Australian Government

Department of Industry, Science, Energy and Resources

National Measurement Institute

Report on Calibration of a GNSS receiver

Septentrio model PolaRx5TR
Serial number: 4701338
with antenna
Septentrio model SEPCHOKE_B3E8
Serial number: 5588

Date(s) of test: 6 December 2020 to 15 December 2020

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The National Measurement Institute is responsible for Australia's units and standards of measurement.
The measurement results presented in this report are traceable to Australia's primary standards.

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MSL New Zealand SEPT receiver calibration 2020

The GNSS receiver designated SEPT was calibrated by transfer of the calibration of AU04.

1. GNSS receiver and signal connections

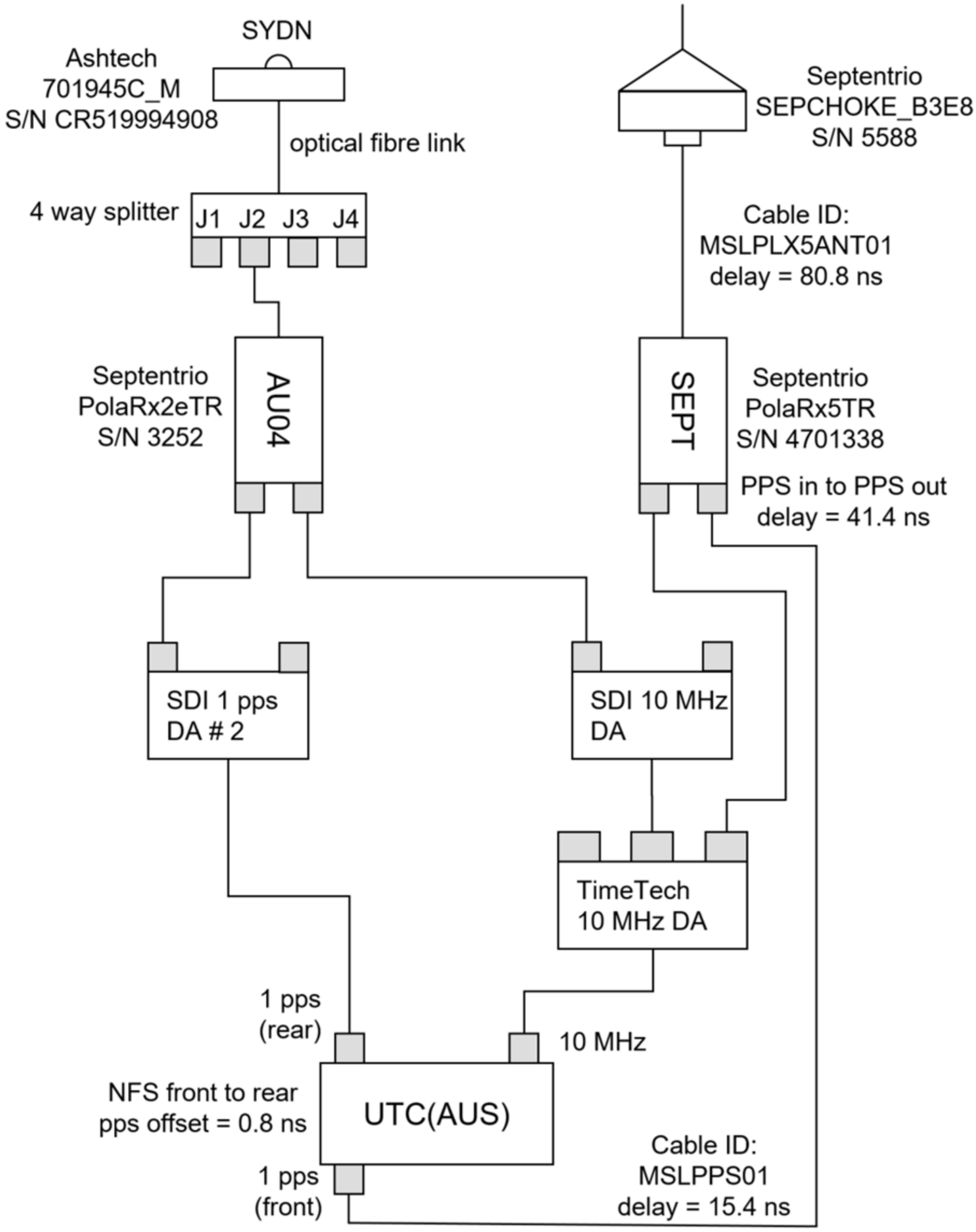


Figure 1 Signal distribution

2. GNSS antenna installations

Figure 2 AU04 antenna

Figure 3 SEPT antenna (left)

3. Event log

Date	Time (UTC)	Event
2020-12-06	0000	Calibration starts
2020-12-15	0000	Calibration ends

4. NMI antenna information

AU04 antenna

Manufacturer	Ashtech
Model	Choke ring antenna 701945C_M
S/N	CR519994908
Coordinates	
Reference frame	ITRF2014
X	- 4648240.92
Y	2560636.46
Z	- 3526317.78

SEPT antenna

Manufacturer	Septentrio
Model	Choke ring antenna SEPCHOKE_B3E8
S/N	5588
Coordinates	
Reference frame	ITRF2014
X	- 4648199.30
Y	2560478.91
Z	- 3526508.78

Antenna coordinates were computed using the AUSPOS positioning service.

5. GNSS receiver information and delays

AU04 receiver

GNSS receiver	
NMI RINEX identifier	SEP1
Manufacturer	Septentrio
Model	PolaRx2eTR
S/N	3252
Delay measurements	
As reported in 1002-2010	

SEPT receiver

GNSS receiver	
NMI RINEX identifier	SEPT
Manufacturer	Septentrio
Model	PolaRx5TR
S/N	4701338
Delay measurements	
Antenna cable	80.8 ns ± 0.3 ns
REF 1 PPS delay	57.5 ns ± 0.2 ns
consisting of:	
1 PPS cable	15.4 ns
Receiver PPS in to PPS out	41.4 ns
NFS front to rear PPS offset	0.8 ns

6. Processing of RINEX observations

RINEX observation files were processed using `dclrinex` (v 19/02/2020) with a fixed baseline using the coordinates reported here.

`dclrinexplot.sh` plots are attached in Appendix A.

The raw (median) delays for the AU04-SEPT comparison were:

Signal	Delay (ns)	u (ns)
C1	2305.76	0.1
P1	2303.68	0.1
P2	2307.04	0.1

The uncertainty is estimated from the TDEV of the comparison, as per the Guidelines.

C1 and P1 delays were checked using CGGTTS time-transfer data generated using `r2cggttts` (v8.3) and compared in common-view to calculate delays. These delays agreed with the `dclrinex`-calculated delays within the 0.1 ns resolution of CGGTTS time-transfer data. Note that the same antenna coordinates were used with both `dclrinex` and `r2cggtts` so this degree of freedom has been removed.

7. Uncertainty analysis

The uncertainty analysis does not include AU04 cable delays because these are already included in the uncertainty of the UTC-AU04 link. The presumption is that the total uncertainty of the SEPT-UTC link is obtained by combining the uncertainty reported here with the uncertainty of the AU04-UTC link.

Uncertainty sources considered are tabulated below:

Source	u (ns)
AU04	
Antenna position Multipath	0.2 0.2
SEPT	
Antenna cable delay REF 1 pps delay Antenna position Multipath	0.3 0.2 0.2 0.2

8. Final GPS signal delays

The original calibration report for the AU04 delays does not provide the C1 delay. This has instead been determined by transfer from the P1 delay and is assigned a nominal uncertainty of 0.1 ns.

Sample calculation: P1 delay

The delay of a GPS signal with respect to the local reference is:

REF – GPS = INT DLY + CAB DLY – REF DLY

For AU04:

REF – GPS = 220.9 + 2480.6 – 345.3 = 2356.2 ns

For SEPT:

REF – GPS = INT DLY + 80.8 – 57.5 = INT DLY + 23.3 ns

So for the raw difference AU04 – SEPT:

2303.7 = 2356.2 – (INT DLY + 23.3)

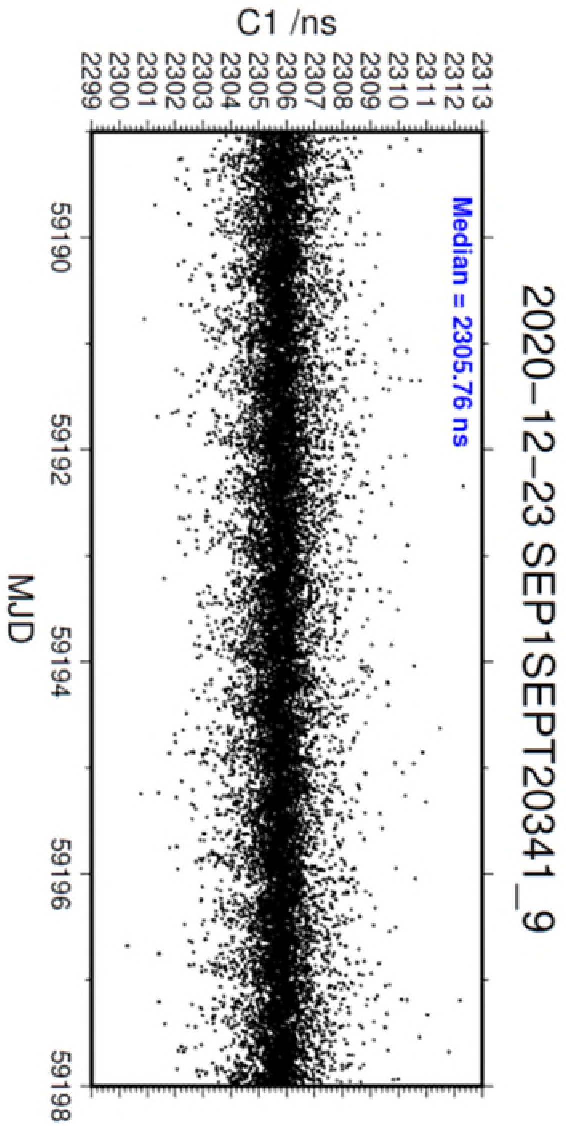
giving:

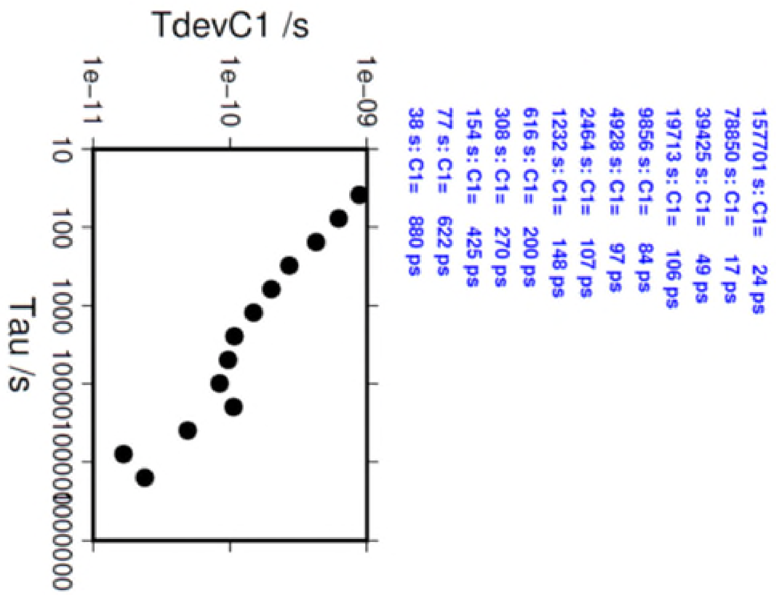
INT DLY = 29.2 ns

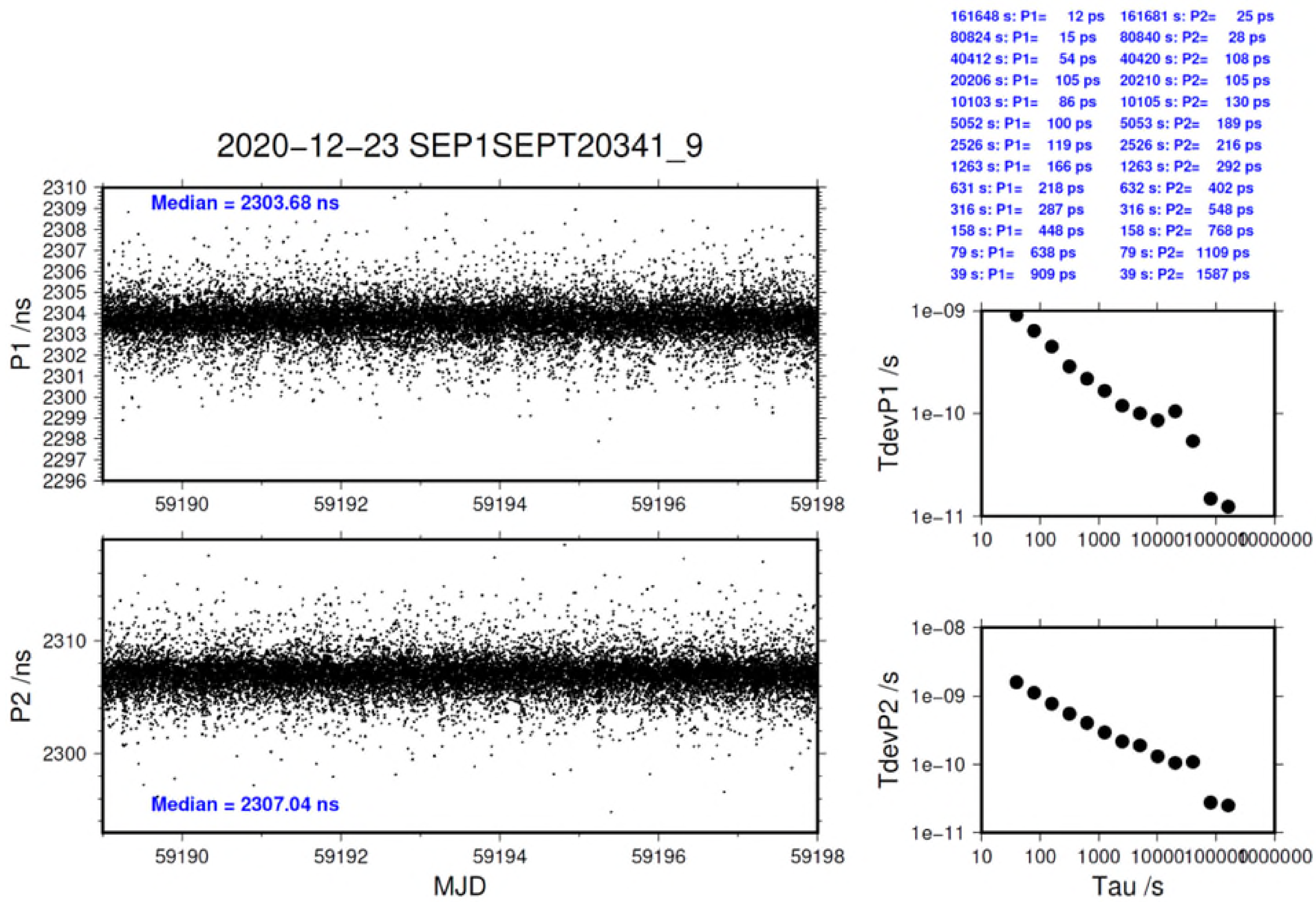
Final signal delays and their uncertainties are tabulated below:

Signal	INT DLY (ns)	u (ns)
C1	30.3	0.6
P1	29.2	0.6
P2	27.0	0.6

Appendix A: `dclrinexplot.sh` output






2020−12−23 SEP1SEPT20341_9
161648 s: P1= 12 ps
80824 s: P1= 15 ps
40412 s: P1= 54 ps
20206 s: P1= 105 ps
10103 s: P1= 86 ps
5052 s: P1= 100 ps
2526 s: P1= 119 ps
1263 s: P1= 166 ps
631 s: P1= 218 ps
316 s: P1= 287 ps
158 s: P1= 448 ps
79 s: P1= 638 ps
39 s: P1= 909 ps
161681 s: P2= 25 ps
80840 s: P2= 28 ps
40420 s: P2= 108 ps
20210 s: P2= 105 ps
10105 s: P2= 130 ps
5053 s: P2= 189 ps
2526 s: P2= 216 ps
1263 s: P2= 292 ps
632 s: P2= 402 ps
316 s: P2= 548 ps
158 s: P2= 768 ps
79 s: P2= 1109 ps
39 s: P2= 1587 ps
Median = 2303.68 ns
P1 /ns
Median = 2307.04 ns
P2 /ns
MJD
TdevP1 /s
TdevP2 /s
Tau /s

Appendix B: Cable delay measurements and REF DLY uncertainty

Cable delays

The delays of the antenna cable and reference cables supplied with the receiver were measured using the insertion method. In figure B.1 the setup for the delay measurement of a cable is shown. For each measurement 100 samples were taken and analysed. The reported value is the mean of these measurements. The measurements were performed using two counters: a Stanford Research Systems model SR620, and an Agilent model 53230A. The results from the two counters agree to within 0.05 ns.

Identification tags were attached to each cable. The antenna cable is marked as MSLPLX5ANT01, and the reference cables as MSLPPS01 and MSLPPS02.

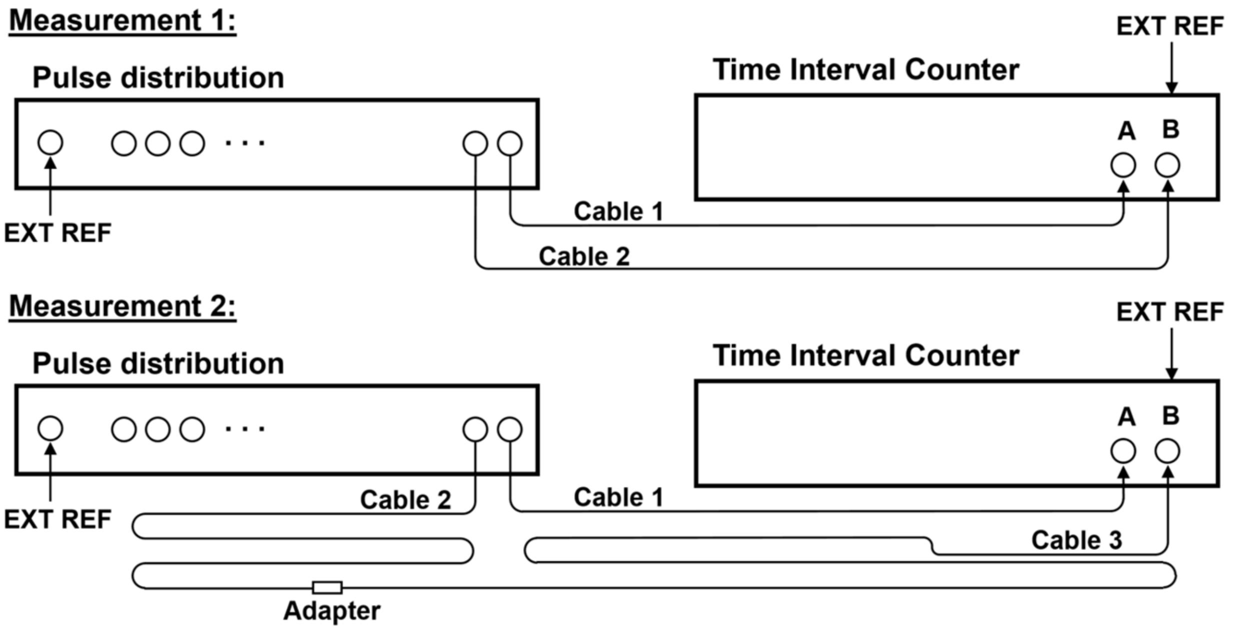


Figure B.1 Cable delay measurement setup

To measure the delay of a cable two measurements are performed. The first measurement uses two cables, each connected to different outputs of a pulse distribution amplifier. Cable 2 should be slightly longer than Cable 1 to ensure a positive offset. The initial delay measurement is done with Cable 1 and Cable 2 connected. The second measurement is done with the cable under test, Cable 3, connected between the counter and Cable 2. The difference between these two measurements is Cable 3 delay plus the delay of any adapters used. The results presented here are the average of the results from the two counters.

The measured delays of the three cables sent with the receiver are:

Cable ID	Measured delay	Standard uncertainty
MSLPLX5ANT01	80.82 ns	0.21 ns
MSLPPS01	15.35 ns	0.11 ns
MSLPPS02	15.35 ns	0.11 ns

Uncertainties

The following contributors were considered in assessing the uncertainty of the cable delay measurements:

- The difference between the delay values obtained with the two counters. This was treated as a rectangular distribution.
- The Type A analysis of every measurement is added with those from the same counter (due to the correlation of using the same counter for both measurements). This gives two Type-A components, one for each counter.
- The effect of adapters – no corrections are applied for the adapters used, but the delay of each adapter is estimated and added as an uncertainty. For the PPS cable delays one BNC(f) to BNC(f) adapter is used. For the antenna cable delay a Type-N (f) to BNC (m) and TNC(f) to BNC(m) adapter is used in addition to the BNC(f) to BNC(f) adapter.

REF DLY uncertainty

The REF DLY value is made up of three components:

- The NFS rear to front PPS offset;
- The cable delay of the cable connecting the receiver to the front PPS output; and
- The PPS in to PPS out delay of the receiver.

The front to rear offset was determined by measuring these values for a number of model 5071A clocks and taking the average of these measurements. The uncertainty of this value is the semi-range of these values, treated as a rectangular distribution. The standard uncertainty is 0.15 ns.

The cable used for connecting the NFS front PPS output to the receiver was MSLPPS01; its measurement and uncertainty is described above. The standard uncertainty is 0.11 ns.

The PPS in to PPS out delay of the receiver was measured using the methodology described in the Guidelines. Its uncertainty is taken as the jitter value for 100 measurements. The standard uncertainty is 0.07 ns.

Combining these values gives the standard uncertainty for the REF DLY determination: 0.20 ns.

Appendix C: Modifying REF DLY for a different PPS in to PPS out value

The receiver internal delay was calibrated with compensation for the PPS-in internal delay disabled. It is thus a requirement to measure this delay.

The REF DLY value is the sum of the cable delay connecting the receiver PPS in to the reference 1PPS output (CAB DLY), and the PPS in to PPS out delay of the receiver (PPSin_PPSout).

REF DLY = CAB DLY + PPSin_PPSout

The PPSin_PPSout value depends on the length of cable connecting the receiver to the 10 MHz output of the reference clock. If this connection is changed (different cable or connection to another clock), the PPSin_PPSout value must be remeasured, and the REF DLY value recalculated to reflect the change in the PPSin_PPSout value. For the PolaRx5TR this value should be between 20 ns and 60 ns (according to “BIPM Guidelines for GNSS equipment calibration – Annex1”, see ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/guidelines/annex-1_operational-procedures-20200623.pdf). This document contains a description of the method for measuring the delay.