REPORT

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BIPM

Relative calibration of GNSS (GPS) receivers at RISE

1. Description of equipment and operations

An internal relative calibration of four GNSS receivers has been performed with respect to a local reference receiver. The reference receiver (SP01) is previously calibrated with CAL_ID 1013-2016. A second reference receiver (SP02), also calibrated with CAL_ID 1013-2016, was at the same measurement period compared to SP01 to show consistency of the measurements. The calibration is performed using measurements of the TOTAL DELAY for each frequency (L1 and L2) with respect to the corresponding, calibrated delays of SP01. Only GPS (codes P1/C1W on L1 and P2/C2W on L2) was calibrated. 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	Dates of measurements	Receiver type	BIPM code	RISE code	RINEX name
RISE	Calibrated 1013-2016	Reference	Javad LGGD	SP01	SP01	SP01
RISE	Calibrated 1013-2016	58239-58258	Javad LGGD	SP02	SP02	SP02
RISE	Not calibrated	58239-58258	Javad Delta	SP03	SP03	SP03
RISE	Not calibrated	58239-58258	Javad OEM	SP04	SP04	SP04
RISE	Not calibrated	58239-58258	PolaRx5TR	SP05	SP05	SP05
RISE	Not calibrated	58239-58258	PolaRx5TR	RIT1	RIT1	RIT1

2. Receiver installations

Table 2 summarizes the receiver installations. The reference clock for all receivers is UTC(SP) 1-PPS and 5/10 MHz sinusoidal signals. The Javad receivers uses 5 MHz and the PolaRx5TR receivers 10 MHz. All receivers are fed from the corresponding antenna via a power splitter indicated by RISE internal name 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.

Table 2. Summary information on receiver installations

Receiver	RISE monument name	Antenna type/ Power splitter	Antenna cable type	Fixed antenna coordinates		
				X	Y	Z
SP01	Pillar 1	JNSCR_C146-22-1 PS1	Andrew Heliax LDF2-50A	3328984.46	761910.42	5369033.90
SP02	Pillar 1	JNSCR_C146-22-1 PS1	Andrew Heliax LDF2-50A	3328984.46	761910.42	5369033.90
SP03	Mast 3	JAVRINGANT_DM PS13	Andrew Heliax FSJ1-50A	3328961.86	761868.28	5369060.13
SP04	Pillar 2	LEIAR25.R4 PS14	Andrew Heliax FSJ1-50A	3328988.18	761918.17	5369031.83
SP05	Mast 3	JAVRINGANT_DM PS13	Andrew Heliax FSJ1-50A	3328961.86	761868.28	5369060.13
RIT1	Pillar 2	LEIAR25.R4 PS14	Andrew Heliax FSJ1-50A	3328988.18	761918.17	5369031.83

3. Data used

Data from 2018-05-01 to 2018-05-20 (MJD 58239-58258) were used for the relative calibration. RINEX (ver. 3.03) data were calculated from raw data collected from each receiver with software JPS2RIN (ver. 2.0.137) for the Javad receivers and software SBF2RIN (ver. 11.3.2) for the Septentrio receivers. 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 delay differences for each receiver relative to the calibrated reference receiver SP01. The results are presented as the mean difference of the Total Delay for each frequency/code relative to the calibrated values for SP01 (ΔTOTDLY). **The calibrated values for SP01 is included in the results**. The statistical uncertainty $\mathbf{u_a}$ represented by the rms of the raw data processing, is given for each receiver pair. Annex A shows plots of raw data and Tdev analysis.

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

Pair	Date	ΔTOTDLY (P1/C1W)	u_{aP1}	ΔTOTDLY (P2/C2W)	u_{aP2}
SP01-SP02	58239-58258	237.9	0.12	252.2	0.11
SP01-SP03	58239-58258	270.7	0.31	267.4	0.22
SP01-SP04	58239-58258	350.3	0.17	348.1	0.17
SP01-SP05	58239-58258	203.1	0.31	197.8	0.21
SP01-RIT1	58239-58258	275.2	0.16	271.8	0.17

5. Uncertainty estimation

Table 4 summarizes the statistical uncertainty contributions for ΔTOTDLY for each receiver pair listed in Table 3. The statistical uncertainty $\mathbf{u_a}$ is represented by the RMS of the raw calibration results. These values are also given in Table 3.

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

Pair	u_{aP1}	u_{aP2}	Description
SP01-SP02	0.12	0.11	RMS of raw data difference
SP01-SP03	0.31	0.22	RMS of raw data difference
SP01-SP04	0.17	0.17	RMS of raw data difference
SP01-SP05	0.31	0.21	RMS of raw data difference
SP01-RIT1	0.16	0.17	RMS of raw data difference

Table 5 summarizes the systematic uncertainty that is attributed to the calibration uncertainty of SP01 and the same for all receiver pairs. The total systematic uncertainty is calculated as

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

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

Uncertainty	Value P1	Value P2	Description
$u_{b,1}$	2.5	2.5	Calibrated Total Delay of SP01 (1013-2016)
$u_{b,2}$	0.5	0.5	Reference clock change of UTC(SP)
$u_{b,3}$	1.0	1.0	Antenna change for SP01
$\mathbf{u_{b,TOT}}$	2.7	2.7	

6. Calibration results

Table 6 summarizes the calibration results. For reference, the present calibration values is given for SP01 and SP02. **The TOTDLY values obtained in March 2016 resulting in CAL_ID 1013-2016 was corrected for a reference clock change in April 2016 and an antenna change in August 2016. These corrected values for SP01 and SP02 are given in Table 6 and the uncertainties corresponding to the changes are given in Table 5.**

The combined uncertainty u_{CAL} is calculated as

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

and the TOTDLY as well as the u_{CAL} for P3 is calculated as P1 + 1.545*(P1-P2).

As the systematic uncertainty $u_{b,TOT}$ dominates u_{CAL}, the combined uncertainty for all TOTDLY (P1, P2, and P3) and for all receivers given in Table 6 is 2.8 ns.

Table 6. Summary of relative calibration results (all values in ns)

Reference system	Cal_ID	Date	TOTDLY (P1/C1W)	TOTDLY (P2/C2W)	TOTDLY (P3)
SP01	1013-2016	2016-03	237.4	253.1	213.1
SP02	1013-2016	2016-03	237.8	252.0	215.8
Calibrated system		**Date**	**TOTDLY (P1/C1W)**	**TOTDLY (P2/C2W)**	**TOTDLY (P3)**
SP02		2018-05	237.9	252.2	215.8
SP03		2018-05	270.7	267.4	275.8
SP04		2018-05	350.3	348.1	353.7
SP05		2018-05	203.1	197.8	211.3
RIT1		2018-05	275.2	271.8	280.1

References

[1] K. Jaldehag, C. Rieck, and P. Jarlemark, “Evaluation of CGGTTS Time Transfer Software Using Multiple GNSS Constellations, “in Proc. of the 32nd European Frequency and Time Forum, Torino, Italy, 2018.

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Performed by

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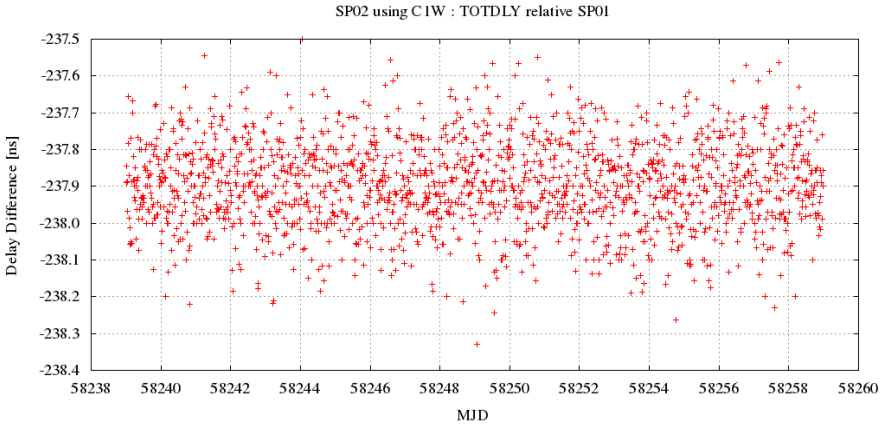
Date & Time: 2018-08-31 09:58:55 +02:00

Kenneth Jaldehag

ANNEX A: Plots of raw data and Tdev analysis

SP02


SP02 using C1W : TOTDLY relative SP01
Delay Difference [ns]
-237.5
-237.6
-237.7
-237.8
-237.9
-238.0
-238.1
-238.2
-238.3
-238.4
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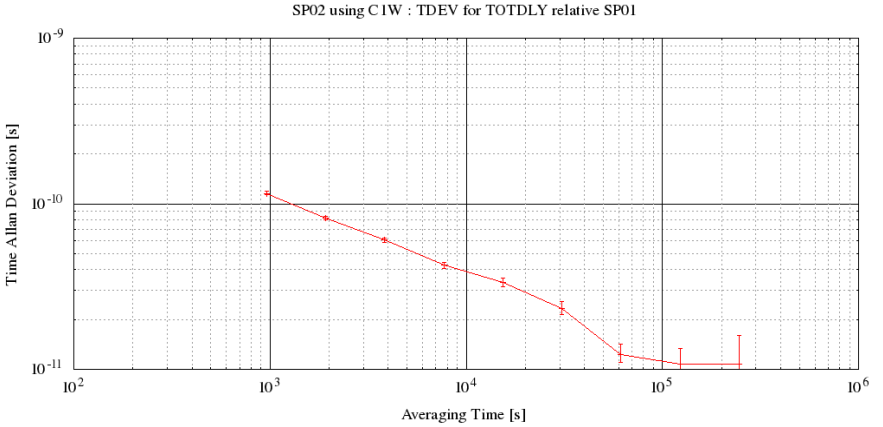
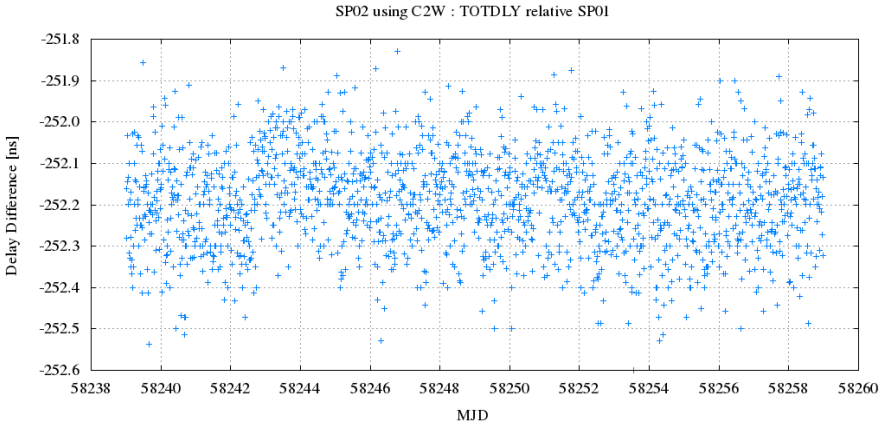
58252
58254
58256
58258
58260
MJD


SP02 using C1W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
10^-9
10^-10
10^-11
10^2
10^3
10^4
10^5
10^6
Averaging Time [s]


SP02 using C2W : TOTDLY relative SP01
Delay Difference [ns]
-251.8
-251.9
-252.0
-252.1
-252.2
-252.3
-252.4
-252.5
-252.6
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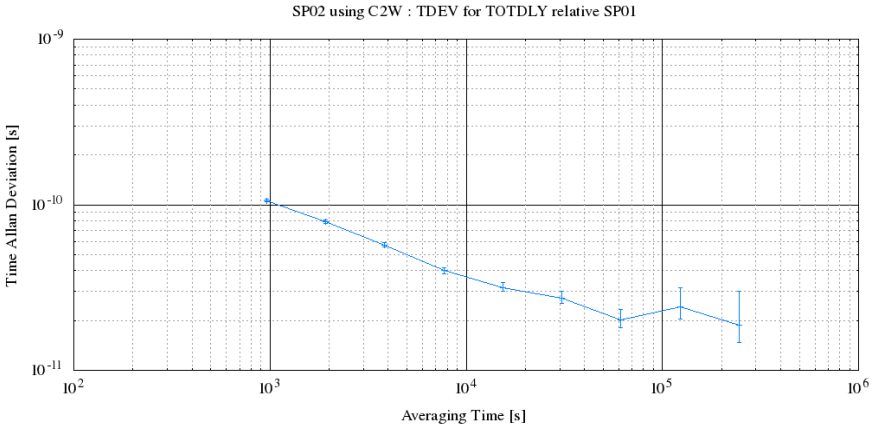
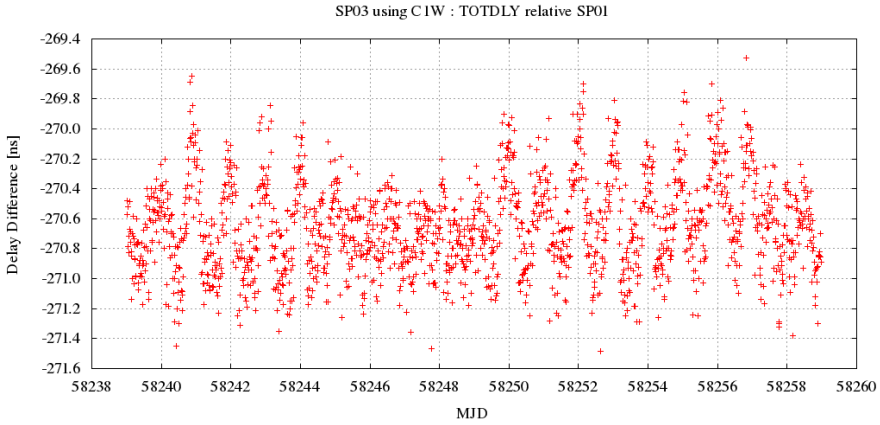
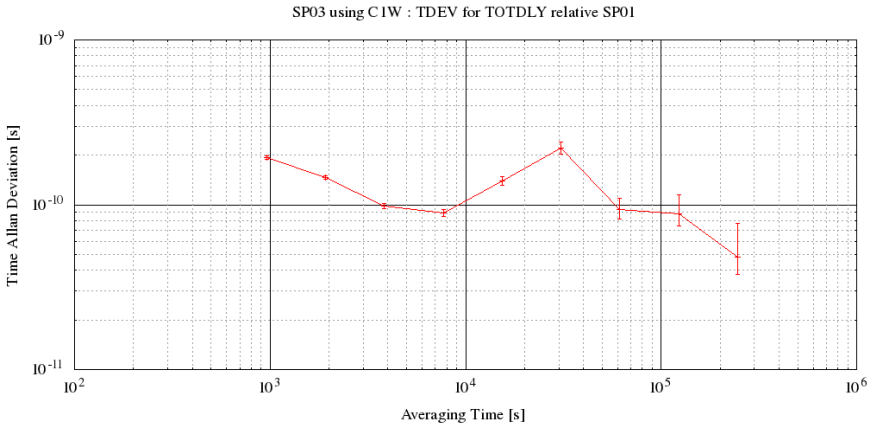
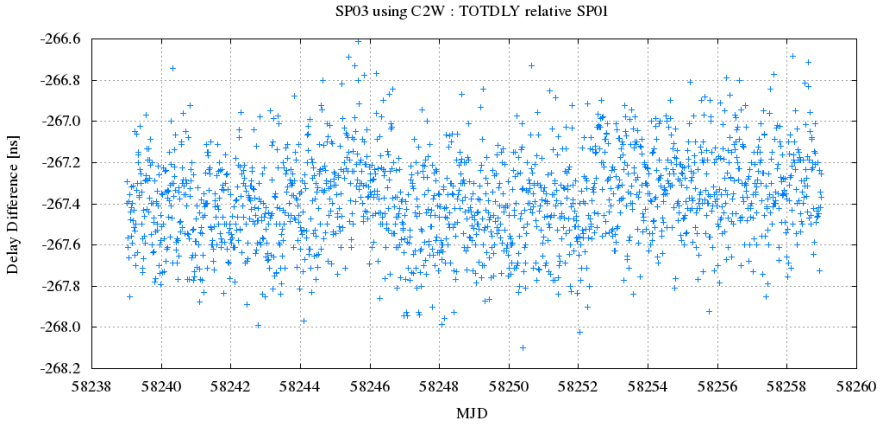
58258
58260
MJD

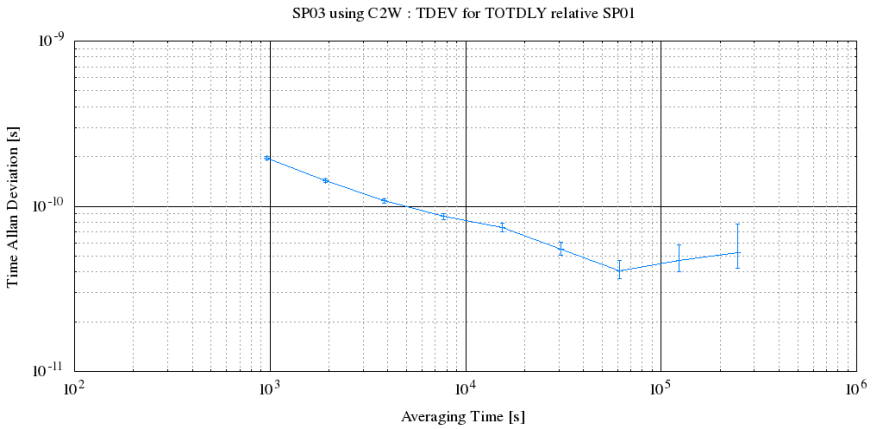

SP02 using C2W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
10^-9
10^-10
10^-11
10^2
10^3
10^4
10^5
10^6
Averaging Time [s]

SP03

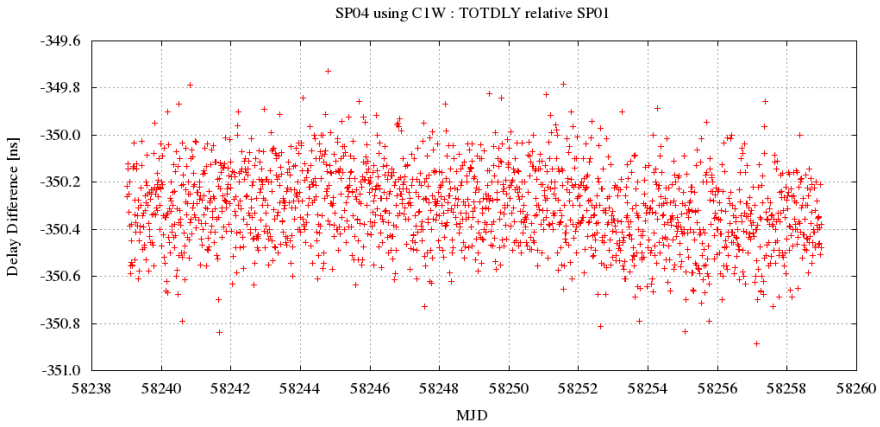

SP03 using C1W : TOTDLY relative SP01
Delay Difference [ns]
MJD


SP03 using C1W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
Averaging Time [s]


SP03 using C2W : TOTDLY relative SP01
Delay Difference [ns]
MJD


SP03 using C2W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
Averaging Time [s]

SP04


SP04 using C1W : TOTDLY relative SP01
Delay Difference [ns]
-349.6
-349.8
-350.0
-350.2
-350.4
-350.6
-350.8
-351.0
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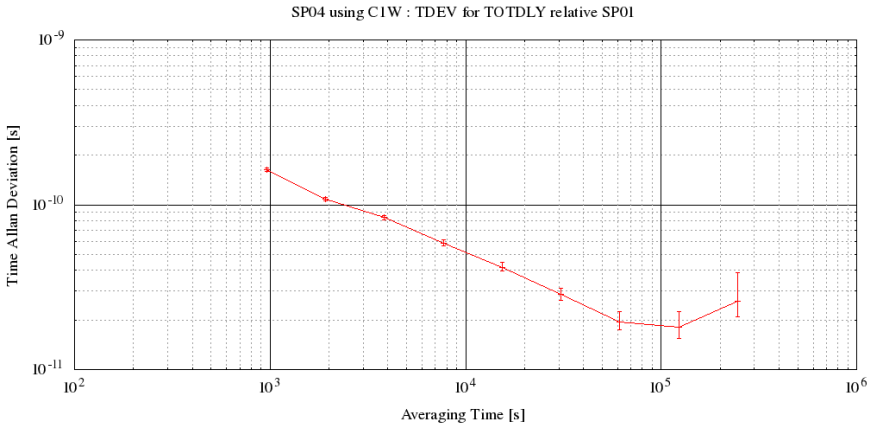
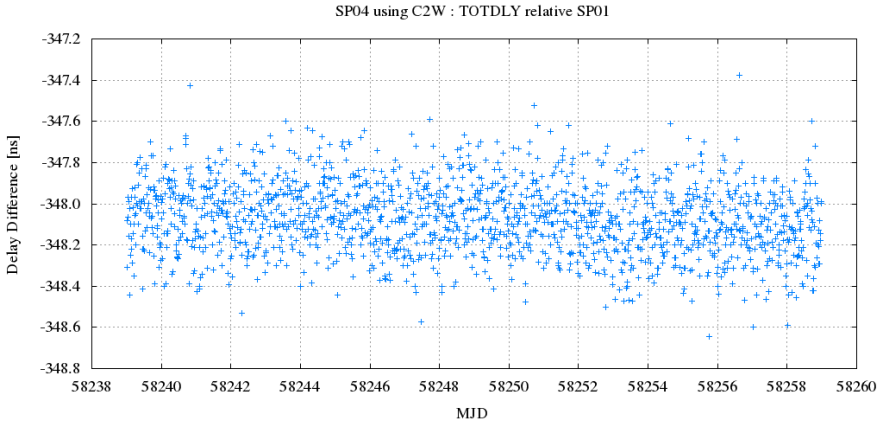

SP04 using C1W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
10-9
10-10
10-11
102
103
104
105
106
Averaging Time [s]


SP04 using C2W : TOTDLY relative SP01
Delay Difference [ns]
-347.2
-347.4
-347.6
-347.8
-348.0
-348.2
-348.4
-348.6
-348.8
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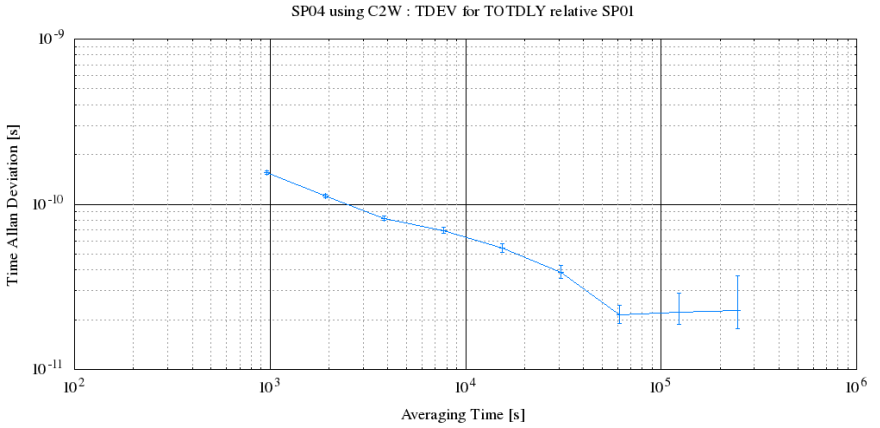
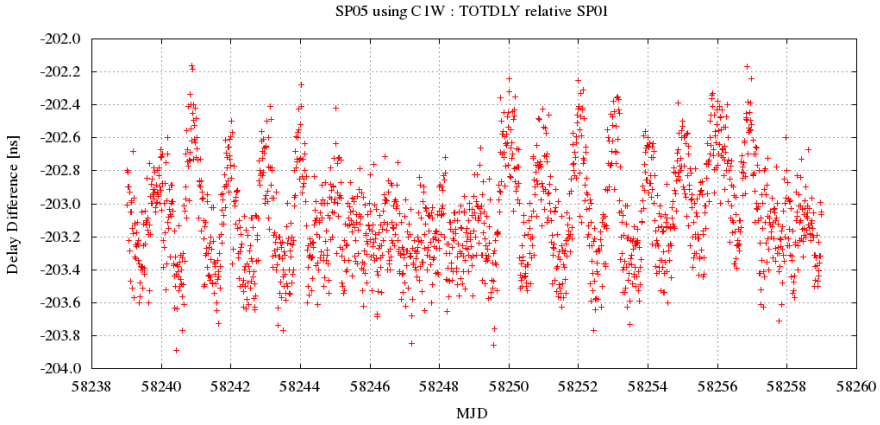

SP04 using C2W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
10-9
10-10
10-11
102
103
104
105
106
Averaging Time [s]

SP05


SP05 using C1W : TOTDLY relative SP01
Delay Difference [ns]
-202.0
-202.2
-202.4
-202.6
-202.8
-203.0
-203.2
-203.4
-203.6
-203.8
-204.0
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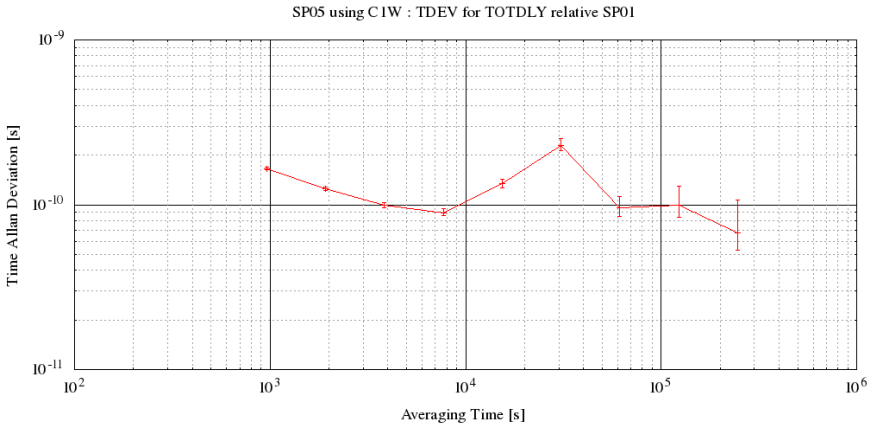
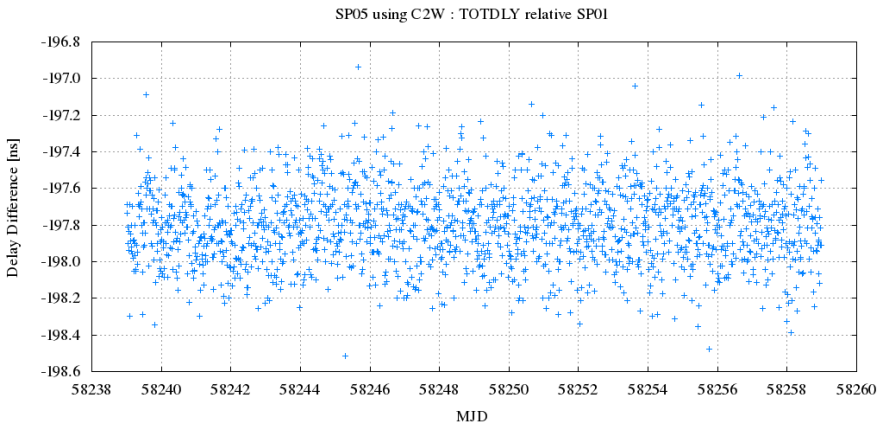
MJD


SP05 using C1W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
10-9
10-10
10-11
10^2
10^3
10^4
10^5
10^6
Averaging Time [s]


SP05 using C2W : TOTDLY relative SP01
Delay Difference [ns]
-196.8
-197.0
-197.2
-197.4
-197.6
-197.8
-198.0
-198.2
-198.4
-198.6
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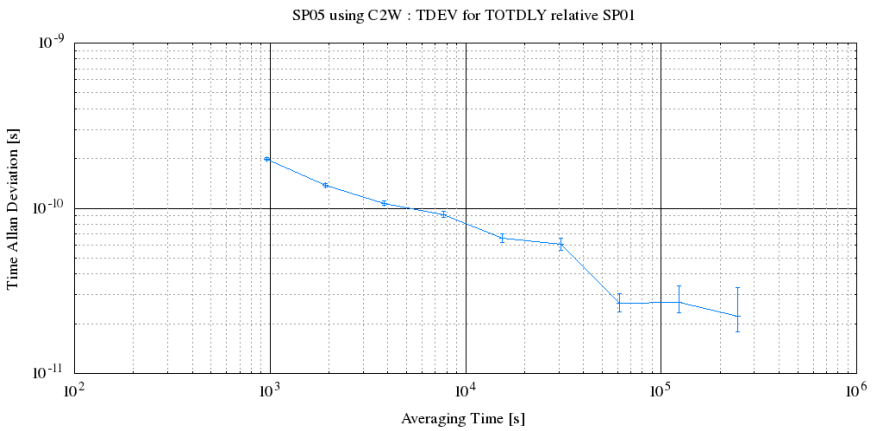
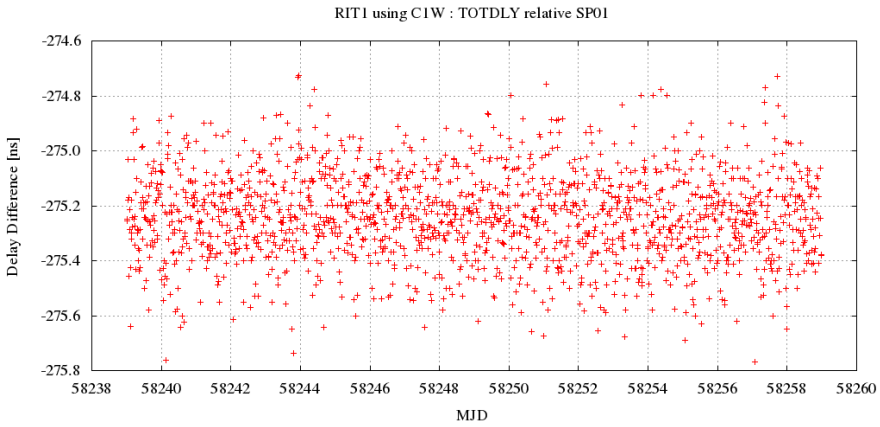
MJD


SP05 using C2W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
10-9
10-10
10-11
10^2
10^3
10^4
10^5
10^6
Averaging Time [s]

RIT1


RIT1 using C1W : TOTDLY relative SP01
Delay Difference [ns]
-274.6
-274.8
-275.0
-275.2
-275.4
-275.6
-275.8
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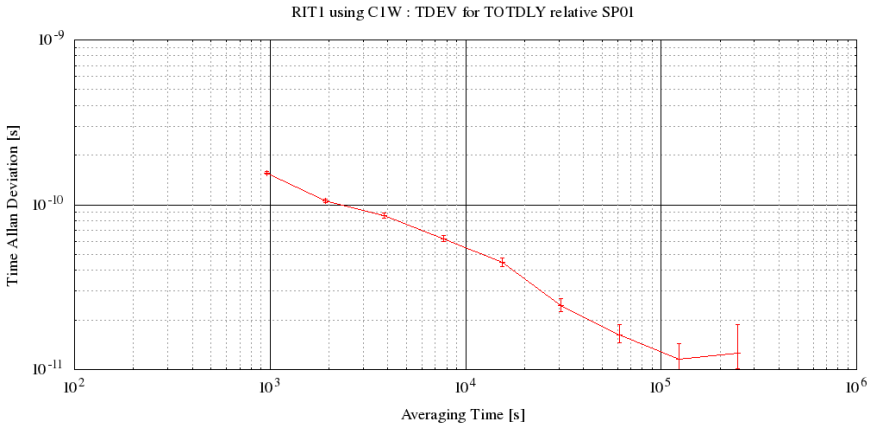
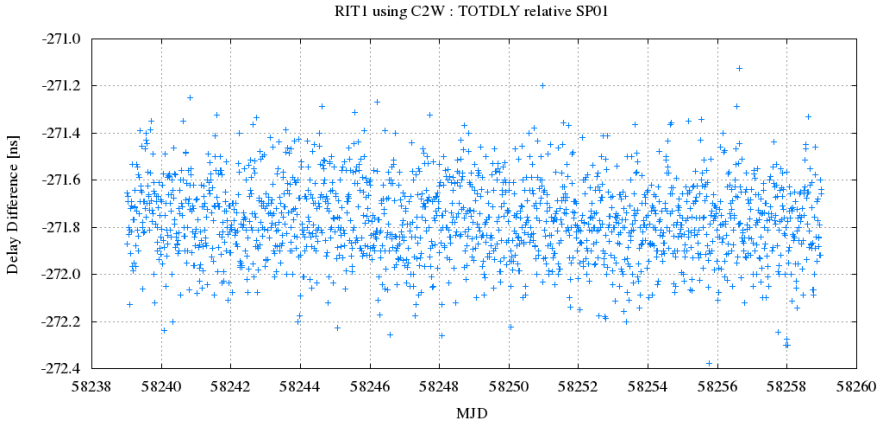
MJD


RIT1 using C1W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
10-9
10-10
10-11
10^2
10^3
10^4
10^5
10^6
Averaging Time [s]


RIT1 using C2W : TOTDLY relative SP01
Delay Difference [ns]
-271.0
-271.2
-271.4
-271.6
-271.8
-272.0
-272.2
-272.4
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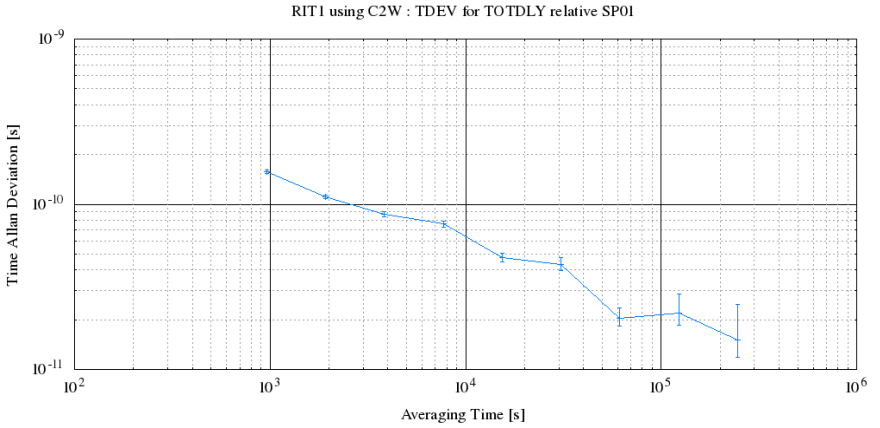
MJD


RIT1 using C2W : TDEV for TOTDLY relative SP01
Time Allan Deviation [s]
10-9
10-10
10-11
10^2
10^3
10^4
10^5
10^6
Averaging Time [s]