

BUREAU INTERNATIONAL DES POIDS ET MESURES

**Relative characterization of GNSS receiver delays
for GPS and GLONASS C/A codes in the L1 frequency band
at the OP, SU, PTB and AOS**

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Abstract

The BIPM conducting a series of relative characterizations of Global Navigation Satellite System (GNSS) receiver delays in time laboratories contributing to TAI. For the second time multi-system GPS/GLONASS receivers have been evaluated for GPS and GLONASS C/A codes. This report presents the results of measurements that took place between 18 November 2008 and 20 July 2009 at the Observatoire de Paris (France) and the National Research Institute for Physicotechnical and Radio Engineering Measurements – VNIIFTRI (Russian Federation), and from 14 October to 9 December 2009 at the Observatoire de Paris (Paris, France), the Physikalisch-Technische Bundesanstalt (Germany), and the Astrogeodynamical Observatory (Poland).

INTRODUCTION

Since 8 January 1990 the BIPM has included in its *Circular T* values of $[UTC - GLONASS\ time]$ from GLONASS measurements recorded as follows [1]:

- at the University of Leeds (LDS), UK, from 8 January 1990 to 27 December 1996 [2]
- at the Van Swinden Laboratorium (VSL)*, the Netherlands, from 1 January 1997 to 31 December 2004
- at the Astrogeodynamical Observatory (AOS), Poland, from 1 January 2005 to now [3]

On 22 June 1990 at approximately 15h30 UTC at the University of Leeds, *GLONASS time* was synchronized to UTC(SU) as follows [1, 4]:

Date 1990 0hUTC	MJD	$[UTC - UTC(SU)]$ / μs	$[UTC - GLONASS\ time]$ / μs
17 June	48059	10.11	48.03
27 June	48069	9.93	9.90

Since then publication of $[UTC - GLONASS\ time]$ in *Circular T* has been continuous and without any intentionally introduced time step. Any new receiver introduced have always been aligned with those being removed. The date of 22 June 1990, 15h30 UTC, is thus the reference date of continuity of the publication of $[UTC - GLONASS\ time]$ in *Circular T*. Time steps of *GLONASS time* of about $-35.3\ \mu s$ on 30 June 1997 and of about 320 ns on 28 October 2009 have been introduced by GLONASS operators (see Figures 1 and 2).

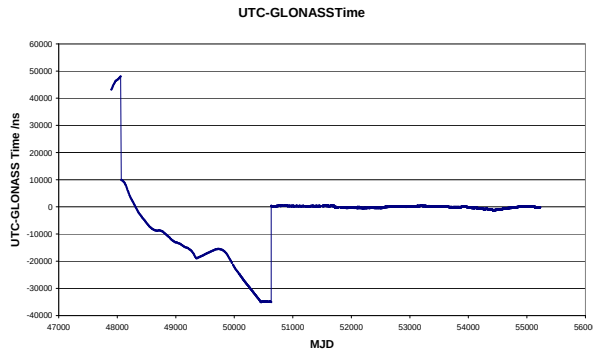


Figure 1. Values of $[UTC - GLONASS\ time]$ from *Circular T* since 8 January 1990.

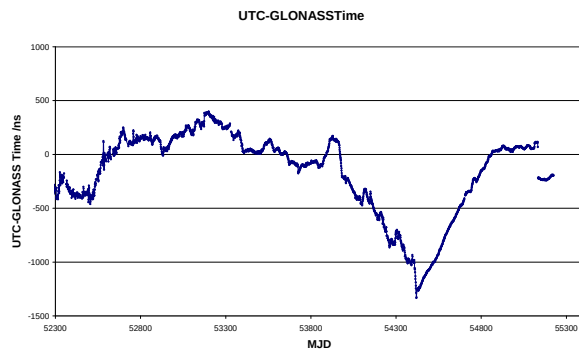


Figure 2. Values of $[UTC - GLONASS\ time]$ from *Circular T* since 26 January 2002.

* Then NMi Van Swinden Laboratorium

None of the GLONASS receivers used in national time laboratories has been absolutely calibrated, but the BIPM is conducting a series of relative characterizations of GNSS receiver delays, including GLONASS, in time laboratories contributing to TAI [5]. For the second time, multi-system GPS/GLONASS receivers have been evaluated for GPS and GLONASS C/A codes on the L1 frequency band (L1C). The first such evaluation took place twelve years ago [6], but at that time the GLONASS constellation was incomplete, the GPS/GLONASS time receivers suffered from large GLONASS frequency biases [7, 8], and very few national time laboratories were equipped with them. Today the GLONASS constellation is nearing completion, and several major time laboratories, including OP (Observatoire de Paris, France), PTB (Physikalisch-Technische Bundesanstalt (Braunschweig, Germany), and SU (National Research Institute for Physicotechnical and Radio Engineering Measurements – VNIIFTRI, Mendeleevo, Russian Federation), are equipped with new GNSS time receivers that are almost unaffected by GLONASS frequency biases. This creates new opportunities for the use of the GLONASS constellation for international time metrology. Already from November 2009 PTB/SU GLONASS common-view link is used for the computation of TAI [1, 3].

Over the last twenty years the OP has often served as the reference laboratory for GPS calibrations. Its GPS time receiver has been compared several times with the absolutely calibrated reference GPS time receiver of the NIST (National Institute of Standards and Technology, Boulder, Colorado). The difference between these two has never exceeded several nanoseconds [5, 9].

For the current exercise (18 November 2008 to 9 December 2009), GPS/GLONASS equipment at the OP was again chosen as reference. The OP GLONASS receiver has been calibrated against the AOS GLONASS reference receiver, source of data for $[UTC - GLONASS\ time]$ in *Circular T*. To check the reproducibility of the measurements, the measurements were organized as round trips beginning and ending at the OP. However, during the measurements involving the OP and the SU it was found that the GPS/GLONASS antenna of the reference receiver at the OP was incorrectly setup, resulting in an increased level of noise. The second part of the current exercise (14 October 2009 to 9 December 2009), involving OP, PTB and AOS, allowed the corrected antenna set-up at the OP to be checked. This time the results at OP showed excellent performance.

Repeated determinations of the differential time corrections for the GNSS time equipment located in the various laboratories should:

- improve the accuracy of access to UTC for the participating laboratories;
- provide valuable information about the stability of GNSS time equipment; and
- serve as provisional relative characterizations of the two-way equipment delays at the laboratories.

EQUIPMENT

Details of the receivers involved are provided in Table 1. More information about the set-up of the equipment at each location is provided in Appendix I.

Table 1. GNSS equipment involved in this comparison.

Part 1

Laboratory	Receiver Maker	Receiver Type	Receiver Version	Receiver Ser. No
OP	AOA	TTR6	-	287
SU	AOA	TTR6	-	414
SU	AOS	TTS-3	HW:80.5, SW:1.124	0026
SU	PikTime	TTS-3	HW:80.5, SW:1.124	0030
SU	PikTime	TTS-3	HW:80.5, SW:1.124	0031
SU	PikTime	TTS-3	HW:80.5, SW:1.124	0032
SU	PikTime	TTS-3	HW:80.5, SW:1.124	0033
BIPM portable receiver	AOS	TTS-3	HW:80.5, SW:1.122	0012

Part 2

Laboratory	Receiver Maker	Receiver Type	Receiver Version	Receiver Ser. No
OP	AOA	TTR6	-	287
OP	AOS	TTS-3	HW:80.5, SW:1.121	0021
AOS	AOS	TTS-2	14.04	023
AOS	AOS	TTS-3	HW:30.2, SW:1.122	0002
PTB	AOS	TTS-2	14.06	014
PTB	AOS	TTS-3	HW:80.5, SW:1.122	0014
BIPM portable receiver	AOS	TTS-3	HW:80.5, SW:1.122	0012

The portable BIPM receiver is equipped with an antenna cable named C130. Its delay, measured at the BIPM, is 136.2 ns with a standard deviation of 0.4 ns. This delay was measured using a double-weight pulse method with a time interval counter steered by an external frequency source (an Active Hydrogen Maser CH1-75, KVARZ). We measured at the very beginning of the linear part of the rising pulse at each end of the cable using a 0.5 V trigger level [10].

The delay of this cable was also measured at the visited laboratories. The results are reported in Appendix II.

CONDITIONS OF COMPARISON

For the present comparison, the portable equipment comprised the receiver, its antenna and a calibrated antenna cable. The laboratories visited supplied: (a) a 10 MHz reference signal; and (b) a series of 1 s pulses from the local reference, UTC(k), via a cable of known delay. In each laboratory the portable receiver was connected to the same clock as the local receiver and the antenna of the portable receiver

was placed close to the local antenna. The differential coordinates of the antenna phase centres were known at each site with standard uncertainties (1σ) of a few centimetres.

RESULTS

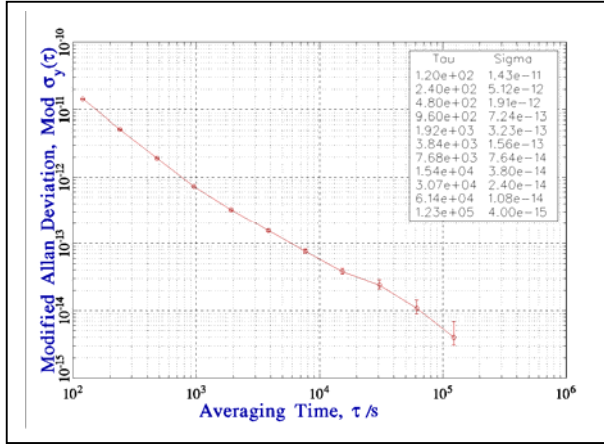
The processing of the comparison data obtained in laboratory k consists first of computing, for each track i , the time differences

$$dt_{k,i} = [UTC(k) - GNSS\ time]_{BIPM,i} - [UTC(k) - GNSS\ time]_{k,i}.$$

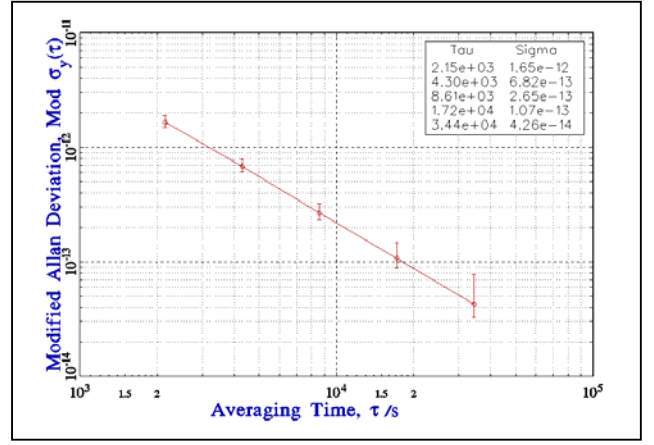
The noise exhibited by the time series dt_k is then analysed, for each of the laboratories visited, by use of the modified Allan variance. In each case, white phase noise was exhibited up to an averaging interval of about one day. We illustrate this in Figure 3 for GPS L1C.

Figure 3. Square root of the modified Allan variance of the time series dt_{Op} for GPS L1C.

Part 1: for the period 18 Nov. 2008 to 20 July 2009



Part 2: for the period 14 Oct. 2009 to 9 Dec. 2009



The one-day averages are reported in Figure 4 and Appendix III for GPS and in Figure 5 and Appendix IV for GLONASS. The level of noise for one-day averaging period is reported in Table 2 for GPS and Table 3 for GLONASS.

Figure 4. GPS L1C daily averages of $dt_{k,i}$ for each laboratory k .

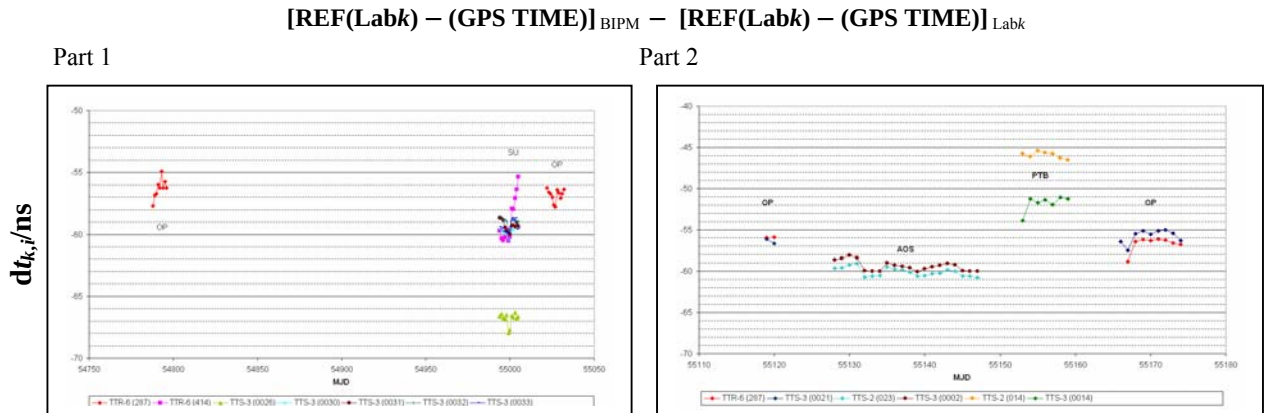
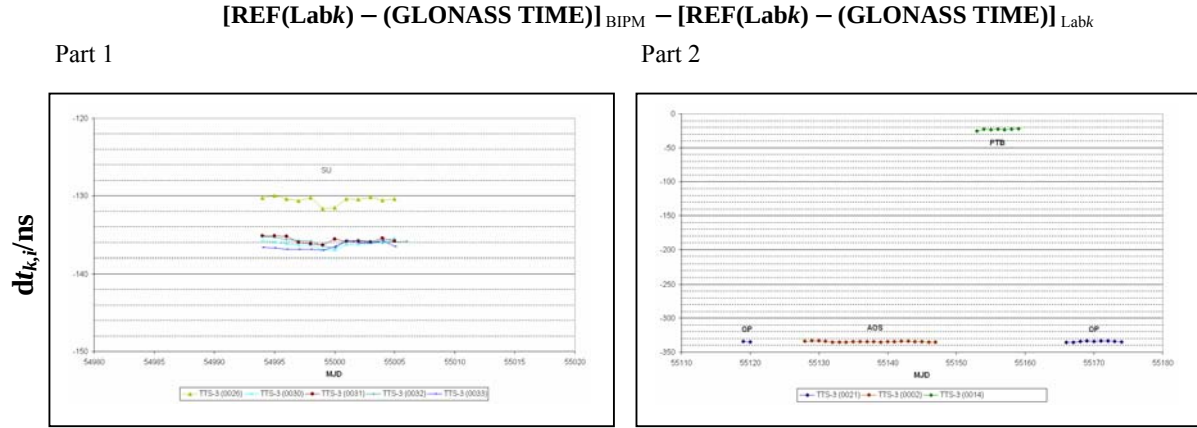


Figure 5. GLONASS L1C daily averages of $dt_{k,i}$ for each laboratory k.

Next, we computed mean offsets for the full duration of each comparison at each location, and the corresponding standard deviations of individual common-view measurements (see Tables 2 and 3).

Table 2. GPS L1C mean offsets for the full duration of the comparison.

Part 1

Lab	Receiver (Serial Number)	Period	Total number of common- views	Mean offset /ns	Standard deviation of individual common- view observations /ns	Level of noise for 1 day /ns	Dispersion of daily mean /ns
OP	TTR-6 (287)	18/11 - 26/11/2008	402	-56.28	2.04	0.4	0.77
SU	TTR-6 (414)	12/06 - 24/06/2009	498	-58.80	2.56	0.6	1.81
SU	TTS-3 (0026)	12/06 - 24/06/2009	9242	-66.80	1.25	0.4	0.50
SU	TTS-3 (0030)	12/06 - 24/06/2009	9211	-59.74	1.08	0.3	0.39
SU	TTS-3 (0031)	12/06 - 24/06/2009	9043	-59.29	1.25	0.3	0.43
SU	TTS-3 (0032)	12/06 - 24/06/2009	9137	-58.96	1.01	0.3	0.34
SU	TTS-3 (0033)	12/06 - 24/06/2009	9181	-59.41	1.08	0.2	0.44
OP	TTR-6 (287)	10/07 - 20/07/2009	469	-56.83	2.63	0.5	0.49

Part 2

Lab	Receiver (Serial Number)	Period	Total number of common- views	Mean offset /ns	Standard deviation of individual common- view observations /ns	Level of noise for 1 day /ns	Dispersion of daily mean /ns
OP	TTR6 (287)	14/10 - 16/10/2009	72	-55.96	2.42	0.7	0.04
OP	TTS-3 (0021)	14/10 - 16/10/2009	1188	-56.40	1.44	0.6	0.36
AOS	TTS-2 (023)	23/10 - 12/11/2009	10389	-60.10	1.40	0.4	0.53
AOS	TTS-3 (0002)	23/10 - 12/11/2009	11400	-59.40	1.25	0.4	0.60
PTB	TTS-2 (014)	13/11 - 19/11/2009	2611	-46.00	1.82	0.5	0.39
PTB	TTS-3 (0014)	13/11 - 19/11/2009	3291	-51.46	1.39	0.5	0.99
OP	TTS-3 (0021)	01/12 - 09/12/2009	4994	-55.70	1.42	0.4	0.82
OP	TTR6 (287)	01/12 - 09/12/2009	314	-56.56	2.36	0.5	0.88

Table 3. GLONASS L1C mean offsets for the full duration of the comparison.

Part 1

Lab	Receiver (Serial Number)	Period	Total number of common- views	Mean offset /ns	Standard deviation of individual common- view observations /ns	Level of noise for 1 day /ns	Dispersio n of daily mean /ns
SU	TTS-3 (0026)	12/06 - 24/06/2009	6475	-130.56	1.52	0.4	0.52
SU	TTS-3 (0030)	12/06 - 24/06/2009	6438	-136.24	1.59	0.3	0.44
SU	TTS-3 (0031)	12/06 - 24/06/2009	6282	-135.82	1.36	0.3	0.41
SU	TTS-3 (0032)	12/06 - 24/06/2009	5751	-135.86	1.11	0.3	0.42
SU	TTS-3 (0033)	12/06 - 24/06/2009	6414	-136.58	1.75	0.3	0.46

Part 2

Lab	Receiver (Serial Number)	Period	Total number of common- views	Mean offset /ns	Standard deviation of individual common- view observations /ns	Level of noise for 1 day /ns	Dispersio n of daily mean /ns
OP	TTS-3 (0021)	14/10 - 16/10/2009	792	-334.39	1.57	0.7	0.19
AOS	TTS-3 (0002)	23/10 - 12/11/2009	4595	-334.84	1.83	0.4	0.67
PTB	TTS-3 (0014)	13/11 - 19/11/2009	2426	-22.85	1.97	0.4	1.12
OP	TTS-3 (0021)	01/12 - 09/12/2009	3338	-334.08	1.68	0.4	0.83

The measurements at the OP during Part 1 were performed with poor antenna set-up of the TTS-3(0021) receiver and the results were unusable: they had large uncertainty and large “closure” (the difference between the first and last sets of measurements made at the OP). Following correction of this problem the OP TTS-3(0021) measurements were performed under excellent conditions and with very good closure of the travelling equipment at the OP during Part 2.

It should be noted that in the past GLONASS time receivers suffered from large GLONASS frequency biases [6, 7]. As observed during this exercise and others recent studies [3], the new generation of GLONASS receivers seems to be unaffected by GLONASS frequency biases: standard deviations of GLONASS measurements are similar to those of GPS.

After averaging the results of the two sets of measurements at the OP, we then derived differential time corrections which should be made (added) to time differences derived during the GPS and GLONASS comparisons of the time scales kept by the laboratories. The results are summarized in Table 4 and 5.

Table 4. GPS L1C: differential time correction d to be added to $[UTC(k_1) - UTC(k_2)]$, and its estimated uncertainty $u(d)$ for the period of comparison (1σ). The reference receiver is the OP TTR6 (287).

Part 1

$[UTC(k_1) - UTC(k_2)]$	d/ns	$u(d)/\text{ns}$
$[UTC(\text{SU})_{\text{TTR6}(414)} - UTC(\text{OP})]$	-2.2	3.0
$[UTC(\text{SU})_{\text{TTS-3}(0026)} - UTC(\text{OP})]$	-10.2	3.0
$[UTC(\text{SU})_{\text{TTS-3}(0030)} - UTC(\text{OP})]$	-3.2	3.0
$[UTC(\text{SU})_{\text{TTS-3}(0031)} - UTC(\text{OP})]$	-2.7	3.0
$[UTC(\text{SU})_{\text{TTS-3}(0032)} - UTC(\text{OP})]$	-2.4	3.0
$[UTC(\text{SU})_{\text{TTS-3}(0033)} - UTC(\text{OP})]$	-2.9	3.0

Part 2

$[UTC(k_1) - UTC(k_2)]$	d/ns	$u(d)/\text{ns}$
$[UTC(\text{OP})_{\text{TTS-3}(0021)} - UTC(\text{OP})]$	-0.2	3.0
$[UTC(\text{AOS})_{\text{TTS-2}(023)} - UTC(\text{OP})]$	-3.8	3.0
$[UTC(\text{AOS})_{\text{TTS-3}(0002)} - UTC(\text{OP})]$	-3.1	3.0
$[UTC(\text{PTB})_{\text{TTS-2}(014)} - UTC(\text{OP})]$	10.3	3.0
$[UTC(\text{PTB})_{\text{TTS-3}(0014)} - UTC(\text{OP})]$	4.8	3.0

Table 5. GLONASS L1C: differential time correction d to be added to $[UTC(k_1) - UTC(k_2)]$, and its estimated uncertainty $u(d)$ for the period of comparison (1σ). The reference receiver for Part 1 and Part 2 is the OP TTS-3 (0021) during Part 2.

Part 1

$[UTC(k_1) - UTC(k_2)]$	d/ns	$u(d)/\text{ns}$
$[UTC(\text{SU})_{\text{TTS-3 (0026)}} - UTC(\text{OP})]$	203.7	5.0
$[UTC(\text{SU})_{\text{TTS-3 (0030)}} - UTC(\text{OP})]$	198.0	5.0
$[UTC(\text{SU})_{\text{TTS-3 (0031)}} - UTC(\text{OP})]$	198.4	5.0
$[UTC(\text{SU})_{\text{TTS-3 (0032)}} - UTC(\text{OP})]$	198.4	5.0
$[UTC(\text{SU})_{\text{TTS-3 (0033)}} - UTC(\text{OP})]$	197.7	5.0

Part 2

$[UTC(k_1) - UTC(k_2)]$	d/ns	$u(d)/\text{ns}$
$[UTC(\text{AOS})_{\text{TTS-3 (0002)}} - UTC(\text{OP})]$	-0.6	3.0
$[UTC(\text{PTB})_{\text{TTS-3 (0014)}} - UTC(\text{OP})]$	311.4	3.0

The uncertainties given in Tables 4 and 5 are conservative; they are mainly driven by the uncertainty due to the ‘round-trip’ reproducibility at the OP. Because of the lack of GLONASS measurements during Part 1 at the OP, ‘closure’ data from Part 2 was used to compute the corrections for the SU GLONASS receivers. As the GLONASS ‘closure’ of Part 2 was performed several months after the GLONASS measurements at SU, we increased the uncertainty of the GLONASS calibration at SU to 5 ns, according to the convention used in *Circular T*.

In comparison to the OP reference receiver, the PTB and SU offsets for GLONASS are large (Table 5) and require appropriate corrections of the receivers involved.

CONCLUSIONS

In the past, GLONASS time receivers suffered from large GLONASS frequency biases [6, 7], and very few national time laboratories were equipped with them. Today the GLONASS constellation is nearing completion, and several major time laboratories, including OP, PTB and SU, are equipped with new GNSS time receivers that are almost unaffected by GLONASS frequency biases. This creates new opportunities for the use of the GLONASS constellation for international time metrology. Already from November 2009 PTB/SU GLONASS common-view link is used for the computation of TAI [1, 3].

The measurements form part of a series of relative characterizations of GNSS receiver delays in time laboratories contributing to TAI. They improve the accuracy of the access to UTC for the participating laboratories. For the second time multi-system GPS/GLONASS receiver have been evaluated for GPS L1C and GLONASS L1C.

The initial measurements at the OP were performed with poor antenna set-up of the TTS-3 (0021) receiver and were unusable. Following correction of this problem the measurements were repeated under excellent conditions and with very good closure of the travelling equipment at the OP for the GPS

and GLONASS. The GPS time equipment of the participating laboratories agrees within several nanoseconds with reference equipment at the OP. At the PTB and SU the offset for GLONASS is large and the receivers need to be physically corrected by the offsets listed in Table 5. After this correction GLONASS data from PTB and SU receivers will be consistent with *GLONASS time* published in *Circular T*.

The CCTF has recommended that differences between UTC and UTC(USNO) as broadcast by GPS, and UTC(SU) as broadcast by GLONASS, be published in *Circular T* [11]. In order to provide accurate access to *GLONASS time* and to UTC(SU) as broadcast by GLONASS, absolute calibration of GLONASS time receivers is required.

FUTURE WORK

- 1) A repeat characterization of the GLONASS receiver delays at the SU would be helpful.
- 2) Further characterization of GLONASS receiver delays at other time laboratories contributing to TAI are needed.
- 3) It should be noted that none of the GLONASS receivers used in national time laboratories has been absolutely calibrated. Absolute calibration of GLONASS time receivers is necessary to get accurate access to *GLONASS time* and UTC(SU) as broadcast by GLONASS.

Acknowledgements

The authors wish to express their gratitude to their colleagues for unreserved collaboration they received. Without this, the work could not have been accomplished.

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Appendix I

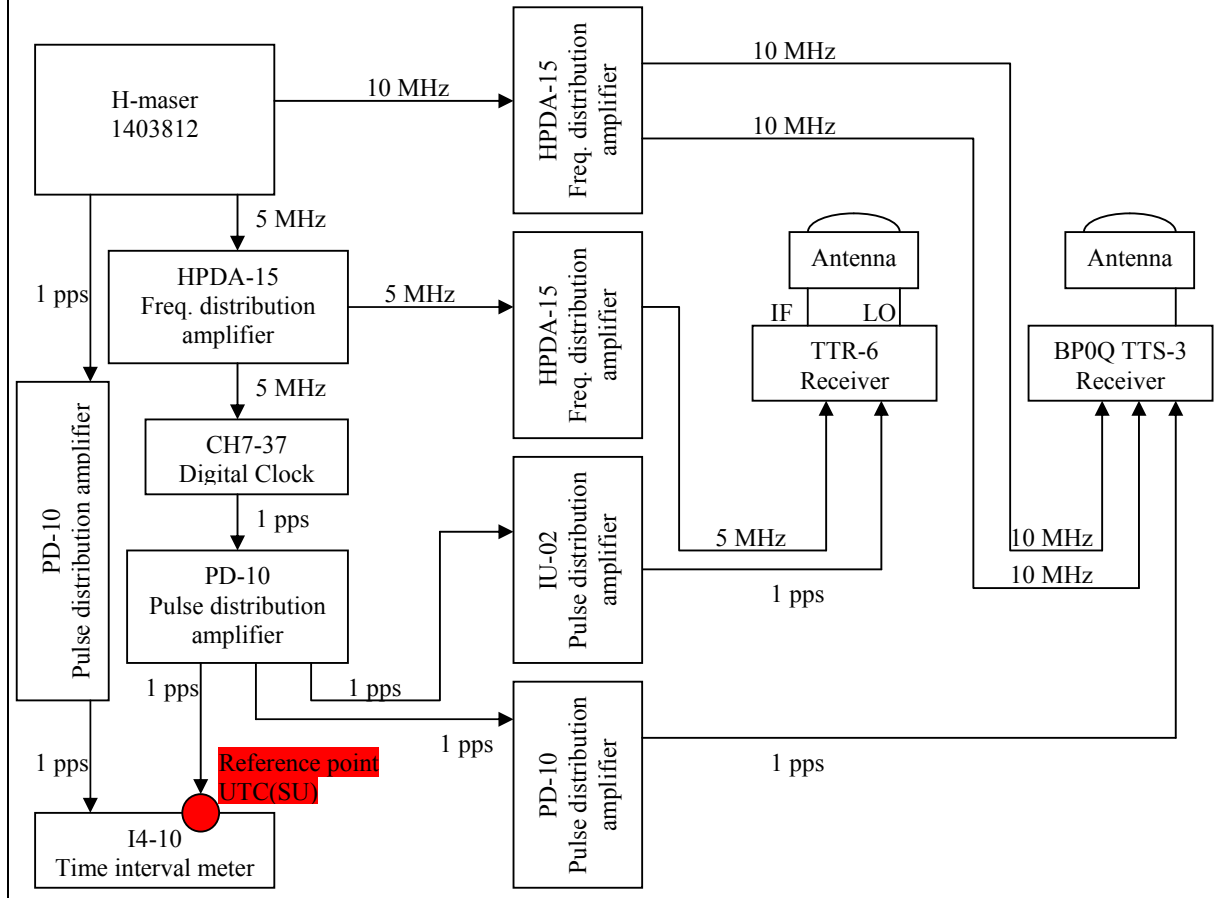
**Set-up of local and portable equipment at each location
(forms completed by the participating laboratories)**

BIPM calibration information sheet

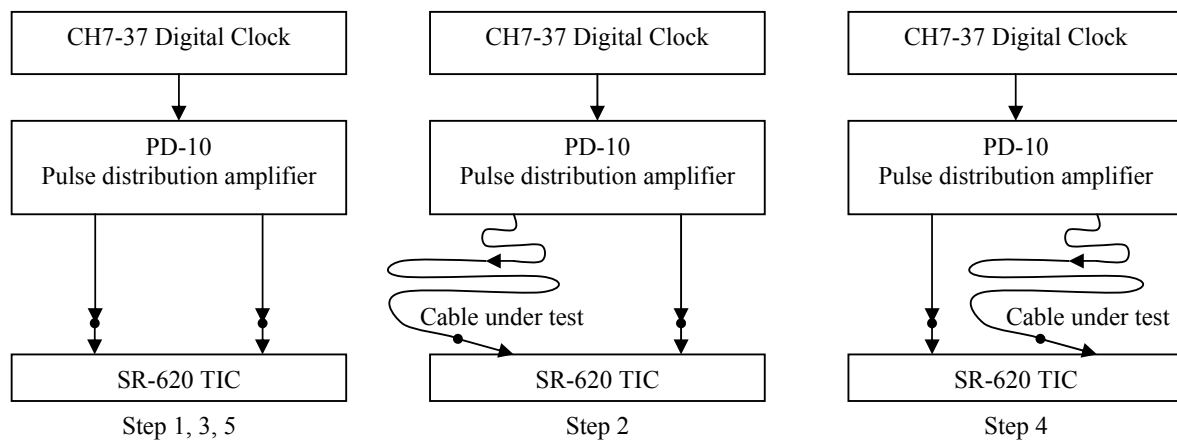
Laboratory:	SU	
Date and hour of the beginning of measurements:	12 June 2009 (54994 MJD 00 h UTC)	
Date and hour of the end of measurements:	24 June 2009 (55006 MJD 00 h UTC)	
Receiver setup information		
	Local:	Portable: BP0Q
• Maker:	Allen Osborne Associates	AOS
• Type:	TTR-6	TTS-3
• Serial number:	414	0012
• Receiver internal delay (GPS) :	57,0 ns	30,5
• Receiver internal delay (GLO) :		0,0
• Antenna cable identification:	C44 (IF) + C43 (LO)	C130
Corresponding cable delay :	154,0 ns	136,2 ns $\pm$ 0,4 ns
• Delay to local UTC :	548,0 ns	347,0 ns
• Receiver trigger level:		
• Coordinates reference frame:	ITRF89	ITRF
Latitude or X m	2845456,86 m	2845464,30 m
Longitude or Y m	2160955,82 m	2160951,93 m
Height or Z m	5265992,23 m	5265990,32 m
Antenna information		
	Local:	Portable:
• Maker:	Allen Osborne Associates	Javad
• Type:		MarAnt+
• Serial number:		1713
If the antenna is temperature stabilised		
• Set temperature value :	-	-
Local antenna cable information		
• Maker:	AOA	
• Type:	KX-15 / RG-58	
• Is it a phase stabilised cable:	No	
• Length of cable outside the building :	9,5 m	
General information		
• Rise time of the local UTC pulse:	12 ns	
• Is the laboratory air conditioned:	Yes	
• Set temperature value and uncertainty :	19,7 °C $\pm$ 0,5 °C	
• Set humidity value and uncertainty :	61% $\pm$ 8%	
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	136,2 ns $\pm$ 0,4 ns	135,6 ns $\pm$ 0,5 ns

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



The method used to calibrate the cables is a double weight method in five steps as shown above.

At each step (i) the TIC gives the result (R_i) of 100 measurements.

The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2} \right) + \left(\frac{R_3 + R_5}{2} \right) - R_4}{2} + \text{corrections}$$

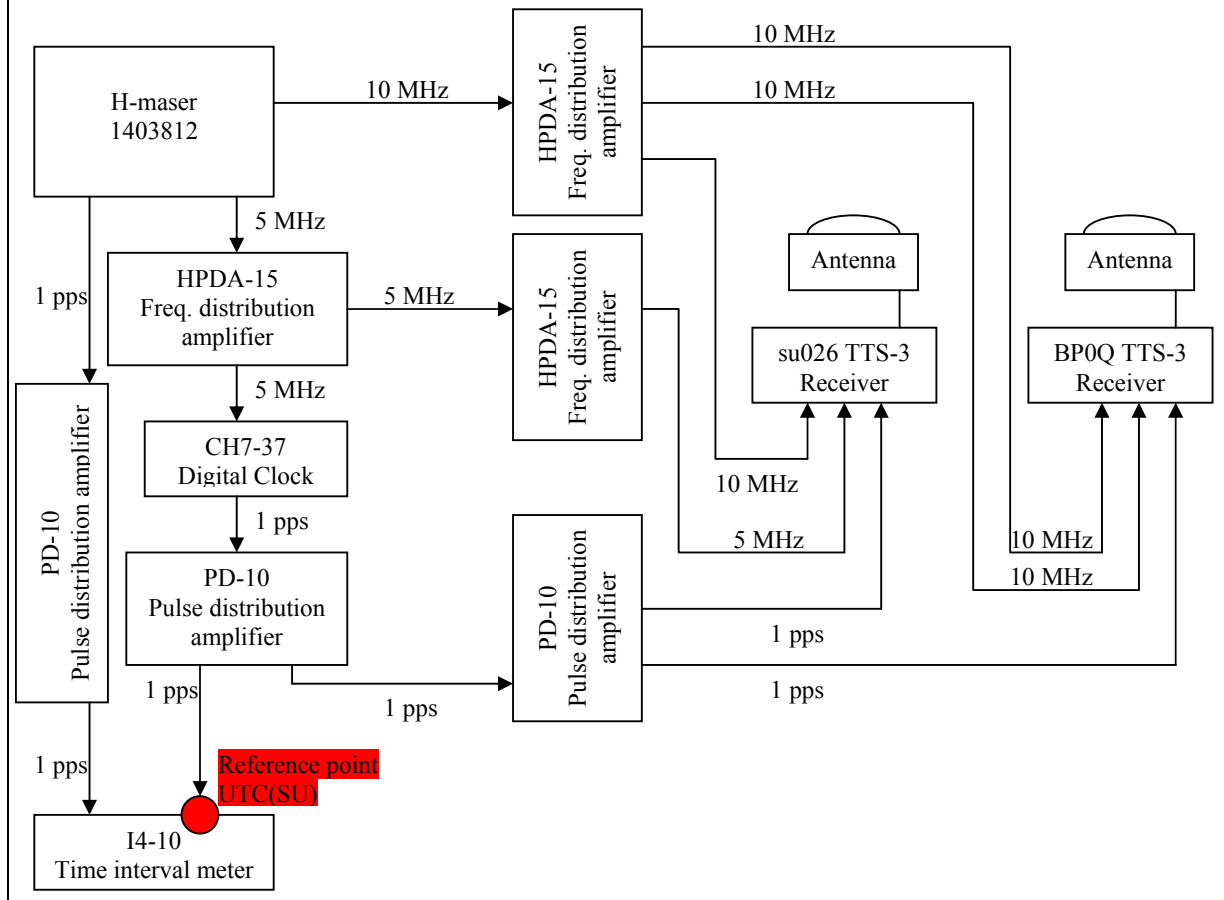
The corrections are estimated delay introduced by adaptors: -0,1 ns / adaptor

BIPM calibration information sheet

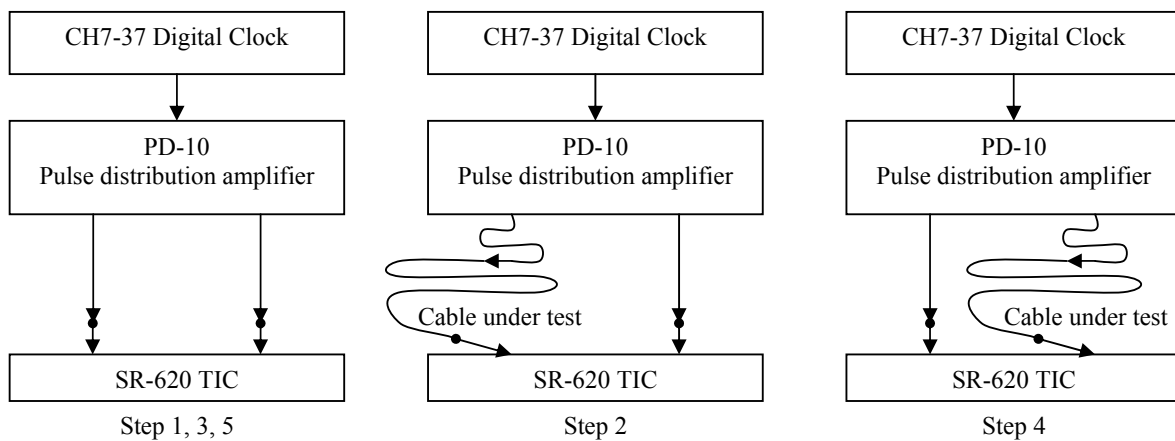
Laboratory:	SU	
Date and hour of the beginning of measurements:	12 June 2009 (54994 MJD 00 h UTC)	
Date and hour of the end of measurements:	24 June 2009 (55006 MJD 00 h UTC)	
Receiver setup information		
	Local: su026	Portable: BP0Q
• Maker:	AOS	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0026	0012
• Receiver internal delay (GPS) :	-34,6 ns	30,5
• Receiver internal delay (GLO) :	-128,2 ns	0,0
• Antenna cable identification:	TTS-3-26	C130
Corresponding cable delay :	142,8 ns	136,2 ns $\pm$ 0,4 ns
• Delay to local UTC :	347,0 ns	347,0 ns
• Receiver trigger level:		
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	2845461,44 m	2845464,30 m
Longitude or Y m	2160957,44 m	2160951,93 m
Height or Z m	5265989,23 m	5265990,32 m
Antenna information		
	Local:	Portable:
• Maker:	Javad	Javad
• Type:	MarAnt+	MarAnt+
• Serial number:	2634	1713
If the antenna is temperature stabilised		
• Set temperature value :	-	-
Local antenna cable information		
• Maker:	AOS	
• Type:	FSJ 1-50A	
• Is it a phase stabilised cable:	Yes	
• Length of cable outside the building :	5 m	
General information		
• Rise time of the local UTC pulse:	3,7 ns	
• Is the laboratory air conditioned:	Yes	
• Set temperature value and uncertainty :	19,7 °C $\pm$ 0,5 °C	
• Set humidity value and uncertainty :	61% $\pm$ 8%	
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	136,2 ns $\pm$ 0,4 ns	135,6 ns $\pm$ 0,5 ns

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



The method used to calibrate the cables is a double weight method in five steps as shown above.

At each step (i) the TIC gives the result (R_i) of 100 measurements.

The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2} \right) + \left(\frac{R_3 + R_5}{2} \right) - R_4}{2} + \text{corrections}$$

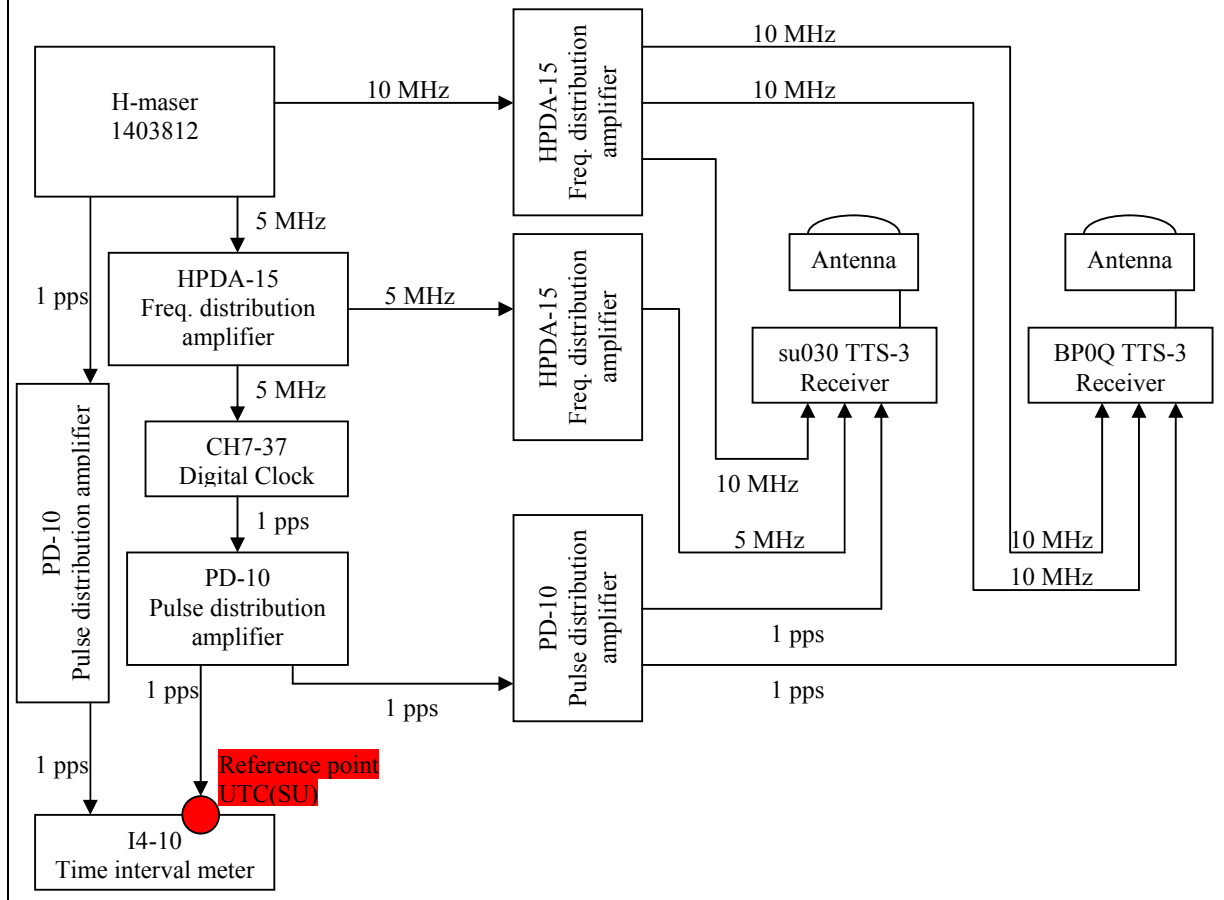
The corrections are estimated delay introduced by adaptors: -0,1 ns / adaptor

BIPM calibration information sheet

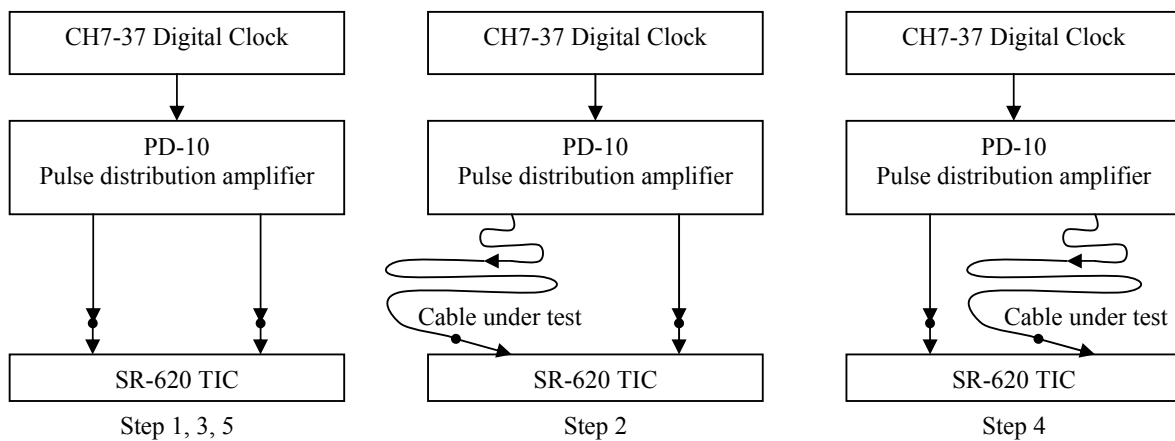
Laboratory:	SU	
Date and hour of the beginning of measurements:	12 June 2009 (54994 MJD 00 h UTC)	
Date and hour of the end of measurements:	24 June 2009 (55006 MJD 00 h UTC)	
Receiver setup information		
	Local: su030	Portable: BP0Q
• Maker:	PikTime	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0030	0012
• Receiver internal delay (GPS) :	-32,6 ns	30,5
• Receiver internal delay (GLO) :	-131,4 ns	0,0
• Antenna cable identification:	TTS-3 SN30	C130
Corresponding cable delay :	141,6 ns	136,2 ns $\pm$ 0,4 ns
• Delay to local UTC :	366,0 ns	347,0 ns
• Receiver trigger level:		
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	2845460,62 m	2845464,30 m
Longitude or Y m	2160958,81 m	2160951,93 m
Height or Z m	5265989,11 m	5265990,32 m
Antenna information		
	Local:	Portable:
• Maker:	Javad	Javad
• Type:	MarAnt+	MarAnt+
• Serial number:	2994	1713
If the antenna is temperature stabilised		
• Set temperature value :	-	-
Local antenna cable information		
• Maker:	AOS	
• Type:	FSJ 1-50A	
• Is it a phase stabilised cable:	Yes	
• Length of cable outside the building :	9 m	
General information		
• Rise time of the local UTC pulse:	3,7 ns	
• Is the laboratory air conditioned:	Yes	
• Set temperature value and uncertainty :	19,7 °C $\pm$ 0,5 °C	
• Set humidity value and uncertainty :	61% $\pm$ 8%	
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	136,2 ns $\pm$ 0,4 ns	135,6 ns $\pm$ 0,5 ns

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



The method used to calibrate the cables is a double weight method in five steps as shown above.

At each step (i) the TIC gives the result (R_i) of 100 measurements.

The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2} \right) + \left(\frac{R_3 + R_5}{2} \right) - R_4}{2} + \text{corrections}$$

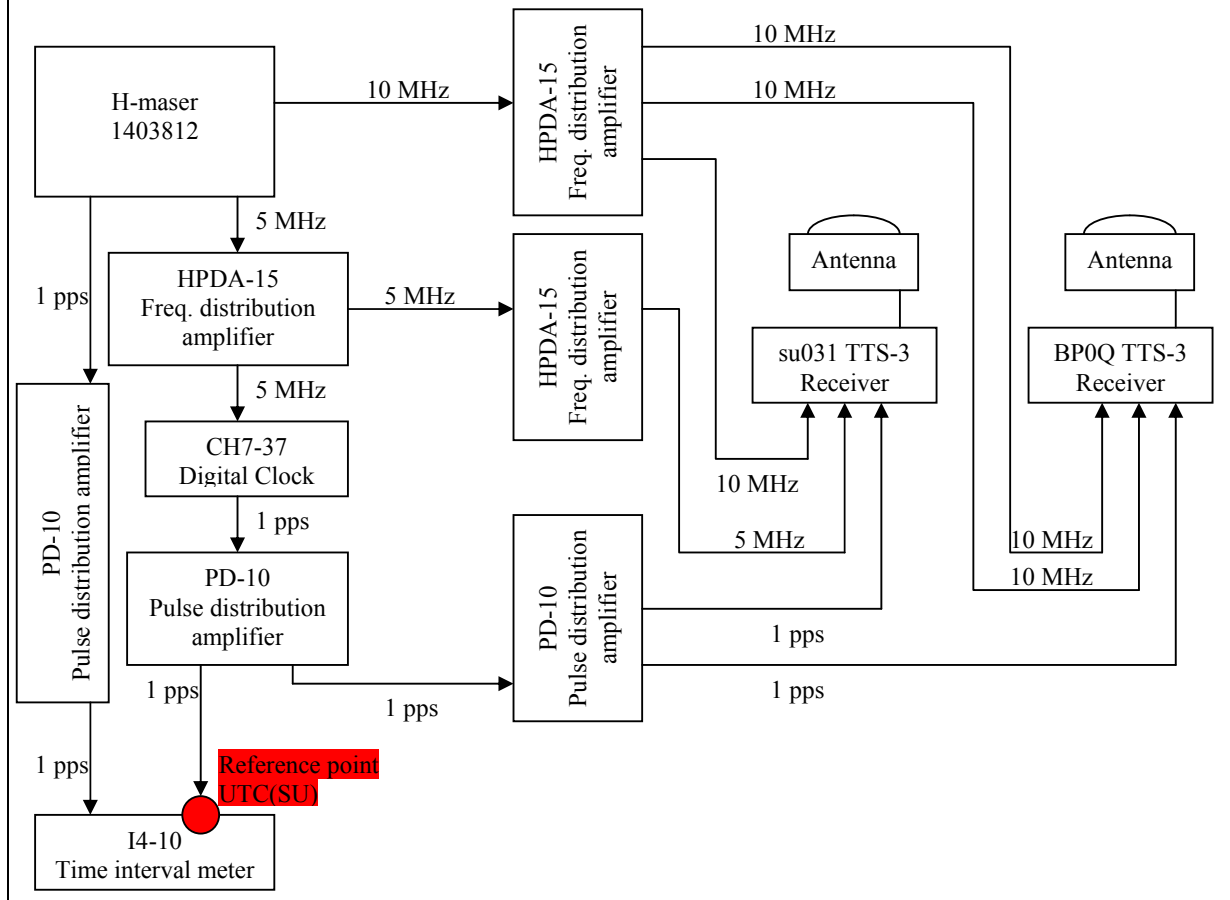
The corrections are estimated delay introduced by adaptors: -0,1 ns / adaptor

BIPM calibration information sheet

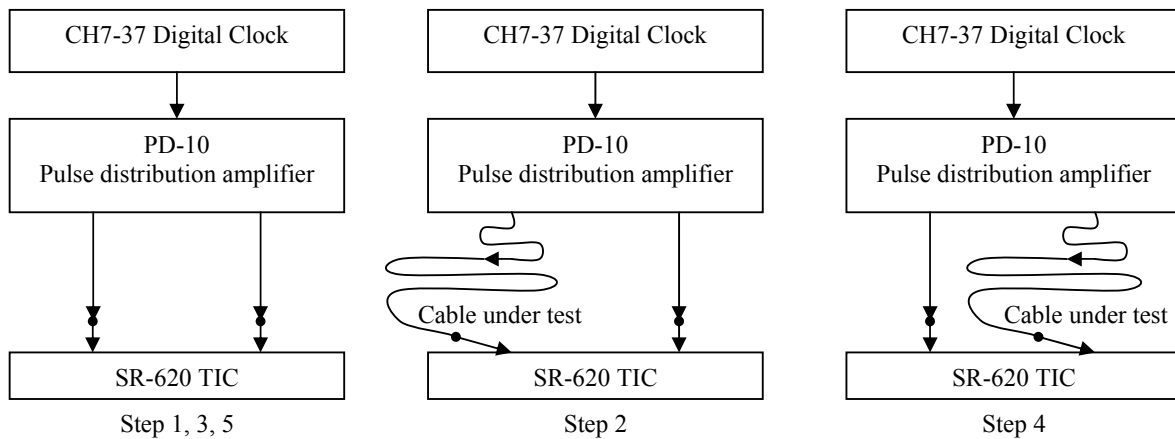
Laboratory:	SU	
Date and hour of the beginning of measurements:	12 June 2009 (54994 MJD 00 h UTC)	
Date and hour of the end of measurements:	24 June 2009 (55006 MJD 00 h UTC)	
Receiver setup information		
	Local: su031	Portable: BP0Q
• Maker:	PikTime	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0031	0012
• Receiver internal delay (GPS) :	-31,5 ns	30,5
• Receiver internal delay (GLO) :	-131,6 ns	0,0
• Antenna cable identification:	TTS-3 SN31	C130
Corresponding cable delay :	140,9 ns	136,2 ns $\pm$ 0,4 ns
• Delay to local UTC :	367,0 ns	347,0 ns
• Receiver trigger level:		
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	2845461,04 m	2845464,30 m
Longitude or Y m	2160958,12 m	2160951,93 m
Height or Z m	5265989,20 m	5265990,32 m
Antenna information		
	Local:	Portable:
• Maker:	Javad	Javad
• Type:	MarAnt+	MarAnt+
• Serial number:	2997	1713
If the antenna is temperature stabilised		
• Set temperature value :	-	-
Local antenna cable information		
• Maker:	AOS	
• Type:	FSJ 1-50A	
• Is it a phase stabilised cable:	Yes	
• Length of cable outside the building :	7,5 m	
General information		
• Rise time of the local UTC pulse:	3,7 ns	
• Is the laboratory air conditioned:	Yes	
• Set temperature value and uncertainty :	19,7 °C $\pm$ 0,5 °C	
• Set humidity value and uncertainty :	61% $\pm$ 8%	
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	136,2 ns $\pm$ 0,4 ns	135,6 ns $\pm$ 0,5 ns

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



The method used to calibrate the cables is a double weight method in five steps as shown above.

At each step (i) the TIC gives the result (R_i) of 100 measurements.

The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2} \right) + \left(\frac{R_3 + R_5}{2} \right) - R_4}{2} + \text{corrections}$$

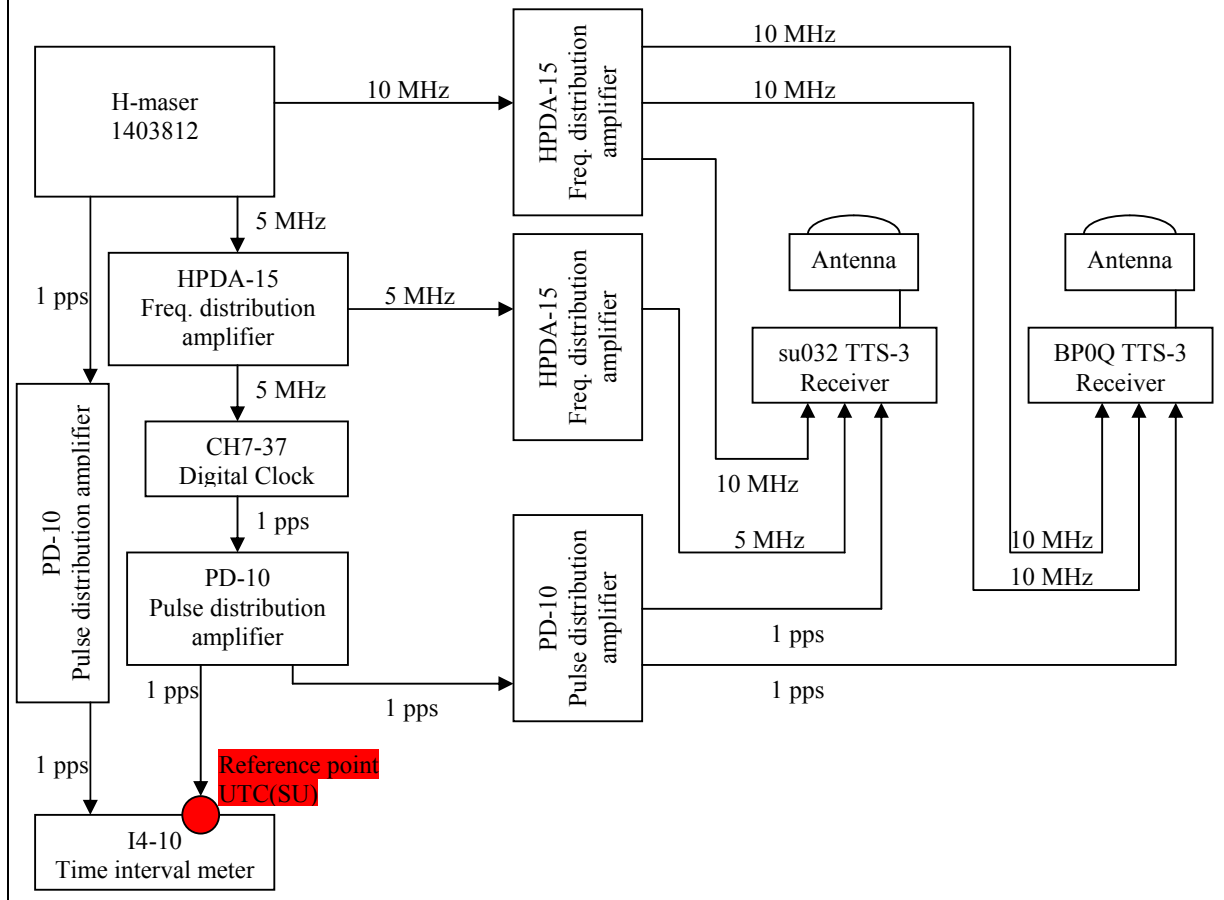
The corrections are estimated delay introduced by adaptors: -0,1 ns / adaptor

BIPM calibration information sheet

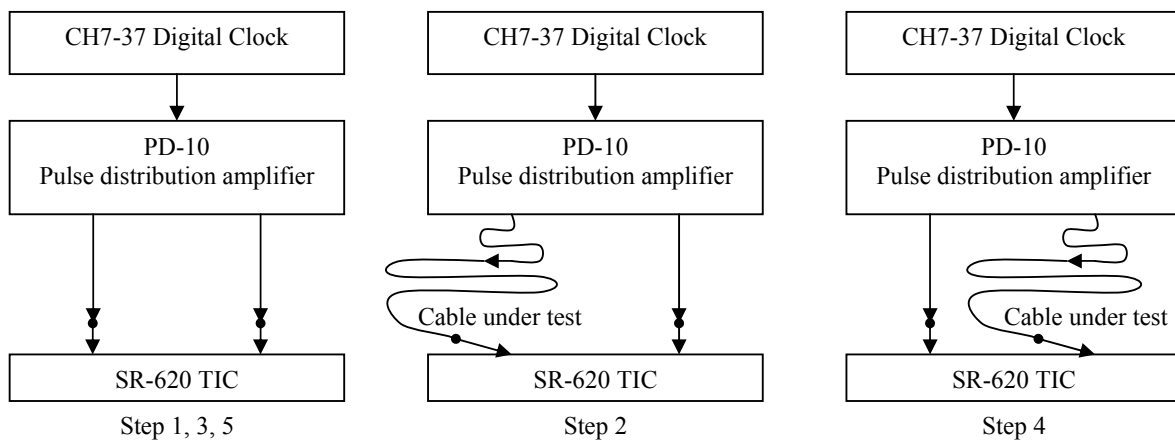
Laboratory:	SU	
Date and hour of the beginning of measurements:	12 June 2009 (54994 MJD 00 h UTC)	
Date and hour of the end of measurements:	24 June 2009 (55006 MJD 00 h UTC)	
Receiver setup information		
	Local: su032	Portable: BP0Q
• Maker:	PikTime	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0032	0012
• Receiver internal delay (GPS) :	-15,1 ns	30,5
• Receiver internal delay (GLO) :	-113,9 ns	0,0
• Antenna cable identification:	TTS-3-032	C130
Corresponding cable delay :	146,8 ns	136,2 ns $\pm$ 0,4 ns
• Delay to local UTC :	377,0 ns	347,0 ns
• Receiver trigger level:		
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	2845459,67 m	2845464,30 m
Longitude or Y m	2160956,91 m	2160951,93 m
Height or Z m	5265990,43 m	5265990,32 m
Antenna information		
	Local:	Portable:
• Maker:	Mira Vista Technologies	Javad
• Type:	TSA-100	MarAnt+
• Serial number:	POL-PT12-7(1) (E)	1713
If the antenna is temperature stabilised		
• Set temperature value :	24 °C	-
Local antenna cable information		
• Maker:	AOS	
• Type:	FSJ 1-50A	
• Is it a phase stabilised cable:	Yes	
• Length of cable outside the building :	5,5 m	
General information		
• Rise time of the local UTC pulse:	3,7 ns	
• Is the laboratory air conditioned:	Yes	
• Set temperature value and uncertainty :	19,7 °C $\pm$ 0,5 °C	
• Set humidity value and uncertainty :	61% $\pm$ 8%	
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	136,2 ns $\pm$ 0,4 ns	135,6 ns $\pm$ 0,5 ns

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



The method used to calibrate the cables is a double weight method in five steps as shown above.

At each step (i) the TIC gives the result (R_i) of 100 measurements.

The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2}\right) + \left(\frac{R_3 + R_5}{2}\right) - R_4}{2} + \text{corrections}$$

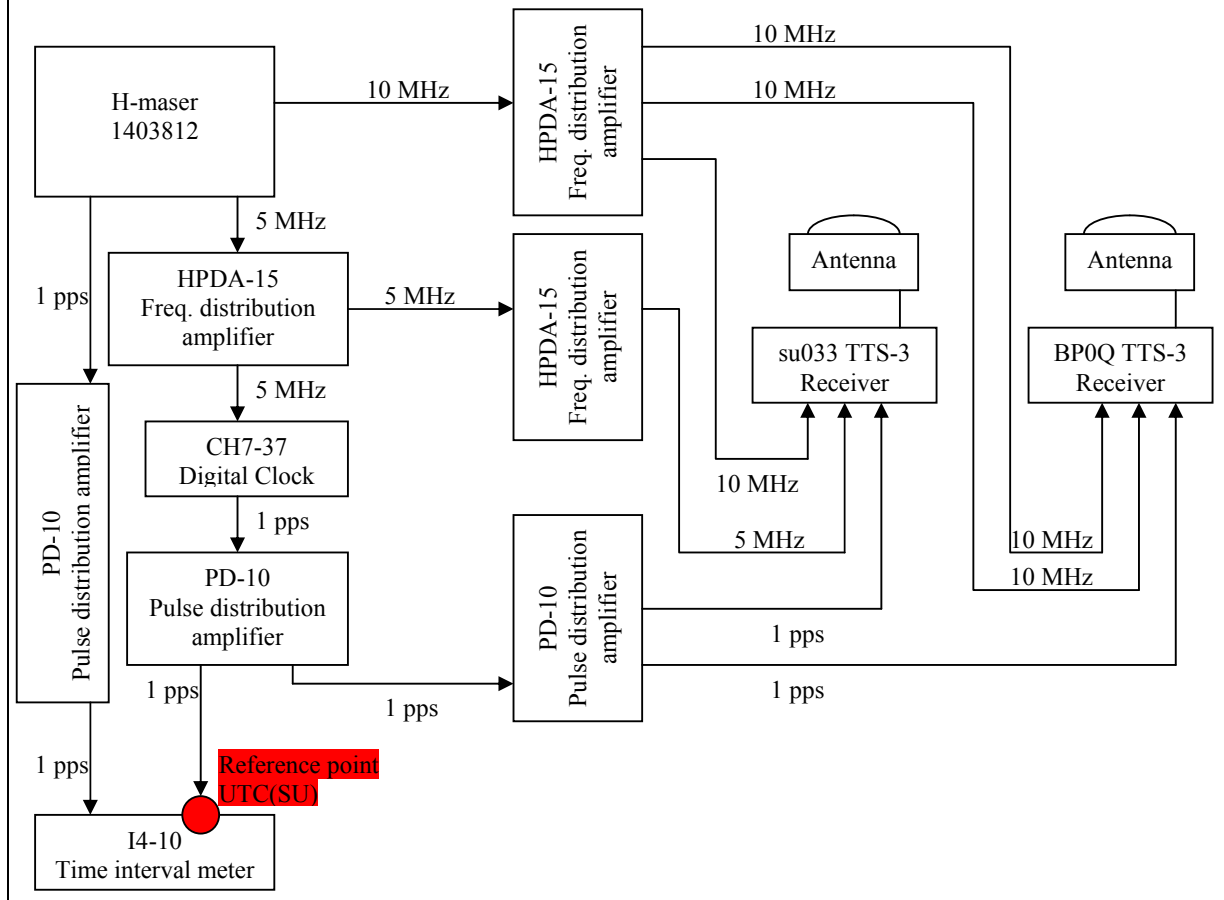
The corrections are estimated delay introduced by adaptors: -0,1 ns / adaptor

BIPM calibration information sheet

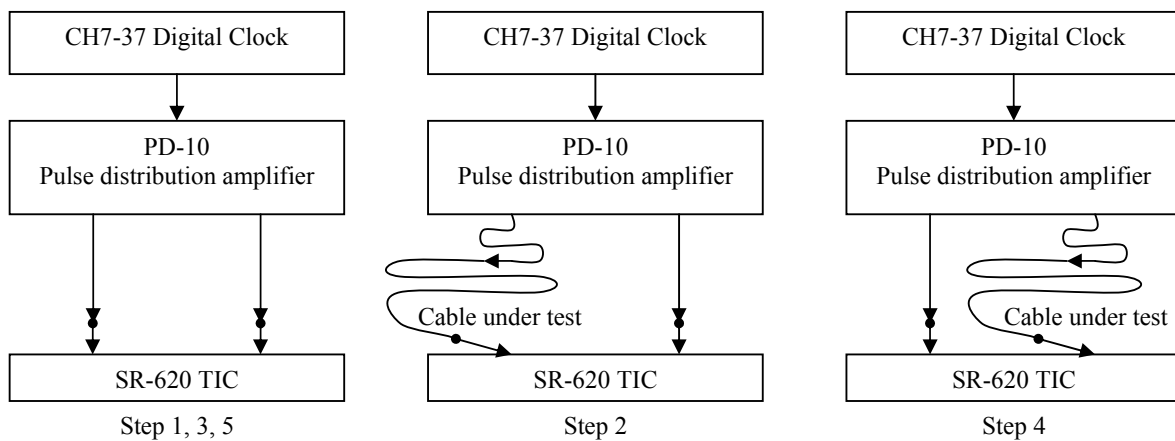
Laboratory:	SU	
Date and hour of the beginning of measurements:	12 June 2009 (54994 MJD 00 h UTC)	
Date and hour of the end of measurements:	24 June 2009 (55006 MJD 00 h UTC)	
Receiver setup information		
	Local: su033	Portable: BP0Q
• Maker:	PikTime	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0033	0012
• Receiver internal delay (GPS) :	-14,4 ns	30,5
• Receiver internal delay (GLO) :	-116,4 ns	0,0
• Antenna cable identification:	TTS-3-033	C130
Corresponding cable delay :	143,4 ns	136,2 ns $\pm$ 0,4 ns
• Delay to local UTC :	367,0 ns	347,0 ns
• Receiver trigger level:		
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	2845460,90 m	2845464,30 m
Longitude or Y m	2160955,63 m	2160951,93 m
Height or Z m	5265990,33 m	5265990,32 m
Antenna information		
	Local:	Portable:
• Maker:	Mira Vista Technologies	Javad
• Type:	TSA-100	MarAnt+
• Serial number:	POL-PT12-7(2) (D)	1713
If the antenna is temperature stabilised		
• Set temperature value :	24 °C	-
Local antenna cable information		
• Maker:	AOS	
• Type:	FSJ 1-50A	
• Is it a phase stabilised cable:	Yes	
• Length of cable outside the building :	7,5 m	
General information		
• Rise time of the local UTC pulse:	3,7 ns	
• Is the laboratory air conditioned:	Yes	
• Set temperature value and uncertainty :	19,7 °C $\pm$ 0,5 °C	
• Set humidity value and uncertainty :	61% $\pm$ 8%	
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	136,2 ns $\pm$ 0,4 ns	135,6 ns $\pm$ 0,5 ns

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



The method used to calibrate the cables is a double weight method in five steps as shown above.

At each step (i) the TIC gives the result (R_i) of 100 measurements.

The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2} \right) + \left(\frac{R_3 + R_5}{2} \right) - R_4}{2} + \text{corrections}$$

The corrections are estimated delay introduced by adaptors: -0,1 ns / adaptor

BIPM calibration information sheet

Laboratory:	LNE-SYRTE (Observatoire de Paris)	
Date and hour of the beginning of measurements:	13/10/2009 @ 9h50 UTC (MJD 55117)	
Date and hour of the end of measurements:	16/10/2009 @ 12h00 UTC (MJD 55120)	

Receiver setup information		
	Local:	Portable: BP0Q
• Maker:	AOS	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0021	0012
• Receiver internal delay (GPS) :	118,08 (internal delay + antenna cable delay)	30,5
• Receiver internal delay (GLO) :	-185,9 (internal delay + antenna cable delay)	0,0
• Antenna cable identification:	Câble N°548	C130
Corresponding cable delay :	cable delay included in internal delay	135,9 ns $\pm$ 0,4 ns
• Delay to local UTC :	350,51 (include constant of continuity = 267ns)	-22, 9624 ns (+/- 267 ns)
• Receiver trigger level:	1 Volt	
• Coordinates reference frame:	ITRF 05	ITRF 2000
Latitude or X m	48° 50' 09" 2483 (X= 4202780,12 m)	48° 50' 09" 1077 (X= 4202783,408 m)
Longitude or Y m	02° 20' 05" 8927 (Y= 171370,43 m)	02° 20' 05" 7572 (Y=171367,803 m)
Height or Z m	124,666 (Z= 4778660,47 m)	124,523 (Z= 4778657,504 m)

Antenna information		
	Local:	Portable:
• Maker:	Javad	Javad
• Type:	MarAnt+	MarAnt+
• Serial number:	1996	1713
If the antenna is temperature stabilised		
• Set temperature value :		-

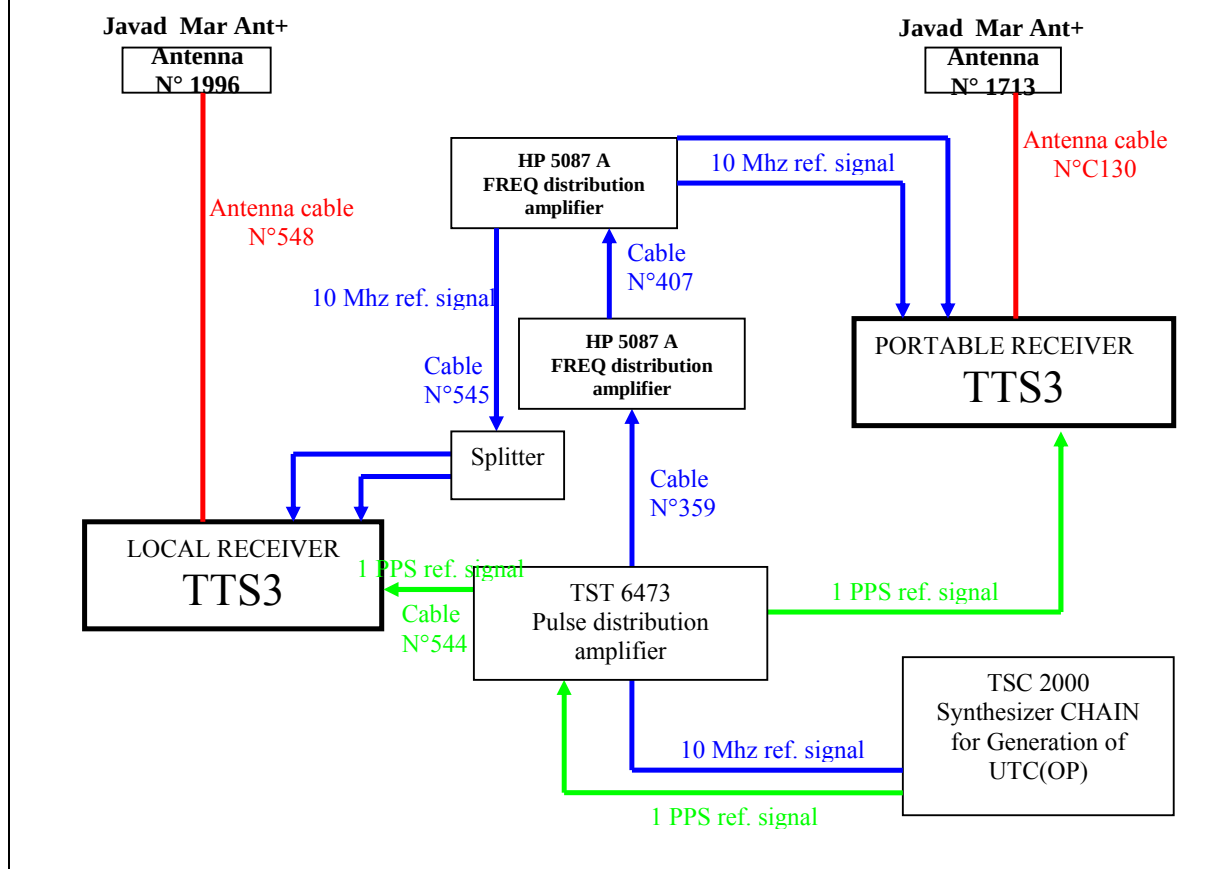
Local antenna cable information	
• Maker:	
• Type:	
• Is it a phase stabilised cable:	no
• Length of cable outside the building :	< 10 meter

General information	
• Rise time of the local UTC pulse:	4 ns
• Is the laboratory air conditioned:	YES
• Set temperature value and uncertainty :	22,5°C +/- 0,5 °C
• Set humidity value and uncertainty :	48% +/- 4%

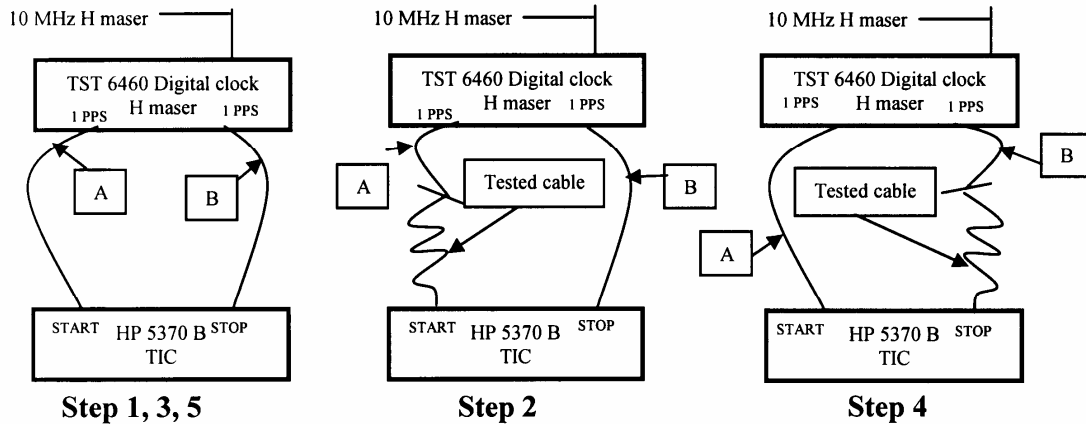
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	135,9 ns $\pm$ 0,4 ns	Not mesured

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



The method used to calibrate the cables is a double wheight method in five steps as shown above.

At each step (i) the TIC gives the result (R_i) of 100 measurments.

The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2} \right) + \left(\frac{R_3 + R_5}{2} \right) - R_4}{2} + \text{corrections}$$

The corrections are the estimated delay introduced by adaptators : - 0,1 ns / adaptor

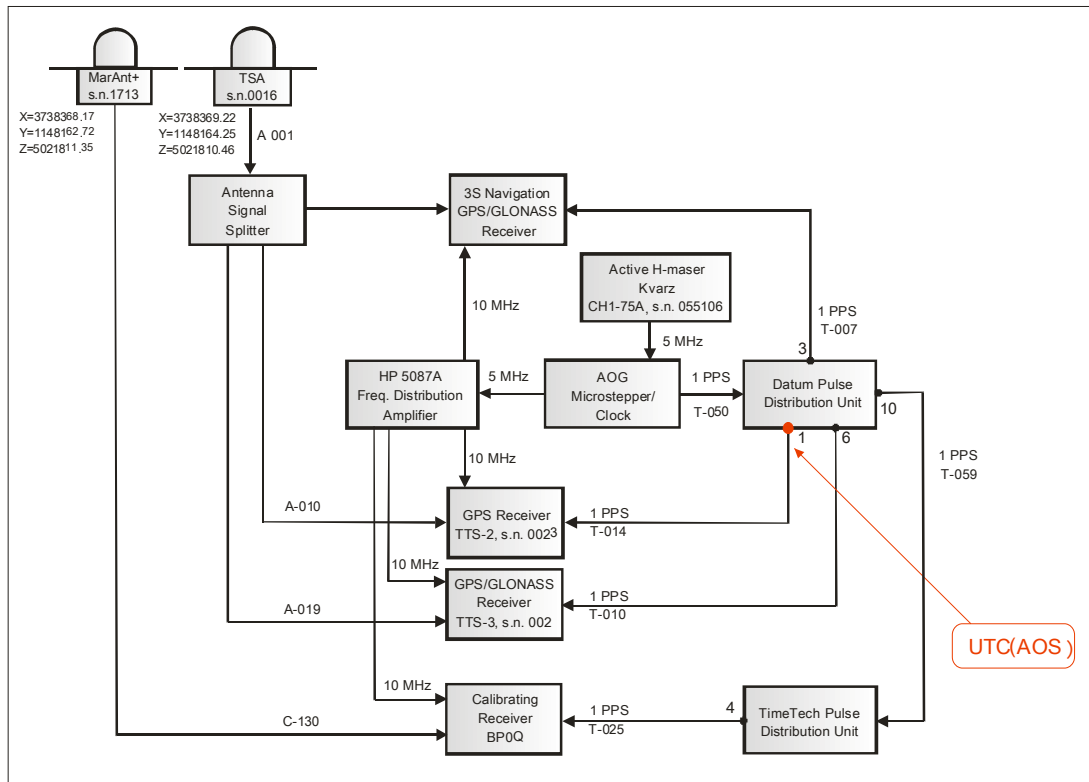
BIPM calibration information sheet

Laboratory:	AOS	
Date and hour of the beginning of measurements:	23. 10. 2009, 13:00 UTC	
Date and hour of the end of measurements:	12. 11. 2009, 09:50 UTC	
Receiver setup information		
	Local:	Portable: BP0Q
• Maker:	AOS	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0002	0012
• Receiver internal delay (GPS) :	-7.1 ns	30.5
• Receiver internal delay (GLO) :	-308.5 ns	0.0
• Antenna cable identification:	A001+ASS+A019*	C130
Corresponding cable delay :	147.1 $\pm$ 0.5 ns	136.2 ns $\pm$ 0.4 ns
• Delay to local UTC :	14.8 ns	73.6 ns
• Receiver trigger level:	0.5 V	0.5 V
• Coordinates reference frame:	ITRF88	ITRF88
Latitude or X m	3738369.22 m	3738368.17 m
Longitude or Y m	1148164.25 m	1148162.72 m
Height or Z m	5021810.46 m	5021811.35 m
Antenna information		
	Local:	Portable:
• Maker:	3S Navigation	Javad
• Type:	TSA-100	MarAnt+
• Serial number:	0016	1713
If the antenna is temperature stabilised		
• Set temperature value :	40.5 °C (105 °F)	-
Local antenna cable information		
• Maker:	Belden	
• Type:	RG-58	
• Is it a phase stabilised cable:	no	
• Length of cable outside the building :	0.5 m	
General information		
• Rise time of the local UTC pulse:	4 ns	
• Is the laboratory air conditioned:	Yes	
• Set temperature value and uncertainty :	(22 $\pm$ 0.5) °C	
• Set humidity value and uncertainty :	(45 $\pm$ 5) %	
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	136.2 ns $\pm$ 0.4 ns	136.3 $\pm$ 0.2 ns

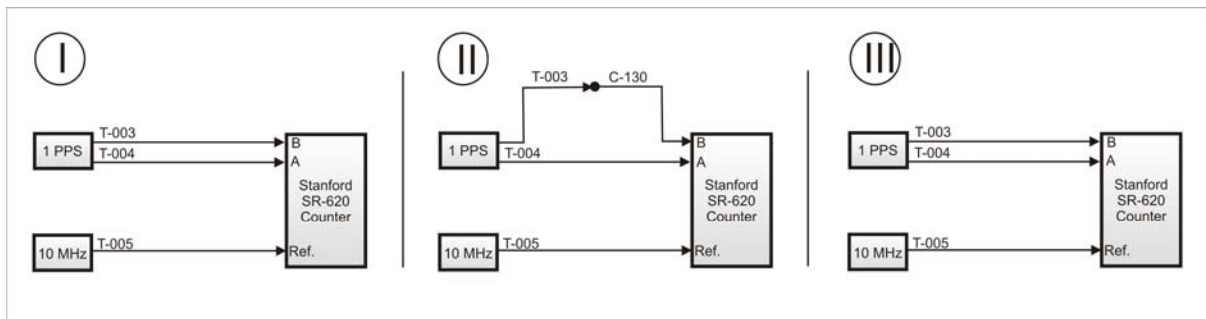
* A001 antenna cable +Antenna signal splitter + A019 antenna cable = 147.1 ns $\pm$ 0.5 ns

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



Pulse method of measurement used for antenna and 1pps cables.

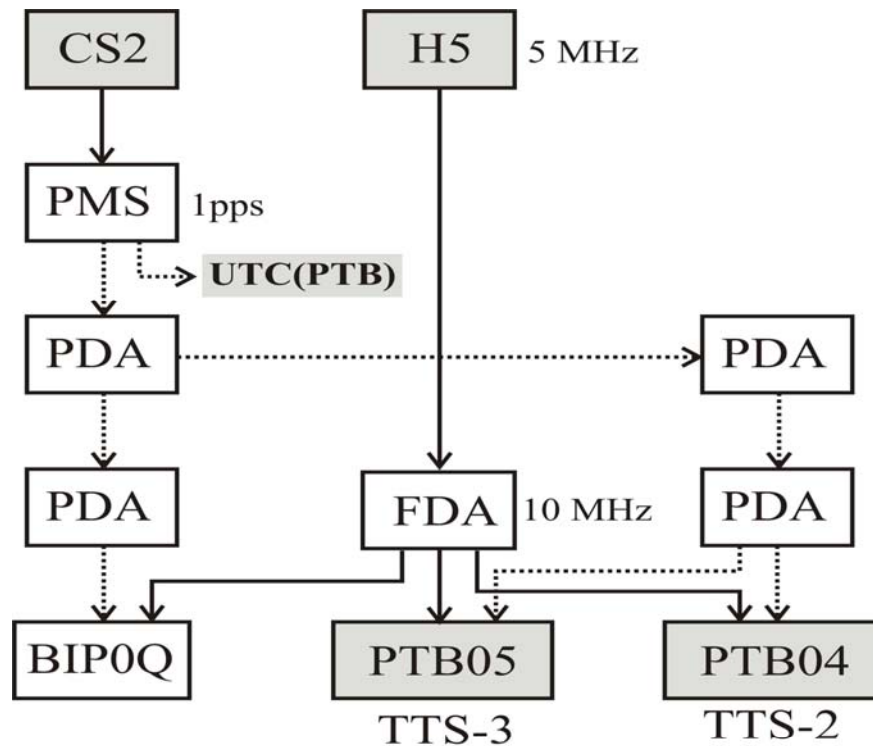
$$\text{Test cable delay} = \text{Meas_II} - (\text{Meas_I} + \text{Meas_III})/2, \quad \text{trig. level} = 0.5 \text{ V}$$

BIPM calibration information sheet

Laboratory:	PTB	
Date and hour of the beginning of measurements:	2009-11-13 (11:00 UTC)	
Date and hour of the end of measurements:	2009-11-19 (07:00 UTC)	
Receiver setup information		
	Local:	Portable: BP0Q
• Maker:	AOS	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0014	0012
• Receiver internal delay (GPS) :	-29.2 ns	30,5
• Receiver internal delay (GLO) :	-29.2 ns	0,0
• Antenna cable identification:	-	C130
Corresponding cable delay :	195.0 ns	136,2 ns $\pm$ 0,4 ns
• Delay to local UTC :	47.9 ns	51.0 ns $\pm$ 0.5 ns
• Receiver trigger level:	0.5 V	0.5 V
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	+3844057.34 (PTB mast P12)	+3844065.12 (PTB mast P2)
Longitude or Y m	+709663.63	+709658.82
Height or Z m	+5023131.42	+5023125.83
Antenna information		
	Local:	Portable:
• Maker:	Javad	Javad
• Type:	MarAnt+	MarAnt+
• Serial number:	MA+#1718	1713
If the antenna is temperature stabilised		
• Set temperature value :	-	-
Local antenna cable information		
• Maker:	-	
• Type:	-	
• Is it a phase stabilised cable:	no	
• Length of cable outside the building :	Approx. 25 m	
General information		
• Rise time of the local UTC pulse:	< 5 ns	
• Is the laboratory air conditioned:	yes	
• Set temperature value and uncertainty :	23,0 $\pm$ 0,5 °C	
• Set humidity value and uncertainty :	Max. 50 %	
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	136,2 ns $\pm$ 0,4 ns	135.8 ns $\pm$ 0.1 ns

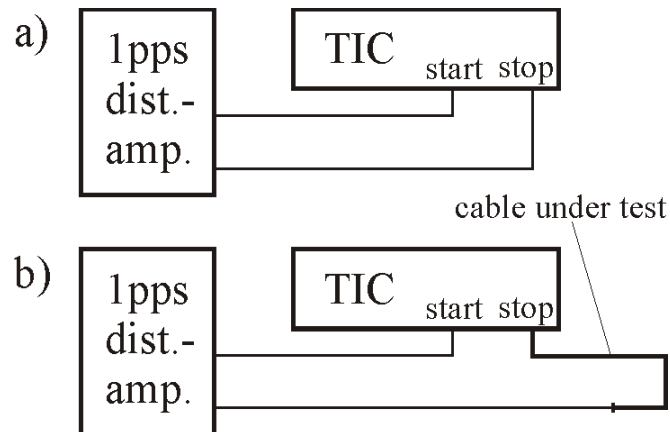
Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



FDA frequency distribution amplifier
PMS phase micro stepper
PDA pulse distribution amplifier

Description of the local method of cable delay measurement:



cable delay = measurement b) – measurement a)

BIPM calibration information sheet

Laboratory:	LNE-SYRTE (Observatoire de Paris)	
Date and hour of the beginning of measurements:	1/12/2009 @ 11h30 UTC (MJD 55166)	
Date and hour of the end of measurements:	9/12/2009 @ 11h00 UTC (MJD 55174)	

Receiver setup information		
	Local:	Portable: BP0Q
• Maker:	AOS	AOS
• Type:	TTS-3	TTS-3
• Serial number:	0021	0012
• Receiver internal delay (GPS) :	118,08 (internal delay + antenna cable delay)	30,5
• Receiver internal delay (GLO) :	-185,9 (internal delay + antenna cable delay)	0,0
• Antenna cable identification:	Câble N°548	C130
Corresponding cable delay :	cable delay included in internal delay	135,9 ns $\pm$ 0,4 ns
• Delay to local UTC :	350,51 (include constant of continuity = 267ns)	278,75 (include constant of continuity = 267ns)
• Receiver trigger level:	1 Volt	
• Coordinates reference frame:	ITRF 05	ITRF 2000
Latitude or X m	48° 50' 09" 2483 (X= 4202780,12 m)	48° 50' 09" 1077 (X= 4202783,408 m)
Longitude or Y m	02° 20' 05" 8927 (Y= 171370,43 m)	02° 20' 05" 7572 (Y=171367,803 m)
Height or Z m	124,666 (Z= 4778660,47 m)	124,523 (Z= 4778657,504 m)

Antenna information		
	Local:	Portable:
• Maker:	Javad	Javad
• Type:	MarAnt+	MarAnt+
• Serial number:	1996	1713
If the antenna is temperature stabilised		
• Set temperature value :		-

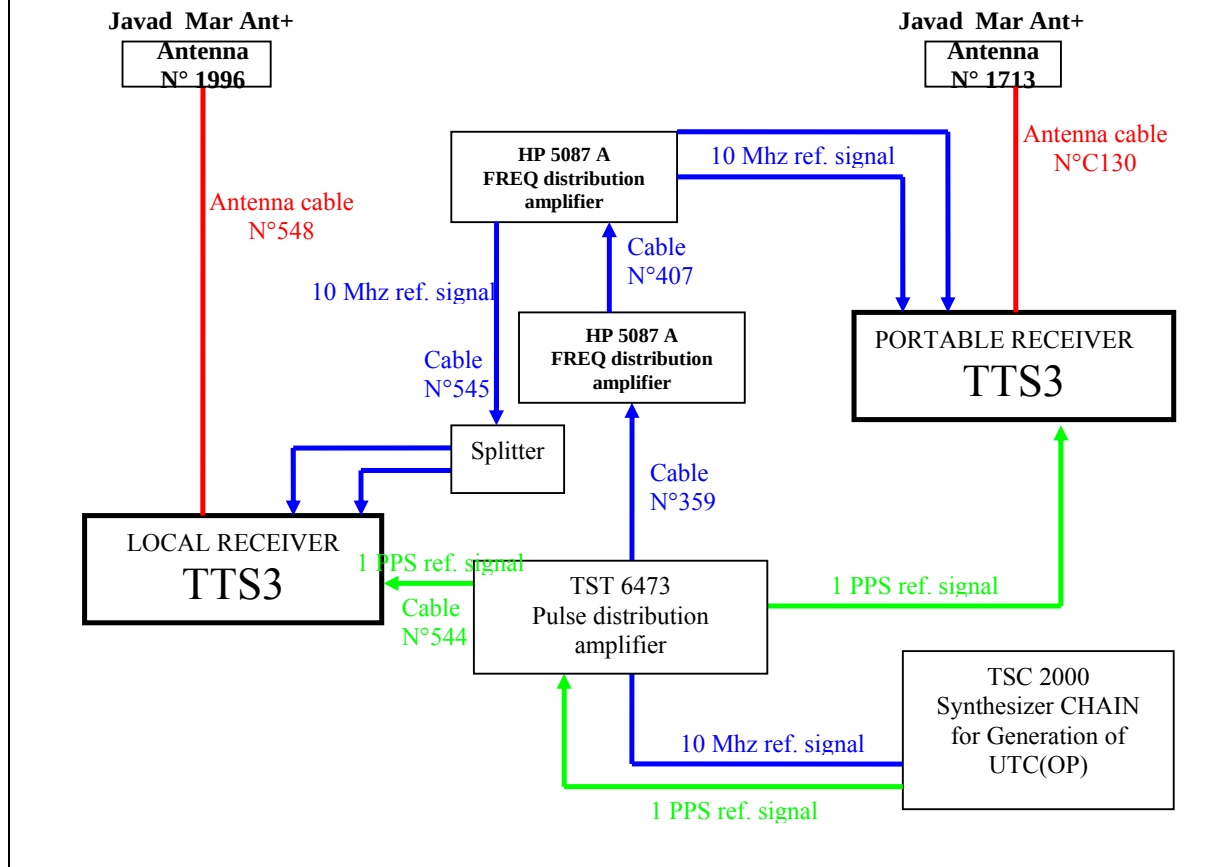
Local antenna cable information	
• Maker:	
• Type:	
• Is it a phase stabilised cable:	no
• Length of cable outside the building :	< 10 meter

General information	
• Rise time of the local UTC pulse:	4 ns
• Is the laboratory air conditioned:	YES
• Set temperature value and uncertainty :	22,5°C +/- 0,5 °C
• Set humidity value and uncertainty :	44% +/- 4%

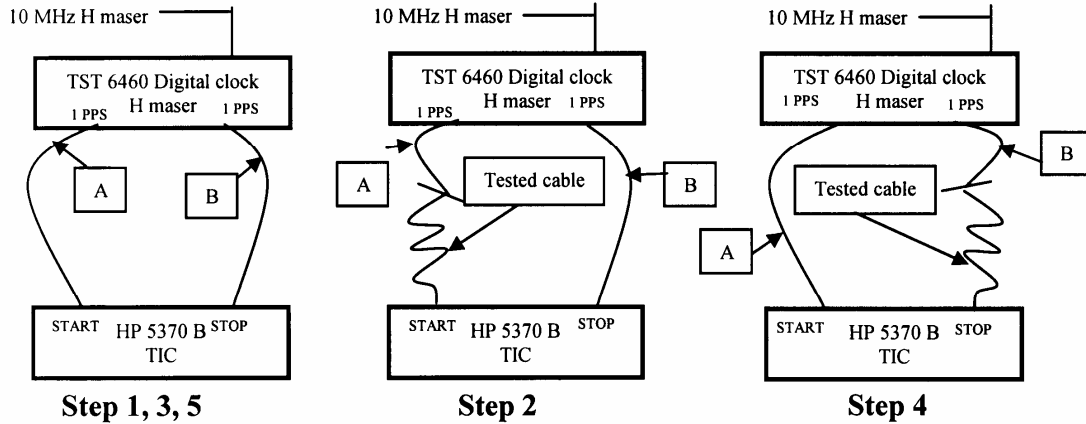
Cable delay control		
Cable identification	delay measured by BIPM	Delay measured by local method
BIPM C130	135,9 ns $\pm$ 0,4 ns	

Plot of the experiment set-up:

Link to the local UTC of both receivers and Antenna positions



Description of the local method of cable delay measurement:



The method used to calibrate the cables is a double wheight method in five steps as shown above.

At each step (i) the TIC gives the result (R_i) of 100 measurements.

The test cable delay is then obtained by the following formula:

$$\text{Delay} = \frac{R_2 - \left(\frac{R_1 + R_3}{2} \right) + \left(\frac{R_3 + R_5}{2} \right) - R_4}{2} + \text{corrections}$$

The corrections are the estimated delay introduced by adaptators : - 0,1 ns / adaptor

Appendix II

Measurement of portable cable at the visited laboratories

Part 1

Laboratory	BIPM C130 cable /ns	Measurement method
BIPM	136.2 ns $\pm$ 0.4	Double Weight Pulse method
OP	-	-
SU	135.6 ns $\pm$ 0.5	Double Weight Pulse method

Part 2

Laboratory	BIPM C130 cable /ns	Measurement method
BIPM	135.9 ns $\pm$ 0.4	Double Weight Pulse method
OP	-	-
AOS	136.3 ns $\pm$ 0.2	Pulse method
PTB	135.8 ns $\pm$ 0.1	Pulse method

Appendix III

GPS L1C daily averages of $dt_{k,i}$ for each laboratory k

Part 1

LAB k	Receiver (Serial Number)	MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Number of individual common views
OP	TTR6 (287)	54788.0	-57.70	2.13	48
		54789.0	-56.85	1.52	48
		54790.0	-56.73	2.00	48
		54791.0	-55.98	2.04	49
		54792.0	-56.23	1.73	48
		54793.0	-54.92	2.33	48
		54794.0	-56.26	1.99	42
		54795.0	-55.72	1.92	47
		54796.0	-56.23	1.86	24
SU	TTR-6 (414)	54994.0	-59.72	2.25	43
		54995.0	-60.35	2.09	39
		54996.0	-60.49	2.50	44
		54997.0	-60.27	2.21	44
		54998.0	-59.60	1.95	41
		54999.0	-60.52	2.65	44
		55000.0	-60.21	2.29	41
		55001.0	-57.95	2.60	38
		55002.0	-57.96	2.86	42
		55003.0	-57.09	2.52	41
		55004.0	-56.35	2.64	42
		55005.0	-55.35	2.20	39
SU	TTS-3 (0026)	54994.0	-66.62	0.99	772
		54995.0	-66.43	1.05	784
		54996.0	-66.72	1.06	767
		54997.0	-66.82	1.17	779
		54998.0	-66.50	1.00	774
		54999.0	-67.94	1.00	773
		55000.0	-67.71	1.06	764
		55001.0	-66.58	1.06	763
		55002.0	-66.68	1.34	777
		55003.0	-66.29	1.21	782
		55004.0	-66.79	1.12	747
		55005.0	-66.67	1.17	760

LAB k	Receiver (Serial Number)	MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Number of individual common views
SU	TTS-3 (0030)	54994.0	-59.57	0.82	756
		54995.0	-59.68	0.85	775
		54996.0	-59.83	0.87	773
		54997.0	-59.84	0.94	782
		54998.0	-59.99	0.95	772
		54999.0	-60.41	0.94	773
		55000.0	-60.43	0.91	756
		55001.0	-59.63	1.90	762
		55002.0	-59.67	1.19	770
		55003.0	-59.41	1.36	785
		55004.0	-59.50	1.00	746
		55005.0	-59.04	1.04	761
SU	TTS-3 (0031)	54994.0	-58.70	1.02	760
		54995.0	-58.71	1.01	771
		54996.0	-58.85	1.08	772
		54997.0	-59.44	1.14	768
		54998.0	-59.72	1.05	760
		54999.0	-59.88	1.07	759
		55000.0	-59.98	1.10	732
		55001.0	-59.33	1.13	757
		55002.0	-59.26	1.47	766
		55003.0	-59.40	1.29	779
		55004.0	-59.02	1.14	728
		55005.0	-59.33	1.17	691
SU	TTS-3 (0032)	54994.0	-58.51	0.83	760
		54995.0	-58.71	0.82	776
		54996.0	-58.91	0.81	763
		54997.0	-58.82	0.83	766
		54998.0	-58.91	0.84	766
		54999.0	-59.59	0.81	754
		55000.0	-59.68	0.85	753
		55001.0	-58.86	0.85	753
		55002.0	-58.67	1.20	775
		55003.0	-58.90	1.25	785
		55004.0	-59.03	0.88	735
		55005.0	-58.93	0.93	751

LAB k	Receiver (Serial Number)	MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Number of individual common views
SU	TTS-3 (0033)	54994.0	-59.39	0.94	772
		54995.0	-59.51	0.85	761
		54996.0	-59.75	0.89	769
		54997.0	-59.84	0.94	775
		54998.0	-59.88	0.92	774
		54999.0	-59.93	1.02	778
		55000.0	-59.44	0.92	748
		55001.0	-58.67	0.96	766
		55002.0	-58.89	1.21	770
		55003.0	-58.69	1.27	787
		55004.0	-59.57	1.02	728
		55005.0	-59.46	0.91	753
OP	TTR6 (287)	55022.0	-56.24	3.12	18
		55023.0	-56.59	2.68	43
		55024.0	-56.71	2.53	46
		55025.0	-56.99	2.66	44
		55026.0	-57.62	2.22	44
		55027.0	-57.77	2.93	46
		55028.0	-56.42	2.49	46
		55029.0	-56.66	2.86	45
		55030.0	-57.06	2.47	46
		55031.0	-56.71	2.09	45
		55032.0	-56.37	2.53	46

Part 2

LAB k	Receiver (Serial Number)	MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Number of individual common views
OP	TTR6 (287)	55119	-55.99	2.44	33
		55120	-55.93	2.44	39
OP	TTS-3 (0021)	55119	-56.16	1.41	615
		55120	-56.67	1.43	573
AOS	TTS-2 (023)	55128	-59.60	2.05	371
		55129	-59.56	1.53	382
		55130	-59.21	1.72	456
		55131	-59.03	1.31	526
		55132	-60.67	1.38	530
		55133	-60.55	1.33	552
		55134	-60.54	1.42	557
		55135	-59.43	1.10	552
		55136	-59.72	1.13	544
		55137	-59.80	1.09	538
		55138	-60.09	1.18	539
		55139	-60.58	1.17	561
		55140	-60.53	1.22	547
		55141	-60.25	1.14	526
		55142	-60.24	1.16	541
		55143	-59.82	1.24	552
		55144	-60.00	1.14	537
		55145	-60.56	1.33	557
		55146	-60.57	1.32	545
		55147	-60.75	1.21	476
AOS	TTS-3 (0002)	55128	-58.65	1.45	409
		55129	-58.46	1.05	421
		55130	-58.10	1.36	506
		55131	-58.36	1.03	561
		55132	-59.90	1.53	582
		55133	-60.00	1.36	589
		55134	-59.99	1.42	598
		55135	-58.97	0.85	595
		55136	-59.27	0.86	584
		55137	-59.39	0.88	591
		55138	-59.55	0.91	579
		55139	-60.03	0.81	610
		55140	-59.69	0.86	596
		55141	-59.46	0.84	590
		55142	-59.30	0.85	598
		55143	-59.05	0.79	615
		55144	-59.20	1.00	619
		55145	-59.90	1.39	616
		55146	-59.96	1.45	616
		55147	-59.96	1.20	525

LAB k	Receiver (Serial Number)	MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Number of individual common views
PTB	TTS-2 (014)	55153	-45.78	2.23	33
		55154	-46.11	1.62	335
		55155	-45.44	2.00	255
		55156	-45.67	1.73	526
		55157	-45.79	1.92	510
		55158	-46.31	1.75	530
		55159	-46.57	1.69	422
PTB	TTS-3 (0014)	55153	-53.93	1.38	34
		55154	-51.23	1.41	426
		55155	-51.75	1.38	334
		55156	-51.38	1.19	656
		55157	-51.94	1.73	658
		55158	-51.10	1.08	659
		55159	-51.27	1.12	524
OP	TTR6 (287)	55167	-58.83	2.35	21
		55168	-56.44	2.08	43
		55169	-56.20	2.33	44
		55170	-56.33	2.76	46
		55171	-56.17	2.02	41
		55172	-56.27	2.50	42
		55173	-56.64	2.05	40
		55174	-56.82	2.15	37
OP	TTS-3 (0021)	55166	-56.46	1.14	16
		55167	-57.51	1.20	654
		55168	-55.51	1.43	432
		55169	-55.15	1.13	661
		55170	-55.54	1.10	667
		55171	-55.15	1.12	659
		55172	-55.01	1.14	659
		55173	-55.42	1.27	663
		55174	-56.31	1.11	583

Appendix IV

GLONASS L1C daily averages of $dt_{k,i}$ for each laboratory k

Part 1

LAB k	Receiver (Serial Number)	MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Number of individual common views
SU	TTS-3 (0026)	54994.0	-130.25	1.24	536
		54995.0	-129.96	1.37	545
		54996.0	-130.41	1.40	530
		54997.0	-130.61	1.36	537
		54998.0	-130.21	1.39	573
		54999.0	-131.66	1.36	570
		55000.0	-131.56	1.35	530
		55001.0	-130.42	1.40	531
		55002.0	-130.44	1.54	550
		55003.0	-130.18	1.49	545
		55004.0	-130.57	1.48	518
		55005.0	-130.41	1.51	510
SU	TTS-3 (0030)	54994.0	-135.78	1.45	538
		54995.0	-135.95	1.47	543
		54996.0	-136.20	1.46	525
		54997.0	-136.38	1.36	535
		54998.0	-136.39	1.51	573
		54999.0	-136.97	1.49	574
		55000.0	-137.03	1.48	515
		55001.0	-136.30	1.44	530
		55002.0	-136.30	1.66	546
		55003.0	-136.11	1.75	545
		55004.0	-135.99	1.58	509
		55005.0	-135.50	1.53	505
SU	TTS-3 (0031)	54994.0	-135.15	1.26	534
		54995.0	-135.17	1.15	536
		54996.0	-135.25	1.30	514
		54997.0	-136.00	1.23	528
		54998.0	-136.20	1.20	563
		54999.0	-136.40	1.24	557
		55000.0	-135.58	1.23	505
		55001.0	-135.92	1.29	520
		55002.0	-135.81	1.57	545
		55003.0	-135.97	1.35	542
		55004.0	-135.48	1.22	489
		55005.0	-135.82	1.18	449

LAB k	Receiver (Serial Number)	MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Number of individual common views
SU	TTS-3 (0032)	54994.0	-135.21	1.10	517
		54995.0	-135.35	0.95	488
		54996.0	-135.65	0.91	464
		54997.0	-135.75	0.89	499
		54998.0	-135.83	0.98	500
		54999.0	-136.49	0.90	490
		55000.0	-136.74	0.90	463
		55001.0	-135.90	0.94	439
		55002.0	-135.71	1.24	438
		55003.0	-135.91	1.29	539
		55004.0	-136.04	0.99	495
		55005.0	-135.90	1.00	419
SU	TTS-3 (0033)	54994.0	-136.68	1.63	531
		54995.0	-136.72	1.71	538
		54996.0	-136.93	1.71	525
		54997.0	-136.93	1.77	538
		54998.0	-136.89	1.67	568
		54999.0	-137.06	1.77	567
		55000.0	-136.58	1.60	520
		55001.0	-135.79	1.64	528
		55002.0	-136.06	1.84	542
		55003.0	-136.10	1.78	543
		55004.0	-135.75	1.73	505
		55005.0	-136.54	1.73	509

Part 2

LAB k	Receiver (Serial Number)	MJD	Mean offset /ns	Standard deviation of individual common view observations /ns	Number of individual common views
OP	TTS-3 (0021)	55119	-334.26	1.51	404
		55120	-334.53	1.61	388
AOS	TTS-3 (0002)	55128	-333.77	3.81	158
		55129	-333.86	2.19	160
		55130	-333.75	2.60	222
		55131	-333.94	1.59	247
		55132	-335.72	1.83	251
		55133	-335.52	1.65	255
		55134	-335.53	1.79	260
		55135	-334.47	1.48	249
		55136	-334.83	1.32	257
		55137	-334.92	1.42	263
		55138	-335.28	1.41	239
		55139	-335.36	1.32	220
		55140	-334.98	1.23	226
		55141	-334.66	1.27	229
		55142	-334.45	1.44	230
		55143	-334.35	1.33	227
		55144	-334.67	1.45	231
		55145	-335.31	1.57	233
		55146	-335.37	1.80	231
		55147	-335.40	1.55	205
PTB	TTS-3 (0014)	55153	-25.51	2.75	29
		55154	-22.77	2.16	409
		55155	-23.57	2.05	417
		55156	-22.57	1.54	419
		55157	-23.18	2.17	411
		55158	-22.38	1.59	407
		55159	-22.34	1.67	334
OP	TTS-3 (0021)	55166	-335.31	2.85	7
		55167	-335.61	1.65	423
		55168	-333.99	1.59	429
		55169	-335.59	1.51	430
		55170	-333.92	1.41	429
		55171	-333.55	1.48	428
		55172	-333.29	1.45	404
		55173	-333.90	1.61	416
		55174	-334.55	1.36	372