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Calibration report :

Relative calibration of CNES GPS receiver CS21.

	Nom et Sigle/ Fonction	Date et Signature
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DIFFUSION CNES				
Sigles	Noms	BPi	Observations pour : Action	Information
DSO/RF/STR	T. ROBERT, D. VALAT, J. DELPORTE	2013		X
DSO/RF	D. PRADINES, C. LAPORTE	2013		X

DIFFUSION EXTERNE			
Sociétés	Noms	Observations pour : Action	Information

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SOMMAIRE

1 SUMMARY.

1.1 GENERAL INFORMATION.

This Calibration Report released by CNES is about the relative calibration of the CNES GPS receiver CS21, using as reference the CNES receiver CS22 that has been calibrated by OP in April 2016 [1].

This calibration campaign took place in June 2017.

1.2 TIMETABLES.

Calibration campaign: June 7-15, 2017 (MJD 57911-57919)

Final issue 0 of the report: February 6, 2018.

1.3 CALIBRATION REPORT CHANGES.

This is Issue 0 of the Calibration report

2 ACRONYM LIST AND REFERENCE DOCUMENTS.

2.1 ACRONYM LIST.

ADEV: Allan deviation, square root of AVAR.
AVAR: Allan variance or two-sample variance.
BIPM: Bureau International des Poids et Mesures, Sèvres, France.
CCTF: Consultative Committee on Time and Frequency.
CGGTTS: CCTF Global GNSS Time Transfer Standard format.
CIPM: Comité International des Poids et Mesures.
GLONASS: Russian GNSS.
GNSS: Global Navigation Satellite System.
GPS: United States of America GNSS.
LNE: Laboratoire National de Métrologie et d'Essais, French NMI.
LNE-SYRTE: French designated laboratory in charge of Time and Frequency units.
MDEV:Modified Allan deviation, square root of MVAR.
MVAR: Modified Allan variance.
NIST: National Institute of Standards and Technology, United States NMI.
NMI: National Metrology Institute.
NRCan: National Ressources Canada.
OP: Observatoire de Paris, France.
PPP: Precise Point Positioning.
PPS: Pulse per second.
PTB: Physikalisch Technisches Bundesanstalt, German NMI.
RINEX: Receiver International Exchange format for Geodesy.
SYRTE: Systèmes de Référence Temps-Espace, OP laboratory where LNE-SYRTE is located.
TDEV: Time Allan deviation, square root of TVAR.
TIC: Time Interval Counter.
TVAR: Time Allan variance derived from AVAR and MVAR.

2.2 REFERENCE DOCUMENTS.

[1] LNE-SYRTE/OP Calibration report, June 10, 2016, Issue 1, Pierre Uhrich, G. Daniele Rovera, Baptiste Chupin. BIPM CAL_ID#1101-2016.

3 DESCRIPTION OF EQUIPMENT AND OPERATIONS.

3.1 REFERENCE RECEPTION CHAIN : CS22

3.1.1 CALIBRATION OF THE RECEPTION CHAIN CS22 BY OP

April 2016 :

In the frame of the future inclusion of UTC(CNES) inside BIPM Circular T, and following a request by CNES to calibrate one GPS receiver, LNE-SYRTE and CNES agreed that the CNES Septentrio PolaRx4 receiver s/n 3008022 named CS22, together with its antenna, would travel to Paris to be implemented in OP.

The report that describes this activity is "LNE-SYRTE/OP Calibration report, June 10, 2016, Issue 1, Pierre Uhrich, G. Daniele Rovera, Baptiste Chupin", BIPM CAL_ID#1101-2016.

Here follows a summary Table.

Table 1. Summary information of the calibration trip.

Institute	Status of equipment	Dates of measurement	Receiver type	BIPM code	RINEX name
OP	Group 1	57485-57492	Ashtech ZXII3-T	OPMT	OPMT
CNES/OP	Group 2/Traveling	57485-57492	Septentrio PolaRx4	CS22	CS22

It was agreed that OP would provide the antenna cable used in Paris. This antenna cable delay should then be taken into account for the implementation back to CNES where one local cable would be used instead.

3.2 MEASUREMENT OF THE LOCAL CNES CABLE DELAY AND IMPLEMENTATION ON CS22 RECEPTION CHAIN AT CNES :

Method : Differential measurement with GPS signal simulator (all values in ns)

Step 1- Measurement of the delay [simulator + receiver + tare_cable + adaptors_1] = 65.53 (σ=0.09) P1 ; 67.46 (σ=0.03) P2

Step 2- Measurement of the delay [simulator + receiver + tare_cable + cable_ant + adaptors_2] = 241.49 (σ=0.12) P1 ; 243.48 (σ=0.04) P2

Step 3- Difference = [cable_ant + adaptors_2 - adaptors_1] = 175.96 (σ=0.15) P1 ; 176.02 (σ=0.05) P2

Step 4 - cable_ant = 176.06 (σ=0.18) P1 ; 176.12 (σ=0.11) P2
NB : There is one more adaptor in the Step1 configuration than in the Step2 configuration. This difference is taken into account in Step4. The usual adaptor delay is 0.1 ns with a conventional uncertainty of 0.1 ns.

Step 5 - Mean P1/P2 = 176.09 ns (σ=0.21)

The CNES cable delay to be taken into account in the CS22 CGGTTS generation files is 176.1 ns.

In line with the OP procedure we use a 1-sigma uncertainty of 0.5 ns for the overall uncertainty budget.

3.3 REFERENCE RECEPTION CHAIN CS22 AS IMPLEMENTED AT CNES AND RECEPTION CHAIN TO BE CALIBRATED :

The method of calibration is the “golden system calibration”. The golden system consists of the CS22 reception chain calibrated by OP with cable replacement as describes in 3.2.

The reception chain to be calibrated (DUT) consists of a Septentrio PolaRx4 S/N: 3001153 named CS21 and its antenna.

All the involved equipment is described inside the BIPM information sheets provided in Annex A for all receivers and both locations.

Table 2. Summary information of the calibration trip.

Institute	Status of equipment	Dates of measurement	Receiver type	BIPM code	RINEX name
CNES	Group 2	57911-57919	Septentrio PolaRx4	CS22	CS22
CNES	Group 2	57911-57919	Septentrio PolaRx4	CS21	CS21

4 DATA USED.

The CS22 and CS21 collected raw data are transformed into RINEX 2.11 format by using the sbf2rin-10.2.0 software. The calibration is consisting in building differential pseudoranges for each code P1 and P2 between the two receivers, these differences being corrected by the known reference (REFDLY) and antenna cable (CABDLY) delays when available. The coordinates of the antenna phase centers are especially computed for the calibration period from RINEX files by using the NRCan PPP software.

The noise of the P1 and P2 differences is the one-sigma statistical uncertainty of the CGGTTS P1 and P2 differences.

Reference delays are measured against the local UTC(CNES) physical reference point according to the OP double weighting technique. Antenna cable delay is obtained from dedicated measurements described above.

For validation purposes, P3 CGGTTS files are computed by using the R2CGGTTS software provided by P. Defraigne (ROB), and CV are built between the two receivers.

5 RESULTS OF RAW DATA PROCESSING.

The first Table here provides a summary of the P1 and P2 delays (INTDLY) computed from the raw differences between RINEX files, together with the REFDLY and CABDLY used for these computations. The REFDLY and CABDLY values were either measured on site or taken as known parameter for a given receiving chain.

Table 3. Summary information on receiver delays (all values in ns).

Receiver	Reference	Dates of measurements	REFDLY	CABDLY	INTDLY P1	INTDLY P2
CS22	OPMT	57485-57492	149.0	176.1	60.3	66.4
CS21	CS22	57911-57919	149.0	166.2	58.0	55.7

The plots of P1 and P2 computed delays (corrected for CABDLY and REFDLY differences) are provided in Annex B.

The CGGTTS P3 CV computed by using these results of the calibration is also made available in Annex B.

6 CALIBRATION RESULTS.

6.1 CS21 AGAINST CS22.

The following Table is providing the computed internal delays INTDLY P1 and P2 for CS21 against CS22.

Table 4. Traveling vs Reference system (all values in ns).

Pair	Date	INTDLY P1	INTDLY P2	P1 – P2
CS21-CS22	57911-57919	58.0	55.7	2.3

6.2 UNCERTAINTY ESTIMATION.

We provide in this Section an estimation of the uncertainty of the differential calibration for the receiver CS21 against CS22. The uncertainty budget has been built according to [1] with addition of the ub,REF in order to provide the required u_{CAL0} values.

The ub,REF is the CS22 U_{CAL0} coming from [1].

The ub,CABDLY_CNES is the uncertainty coming from the antenna cable replacement operated by CNES.

The details on the systematic uncertainties are provided in Annex C.

We obtain about 1.46 ns for P3 uncertainty U_{CAL0} for CS21.

Table 5. Uncertainty contributions.

Value u_a(P3) is computed from: [P1 + 1.545 x (P1 - P2)].

Unc.	Value P1 (ns)	Value P2 (ns)	Value P1-P2 (ns)	Value P3 (ns)	Description
ua(Ref-DUT)	0.25	0.32			STDEV
ua	0.25	0.32	0.40	0.81	
Misclosure					
ub,1	N/A	N/A	N/A	N/A	
Systematic components related to RAWDIF					
ub,11	0.05	0.05	0.05	0.05	Position error (ref)
ub,12	0.05	0.05	0.05	0.05	Position error (DUT)
ub,13	0.05	0.05	0.05	0.05	Multipaths (ref)
ub,14	0.05	0.05	0.05	0.05	Multipaths (DUT)
Link of the Traveling system to local UTC(k)					
ub,21	0.3	0.3		0.3	REFDLY(DUT)
Link of the Reference system to its local UTC(k)					
ub,31	0.3	0.3		0.3	REFDLY(ref)
Antenna cable delays					
ub,41	0.5	0.5		0.5	CABDLY(ref)
ub,42	0.5	0.5		0.5	CABDLY(DUT)
ub,SYS				0.83	
ub,REF				0.84	
ub,CABDLY_CNES				0.21	CABDLY(ref) replacement
U_{CAL0}				1.46	Quadratic sum of ua, ub,SYS and ub,REF

7 FINAL RESULTS FOR THE SYSTEM TO CALIBRATE.

The next Table provides a summary of the relative calibration results for CS21 receiver.

Table 6. Summary information on the calibration trip.

Reference system	Cal_Id	Date	u_{CAL}(P3) / ns	INTDLY P1 / ns	INTDLY P2 / ns
CS22	1101-2016	2017-06	0.9	60.3	66.4
DUT	Cal Id	Date	u_{CAL}(P3) / ns	INTDLY P1 / ns	INTDLY P2 / ns
CS21		2018-02	1.5	58.0	55.7

8 CONTACT

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ANNEXES.

Annex A. BIPM information sheets.

Annex B. Plots of raw data.

Annex C. Details on the systematic uncertainties.

Annex A. BIPM information sheets.

Cal_Id ??? Version 1.0 / 2018-02

BIPM Information Sheet

Laboratory	CNES	
Date and hour start of measurements	57911	
Date and hour end of measurements	57919	
Information on the system		
	Ref	**DUT**
4-character BIPM code	CS22	CS21
Receiver maker and type Receiver serial number	Septentrio PolaRx4 S/N: 3008022	Septentrio PolaRx4 S/N: 3001153
1 PPS trigger level /V	1.0	1.0
Antenna cable maker and type Phase stabilized cable (Y/N)	CNES_KX13 n° 3 Y	CNES_KX13 n° 2 Y
Cable length outside building /m	≈ 60	≈ 50
Antenna maker and type Antenna serial number	AEROANTENNA AERAT2775_43 S/N : 5614	Septentrio B3E6 S/N B3E6_2
Temperature if stabilized /°C	N/A	N/A
Measured delays / ns		
	Ref	**DUT**
Delay from local UTC(k) to receiver 1 PPS_IN	15.502 ns	10.895 ns
Delay from 1 PPS_IN to internal reference	153.745 ns	138.119 ns
Antenna cable delay	176.1 ns	166.2 ns
Splitter delay	N/A	N/A
Additional cable delay	N/A	N/A
Data used for the generation of CGGTTS files		

	Ref	DUT
INT DLY (GPS) /ns	60.3 (P1) 66.4 (P2)	58.0 (P1) 55.7 (P2)
INT DLY (GLONASS) /ns	N/A	N/A
CAB DLY /ns	176.1	166.2
REF DLY /ns	149.0	149.0
Coordinate reference frame	ITRF	ITRF
Latitude or X /m	+4627840.58	+4627840.50
Longitude or Y /m	+119863.73	+119864.64
Height or Z /m	+4372994.55	+4372994.58

General information	
Rise time of local UTC pulse	0.5 ns
Air conditioning (Y/N)	yes
Set temperature value and uncertainty	22 ± 1 °C
Set humidity value and uncertainty	50 ± 10 %

Annex B. Plots of raw data.

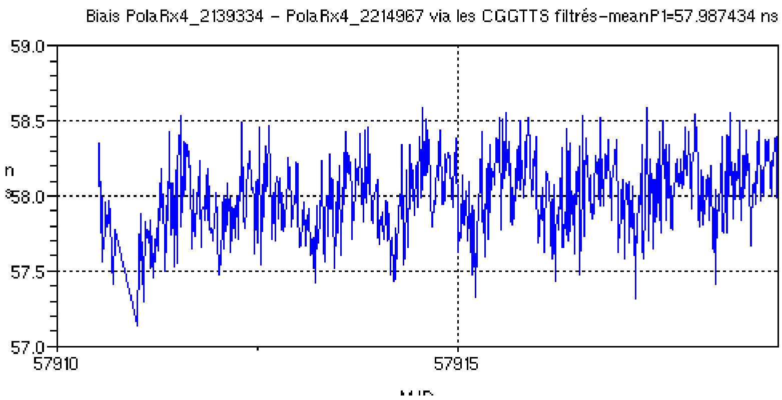

Figure B_1. P1 -code delays of CS21 receiver against CS22.

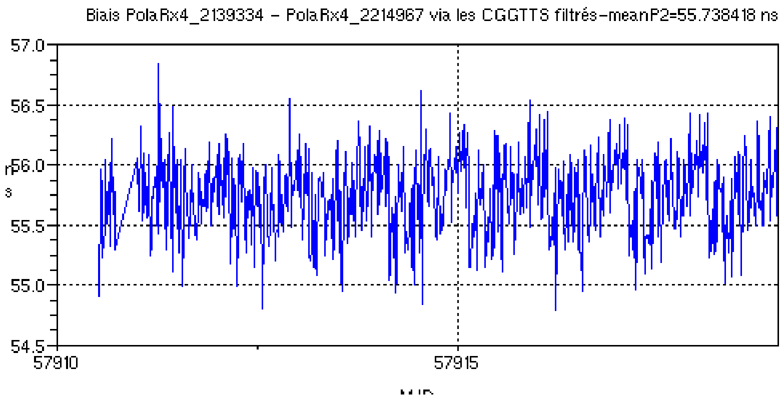

Figure B_2. P2 -code delays of CS21 receiver against CS22.

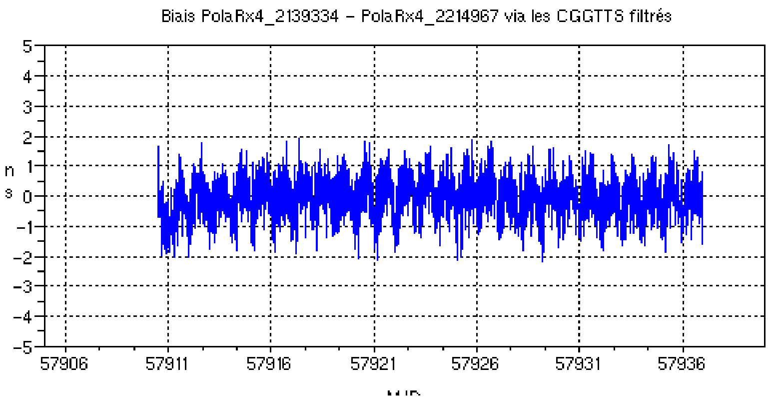

Figure B_3. P2 -code delays of CS21 receiver against CS22.

Annex C. Details on the systematic uncertainties.

Annex C. Details on the systematic uncertainties.

We provide here a detailed description of the systematic uncertainties as they are appearing inside the uncertainty budgets provided in the calibration report.

- All u_a(ReceiverA-ReceiverB) are based on a STDEV analysis.

- The u_b misclosure appearing in the uncertainty budget is only based on the P3 CV offset between the traveling equipment CS22 and the reference equipment OPMT, after application of the CS22 calibrated delays.

- The u_b uncertainty on the position error is estimated according to the accuracy of the PPP solution computed by using the NRCan software together with IGS products. We have chosen an u_b of about 50 ps for these lines of the uncertainty budgets.

- The u_b uncertainty on multipaths is an arbitrary estimate. We do not have any knowledge about papers describing the optimal way to compute such an estimate.

- About the REFDLY measurements for Septentrio receivers, we assume from past experience that delays based on a TIC by applying the double-balance technique can be measured within an uncertainty of about 200 ps. In addition, we take into account the noise of such data (called “Jitter” on a SR620 TIC), which is added quadratically. By considering 90 ps for Septentrio PPS_OUT data as typical value, we obtain for Septentrio REFDLY value an u_b estimate of about 220 ps.

- For Ashtech ZXII3-T receivers, we have to consider two measurements for the REFDLY computation. First the PPS_IN cable delay measurement based on a TIC and assuming a negligible noise (typically below 10 ps), which leads to a figure of about 200 ps. Second the 20 MHz to PPS_IN additional delay, which is measured by using an oscilloscope, within an uncertainty of about 300 ps. By computing the quadratic sum of both values, we obtain for Ashtech REFDLY value an u_b estimate of about 360 ps.

- By considering the simplest technique for antenna cable delay measurement, which would be based on a 1 PPS signal and a TIC, we assume an u_b estimate of about 0.5 ns.

These choices or assumptions are most probably leading to a conservative uncertainty budget for the relative calibration of GPS receivers, except for the misclosure. Note that this computation is achieved without considering any additional uncertainty estimates on the reference receiver delays.

END OF DOCUMENT