Rapport BIPM-98/7

BUREAU INTERNATIONAL DES POIDS ET MESURES

DIFFERENTIAL TIME CORRECTIONS FOR GPS TIME EQUIPMENT LOCATED AT THE OP, VSL, NPL, DTAG, PTB, TUG, IEN, ROA, IPQ AND OCA: 3RD EVALUATION

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June 1998

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Abstract

Following a suggestion at the 4th meeting of the CCDS Working Group on Two-Way Satellite Time Transfer (TWSTT), the BIPM decided to conduct a series of differential calibrations of GPS equipment located in European time laboratories equipped with two-way stations. Repeated calibrations of this kind should provide valuable information about the stability of GPS time equipment and serve as provisional differential calibrations for two-way equipment. This report concerns the 3rd such exercise. It took place from 5 February 1998 to 16 May 1998 and involved the circulation of a portable GPS time receiver among ten laboratories in Europe.

Résumé

Suivant une suggestion exprimée lors de la 4e réunion du Groupe de travail du CCDS sur les comparaisons d'horloges par aller et retour sur satellite, le BIPM a décidé de conduire une série d'étalonnages différentiels des équipements de réception du temps du GPS, situés dans des laboratoires de temps européens équipés de stations bidirectionnelles. Des étalonnages répétés de ce type devraient fournir de précieuses informations sur la stabilité des équipements GPS et servir d'étalonnages différentiels provisoires aux équipements bidirectionnels. Ce rapport concerne la troisième de ces campagnes. Elle a eu lieu entre le 5 février 1998 et le 16 mai 1998 et a consisté à transporter un récepteur du temps du GPS d'un site à l'autre selon une boucle fermée qui a impliqué dix laboratoires en Europe.

INTRODUCTION

Following a suggestion at the 4th meeting of the CCDS Working Group on Two-Way Satellite Time Transfer [1], the BIPM is conducting a series of differential calibrations of GPS equipment located in eight European time laboratories equipped with two-way stations [2, 3]: the NMi Van Swinden Laboratorium (VSL), Delft, the Netherlands, the National Physical Laboratory (NPL), Teddington, United Kingdom, the Deutsche Telekom AG (DTAG), Darmstadt, Germany, the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany, the Technical University of Graz (TUG), Graz, Austria, the Istituto Elettrotechnico Nazionale Galileo Ferraris (IEN), Turin, Italy, the Real Instituto Observatorio de la Armada (ROA), San Fernando, Spain, and the Observatoire de la Côte d'Azur (OCA), Grasse, France. The Institute Portugues da Qualidade (IPQ), Monte da Caparica, also participated in this exercise. This laboratory is not equipped with two-way station, but its GPS time equipment has to be calibrated.

The GPS time equipment located at the Observatoire de Paris (OP), Paris, France, was chosen, as for previous trips, as reference: to check the reproducibility of the measurements, these exercises are organized as round trips beginning and ending at the OP. Although the OP is not equipped with a two-way station, it serves as pivot laboratory for the GPS links used for TAI computation. The OP receiver also serves as reference for many international comparisons of GPS time equipment. It has been compared ten times in the last twelve years with the NIST 'on line', absolutely-calibrated GPS time receiver. The differences between these two receivers have never exceeded a few nanoseconds.

Repeated determinations of the differential time corrections between GPS time equipment located in the laboratories visited should:

- improve the accuracy of involved GPS time links,
- provide valuable information about the stability of GPS time equipment,
- serve as provisional differential calibrations of the two-way equipment.

This report details the 3rd such exercise. It took place from 5 February 1998 to 16 May 1998. Succeeding visits are scheduled to take place at four to five month intervals.

EQUIPMENT

All the receivers involved in this comparison are single-channel, C/A code, 0.5 V trigger level, NBS type receivers. Their principal characteristics are:

OP:	Maker: Allen Osborne Associates, Type: NBS/TTR5, Receiver Ser. No: 051, Internal delay: 54 ns.
VSL:	Maker: VSL, Type: NBS/TTR5, Receiver Ser. No: VSL01.
NPL:	Maker: Allen Osborne Associates, Type: NBS/TTR5A, Receiver Ser. No: 276.
DTAG:	Maker: VSL, Type: NBS/TTR5, Receiver Ser. No: VSL19.
PTB:	Maker: Rockwell Collins, Type: NBS/TTR5.
TUG:	Maker: NBS, Type: NBS, Receiver Ser. No: 12.
IEN:	Maker: NBS, Type: NBS, Receiver Ser. No: 31.
ROA:	Maker: Allen Osborne Associates, Type: NBS/TTR6, Receiver Ser. No: 253.
IPQ:	Maker: Allen Osborne Associates, Type: NBS/TTR6, Receiver Ser. No: 279.

OCA:	Maker:	Allen Osborne Associates,
	Type:	NBS/TTR5,
	Receiver Ser. No: 053.	
Portable receiver:	Maker:	Allen Osborne Associates,
BIPM3	Type:	NBS/TTR6,
	Receiver Ser. No: 277.	

As these receivers use identical software of NBS type, any imperfections in the software cancel during a zero-baseline comparison. The main source of errors is thus variation in hardware.

The portable BIPM3 receiver was equipped with four cables:

- portable IF (Intermediate Frequency) antenna cable C1: 235.5 ns, uncertainty of 0.40 ns (1 σ).

- portable LO (Local Oscillator) antenna cable C2.

- portable IF (Intermediate Frequency) spare antenna cable C3: 232.1 ns, uncertainty of 0.40 ns (1 σ).

- portable IF local UTC cable C4: 170.0 ns, uncertainty of 0.40 ns (1 σ).

Delays in the cables C1, C3 and C4 were measured at the BIPM using the pulse method with a time intervallometer steered by an external frequency source, an HP 5071A clock. 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 [4].

Delays in cables C1 and C4 were also measured at the laboratories visited. Results are reported in Appendix I. Different methods of measurement were employed. We observe that group delay measurements using the MITREX modem at 70 MHz [4] differ from those given by the pulse method by about 2 ns for the C1 cable and may reveal the ultimate accuracy of the pulse method. However, any imperfection in the measurement delay of portable equipment, if constant throughout the trip, cancels in the determination of differential time corrections between the laboratories involved.

Detailed information on the equipment at each location is provided in Appendix II.

CONDITIONS OF COMPARISON

For the present comparison, the portable equipment took the form of the receiver, its antenna and a calibrated antenna cable. The laboratories visited supplied a) a 5 MHz reference signal, 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 uncertainties of a few centimetres. During the comparisons the receivers were programmed with the *BIPM Common-View International Schedules No 29 and 30* for Europe.

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)-$GPS\ time$]$_{BIPM3,i}$-[UTC(k)-$GPS\ time$]$_{k,i}$.

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, this exhibits white phase noise up to an averaging interval of about one day. We illustrate this in Figure 1 which shows the computation for the OP over about twenty days period following the trip.

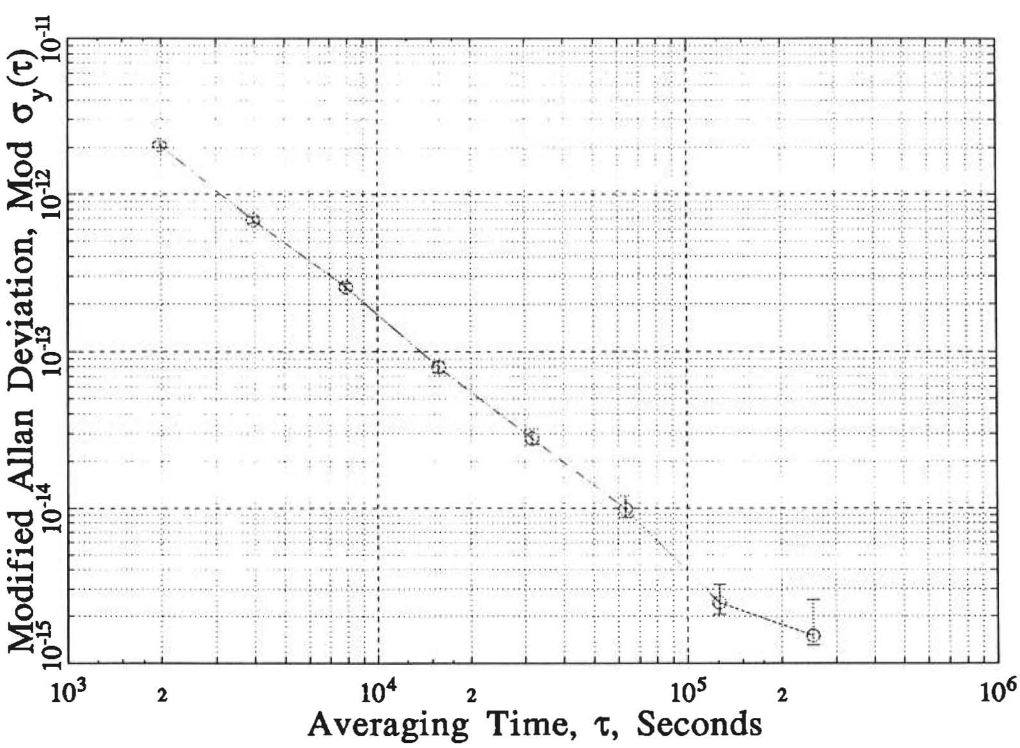

Figure 1. Square root of the modified Allan variance of the time series dt_{OP} for the period: 4 – 16 May 1998.

One-day averages are reported in Figure 2 and Appendix III. The level of noise for a one-day period is reported in Table 1.

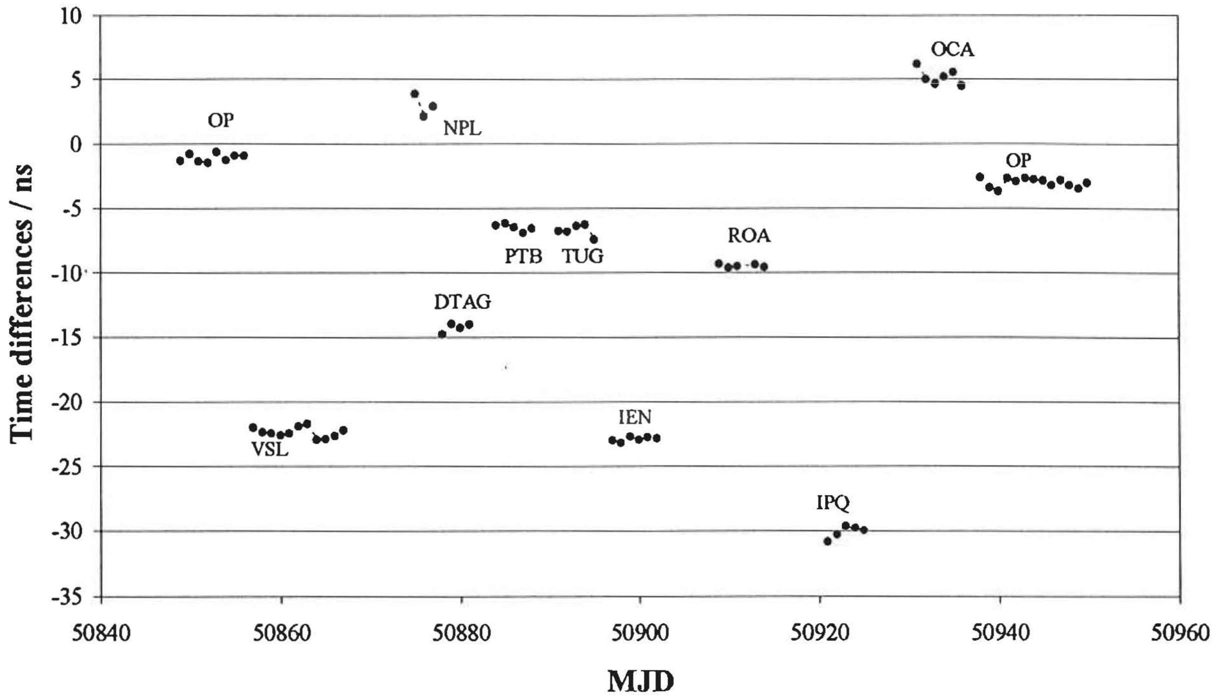

Figure 2. Daily averages of $dt_{k,i}$ for each laboratory.

The one-day averages exhibit systematic effects which we characterized by the dispersion of the daily mean also listed in Table 1. These systematic effects are caused by hardware instability, often linked to the sensitivity of GPS time equipment to environmental conditions [5,6,7].

Next, we computed mean offsets for the full duration of comparison at each location, and the corresponding standard deviations of individual common views (Table 1).

Table 1. Mean offsets for the full duration of comparison at each location.

Lab	Period 1998	Total number of common views	Mean offset /ns	Standard deviation of individual common view /ns	Level of noise for 1 day /ns	Dispersion of daily mean /ns
OP	5-12 Feb	308	-1.0	3.5	0.4	0.3
VSL	13-23 Feb	363	-22.4	2.0	0.3	0.4
NPL	3-5 Mar	32	1.9	2.0	0.4	0.9
DTAG	6-9 Mar	-	-	-	-	-
PTB	12-16 Mar	210	-7.5	2.9	0.3	0.3
TUG	19-23 Mar	171	-7.6	2.0	0.3	0.5
IEN	25-30 Mar	187	-22.8	1.7	0.3	0.2
ROA	6-10 Apr	184	-9.5	1.6	0.2	0.1
IPQ	18-22 Apr	95	-30.0	1.9	0.3	0.5
OCA	28 Apr - 3 May	137	5.1	2.3	0.5	0.6
OP	4-16 May	538	-3.0	2.4	0.3	0.3

The repeated measurements at the OP give an indication of the reproducibility of the comparisons. At the beginning and at the end of this exercise they show offsets of −1.0 ns and -3.0 ns (Table 1 and Figure 2). In between (100 days), the portable receiver was packed and unpacked, with associated vibrations and temperature changes. Changes of a few nanoseconds in differential delays between local and portable receivers were observed during calibration in several of the laboratories visited (Figure 2). The possibility that changes also occurred in the delay of the OP receiver is not excluded. It is now well documented, and generally admitted, that GPS time equipment is sensitive to external temperature [5, 6, 7].

From the preceding table, after averaging the two measurements at the OP, we derived differential time corrections which should be added to the values derived during the GPS comparisons of the time scales kept by the laboratories visited. They are reported in Table 2. In the same table we report calibration results from the 1st and 2nd trip [8, 9].

Table 2. Differential time correction *d* to be added to[$UTC(k_1)$-$UTC(k_2)$].
A single 1σ uncertainty, $u(d)$, has been estimated for each trip: 3 ns for 1st trip and 2 ns for 2nd and 3rd trip.

[$UTC(k_1)$-$UTC(k_2)$]	*d*/ns		
	1st trip	2nd trip	3rd trip
[*UTC*(VSL)-*UTC*(OP)]	-2	-23	-20
[*UTC*(DTAG)-*UTC*(OP)]	+3	+6	-
[*UTC*(PTB)-*UTC*(OP)]	+2	+4	-6
[*UTC*(NPL)-*UTC*(OP)]	-4	-2	+4
[*UTC*(TUG)-*UTC*(OP)]	-10	-5	-6
[*UTC*(IEN)-*UTC*(OP)]	-17	-15	-21
[*UTC*(OCA)-*UTC*(OP)]	+4	+8	+7
[*UTC*(ROA)-*UTC*(OP)]			-8
[*UTC*(IPQ)-*UTC*(OP)]			-28

The uncertainties $u(d)$ associated with the values *d* given in Table 2 are conservative. The principal uncertainty is that due to the 'round-trip' reproducibility at the OP, but some other elements are significant, particularly the effect of changing the portable antenna cable during the 1st trip, and the level of noise in individual receivers.

DISCUSSION

The results of the 3rd series of BIPM differential calibrations of GPS time equipment in European time laboratories equipped with two-way stations mostly confirm the results of the 1st and 2nd trip to within the uncertainties involved.

For all laboratories but PTB, we observe that changes in delays of 1 ns to 6 ns, took place between the 2nd and the 3rd trips. These changes occurred in different directions.

The change of –10 ns at the PTB is probably due to the particularly poor conditions at the PTB under which the 3rd trip took place [10].

At the DTAG, the building construction work which took place during the 3rd trip made collected data useless [11].

To clarify the matter of changes in the delays experienced in GPS time equipment, we await the results of the next calibration round.

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.

REFERENCES

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[8] W. Lewandowski and P. Moussay, "Determination of Differential Time Corrections between GPS Time Equipment Located the OP, NPL, VSL, DTAG, PTB, TUG, IEN and OCA", *Rapport BIPM-97/5*, October 1997.

[9] W. Lewandowski and P. Moussay, "Determination of Differential Time Corrections between GPS Time Equipment Located the OP, CH, SP, VSL, DTAG, PTB, NPL, TUG, IEN and OCA", *Rapport BIPM-98/1*, February 1998.

[10] P. Hetzel, personal communication, April 1998.

[11] A. Soering, personal communication, April 1998.

Appendix I

Measurement of portable cables at the visited laboratories

BIPM C1 cable

Laboratory	Trip 2 /ns	Trip 3 /ns	Measurement method	Uncertainty 1σ /ns
BIPM	235.5	235.5	Pulse method	0.4
OP before trip		236.5	Dual weighing	0.3
OP after trip	236.5	236.5		0.3
VSL	234.5	234.4	Mitrex	
VSL	236.8	235.7	Pulse method	
PTB	234.7	234.1	Mitrex	
PTB	235.3	235.3	Pulse method	
TUG	234.8	234.3	Mitrex	
IEN	234.7		Mitrex	
IEN	236.0		Pulse method	
OCA	236.7	235.76	Pulse method	
CH	235.95		Pseudo-reflectometry	
SP	235.8		Pulse method	
ROA		235.2	Pulse method	0.013 (2σ)
IPQ		235.96	Pulse method	0.062

BIPM C4 cable

Laboratory	Trip 2 /ns	Trip 3 /ns	Measurement method	Uncertainty 1σ /ns
BIPM	170.0	170.0	Pulse method	0.4
OP before trip		170.5	Dual weighing	0.3
OP after trip	170.5	170.5		0.3
VSL	170.7	170.0	Pulse method	
IEN	169.7		Mitrex	
IEN	170.4		Pulse method	
CH	170.3		Pseudo-reflectometry	
SP	170.0		Pulse method	
ROA		169.9	Pulse method	
IPQ		170.4	Pulse method	0.041

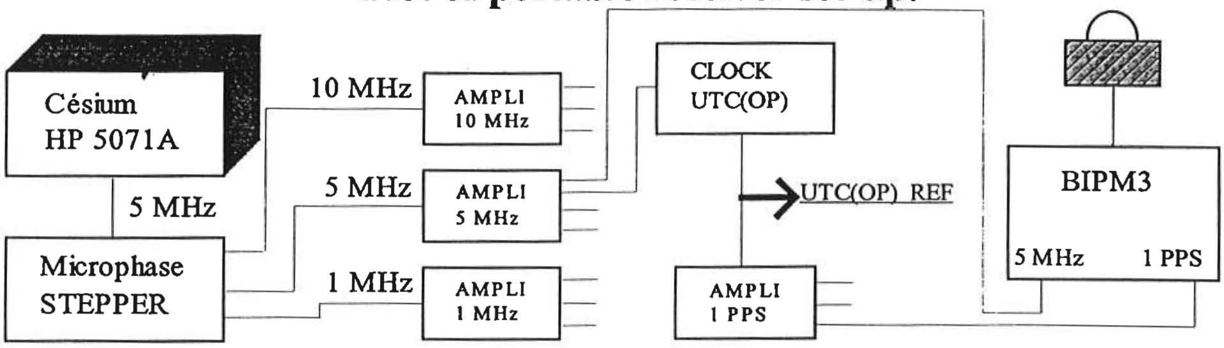
Appendix II

Set-ups of local and portable equipment at each location (forms filled at laboratories)

BIPM GPS calibration information sheet

Laboratory:	LPTF	
Date and hour of the beginning of measurements:	02-05-98	09h58 UT
Date and hour of the end of measurements:	02-12-98	08h00 UT

Plot of portable receiver set-up:



Rise time of the local UTC pulse: 5 ns

Receiver information

	Local:	Portable: BIPM3
• Maker:	Allen Osborne Associates	Allen Osborne Associates
• Type:	TTR5	TTR6
• Serial number:	SN 051	SN 277
• Receiver internal delay :	54 ns	57 ns
• IF Antenna cable identification:	n° 505	n° 1
Corresponding cable delay :	168 ns	236 ns
• UTC cable identification:	n° 503	n° 494
Corresponding cable delay :	37 ns	48 ns
Delay to local UTC :	304 ns	315 ns
• Receiver trigger level:	0.5 V	0.5 V
• Coordinates reference frame:	ITRF 88	ITRF 88
Latitude:	48°50'09''.2369	48°50'09''.0999
Longitude:	02°20'05''.8730	02°20'05''.7389
Height:	124.51 m	124.58 m

Description of the local method of cable delay measurement:

Dual weighing method using a time interval counter HP 5370 triggered by 1 PPS from BNM-LPTF hydrogen maser.
The time base of the time interval counter is steered by 10 MHz maser.
The process is repeated twice.
Final result is the mean value of both evaluations of the cable delay.

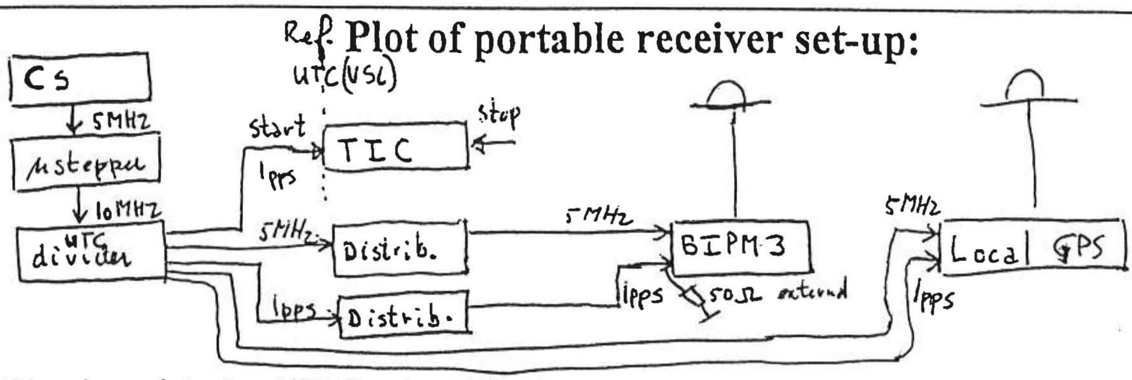
Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	236.453 ns ± 300 ps
BIPM portable UTC cable C4	170.0 ns	170.475 ns ± 300 ps

BIPM GPS calibration information sheet

Laboratory:	NMi Van Swinden Laboratorium Delft
Date and hour of the beginning of measurements:	1998-02-13 MJD 50857 18:10 UTC
Date and hour of the end of measurements:	1998-02-23 MJD 50867 08:46 UTC

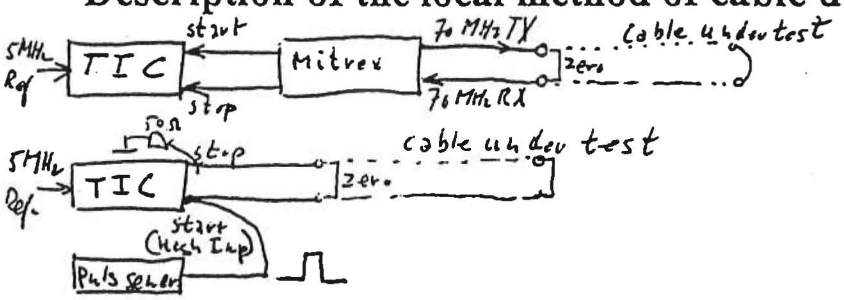
Plot of portable receiver set-up:



Rise time of the local UTC pulse: 5 ns

Receiver information		
	Local:	**Portable: BIPM3**
• Maker:	VSL	Allen Osborne Associates
• Type:	VSL (NBS type)	TTR6
• Serial number:	VSL 01	SN 277
• Receiver internal delay :	63.9	57 ns
• IF Antenna cable identification:	Cable 8	cable 9
Corresponding cable delay :	657.6 ns	652 ns
• UTC cable identification:	local	local
Corresponding cable delay :		
Delay to local UTC :	5.5 ns @ 0,5 V trigger	27 ns @ 0,5 V trigger
• Receiver trigger level:	+0,5 V	+0.5 V
• Coordinates reference frame:	ITRF	ITRF
Latitude:	51° 55' 59".0833	51° 59' 59".1570
Longitude:	4° 22' 51".7965	4° 22' 51.8460
Height:	71.67 m	71.53 m

Description of the local method of cable delay measurement:

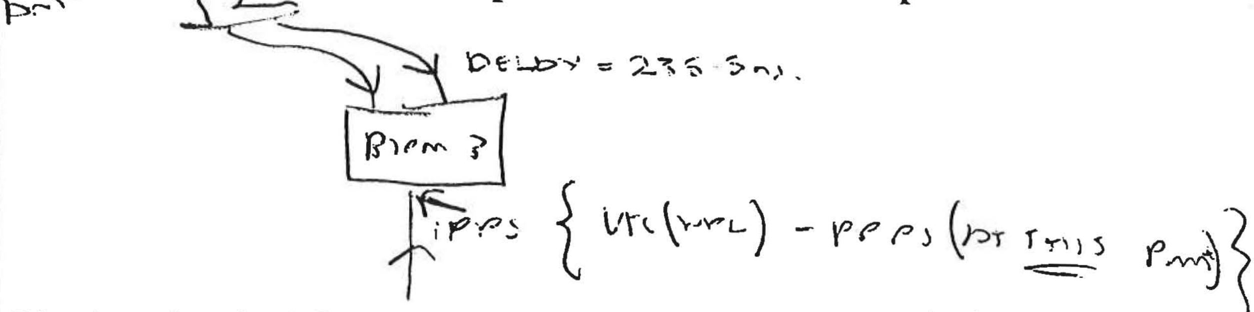


Cable delay control		
Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	235.7 (pulse) 234.4 (Mitrex)
BIPM portable UTC cable C4	170.0 ns	170.0 (pulse)

BIPM GPS calibration information sheet

Laboratory:	NPL
Date and hour of the beginning of measurements:	
Date and hour of the end of measurements:	

Plot of portable receiver set-up:



Rise time of the local UTC pulse: ______ = +6 ns

Receiver information

	Local:	Portable: BIPM3
• Maker:	ALLEN OSBORNE ASSOCIATES	Allen Osborne Associates
• Type:	TTR 5A	TTR6
• Serial number:		SN 277
• Receiver internal delay :	68.5 ns	57 ns
• IF Antenna cable identification:		
Corresponding cable delay :	124.5 ns	235.5 ns
• UTC cable identification:	—	
Corresponding cable delay :	—	
Delay to local UTC :	7 ns	6 ns
• Receiver trigger level:	DON'T KNOW	0.5 V
• Coordinates reference frame:	DON'T KNOW	DON'T KNOW.
Latitude:	51° 25' 15.3368'	51° 25' 15.3710'
Longitude:	359° 39' 40.3364'	359° 39' 40.2883'
Height:	66.45 m	60.23 m

Description of the local method of cable delay measurement:

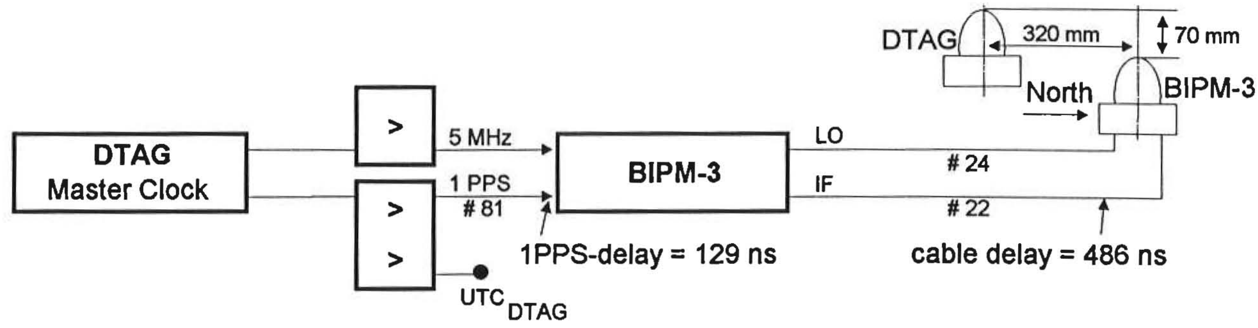
Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	NOT MEASURED
BIPM portable UTC cable C4	170.0 ns	NOT USED

BIPM GPS calibration information sheet

Laboratory:	DTAG
Date and hour of the beginning of measurements:	Mar. 06, 1998 16:00 UTC
Date and hour of the end of measurements:	Mar. 10, 1998 10:00 UTC

Plot of portable receiver set-up:

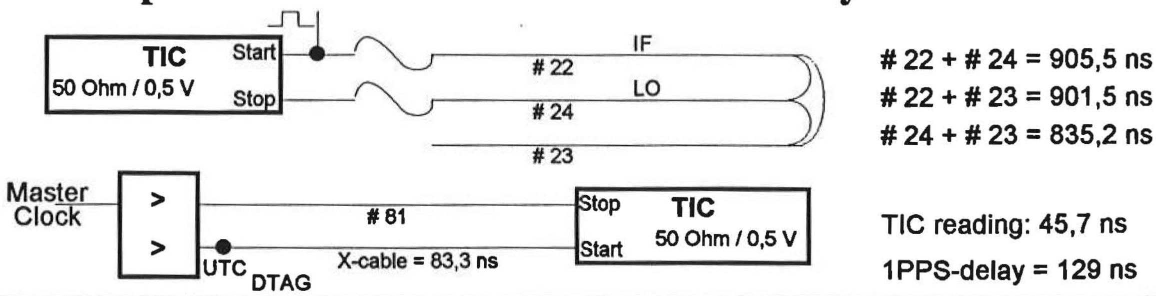


Rise time of the local UTC pulse: 11 ns

Receiver information

	Local:	Portable: BIPM3
• Maker:	Van Swinden Laboratory	Allen Osborne Associates
• Type:	NBS	TTR6
• Serial number:	19	SN 277
• Receiver internal delay :	61,1 ns	57 ns
• IF Antenna cable identification:	# 21	# 22
Corresponding cable delay :	486 ns	486 ns
• UTC cable identification:	# 28	
Corresponding cable delay :		
Delay to local UTC :	75,1 ns	129 ns
• Receiver trigger level:	0,5 V	0.5 V
• Coordinates reference frame:	WGS 84	
Latitude:	N 49° 52' 5,624''	
Longitude:	E 008° 37' 29,762''	
Height:	+ 204,16 m	

Description of the local method of cable delay measurement:



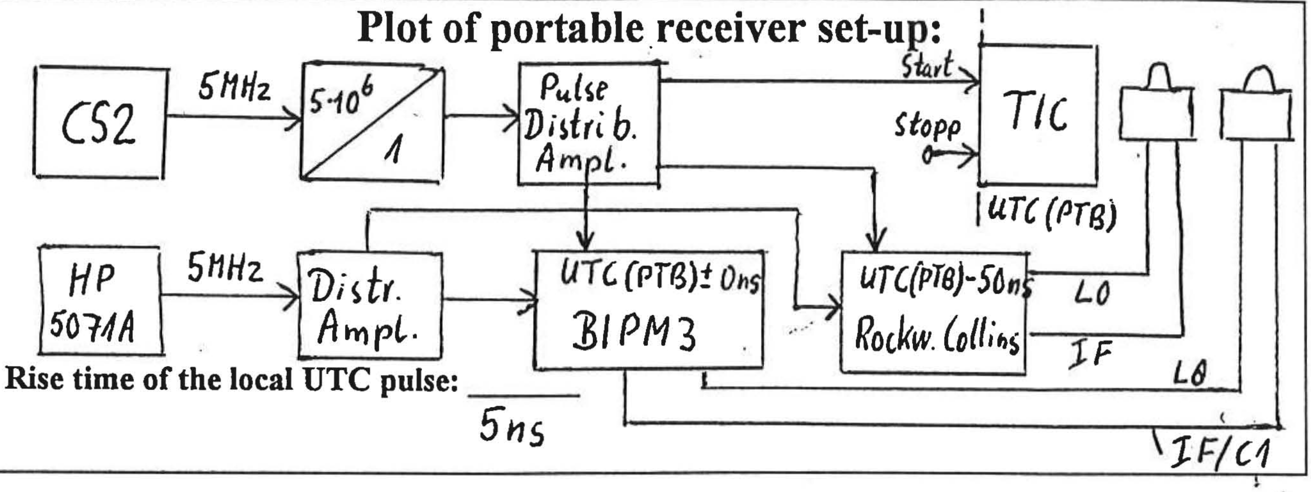
Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	-
BIPM portable UTC cable C4	170.0 ns	-

BIPM GPS calibration information sheet

Laboratory:	PTB
Date and hour of the beginning of measurements:	50884 1998-03-12 09:46 UTC
Date and hour of the end of measurements:	50889 1998-03-17 06:14 UTC

Plot of portable receiver set-up:

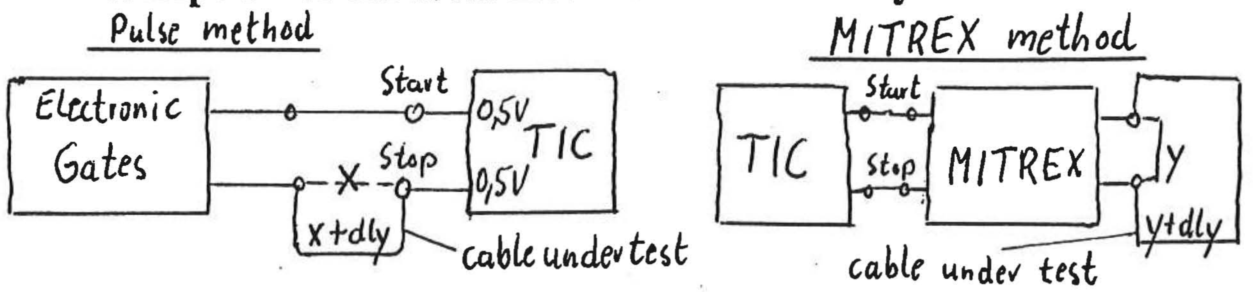


Rise time of the local UTC pulse: 5ns

Receiver information

	Local: PTB 01	Portable: BIPM3
• Maker:	Rockwell Collins	Allen Osborne Associates
• Type:	NBS-type	TTR6
• Serial number:	—	SN 277
• Receiver internal delay :	77ns	57 ns
• IF Antenna cable identification:	AT06/IF	C1
Corresponding cable delay :	626ns (676ns)	235ns
• UTC cable identification:	PTB	PTB
Corresponding cable delay :	—	—
Delay to local UTC :	-50ns (0ns)	0ns
• Receiver trigger level:	0,5V	0.5 V
• Coordinates reference frame:	ITRF 88	ITRF 88
Latitude:	N 52° 17' 44,481"	N 52° 17' 46,080"
Longitude:	E 10° 27' 39,728"	E 10° 27' 34,895"
Height:	156,61 m	130,2 m

Description of the local method of cable delay measurement:



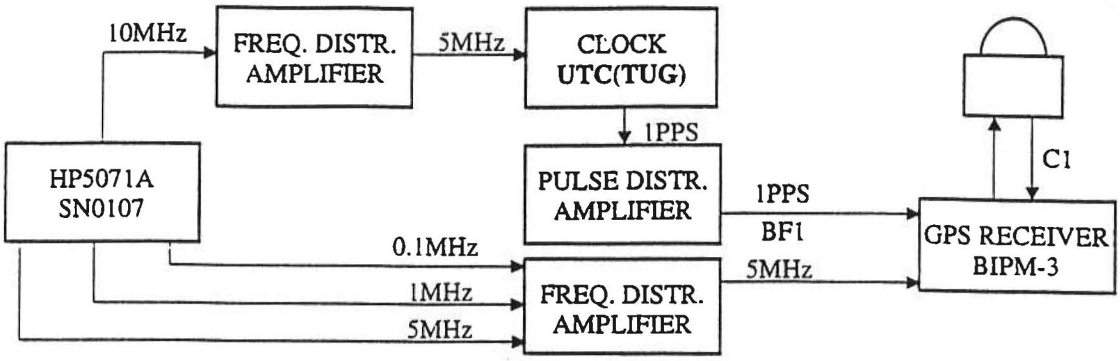
Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	235,3 (pulse method)
BIPM portable ~~UTC~~ cable ~~C4~~ C1	~~170.0 ns~~	234,1 (MITREX)

BIPM GPS calibration information sheet

Laboratory:	TUG
Date and hour of the beginning of measurements:	19.3.1998 (MJD 50891) 19:06
Date and hour of the end of measurements:	23.3.1998 (MJD 50895) 10:20

Plot of portable receiver set-up:

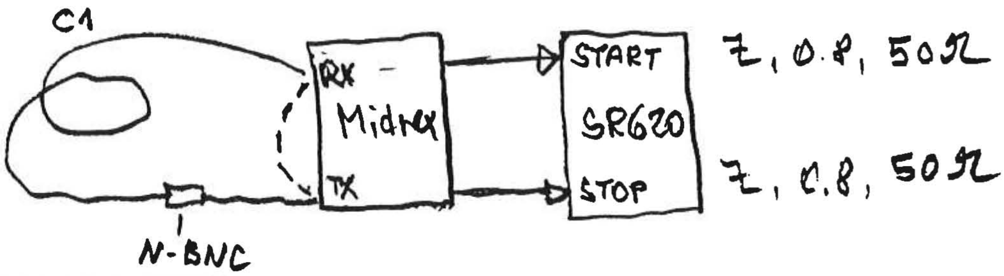


Rise time of the local UTC pulse: _5 ns______

Receiver information

	Local:	Portable: BIPM3
• Maker:	NBS	Allen Osborne Associates
• Type:	NBS	TTR6
• Serial number:	12	SN 277
• Receiver internal delay :	55.6 ns	57 ns
• IF Antenna cable identification:	412A	C1
Corresponding cable delay :	222 ns	235 ns
• UTC cable identification:	A1	BF1
Corresponding cable delay :	34.3 ns	40.7 ns
Delay to local UTC :	34.3 ns	108 ns
• Receiver trigger level:		0.5 V
• Coordinates reference frame:	ITRF 88	ITRF 88
Latitude:	N 47 04 01.6882	N 47 04 01.6395
Longitude:	E 15 29 36.6710	E 15 29 36.6710
Height:	540.31 m	540.31 m

Description of the local method of cable delay measurement:



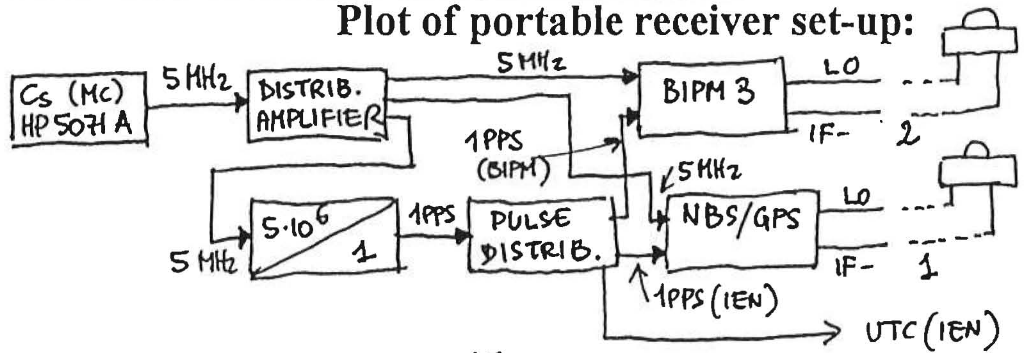
Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	234.3 ns
BIPM portable UTC cable C4	170.0 ns	

BIPM GPS calibration information sheet

Laboratory:	IEN
Date and hour of the beginning of measurements:	50897 ; 98-03-25 ; 16:19:30 UTC
Date and hour of the end of measurements:	50902 ; 98-03-30 ; 08:00 UTC

Plot of portable receiver set-up:



Rise time of the local UTC pulse: 15 ns

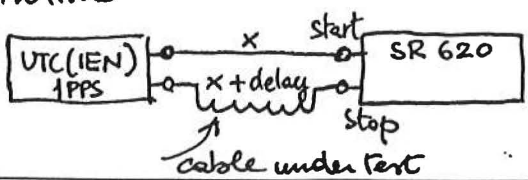
Receiver information

	Local:	Portable: BIPM3
• Maker:	NBS	Allen Osborne Associates
• Type:	NBS/GPS TIME TRANSFER	TTR6
• Serial number:	031	SN 277
• Receiver internal delay :	253 ns (*)	57 ns
• IF Antenna cable identification:	IF 1	IF 2
Corresponding cable delay :	(nominal value : 230 ns)	(nominal value : 236 ns)
• UTC cable identification:	1PPS (IEN)	1PPS (BIPM)
Corresponding cable delay :	not available	not available
Delay to local UTC :	12,3 ns	14,3 ns
• Receiver trigger level:	0,5 V	0.5 V
• Coordinates reference frame:	(ITRF 88)	ITRF 88
Latitude:	45°00'54,048" N	45°00'53,987" N
Longitude:	7°38'20,709" E	7°38'20,686" E
Height:	306,64 m	306,64 m

Description of the local method of cable delay measurement:

(*) We cannot separate the contributions of the IF antenna cable delay and the internal receiver delay.

PULSE METHOD



trigger levels : +0,5 V

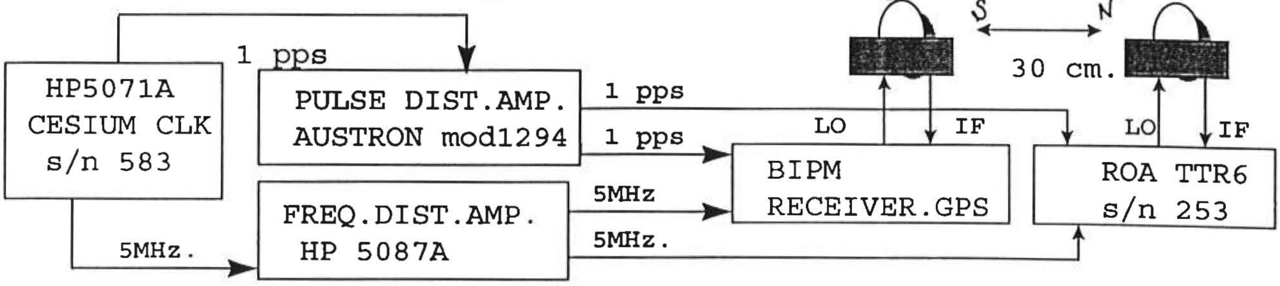
Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	—
BIPM portable UTC cable C4	170.0 ns	—

BIPM GPS calibration information sheet

Laboratory:	R.O.A.
Date and hour of the beginning of measurements:	DJM=50909 ;98-04-06 ; 15 :30 UTC
Date and hour of the end of measurements:	DJM=50916 ;98-04-06 ; 07 :45 UTC

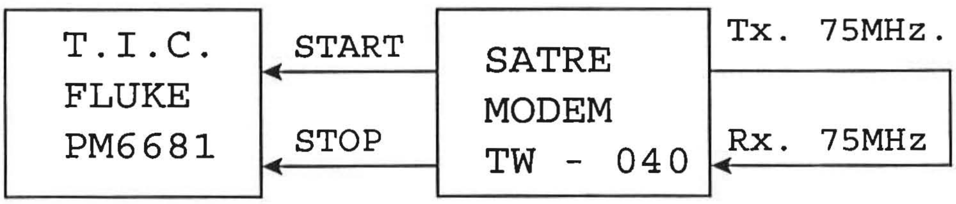
Plot of portable receiver set-up:



Rise time of the local UTC pulse : < 7 ns

Receiver information		
	Local:	**Portable: BIPM3**
• Maker:	Allen Osborne Associates	Allen Osborne Associates
• Type:	TTR6	TTR6
• Serial number:	SN 253	SN 277
• Receiver internal delay :	50 ns	57 ns
• IF Antenna cable identification:	IF	C1
Corresponding cable delay :	234 ns	235.2 ns
• UTC cable identification:	ROA	ROA
Corresponding cable delay :	0 ns	0 ns
Delay to local UTC :	0 ns	0 ns
• Receiver trigger level:	0.5 V.	0.5 V
• Coordinates reference frame:	ITRF	
Latitude:	36° 27' 51.3830" N	
Longitude:	353° 47' 37.8460	
Height:	76.00 m	

Description of the local method of cable delay measurement:

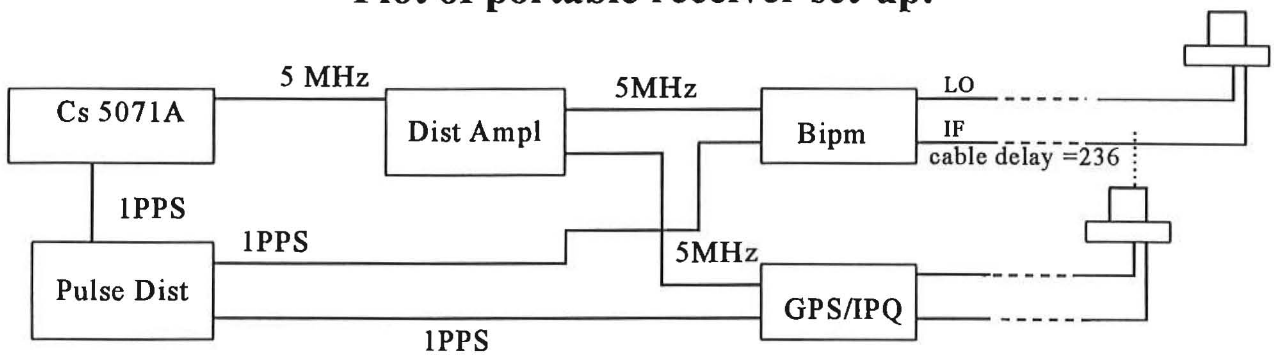


Cable delay control		
Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	235.2 ns ± 13.6 10^{-12} (K=2)
BIPM portable UTC cable C4	170.0 ns	169.9 ns

BIPM GPS calibration information sheet

Laboratory:	IPQ
Date and hour of the beginning of measurements:	98.04.18 (MJD 50921) 10:58
Date and hour of the end of measurements:	98.04.22 (MJD 50925) 9.56

Plot of portable receiver set-up:



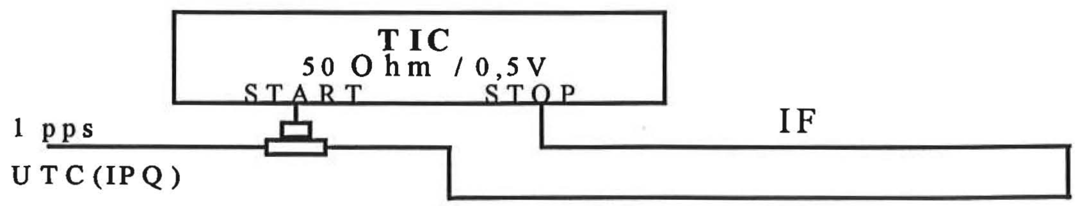
Rise time of the local UTC pulse: 7,689 σ =164 ps

Receiver information

	Local:	Portable: BIPM3
• Maker:	Allen Osborne Associates	Allen Osborne Associates
• Type:	TTR6	TTR6
• Serial number:	279	SN 277
• Receiver internal delay :	51ns	57 ns
• IF Antenna cable identification:	IF	C1
Corresponding cable delay :	88 ns	236 ns
• UTC cable identification:	IPQ1	IPQ
Corresponding cable delay :		
Delay to local UTC :		
• Receiver trigger level:	0.5 V	0.5 V
• Coordinates reference frame:	ITRF 92 epoch 1988	ITRF 92 epoch 1988
Latitude:	38° 40′15,9074″	38° 40′ 16,0057″
Longitude:	350° 48′50,1838 ″	350° 48′ 50,2040″
Height:	155,86m	155,32m

Description of the local method of cable delay measurement:

Pulse method



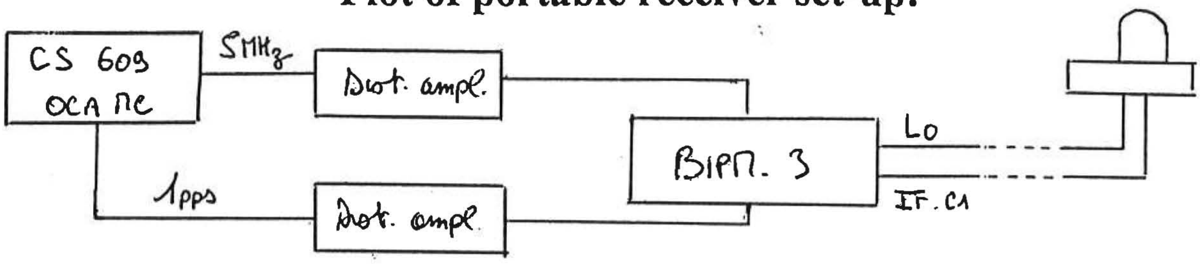
Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	235,958 ns σ 61,9 ps
BIPM portable UTC cable C4	170.0 ns	170,398 ns σ 41,1 ps

BIPM GPS calibration information sheet

Laboratory:	OCA - CERGA
Date and hour of the beginning of measurements:	1998-04-27 50930 09:06 UT
Date and hour of the end of measurements:	1998-05-04 50937 06:14 UT

Plot of portable receiver set-up:

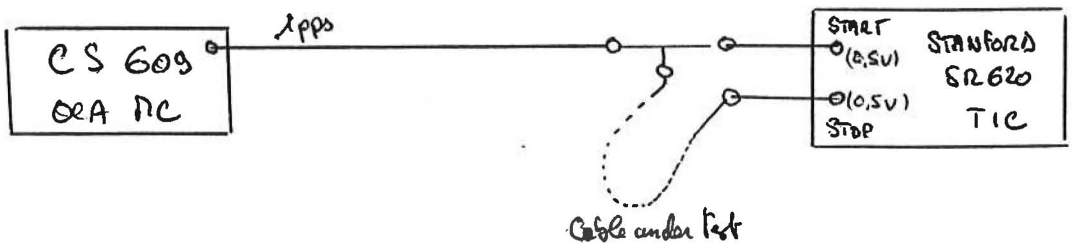


Rise time of the local UTC pulse: _______

Receiver information

	Local: NBS 07	Portable: BIPM3
• Maker:	ALLEN OSBORNE ASSOCIATES	Allen Osborne Associates
• Type:	TTR5	TTR6
• Serial number:	SN 053	SN 277
• Receiver internal delay :	194 ns Total delay	57 ns
• IF Antenna cable identification:	Receiver + IF antenna cable	C1
Corresponding cable delay :		236 ns
• UTC cable identification:	OCA	OCA
Corresponding cable delay :	/	/
Delay to local UTC :	85 ns	87.5 ns
• Receiver trigger level:	0,5 V	0.5 V
• Coordinates reference frame:		
Latitude:	43° 45' 17,3779" N	43° 45' 17,3779" N
Longitude:	06° 55' 16,8228" E	06° 55' 16,8641" E
Height:	1322,50	1322,50

Description of the local method of cable delay measurement:



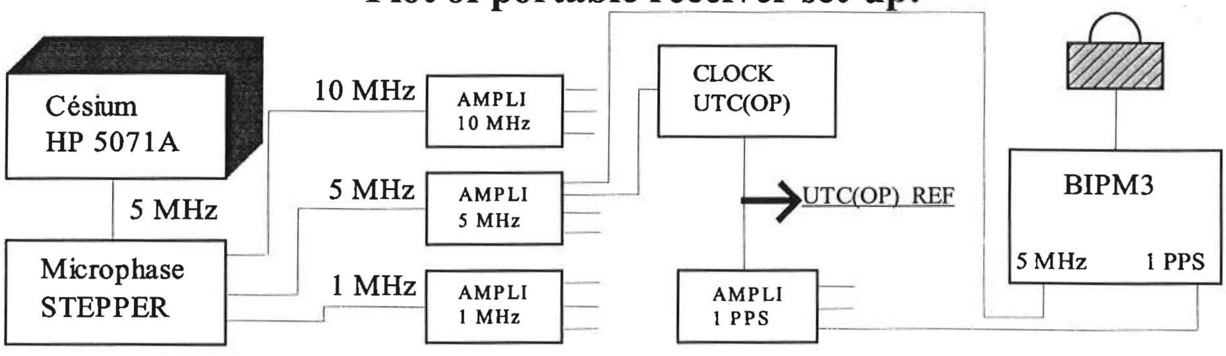
Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	235,76 ns
BIPM portable UTC cable C4	170.0 ns	/

BIPM GPS calibration information sheet

Laboratory:	LPTF	
Date and hour of the beginning of measurements:	05-05-98	12h44 UT
Date and hour of the end of measurements:	05-18-98	04h18 UT

Plot of portable receiver set-up:



Rise time of the local UTC pulse: 5 ns

Receiver information

	Local:	Portable: BIPM3
• Maker:	Allen Osborne Associates	Allen Osborne Associates
• Type:	TTR5	TTR6
• Serial number:	SN 051	SN 277
• Receiver internal delay :	54 ns	57 ns
• IF Antenna cable identification:	n° 505	n° 1
Corresponding cable delay :	168 ns	236 ns
• UTC cable identification:	n° 503	n° 494
Corresponding cable delay :	37 ns	48 ns
Delay to local UTC :	304 ns	315 ns
• Receiver trigger level:	0.5 V	0.5 V
• Coordinates reference frame:	ITRF 88	ITRF 88
Latitude:	48°50'09''.2369	48°50'09''.0999
Longitude:	02°20'05''.8730	02°20'05''.7389
Height:	124.51 m	124.58 m

Description of the local method of cable delay measurement:

Dual weighing method using a time interval counter HP 5370 triggered by 1 PPS from BNM-LPTF hydrogen maser.
The time base of the time interval counter is steered by 10 MHz maser.
The process is repeated twice.
Final result is the mean value of both evaluations of the cable delay.

Cable delay control

Cable identification	delay measured by BIPM	delay measured by local method
BIPM portable IF antenna cable C1	235.5 ns	236.489 ns ± 300 ps
BIPM portable UTC cable C4	170.0 ns	170.549 ns ± 300 ps

Appendix III

Daily results of the comparisons

Lab	Date 1998	Number of individual common views	Mean Offset /ns	Standard deviation of individual common view /ns	Standard deviation of the mean /ns
OP	Feb 05	28	-1.25	3.18	0.6
	Feb 06	43	-0.75	2.80	0.43
	Feb 07	43	-1.30	3.43	0.52
	Feb 08	46	-1.44	3.09	0.46
	Feb 09	46	-0.58	2.88	0.42
	Feb 10	46	-1.23	3.45	0.51
	Feb 11	43	-0.88	3.22	0.49
	Feb 12	13	-0.9	3.3	0.92
VSL	Feb 13	11	-21.95	1.79	0.54
	Feb 14	41	-22.30	1.72	0.27
	Feb 15	41	-22.40	1.95	0.3
	Feb 16	15	-22.53	2.02	0.52
	Feb 17	40	-22.39	1.98	0.31
	Feb 18	41	-21.84	1.72	0.27
	Feb 19	38	-21.65	1.59	0.26
	Feb 20	42	-22.87	2.28	0.35
	Feb 21	41	-22.86	2.3	0.36
	Feb 22	42	-22.6	2.26	0.35
	Feb 23	11	-22.16	2.13	0.64
NPL	Mar 03	9	2.87	2.23	0.74
	Mar 04	13	1.15	1.65	0.46
	Mar 05	10	1.93	2.93	0.93
DTAG	Mar 06	-	-	-	-
	Mar 07	-	-	-	-
	Mar 08	-	-	-	-
	Mar 09	-	-	-	-
PTB	Mar 12	29	-7.25	3	0.56
	Mar 13	45	-7.14	2.18	0.32
	Mar 14	45	-7.44	2.48	0.37
	Mar 15	45	-7.86	2.77	0.41
	Mar 16	46	-7.51	2.96	0.44
TUG	Mar 19	12	-7.71	1.83	0.53
	Mar 20	46	-7.75	1.73	0.26
	Mar 21	47	-7.34	2.11	0.31
	Mar 22	46	-7.21	2.05	0.3
	Mar 23	20	-8.39	1.76	0.39

Lab	Date 1998	Number of individual common views	Mean offset /ns	Standard deviation of individual common view /ns	Standard deviation of the mean /ns
IEN	Mar 25	14	-22.96	1.48	0.39
	Mar 26	41	-23.12	1.91	0.3
	Mar 27	40	-22.66	1.95	0.31
	Mar 28	40	-22.9	1.47	0.23
	Mar 29	39	-22.69	1.3	0.21
	Mar 30	13	-22.77	1.53	0.42
ROA	Apr 06	16	-9.32	1.8	0.45
	Apr 07	43	-9.59	1.58	0.24
	Apr 08	47	-9.5	1.59	0.23
	Apr 09	34	-9.34	1.48	0.25
	Apr 10	44	-9.58	1.81	0.27
IPQ	Apr 18	12	-30.82	2.74	0.79
	Apr 19	19	-30.27	0.92	0.21
	Apr 20	27	-29.6	1.71	0.33
	Apr 21	33	-29.78	1.91	0.33
	Apr 22	4	-29.97	1.49	0.74
OCA	Apr 28	18	6.16	2.4	0.57
	Apr 29	19	5	1.72	0.39
	Apr 30	20	4.67	1.91	0.43
	May 01	20	5.19	1.98	0.44
	May 02	27	5.53	2.96	0.57
	May 03	33	4.51	2.4	0.42
OP	May 04	22	-2.6	3.11	0.66
	May 05	44	-3.36	2.52	0.38
	May 06	43	-3.66	2.06	0.31
	May 07	42	-2.67	1.98	0.3
	May 08	44	-2.9	2.62	0.39
	May 09	44	-2.65	2.67	0.4
	May 10	44	-2.75	2.21	0.33
	May 11	44	-2.83	2.05	0.31
	May 12	42	-3.18	2.09	0.32
	May 13	44	-2.81	2.27	0.34
	May 14	42	-3.2	2.49	0.38
	May 15	41	-3.45	1.7	0.26
	May 16	42	-2.98	1.88	0.29