Relative calibration of NRCC GNSS receiver at NRC

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Introduction

An internal calibration of a new GNSS receiver has been performed with respect to a local reference receiver at NRC. The reference receiver, Septentrio PolaRx4TRpro (SN: 31022286, NRC ID: NRC4), had been calibrated against NIST travelling receiver as part of Group 2 calibrations (BIPM calibration ID: CAL_ID 1019_2017). For NRC4 only GPS internal delays for the P1 and P2 code measurements were calibrated. The new receiver under calibration is Septentrio PolaRx5TR, (SN: 4701362, NRC ID: NRCC).

The reference clock (NRC ID: clckA) for the two receivers was derived from a hydrogen maser (NRC ID: VM1). The 1 PPS and 10 MHz signals are derived from the same signal box (NRC ID: Septentrio Signal Box or SSB). The 1 PPS signals from SSB are within 0.1 ns at their outputs. The receivers are connected to different GNSS antennas. Each antenna cable is connected to a GNSS signal splitter and then to the receiver. The antenna's coordinates for NRCC have been determined using the NRCan online PPP service based on 3 days of measurements.

Data from March 07, 2020 to March 14, 2020 (MJD 58915 - 58922) were used for this relative calibration. RINEX (ver. 3.02 and ver. 3.04 for NRC4 and NRCC, respectively) files were created from the raw data collected from each receiver using the program SBF2RIN (ver. 1.10.5 and ver. 18.0.0 for NRC4 and NRCC, respectively). The difference of the TOTAL DELAY between the two receivers was calculated using the program DCLRINEX from BIPM (last modified: 20180302) with the corresponding brdc GPS navigation files.

Annex A shows all the relevant information for the two receivers used in this calibration.

Figure 1 shows the setup diagram of the two receivers in our lab.

Results

The calculation of the internal delays of the receiver under calibration, B, with respect to the reference receiver, A, is based on the following equation

$$\Delta\text{TOTDEL(Pi)}_{A-B} = \Delta\text{CABDEL}_{A-B} + \Delta\text{INTDEL(Pi)}_{A-B} - \Delta\text{REFDEL}_{A-B},$$

where $\Delta\text{TOTDEL(Pi)}_{A-B}$ is the TOTAL DELAY difference between the two receivers (A and B) given as the output of the DCLRINEX program for the *pseudorange* measurements for the Pi code. $\Delta\text{TOTDEL}_{NRC4-NRCC}(P1) = -123.58$ ns and $\Delta\text{TOTDEL}_{NRC4-NRCC}(P2) = -115.10$ ns.

$\Delta\text{CABDEL}_{A-B}$ is the antenna cable delay difference (including the delays of the surge arrestor and the signal splitter if they are known). The measured delay values for all relevant components (cables, surge arrestors, and signal splitters) for the two receivers are given in Figure 1 and Annex A.

$\Delta\text{INTDEL(Pi)}_{A-B}$ is the internal delay difference and it is frequency-dependent. For the reference receiver NRC4, $\text{INTDEL}_{NRC4}(P1) = 62.4$ ns and $\text{INTDEL}_{NRC4}(P2) = 65.5$ ns from the 2017 calibration (CAL_ID 1019_2017).

$\Delta REFDEL_{A-B}$ is the reference delay ($X_O + X_P$) difference. NRCC has been set in the "auto-compensation off" mode. The internal reference delay X_O of each receiver (i.e. the delay between the 1 PPS input and the latching point of the receiver, which is the 1 PPS output of the receiver for both receivers in this calibration) has been carefully measured following the BIPM GPS receiver calibration guidelines. The X_P represents the cable delay from the lab reference point (1 PPS #1 of the SSB) to the 1 PPS input of the receiver (See Figure 1). The X_O and X_P are given in Table 1 for the two receivers in this calibration.

Table 1: The X_O and X_P values for the two receivers in this calibration.

	X_O (ns)	X_P (ns)
NRC4	142.03	1.91
NRCC	32.53	4.82

From the results of this calibration, the internal delays of NRCC were calculated as $INTDEL_{NRCC}(P1)$ = 33.69 ns and $INTDEL_{NRCC}(P2)$ = 28.31 ns, using data shown in Annex A.

Uncertainty

For a GPS link comprising a pair of receivers, A and B, the total uncertainty u_{A-B} can be calculated as the square root of the quadrature sum of all statistical and systematic uncertainties in the calibration, shown in Table 2. The statistical uncertainty of $\Delta TOTDEL_{NRC4-NRCC}$ was the minimum of the TDEV (see Figure 2).

Table 2: Uncertainties for the measurement between the NRC4 and NRCC.

quantity	Uncertainty	P1 (ns)	P2 (ns)
$\Delta TOTDEL_{NRC4-NRCC}$	u_a	0.05	0.01
NRC4 antenna position	u_b	0.05	
NRCC antenna position	u_b	0.05	
NRC4 multipath	u_b	0.10	
NRCC multipath	u_b	0.10	
$REFDEL_{NRC4}$	u_b	0.10	
$REFDEL_{NRCC}$	u_b	0.10	
$CABDEL_{NRC4}$	u_b	0.50	
$CABDEL_{NRCC}$	u_b	0.50	
$\Delta INTDEL_{NRC4-NRCC}$	u_{NRCC}	0.74	0.74

Conclusion

We have performed an internal GPS receiver calibration for a new PolaRx5TR receiver (NRCC) with respect to a calibrated co-located PolaRx4TRpro receiver (NRC4). We found that the GPS internal delays of the NRCC are 33.69 ±0.74 ns and 28.31±0.74 ns for the P1 and P2 code, respectively. These values were used for the generation of the CGGTTS files (GZ) of the NRCC receiver using the R2CGGTTS program. The data files associated with NRCC including the RINEX observation, GZ, and LZ files are submitted to the BIPM ftp site.

Annex A - Information Sheet

Laboratory:	National Research Council Canada
Date and hour of the beginning of measurements:	March 07, 2020, DoY 067, 00:00:00
Date and hour of the end of measurements:	March 14, 2020, DoY 074, 23:59:30

Information on the system

	Ref:	DUT:
4-character BIPM code	NRC4	NRCC
• Receiver maker and type: Receiver serial number:	Septentrio, PolaRx4TR^{pro} 31022286	Septentrio, PolaRx5TR 4701362
1 PPS trigger level /V:	1.0 V	1.0 V
• Antenna cable maker and type: Phase stabilised cable (Y/N):	Andrea, Heliax, LDF2-50 Y	Andrea Heliax, LDF2-50 3/8” Y
Length outside the building /m:	~ 1.5 m	~ 8 m
• Antenna maker and type: Antenna serial number:	ASH701945E_M SNOW CR52002205	PolaNt Choke Ring B3/E6 5645
Temperature (if stabilized) /°C		

Measured delays /ns

	Local:	Travelling:
• Delay from local reference to receiver 1 PPS-in:	1.91 ns	4.82 ns
Delay from 1 PPS-in to internal Reference (if different): (see section 2 for details)	142.03 ns	32.53 ns
• Antenna cable delay:	269.30 ns	305.50 ns
Splitter delay (if any):	unknown	9.50 ns

Data used for the generation of CGGTTS files for reference receiver (NRC4)

• INT DLY (GPS) /ns:	62.4 ns (P1), 65.5 ns (P2)
• INT DLY (GLONASS) /ns:	N/A
• CAB DLY /ns:	269.30 ns
• REF DLY /ns:	142.03 + 1.91 = 143.94 ns
• Coordinates reference frame:	
Latitude or X /m:	1112801.18 m
Longitude or Y /m:	-4341502.35 m
Height or Z /m:	4522925.16 m

General information

• Rise time of the local UTC pulse:	2.532 ns
• Is the laboratory air conditioned:	YES
Set temperature value and uncertainty:	21.0 ± 1.0 ℃
Set humidity value and uncertainty:	

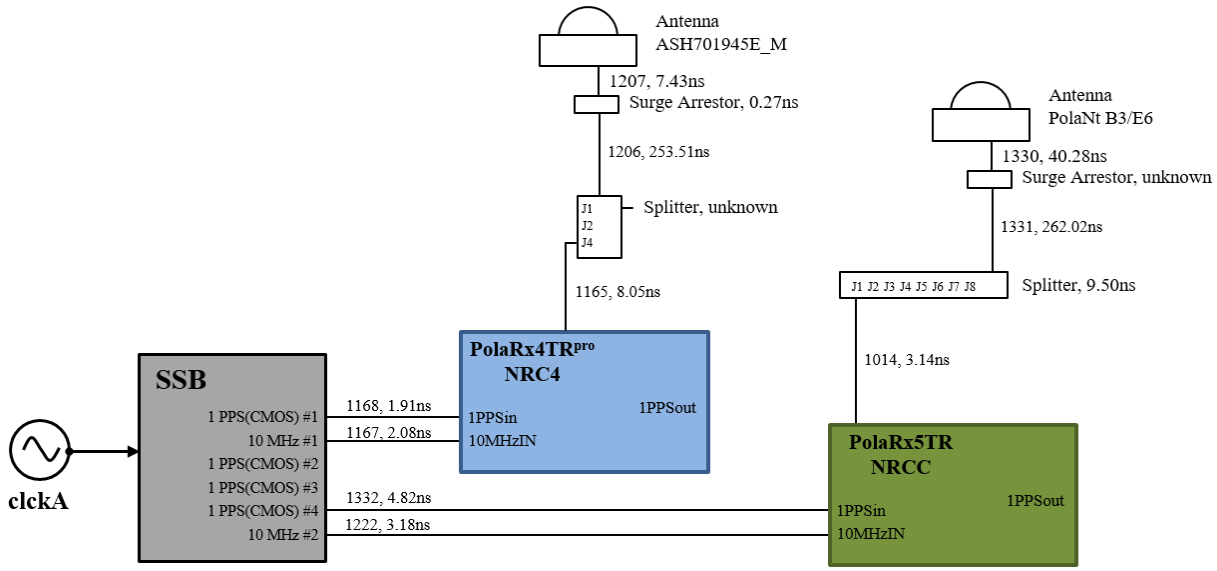

Figure 1: NRCC and NRC4 setup during the calibration campaign. The coaxial cables have been labeled with internal reference number and the corresponding delay. Note that the reference point for the calibration is the 1 PPS (CMOS) #1 in the SSB. Power splitter for NRCC antenna signal: NHIRMLDCBS1X8-N/5.0/110, GPS Networking. The NRCC antenna coordinates: X = 1112799.18 m, Y = -4341498.52 m, and Z = 4522929.44 m.

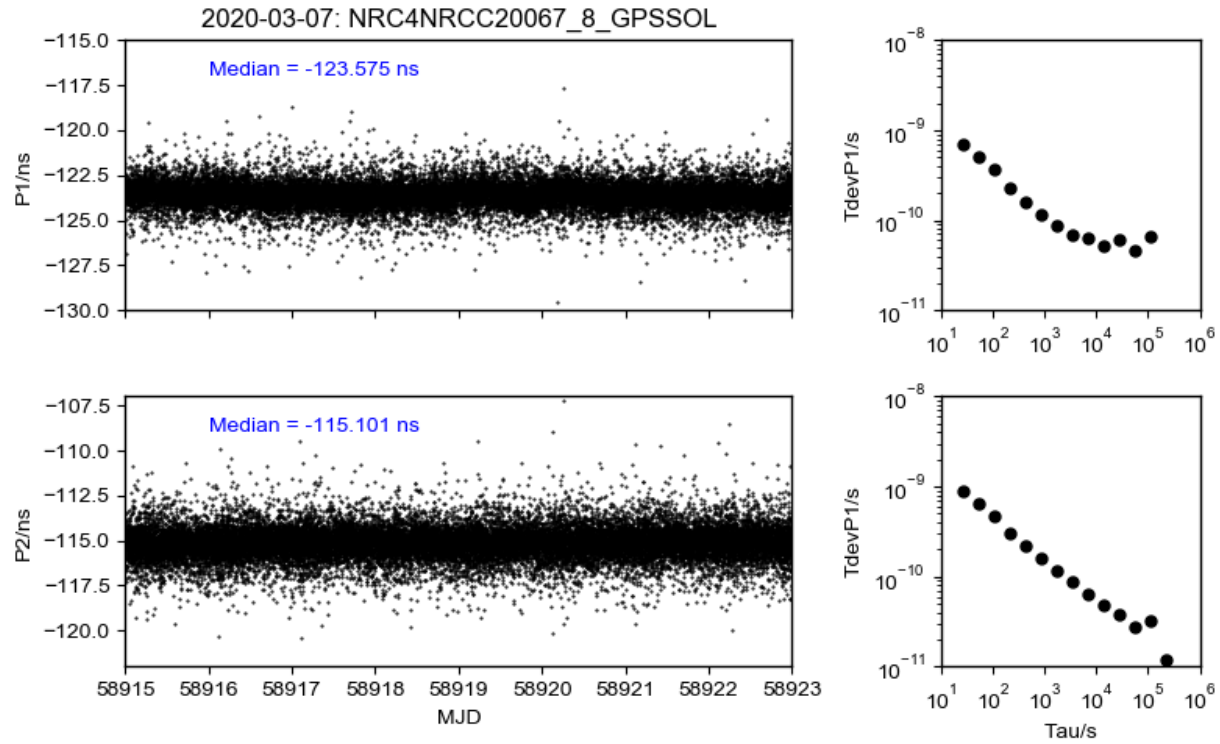

Figure 2: P1 and P2 total differences and TDEV between the NRC4 and NRCC.