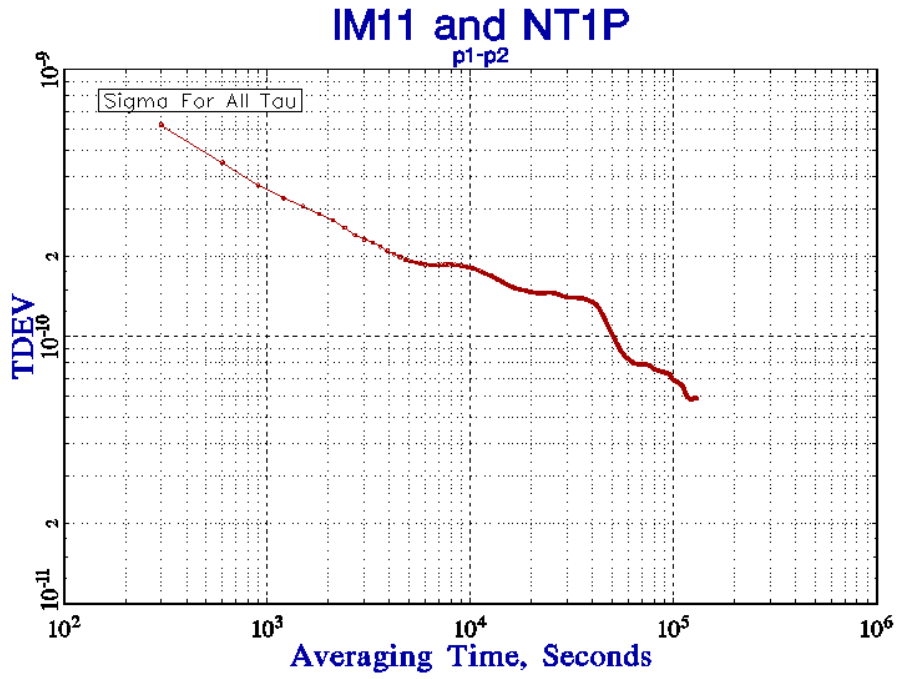

IM11 and NT1P
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM11 and NT1P p2
mean = 106.42(ns) std = 0.50(ns)
Time Difference (ns)
MJD

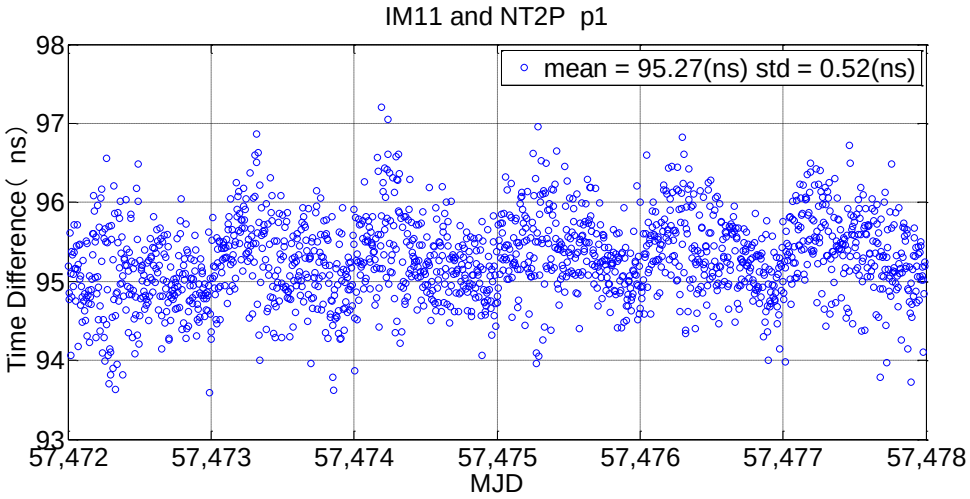

IM11 and NT1P
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

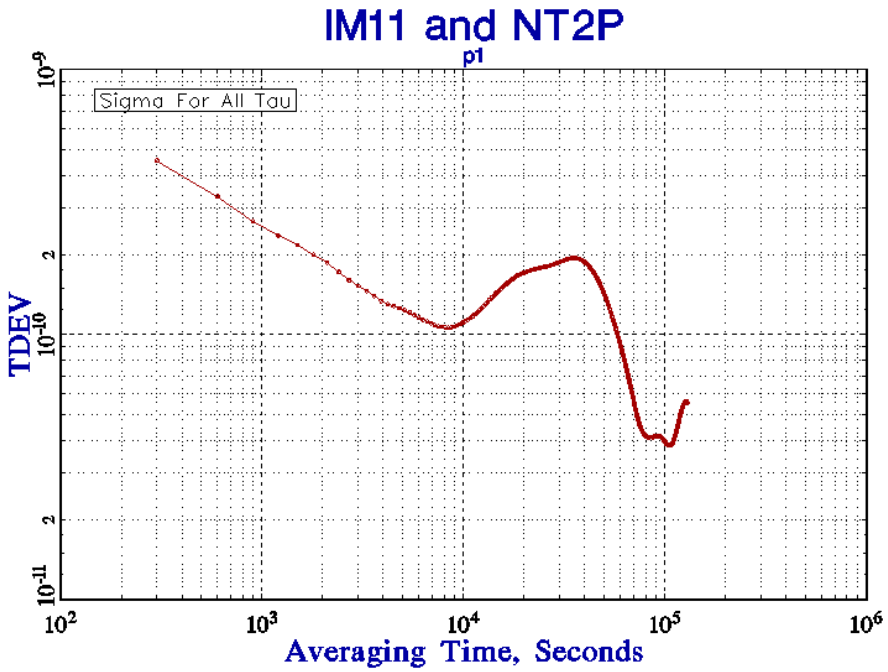

IM11 and NT1P p3
mean = -34.67(ns)
Time Difference (ns)
MJD


IM11 and NT1P p1-p2
mean = -3.57(ns) std = 0.67(ns)
Time Difference (ns)
MJD

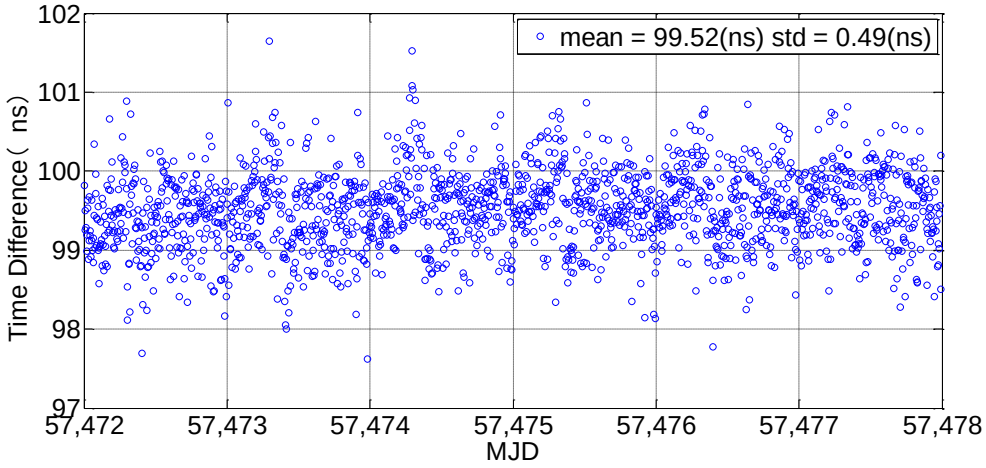

IM11 and NT1P
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

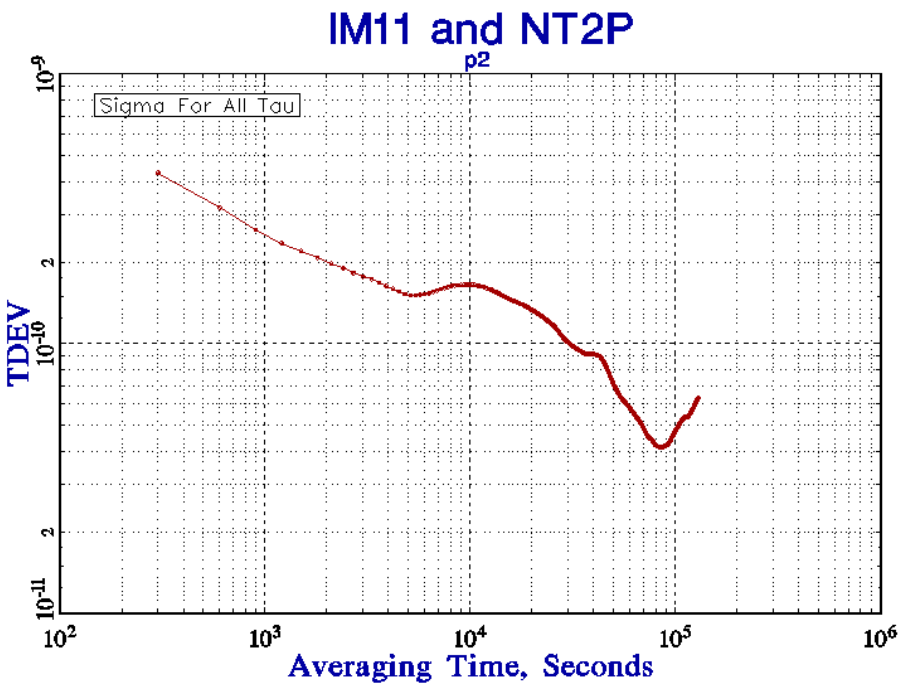
IMEK-NTP2

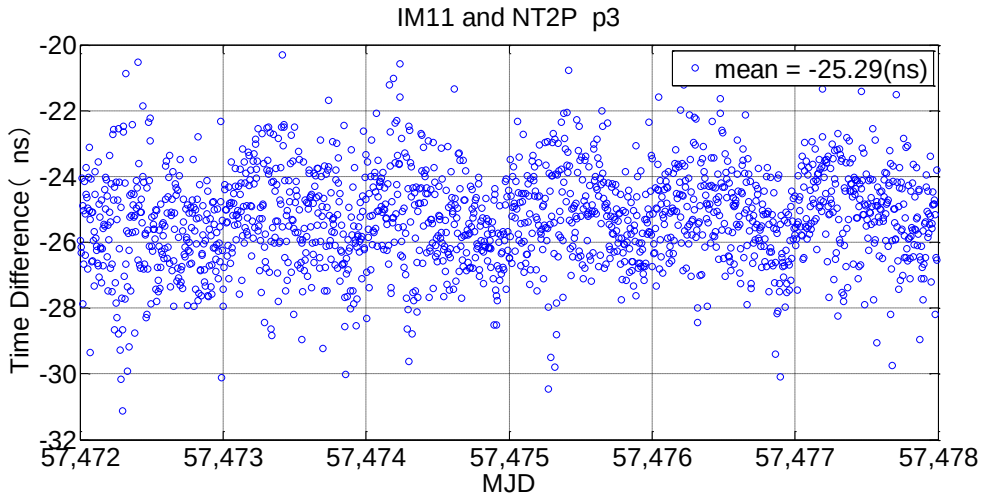

IM11 and NT2P p1
mean = 95.27(ns) std = 0.52(ns)
Time Difference (ns)
MJD

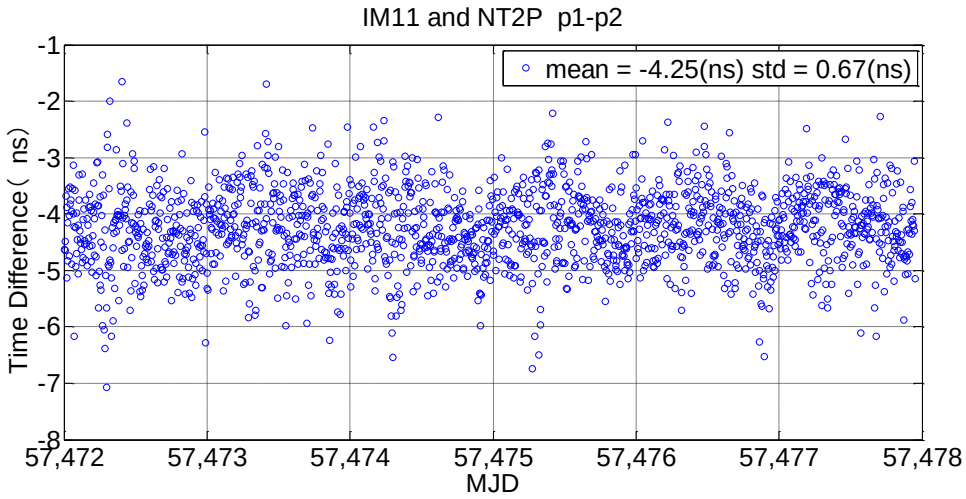


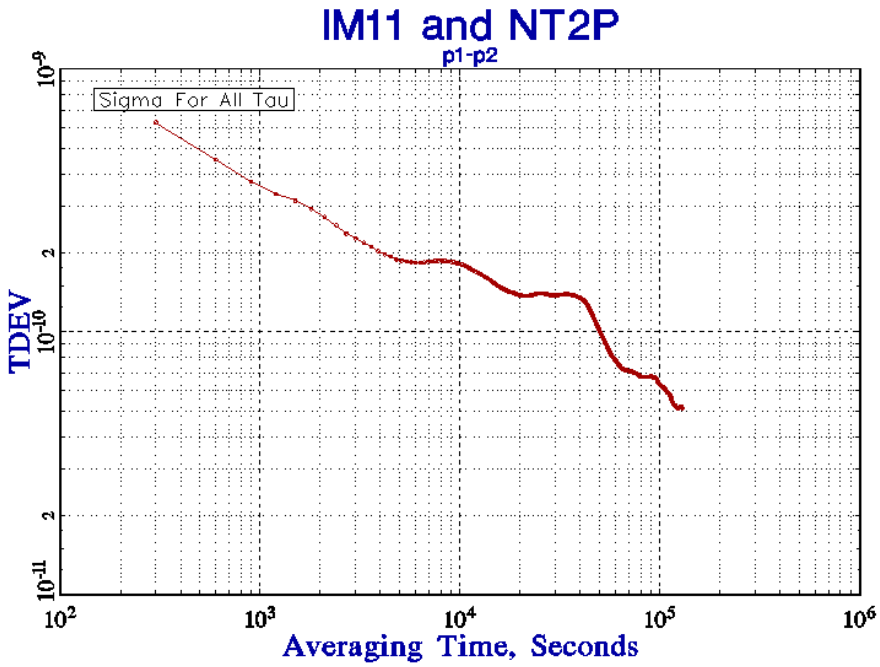
IM11 and NT2P p2



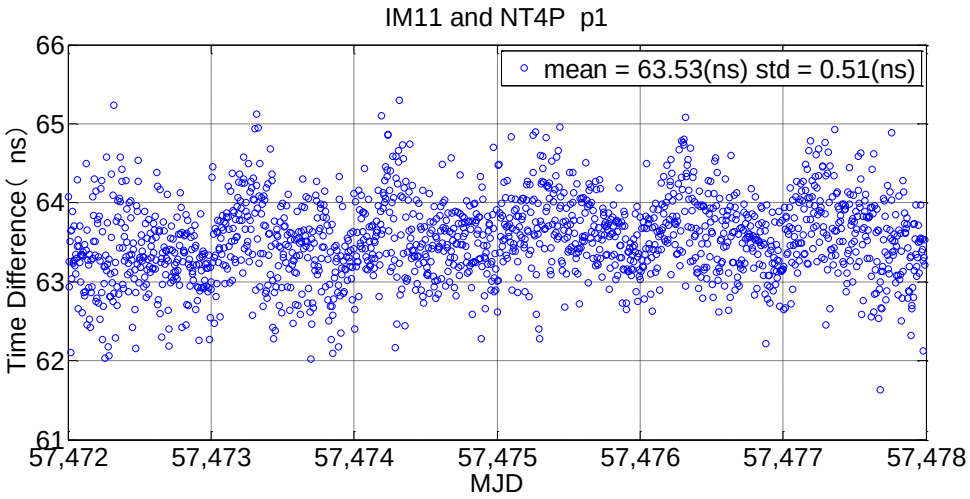

IM11 and NT2P
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

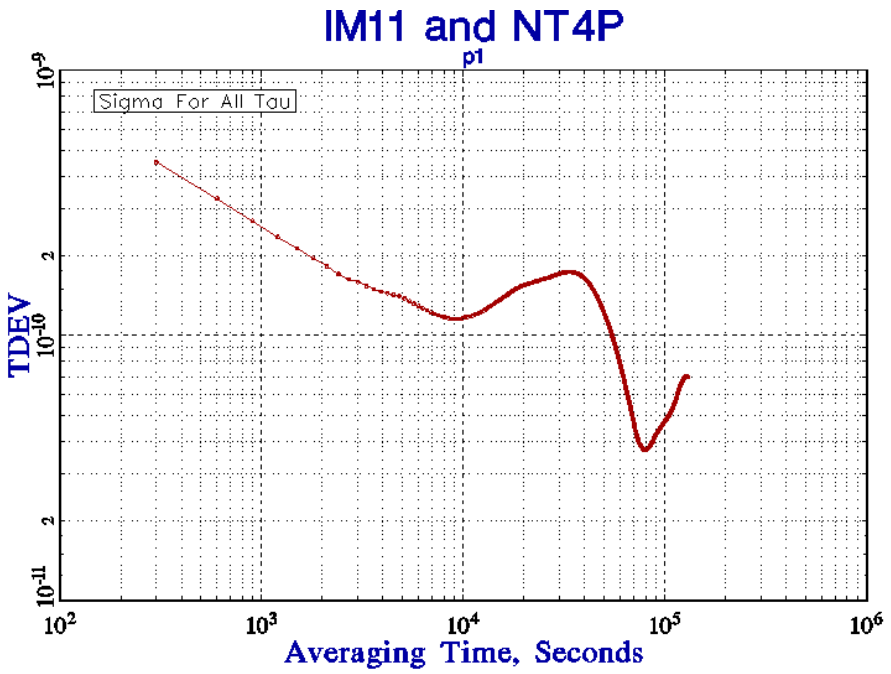

IM11 and NT2P p3
mean = -25.29(ns)
Time Difference (ns)
MJD


IM11 and NT2P p1-p2
mean = -4.25(ns) std = 0.67(ns)
Time Difference (ns)
MJD

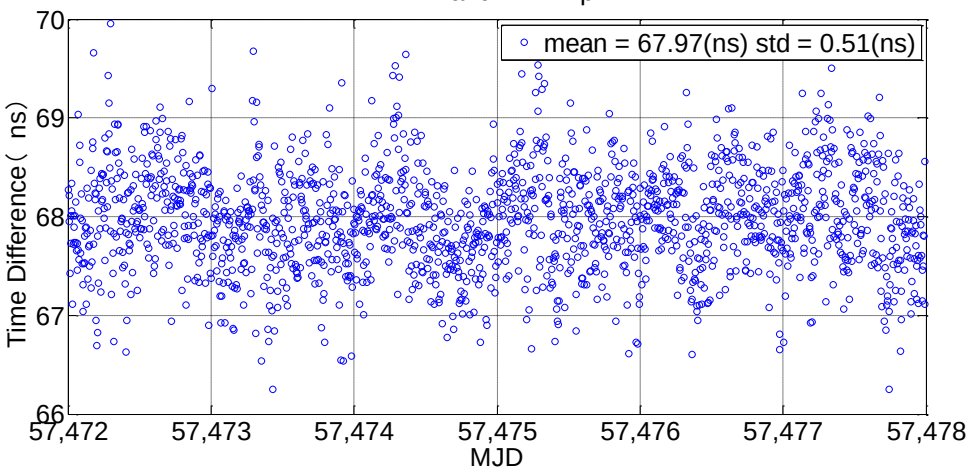

IM11 and NT2P
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

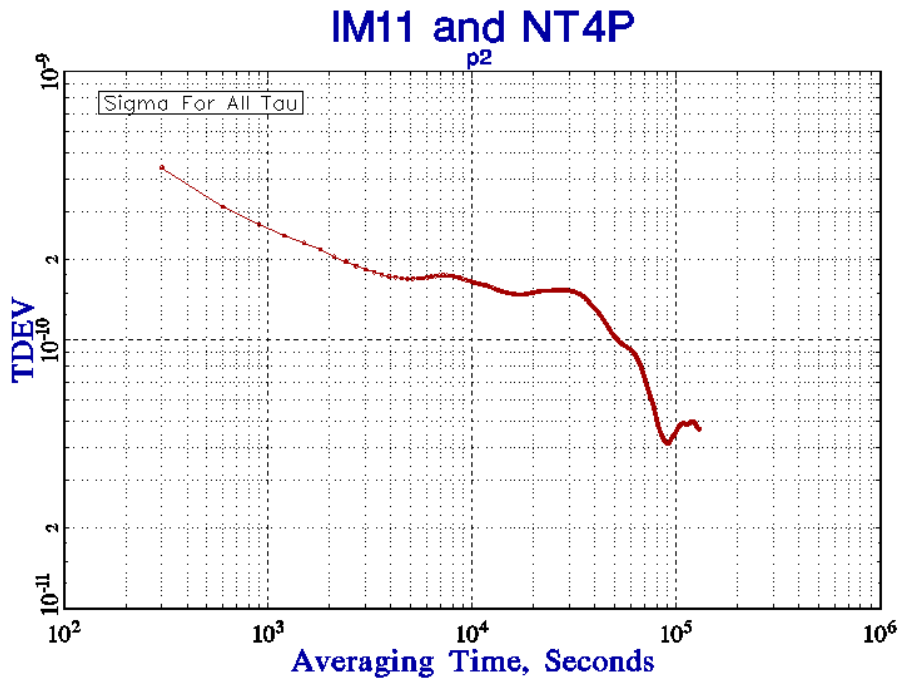
IMEK-NTP4

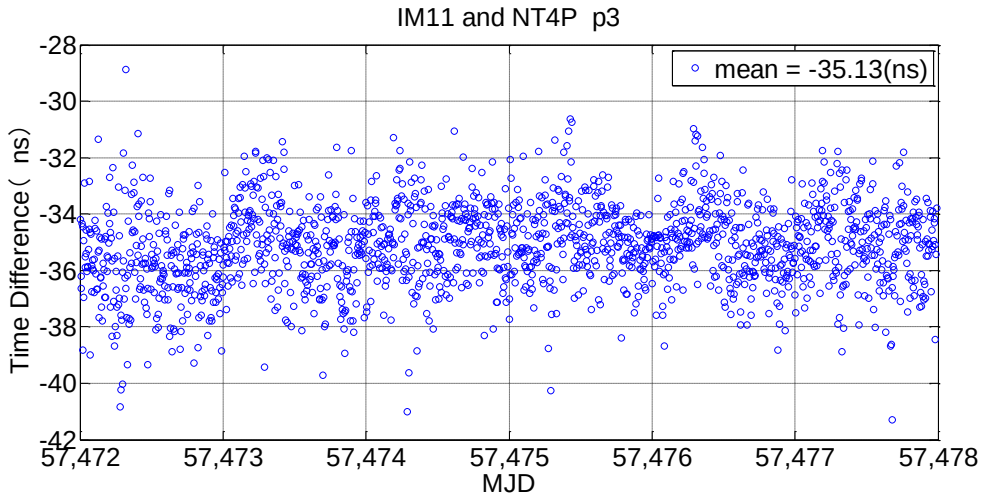

IM11 and NT4P p1
mean = 63.53(ns) std = 0.51(ns)
Time Difference (ns)
MJD

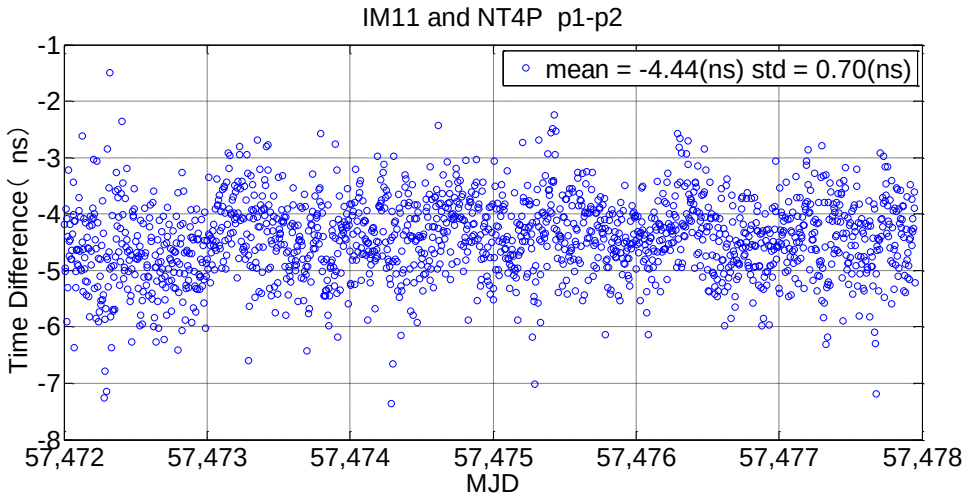


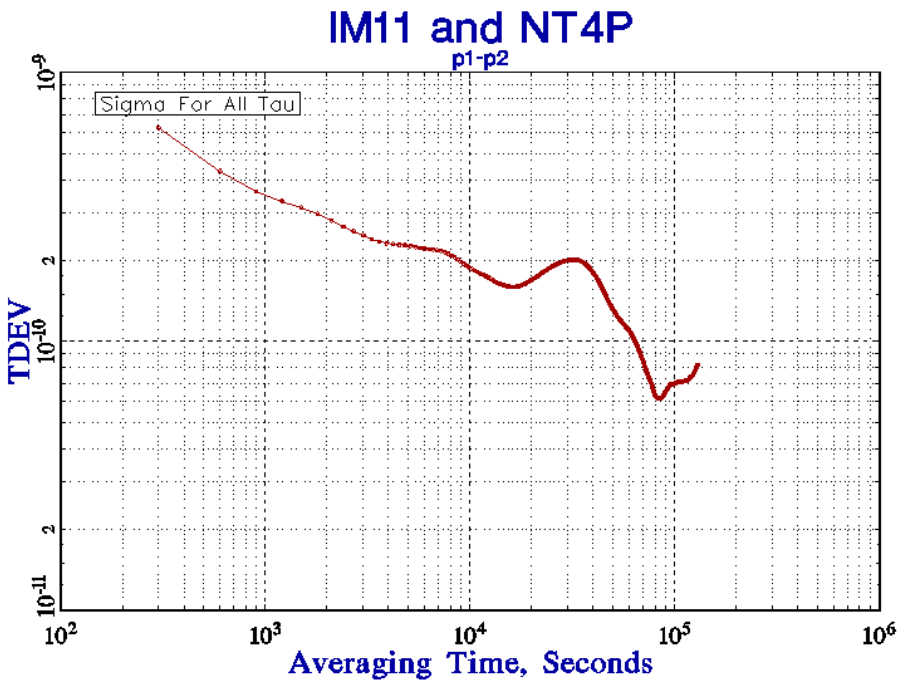
IM11 and NT4P p2



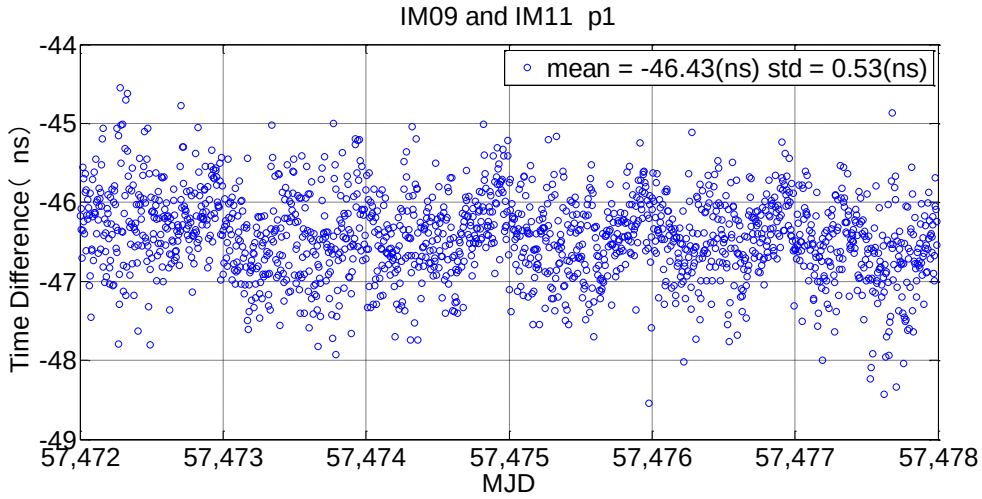

IM11 and NT4P
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

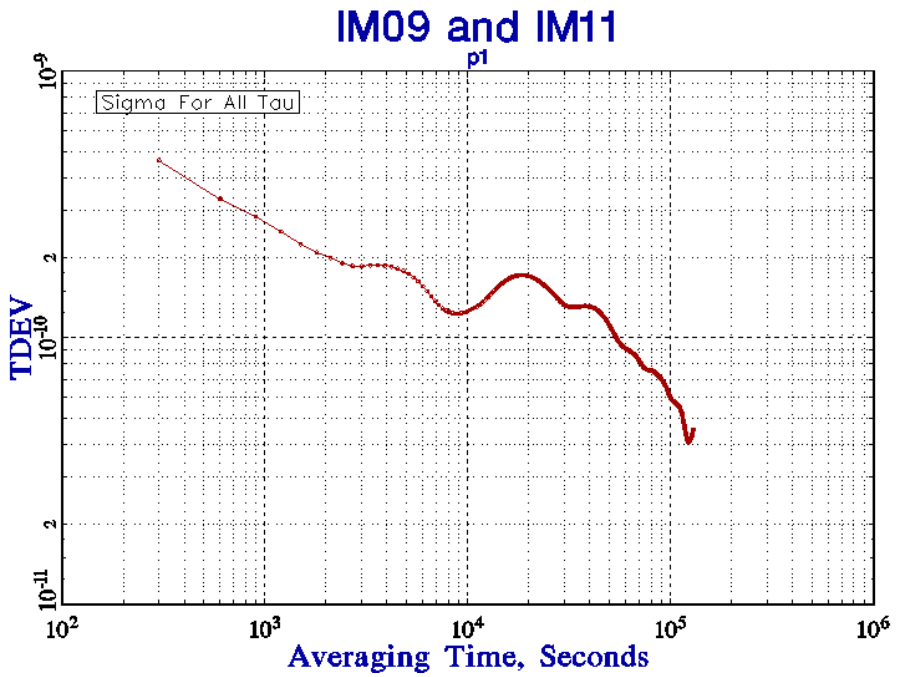

IM11 and NT4P p3
mean = -35.13(ns)
Time Difference (ns)
MJD

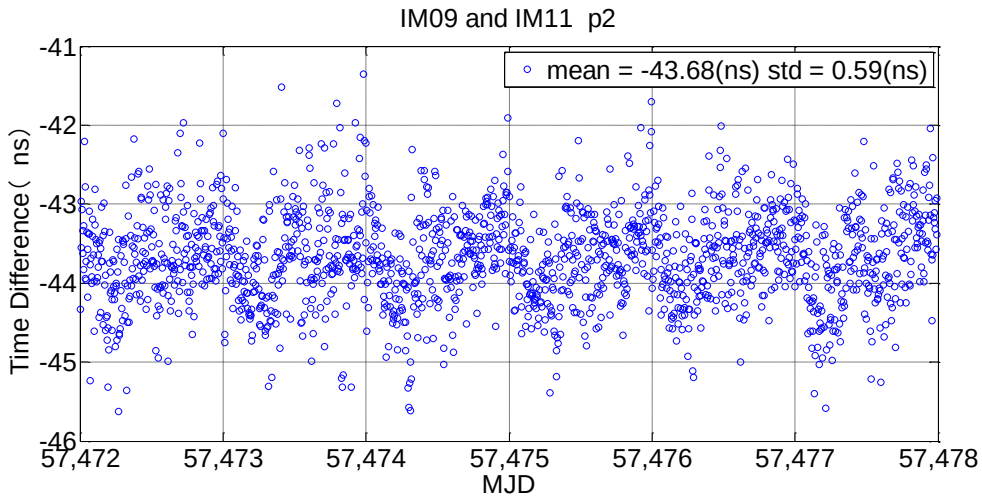

IM11 and NT4P p1-p2
mean = -4.44(ns) std = 0.70(ns)
Time Difference (ns)
MJD

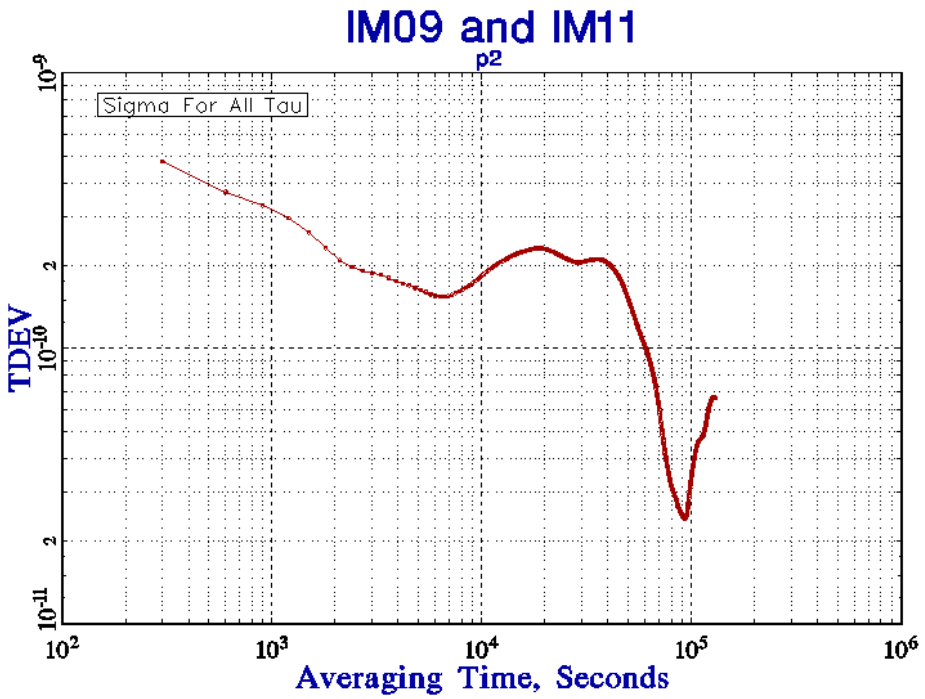

IM11 and NT4P
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

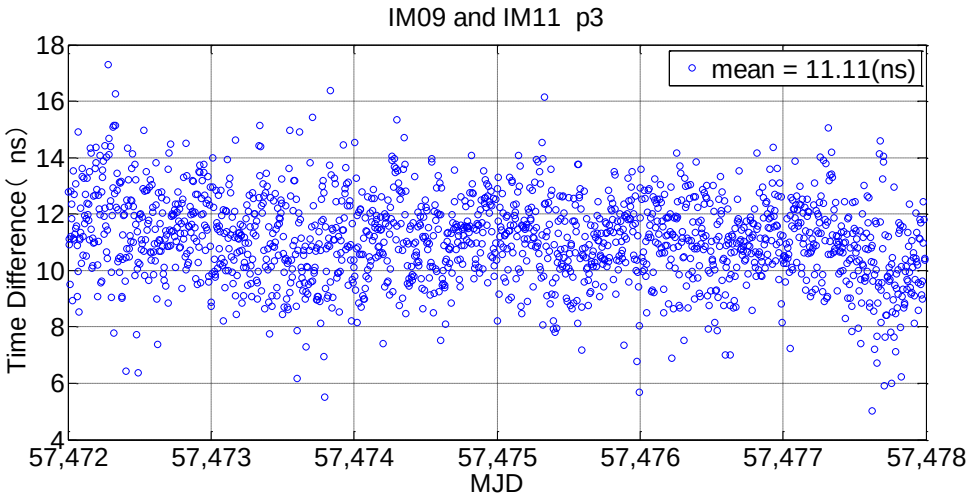
IMEC-IMEK

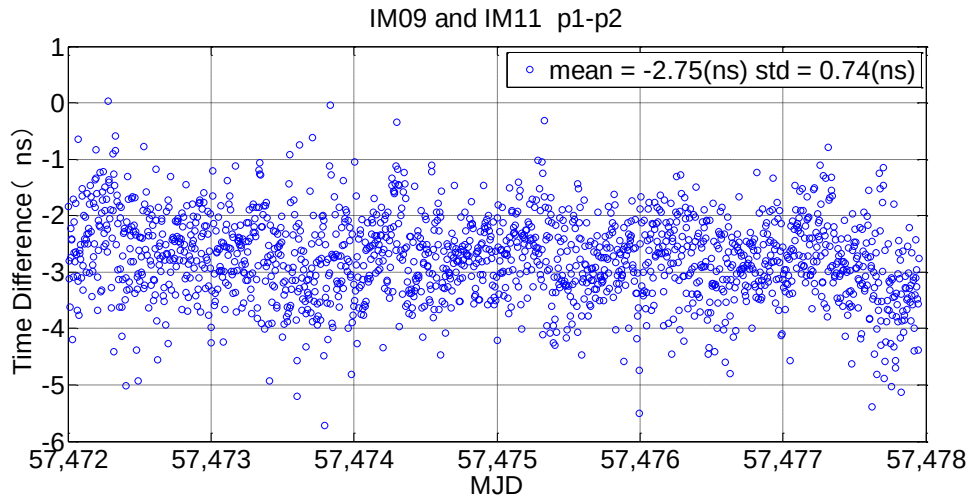

IM09 and IM11 p1
mean = -46.43(ns) std = 0.53(ns)
Time Difference (ns)
MJD

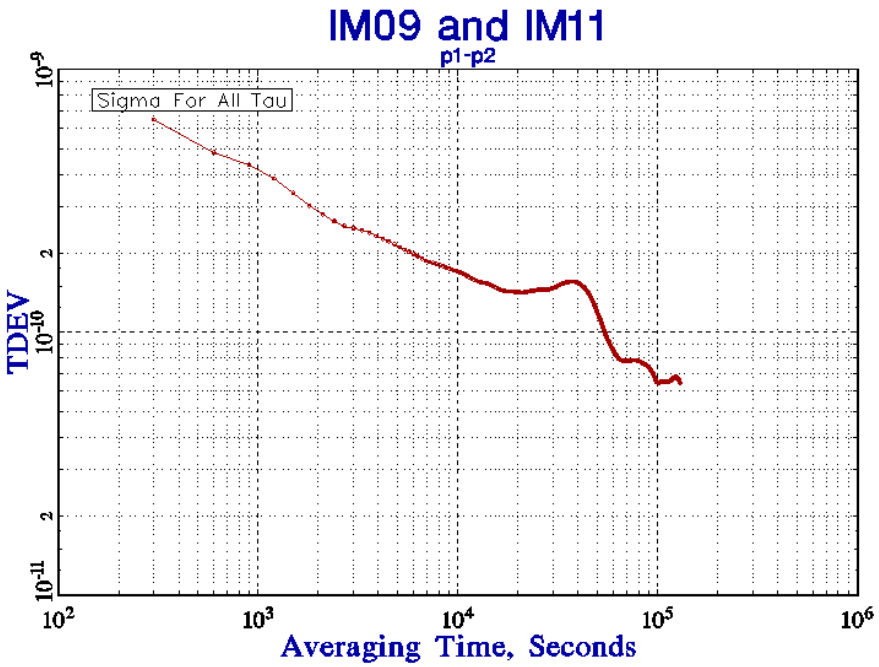

IM09 and IM11
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM09 and IM11 p2
mean = -43.68(ns) std = 0.59(ns)
Time Difference (ns)
MJD


IM09 and IM11
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

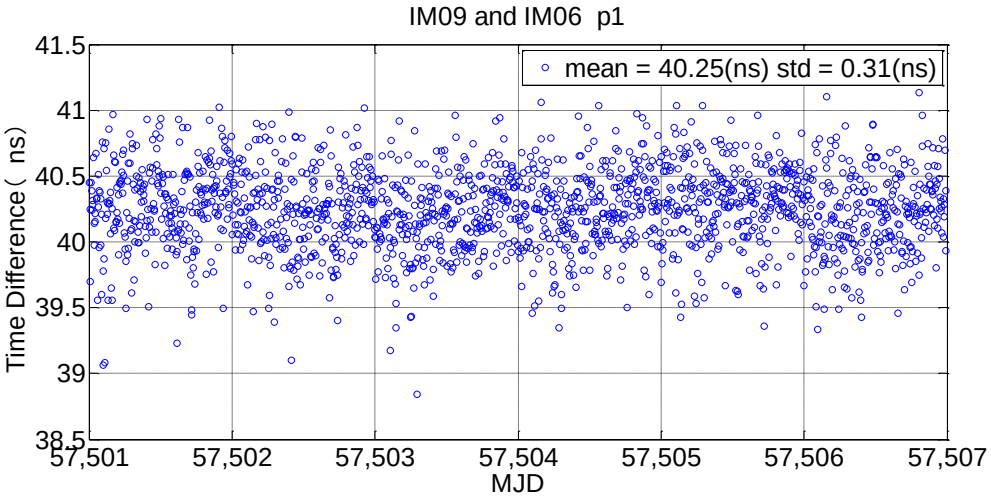

IM09 and IM11 p3
mean = 11.11(ns)
Time Difference (ns)
MJD

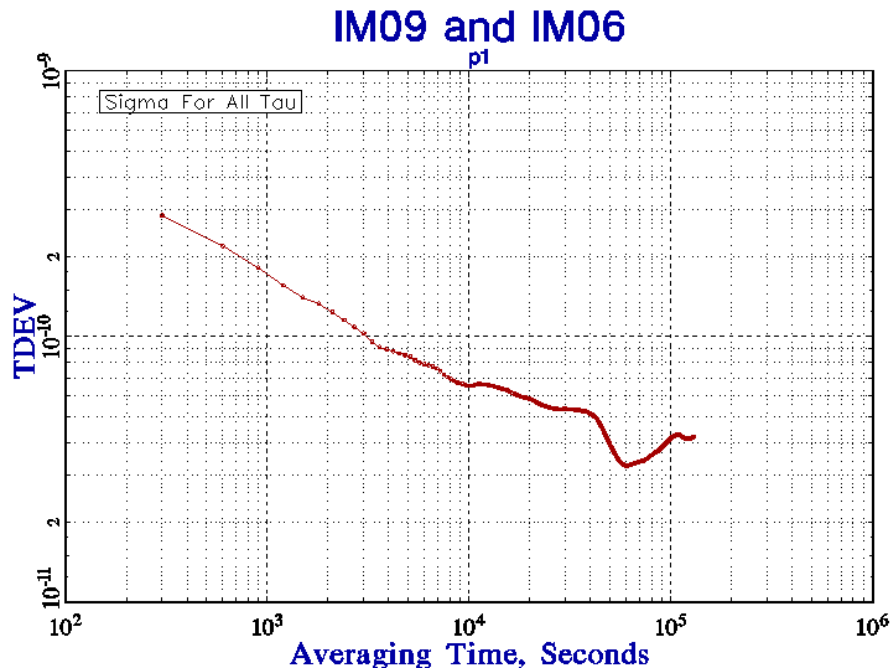

IM09 and IM11 p1-p2
mean = -2.75(ns) std = 0.74(ns)
Time Difference (ns)
MJD

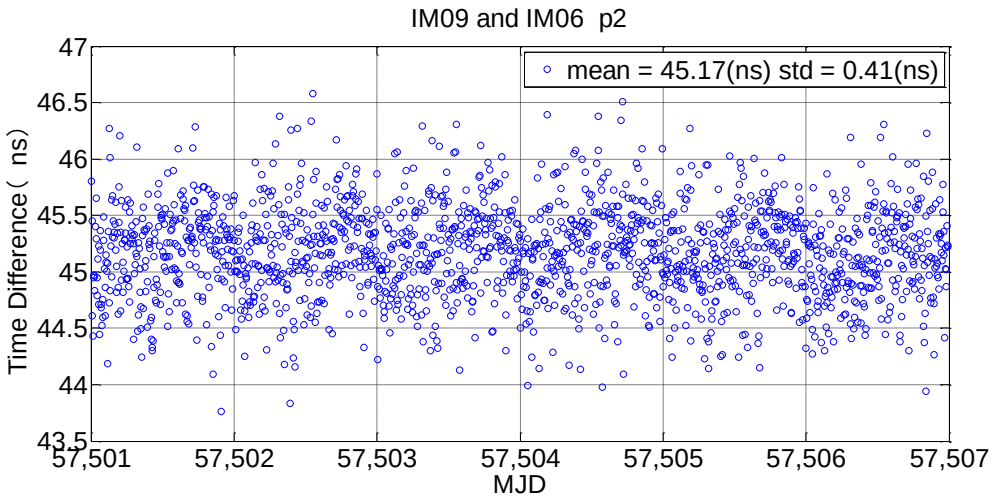


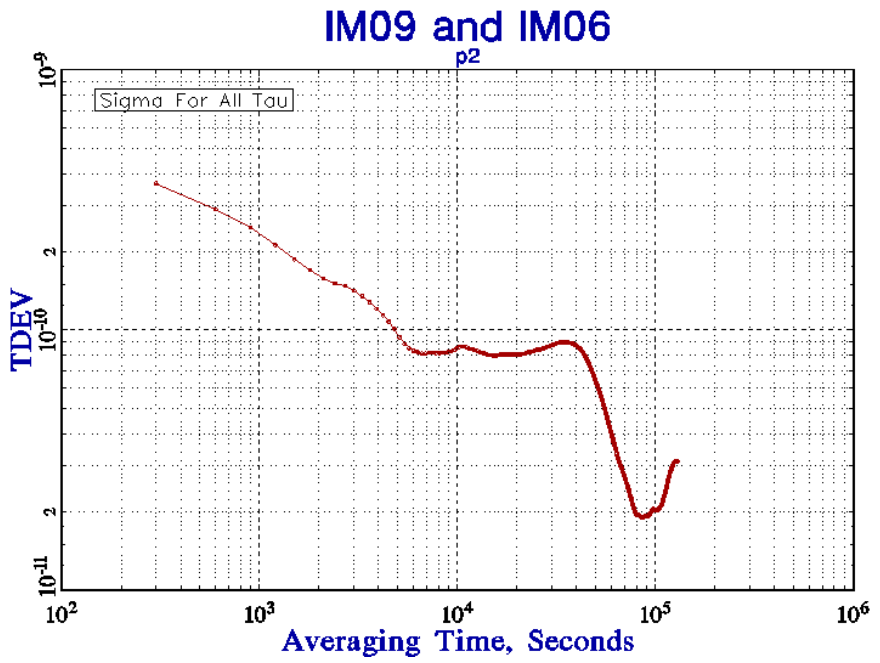
3. Closure CCD after calibration

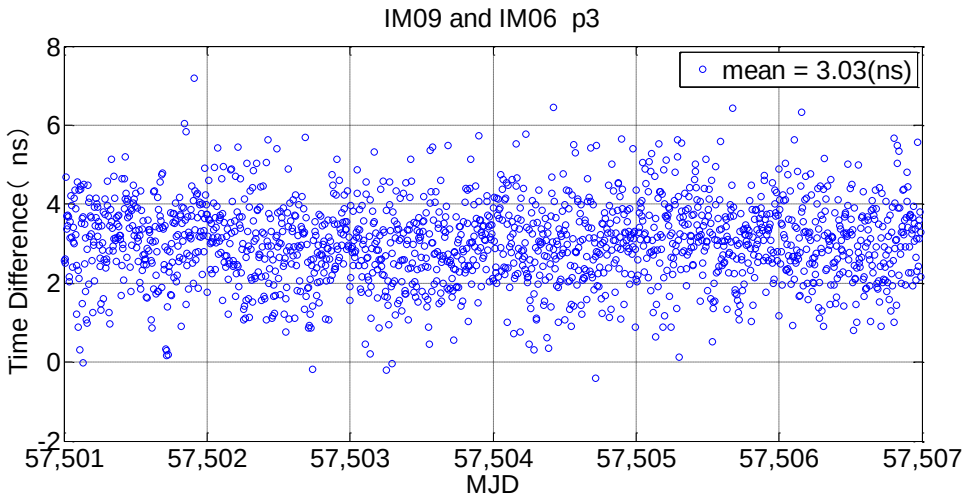
IMEC-IMEJ

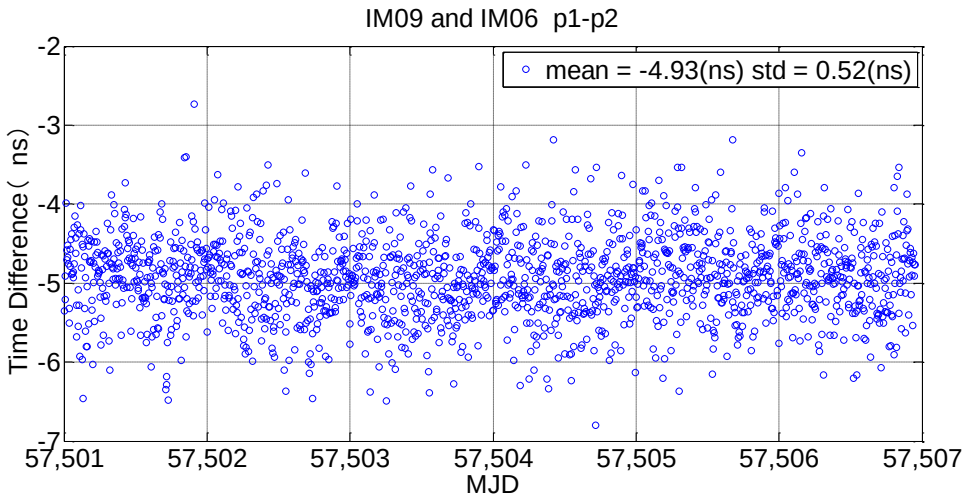


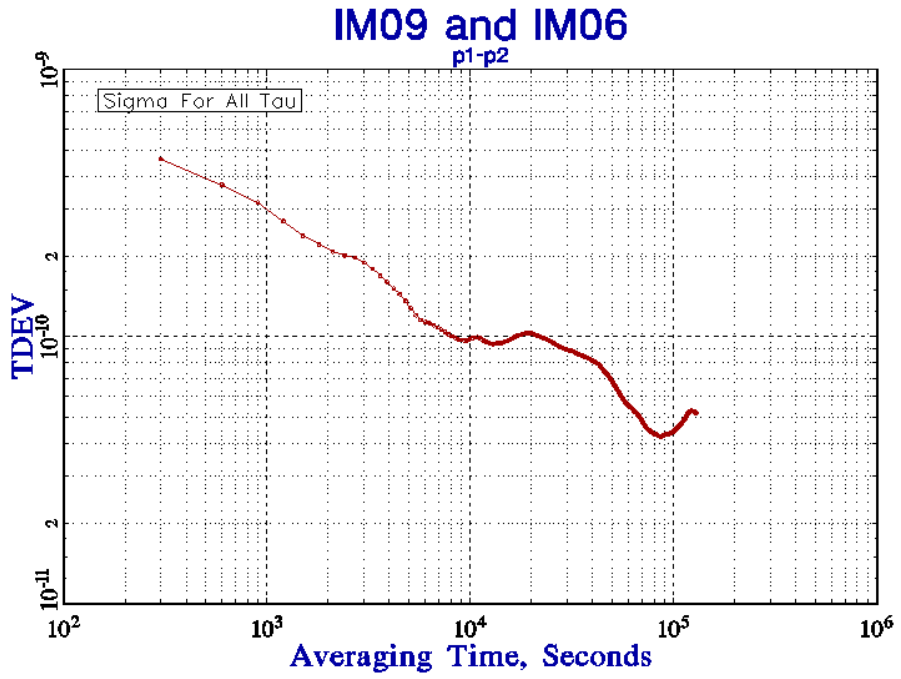

IM09 and IM06
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM09 and IM06 p2
mean = 45.17(ns) std = 0.41(ns)
Time Difference (ns)
MJD

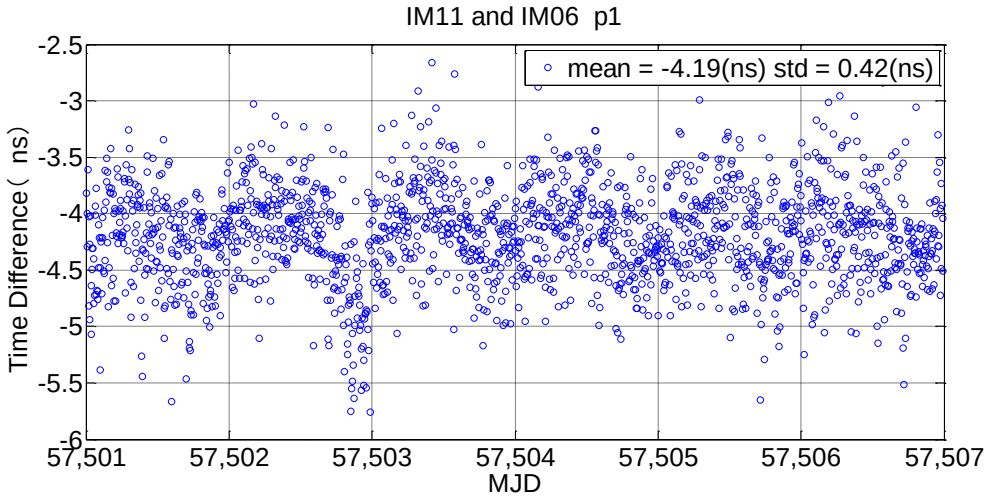

IM09 and IM06
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

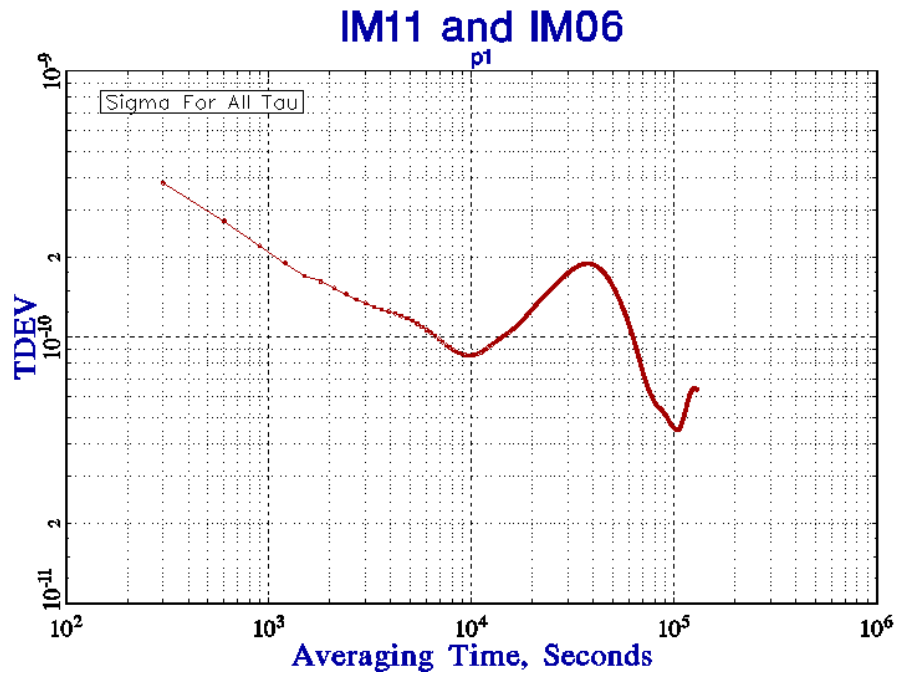

IM09 and IM06 p3
mean = 3.03(ns)
Time Difference (ns)
MJD

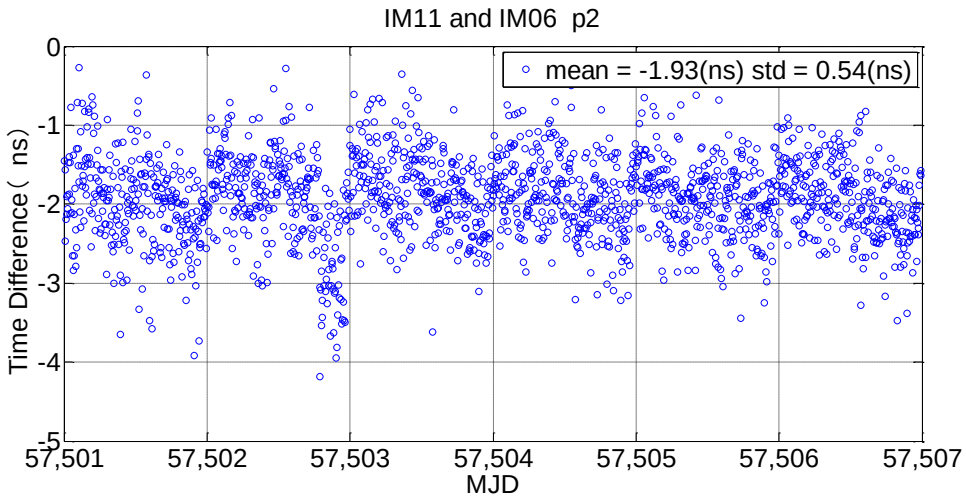

IM09 and IM06 p1-p2
mean = -4.93(ns) std = 0.52(ns)
Time Difference (ns)
MJD

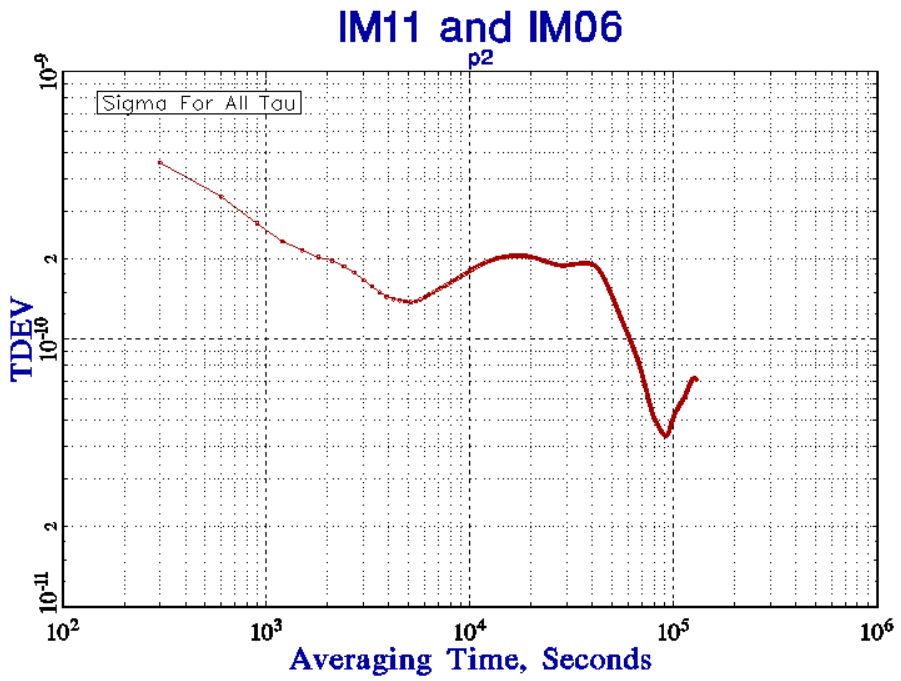

IM09 and IM06
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

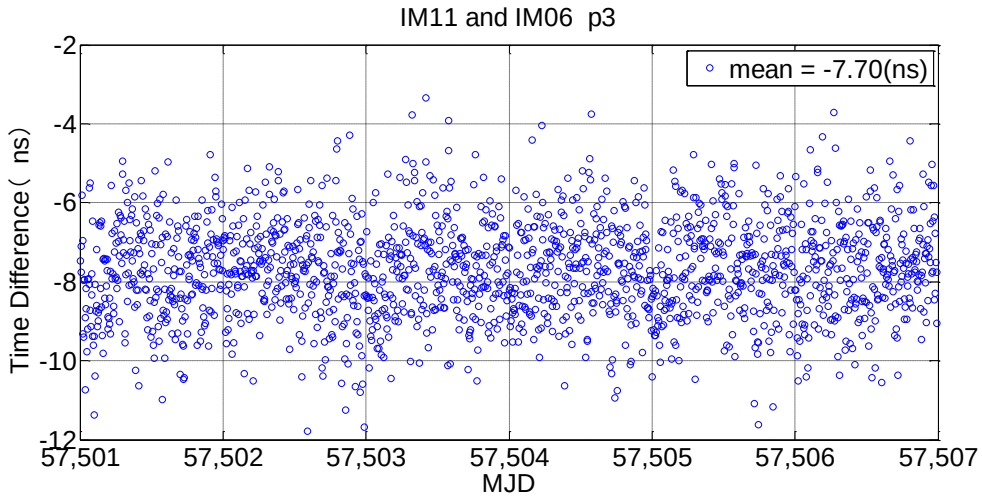
IMEK-IMEJ

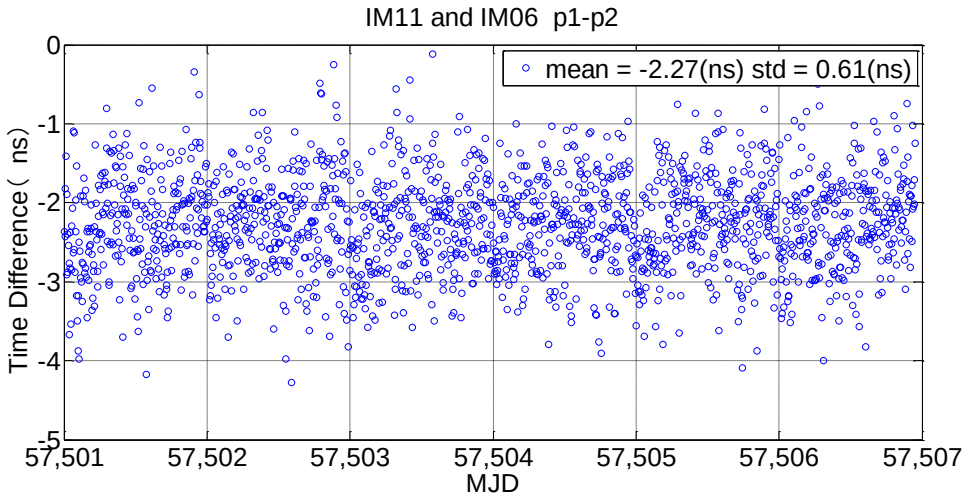

IM11 and IM06 p1
mean = -4.19(ns) std = 0.42(ns)
Time Difference (ns)
MJD

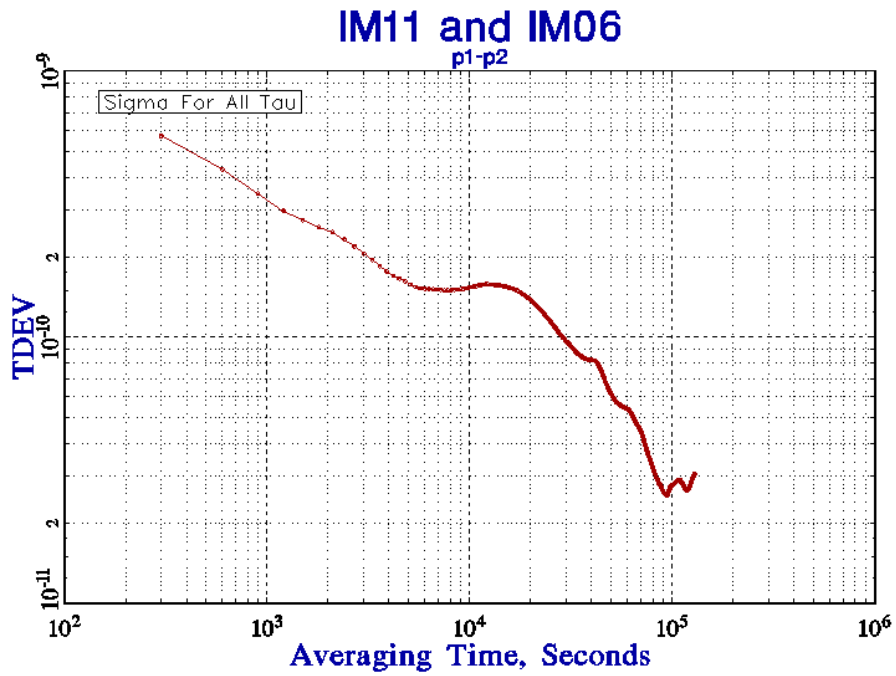

IM11 and IM06
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM11 and IM06 p2
mean = -1.93(ns) std = 0.54(ns)
Time Difference (ns)
MJD

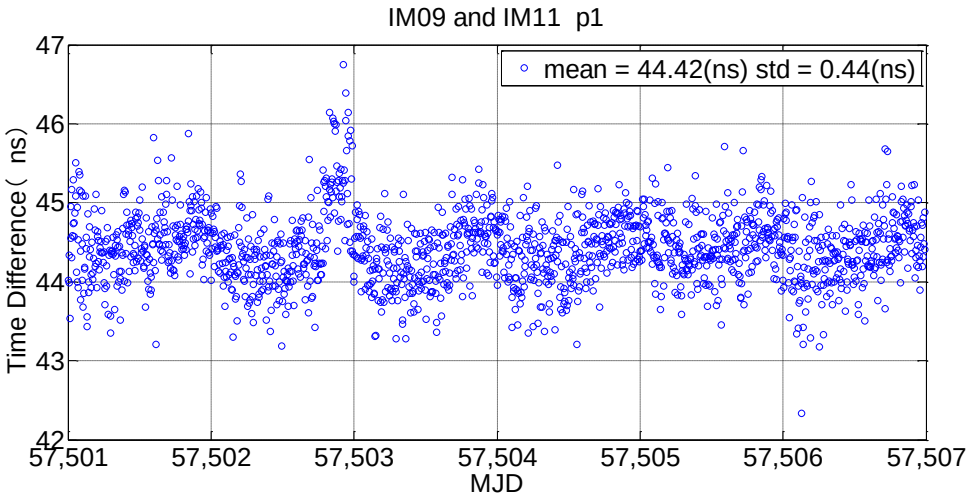

IM11 and IM06
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

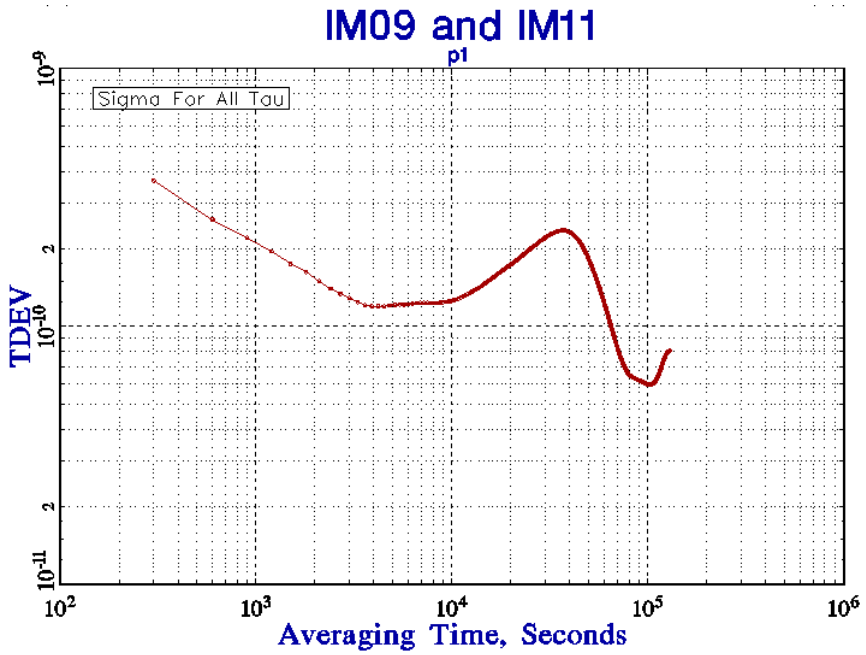

IM11 and IM06 p3
mean = -7.70(ns)
Time Difference (ns)
MJD

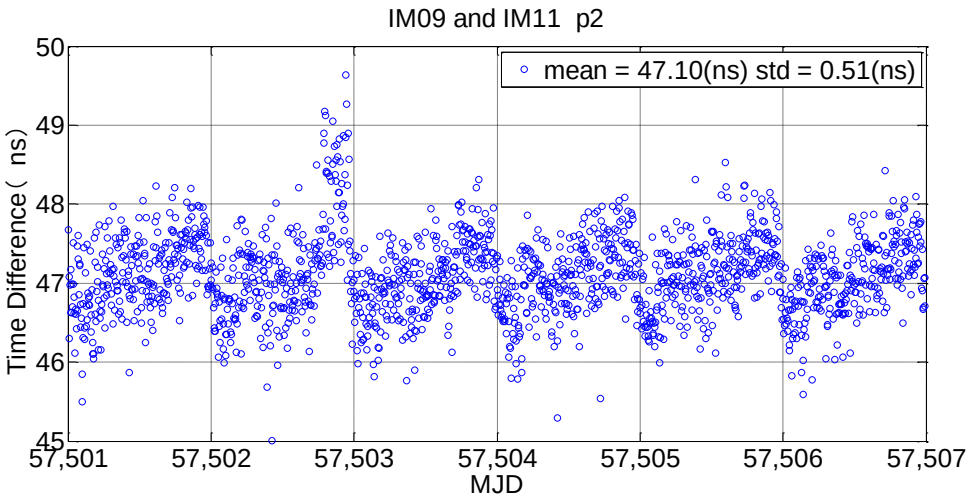

IM11 and IM06 p1-p2
mean = -2.27(ns) std = 0.61(ns)
Time Difference (ns)
MJD

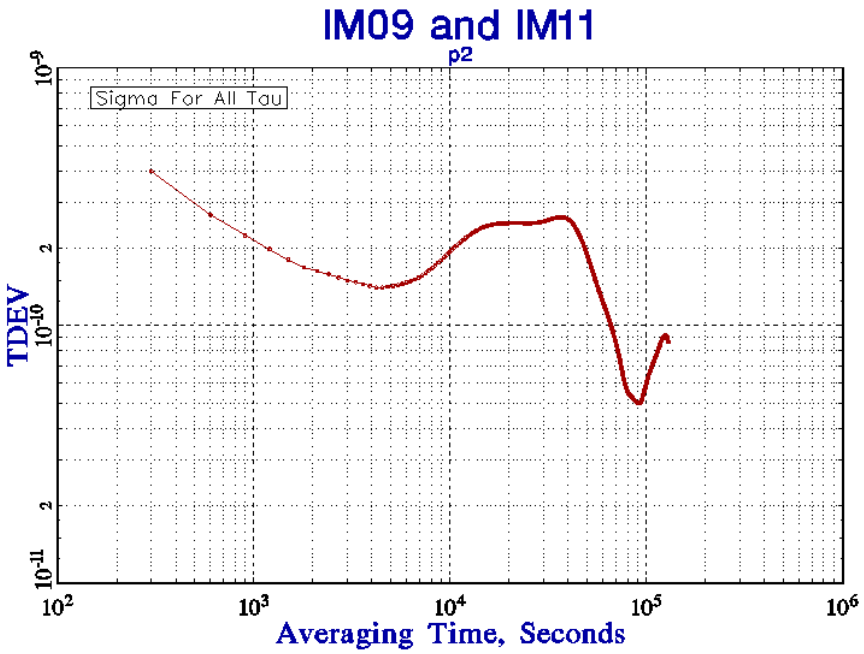

IM11 and IM06
p1-p2
Sigma For All Tau
TDEV
Averaging Time, Seconds

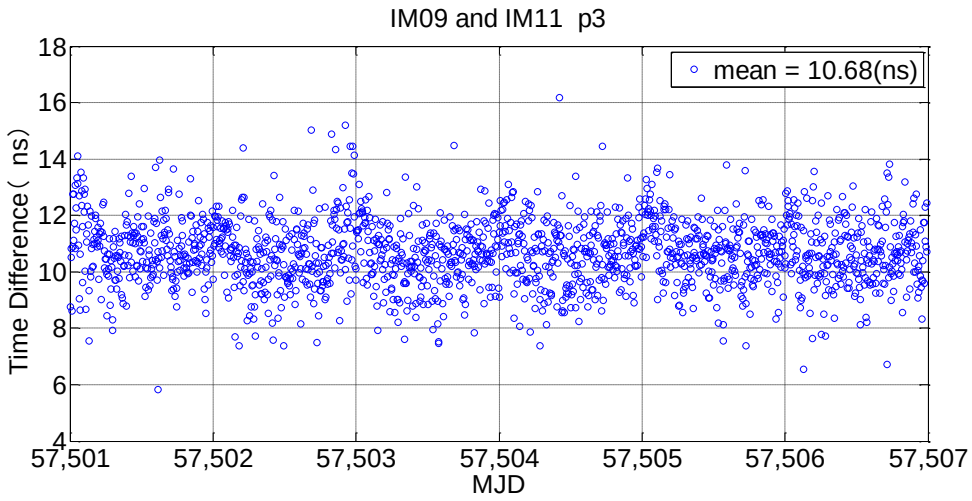
IMEC-IMEK

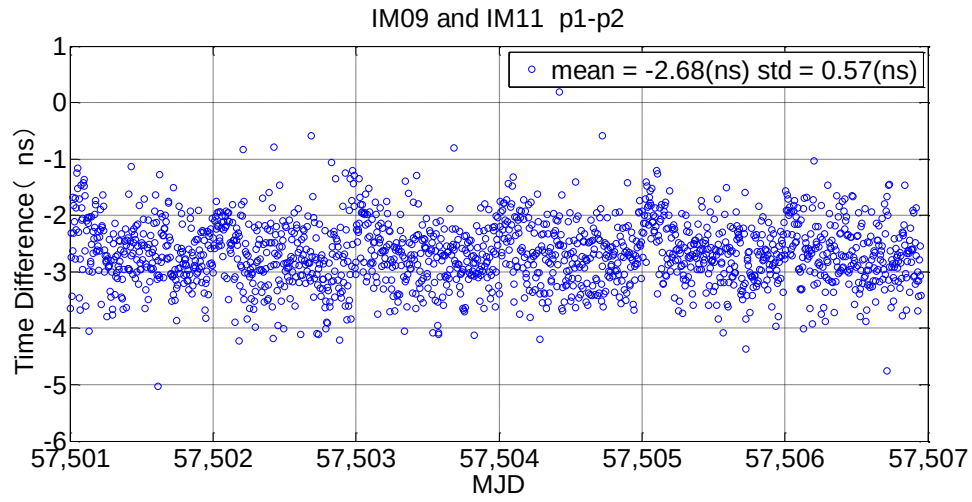

IM09 and IM11 p1
mean = 44.42(ns) std = 0.44(ns)
Time Difference (ns)
MJD

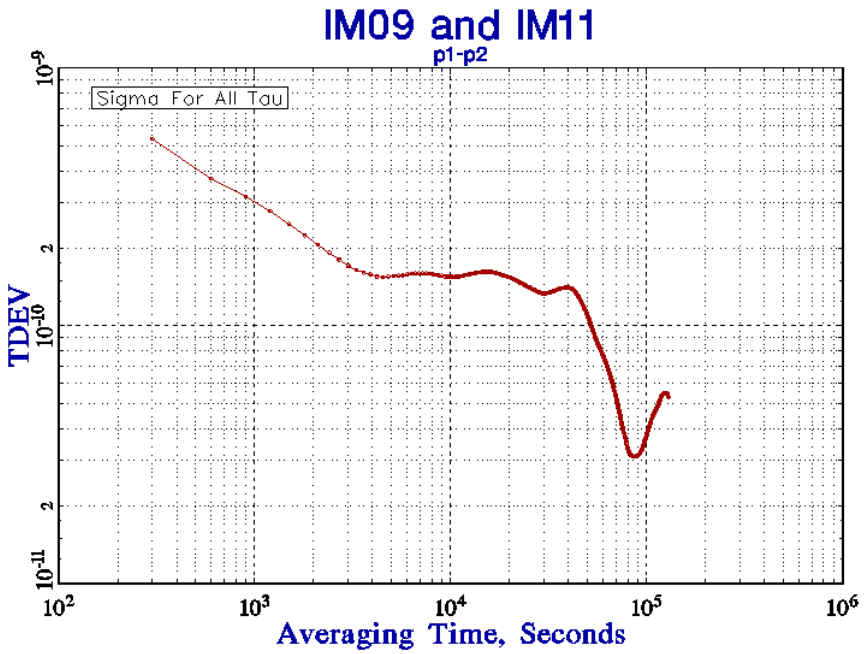

IM09 and IM11
p1
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM09 and IM11 p2
mean = 47.10(ns) std = 0.51(ns)
Time Difference (ns)
MJD


IM09 and IM11
p2
Sigma For All Tau
TDEV
Averaging Time, Seconds


IM09 and IM11 p3
mean = 10.68(ns)
Time Difference (ns)
MJD


IM09 and IM11 p1-p2
mean = -2.68(ns) std = 0.57(ns)
Time Difference (ns)
MJD


IM09 and IM11
p1-p2
Sigma For All Tau
TDEV
10^{-9}
2
10^{-10}
2
10^{-11}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
Averaging Time, Seconds

Annex 3 - Information Sheet

(to be repeated for each calibrated system)

Laboratory：	NTSC
Date and hour of the beginning of measurements:	UTC time 0:00 am March 25,2016
Date and hour of the end of measurements:	UTC time 0:00 am March 30,2016

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NTP1	IM09/IM11
Receiver maker and type: Receiver serial number：	maker: Septentrio type: PolaRx4TR_PRO serial number:3002043	maker: IM09 NIM/IM11 Dicom type: IM09 NIMTFGNSS-2/ IM11 GTR51 serial number: IM09 SN201401/ IM11 1405004
1 PPS trigger level /V:	0~2	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	maker: type: Phase stabilised cable:	maker: IM09 Jiangxichuanglian/IM11 type: IM09 5DFB-50/IM11 Phase stabilised cable:N
Length outside the building /m:	15.0	15.0
Antenna maker and type: Antenna serial number:	maker: Septentrio type: SEPCHOKE_MC serial number: 5312	maker: IM09 AeroAntenna/ IM11 Novatel type: IM09 AERAT1675_200 /IM11 NOV703GGG serial number: IM09 5098 /IM11 NEG14100010
Temperature (if stabilised) /°C		

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to	222.8	IM09 226.1/

receiver 1 PPS-in:		IM11 247.5
Delay from 1 PPS-in to internal Reference (if different):		
Antenna cable delay:	209.0	IM09 203.0/ IM11 177.1
Splitter delay (if any):		
Additional cable delay (if any):		

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	−132. 9
INT DLY (GLONASS) /ns:	0
CAB DLY /ns:	209.4
REF DLY /ns:	208.5
Coordinates reference frame:	WGS84
Latitude or X /m:	-1735233.40
Longitude or Y /m:	+4976844.43
Height or Z /m:	+3580530.51

General information

Rise time of the local UTC pulse	2ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	23.3°C~24.3°C ±0.5°C
Set humidity value and uncertainty:	32.1%~42.3% ±3%

(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 - Information Sheet

(to be repeated for each calibrated system)

Laboratory：	NTSC
Date and hour of the beginning of measurements:	UTC time 0:00 am March 25,2016
Date and hour of the end of measurements:	UTC time 0:00 am March 30,2016

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NTP2	IM09/IM11
Receiver maker and type: Receiver serial number：	maker: Septentrio type: PolaRx4TR_PRO serial number:3002046	maker: IM09 NIM/IM11 Dicom type: IM09 NIMTFGNSS-2/ IM11 GTR51 serial number: IM09 SN201401/ IM11 1405004
1 PPS trigger level /V:	0~2	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	maker: type: Phase stabilised cable:	maker: IM09 Jiangxichuanglian/IM11 type: IM09 5DFB-50/IM11 Phase stabilised cable:N
Length outside the building /m:	15.0	15.0
Antenna maker and type: Antenna serial number:	maker: Septentrio type: SEPCHOKE_MC serial number: 5312	maker: IM09 AeroAntenna/ IM11 Novatel type: IM09 AERAT1675_200 /IM11 NOV703GGG serial number: IM09 5098 /IM11 NEG14100010
Temperature (if stabilised) /°C		

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to	232.9	IM09 226.1/

receiver 1 PPS-in:		IM11 247.5
Delay from 1 PPS-in to internal Reference (if different):		
Antenna cable delay:	221.0	IM09 203.0/ IM11 177.1
Splitter delay (if any):		
Additional cable delay (if any):		

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	-123.2
INT DLY (GLONASS) /ns:	0
CAB DLY /ns:	217.0
REF DLY /ns:	207.8
Coordinates reference frame:	WGS84
Latitude or X /m:	-1735233.40
Longitude or Y /m:	+4976844.43
Height or Z /m:	+3580530.51

General information

Rise time of the local UTC pulse	2ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	23.3℃~24.3℃ ±0.5℃
Set humidity value and uncertainty:	32.1%~42.3% ±3%

(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 5 - Information Sheet

(to be repeated for each calibrated system)

Laboratory：	NTSC
Date and hour of the beginning of measurements:	UTC time 0:00 am March 25,2016
Date and hour of the end of measurements:	UTC time 0:00 am March 30,2016

Information on the system

	Local:	**Travelling:**
4-character BIPM code	NTP4	IM09/IM11
Receiver maker and type: Receiver serial number：	maker: Septentrio type: PolaRx4TR_PRO serial number:3007595	maker: IM09 NIM/IM11 Dicom type: IM09 NIMTFGNSS-2/ IM11 GTR51 serial number: IM09 SN201401/ IM11 1405004
1 PPS trigger level /V:	0~2	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	maker: type: Phase stabilised cable:	maker: IM09 Jiangxichuanglian/IM11 type: IM09 5DFB-50/IM11 Phase stabilised cable:N
Length outside the building /m:	15.0	15.0
Antenna maker and type: Antenna serial number:	maker: Septentrio type: SEPCHOKE_MC serial number: 5392	maker: IM09 AeroAntenna/ IM11 Novatel type: IM09 AERAT1675_200 /IM11 NOV703GGG serial number: IM09 5098 /IM11 NEG14100010
Temperature (if stabilised) /° C		

Measured delays /ns

	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in:	191.1	IM09 226.1/ IM11 247.5

Delay from 1 PPS-in to internal Reference (if different):		
Antenna cable delay:	208.0	IM09 203.0/ IM11 177.1
Splitter delay (if any):		
Additional cable delay (if any):		

Data used for the generation of CGGTTS files

INT DLY (GPS) /ns:	30.2
INT DLY (GLONASS) /ns:	0
CAB DLY /ns:	208.0
REF DLY /ns:	330.0
Coordinates reference frame:	WGS84
Latitude or X /m:	-1735233.36
Longitude or Y /m:	+4976846.02
Height or Z /m:	+3580528.43

General information

Rise time of the local UTC pulse	2ns
Is the laboratory air conditioned	Yes
Set temperature value and uncertainty:	23.3°C~24.3°C ±0.5°C
Set humidity value and uncertainty:	32.1%~42.3% ±3%

(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