REPORT

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Reference
Calibration report 2024:09

BIPM

Relative calibration of a GNSS receiver at RISE

1. Description of equipment and operations

An internal relative calibration of one GNSS receiver has been performed with respect to a local reference receiver. The reference receiver (SP07) is previously calibrated within CAL_ID 1018-2022. The new receiver (SP08, by RISE suggested BIPM code) has been permanently installed at RISE recently, and was not calibrated before.

The relative calibration was performed using differential measurements of the common-clock differences for each frequency band (GPS: L1 and L2 and GAL: E1 and E5a) between the calibrated receiver SP07 and SP08. For GPS, pseudorange codes C1W on L1 and C2W on L2 was calibrated. For GAL pseudorange codes C1C on E1 and C5Q on E5a was calibrated. These pseudorange codes are given according to RINEX format version 3.04.

In the following (except for the figures in Annex A), the pseudorange codes C1W and C2W will be denoted P1 and P2, and C1C and C5Q will be denoted E1 and E5a, in order to follow the denotation of the 1018-2022 report.

Table 1 summarizes the receivers involved in the relative calibration as well as the measurement period.

Table 1. Summary information on the calibration

Institute	Status of equipment	MJD dates of measurements	Receiver type	BIPM code	RISE code	RINEX name
RISE	Calibrated 1018-2022	Reference	PolaRx5TR	SP07	SP07	RIT2
RISE	Not calibrated	60545-60555	PolaRx5TR	SP08	SP08	RIT3

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2. Receiver installations

Table 2 summarizes the receiver installations. The reference clock for both receivers is UTC(SP) 1-PPS and 10 MHz sinusoidal signals. Both receivers are fed from the corresponding antenna via a power splitter indicated in the table by RISE internal names as given in the RISE equipment register. The antenna cable type is given for reference. The fixed antenna coordinates are used when creating CGGTTS data from RINEX data as explained in Section 3.

The mode of operation of both receivers is "auto-compensation OFF".

Table 2. Summary information on receiver installations

Receiver	**RISE monument name**	**Antenna type/ Power splitter**	**Antenna cable type**	**Fixed antenna coordinates**		
				X	Y	Z
SP07	Pillar1	TRM159800.00 PS1	Andrew Heliax LDF2-50A	3328984.40	761910.47	5369033.95
SP08	Pillar 2	LEIAR25.R4 PS14	Andrew Heliax FSJ1-50A	3328988.29	761918.19	5369032.01

3. Data used

Data from 2024-08-23 to 2024-09-02 (MJD 60545-60555) were used for the relative calibration. RINEX (ver. 3.04) data were calculated from raw data collected from each receiver with software SBF2RIN (ver. 15.6.1). CGGTTS data were calculated from RINEX data using the software RISEGNSS [1] developed at RISE.

4. Results of raw data processing

Table 3 summarizes the calculated common-clock differences based on CGGTTS data for receiver SP08 relative to the calibrated reference receiver SP07. The results are based on applying the calibrated TOTDLY for SP07, according to CAL_ID 1018-2023, and by applying a zero delay, including INTDLY, REFDLY and CABDLY, for SP08.

The results are presented as the (uncalibrated) mean common-clock difference (ΔCLKDIFF) for each frequency/code and, for reference, the ionosphere-free linear combinations P3 and E3, and are considered as an estimation of the TOTDLY for SP08.

Annex A shows plots of raw data and Tdev analysis.

Table 3. Summary of the raw calibration results (all values in ns)

Pair	**MJD date**	**ΔCLKDIFF GPS P1**	**ΔCLKDIFF GPS P2**	**ΔCLKDIFF GPS P3**
SP07-SP08	60545-60555	266.5	264.7	269.3
Pair	**MJD date**	**ΔCLKDIFF GAL E1**	**ΔCLKDIFF GAL E5a**	**ΔCLKDIFF GAL E3**
SP07-SP08	60545-60555	269.0	268.1	270.2

5. Uncertainty estimation

Table 4 summarizes the calculated statistical uncertainty for ΔCLKDIFF listed in Table 3. The statistical uncertainty $\mathbf{u_a}$ is represented by the RMS of the raw data difference.

Table 4. Statistical uncertainty contributions (all values in ns)

Pair	$\mathbf{u_{aP1}}$	$\mathbf{u_{aP2}}$	$\mathbf{u_{aP3}}$	Description
SP07-SP08	0.13	0.10	0.37	RMS of raw data difference
Pair	$\mathbf{u_{aE1}}$	$\mathbf{u_{aE5a}}$	$\mathbf{u_{aE3}}$	**Description**
SP07-SP08	0.10	0.08	0.24	RMS of raw data difference

Table 5 and Table 6 summarize the systematic uncertainty that is attributed to the calibration uncertainty of SP07 for GPS and GAL, respectively. The values are extracted from the report by OP “2023_G1-G2_Calibration-Report_1018-2022_V1_1-1”. The aging contribution is calculated as $\left(0.4 \cdot \sqrt{23} - 1\right)$ where 23 is the time in months since last calibration of SP07 in 2022.

The total systematic uncertainty is calculated as

$$\mathbf{u_{b,TOT}} = \sqrt{\sum_n \mathbf{u_{b,n}^2}}$$

Table 5. Systematic uncertainty contributions for GPS (all values in ns)

Uncertainty	Value P1	Value P2	Value P3	Description
$u_{b,1}$	1.1	0.7	1.8	Uncertainty of SP07 (from OP report)
$u_{b,2}$	0.9	0.9	0.9	Aging of SP07 since 2022-10
$\mathbf{u_{b,TOT}}$	1.5	1.2	2.0	

Table 6. Systematic uncertainty contributions for GAL (all values in ns)

b	Value E1	Value E5a	Value E3	Description
$u_{b,1}$	1.1	0.7	2.2	Uncertainty of SP07 (from OP report)
$u_{b,2}$	0.9	0.9	0.9	Aging of SP07 since 2022-10
$\mathbf{u_{b,TOT}}$	1.5	1.2	2.4	

The combined uncertainty $\mathbf{u_{CAL}}$ is calculated as

$$\mathbf{u_{CAL}} = \sqrt{\mathbf{u_a^2} + \mathbf{u_b^2}}$$

but clearly dominated by $\mathbf{u_b}$ and not listed here.

6. Calibration results

Table 7 summarizes the calibration results. For reference, the present calibration values from CAL_ID 1018-2022 are given for SP07.

Since the systematic uncertainty is dominating, as calculated in the previous section, and considering that the combined (conventional) uncertainty according to the calculations in the OP-report for SP07 is 2.5 ns for GPS and 2.7 ns for GAL, it is suggested that SP08 is attributed to the same combined uncertainties as those of SP07.

Table 7. Summary of relative calibration results (all values in ns)

System	Cal_ID	Date	TOTDLY P1	TOTDLY P2	TOTDLY E1	TOTDLY E5a
SP07	1018-2022	2022-10	231.7	228.2	234.6	238.1
SP08		2024-09	266.5	264.7	269.0	268.1

References

[1] K. Jaldehag, P. Jarlemark, and C. Rieck, "Further Evaluation of CGGTTS Time Transfer Software, "in Proc. of the 2019 Joint Conference of the IEEE International Frequency Control Symposium and European Frequency and Time Forum (EFTF/IFC), Orlando, Florida, USA, 2019.

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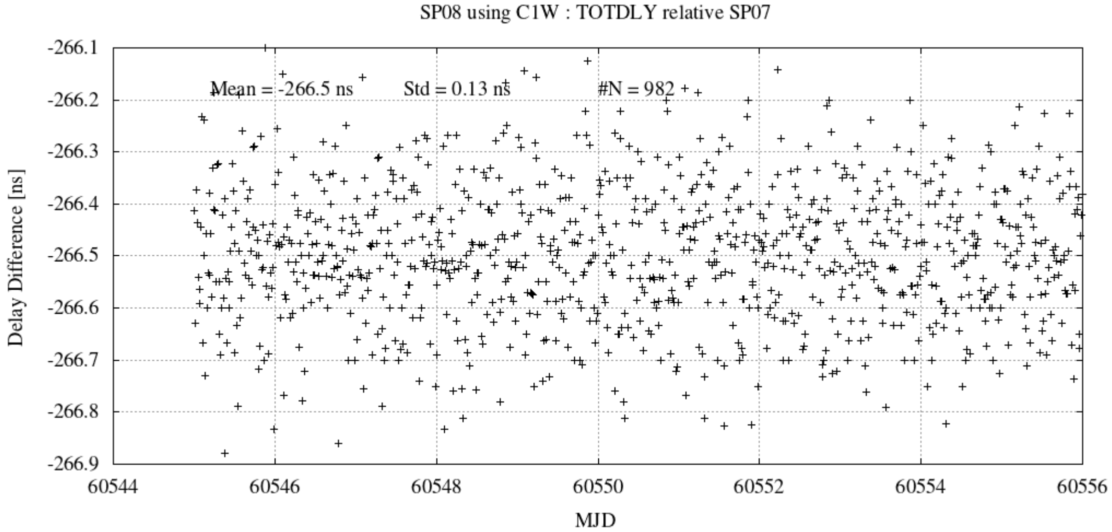
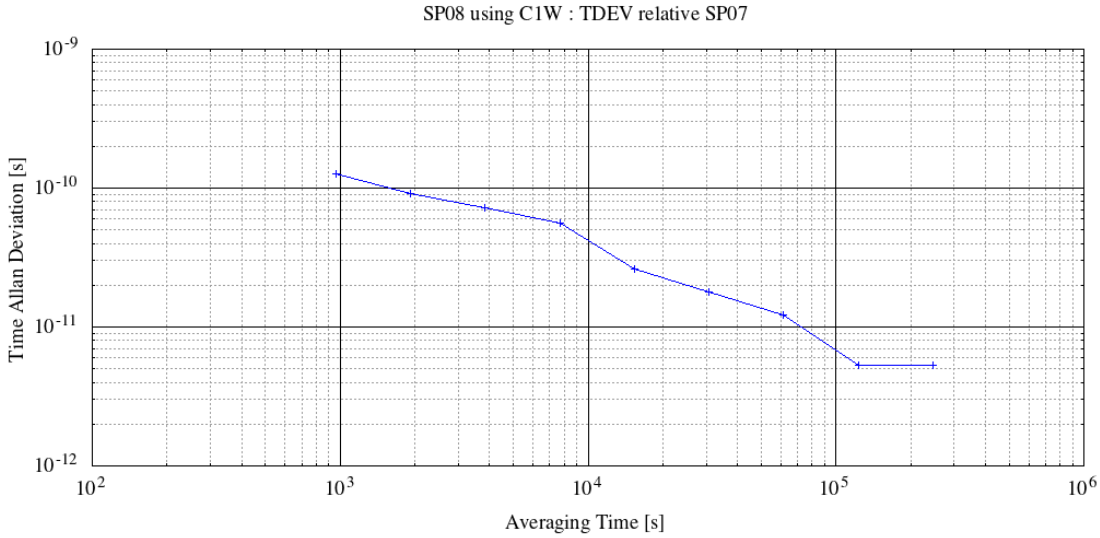
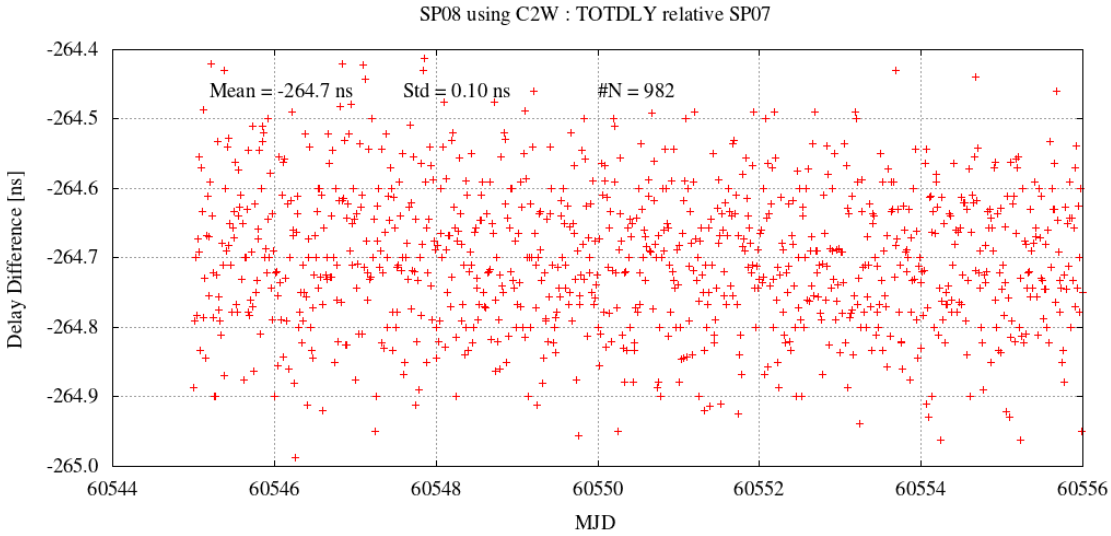
ANNEX A: Plots of raw data and Tdev analysis

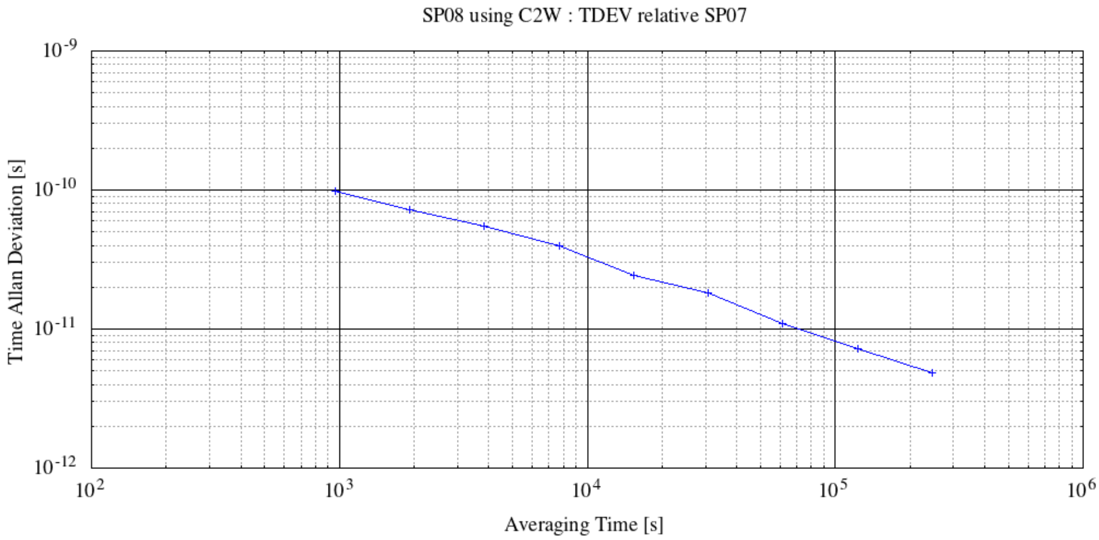
SP07-SP08 P1/C1W



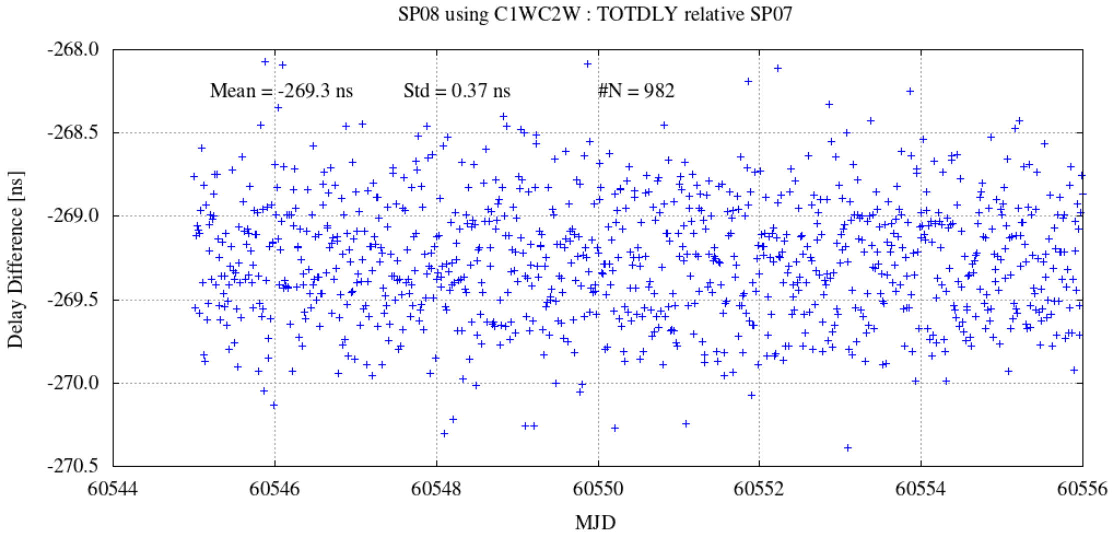


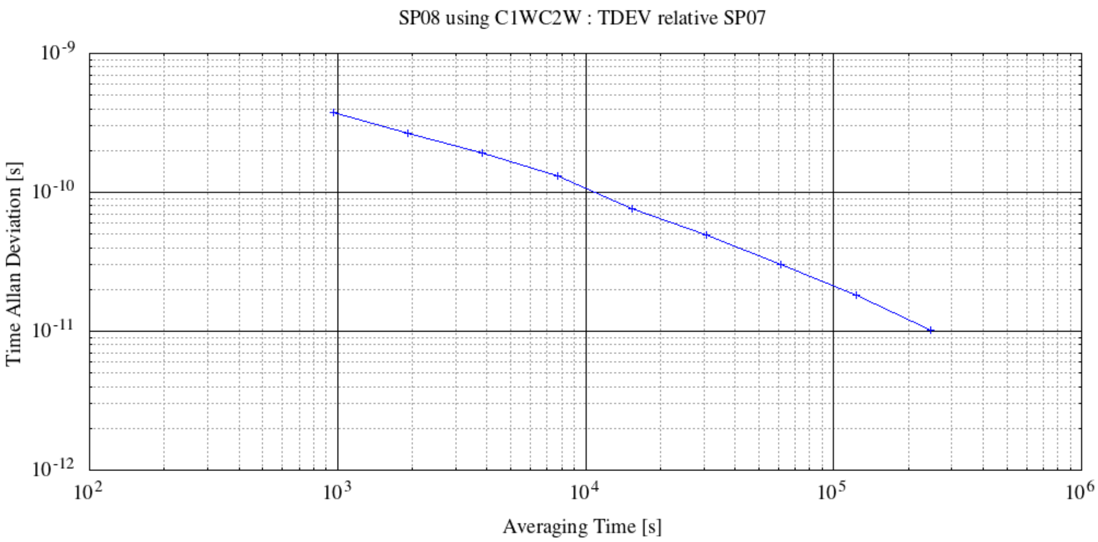
SP07-SP08 P2/C2W



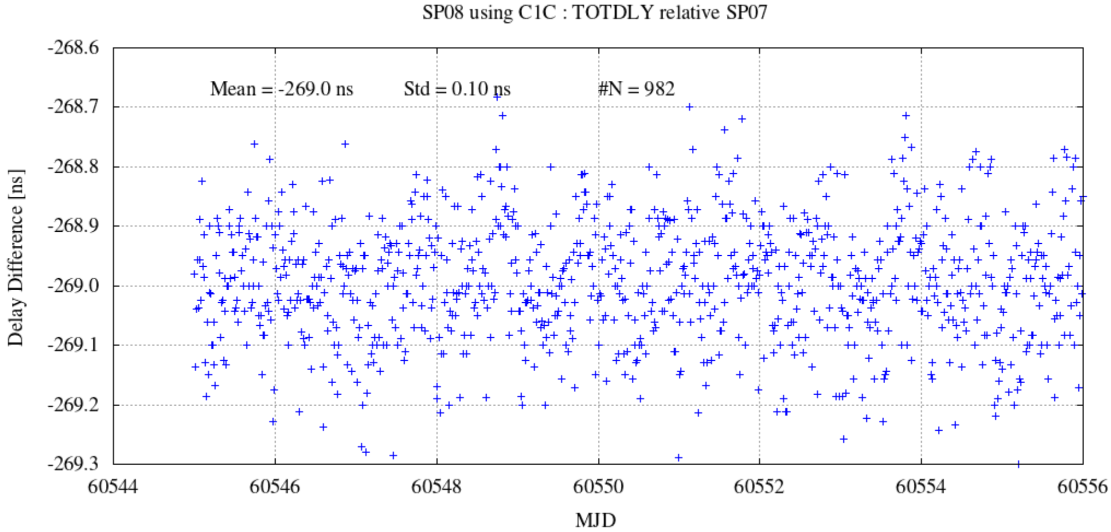


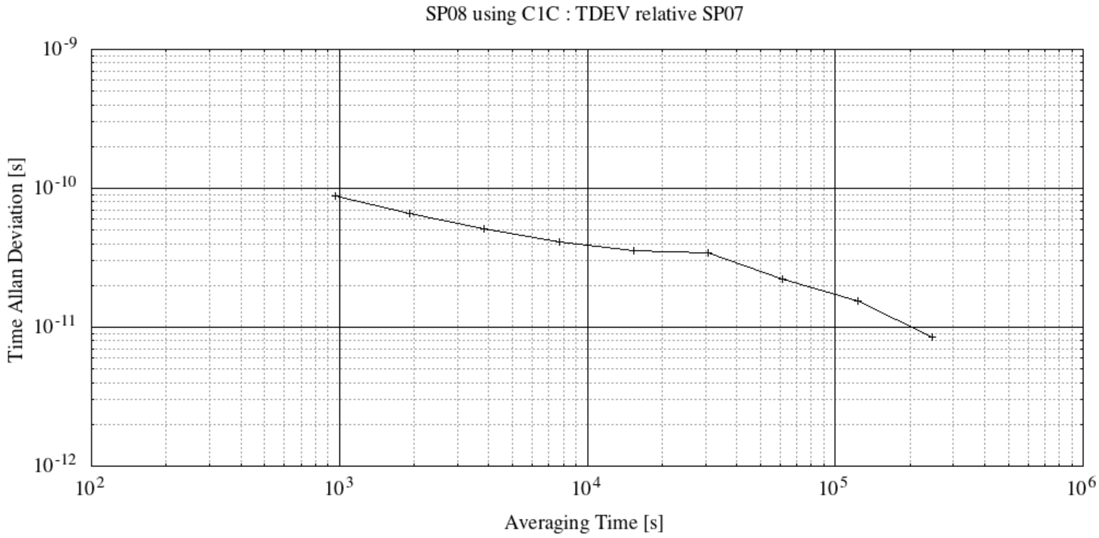
SP07-SP08 P3/C1WC2W



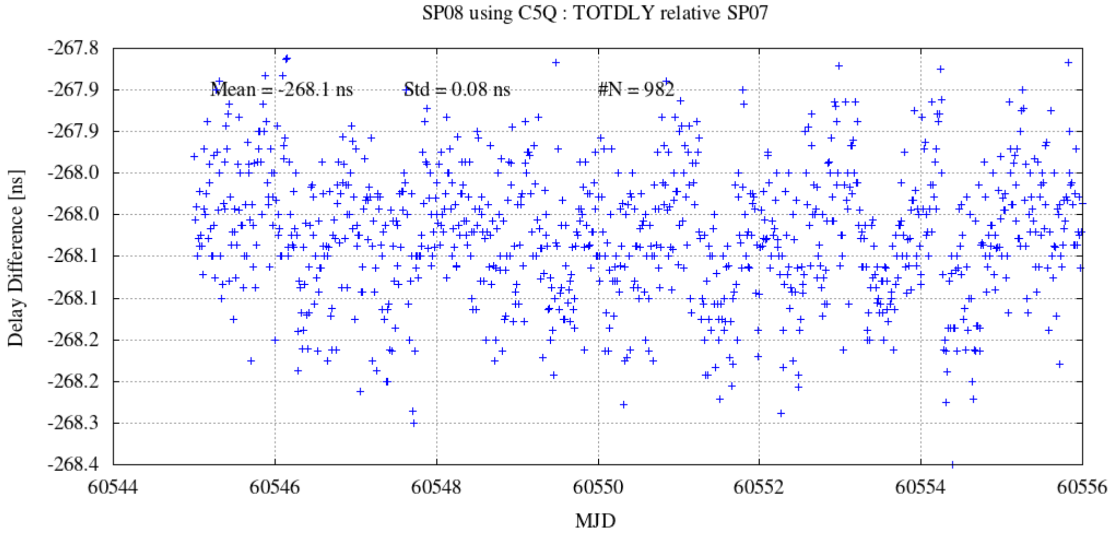


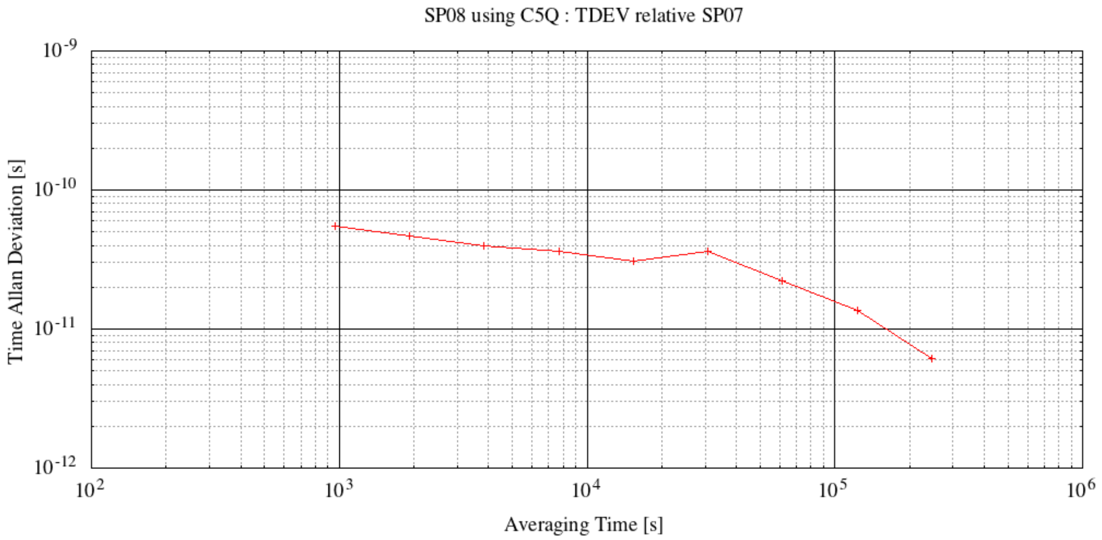
SP07-SP08 E1/C1C





SP07-SP08 E5a/C5Q





SP07-SP08 E3/C1CC5Q