Final Report on EURAMET Project No. 1018

"Survey of GNSS receivers in use for time transfer in T&F labs (P1018)"

André Stefanov, METAS, andre.stefanov@metas.ch

Introduction

UTC is computed from the results of clock comparisons between all laboratories participating to TAI and the pivot laboratory PTB. Those comparisons are performed either by TWSTFT or by using GPS receivers. The links are affected by type A ("noise") and type B ("calibration") uncertainties.

For the computation of UTC, and as long as there are no calibration changes, it is the type A uncertainty only which is relevant. The initial phases of the clocks are set by the algorithm and the weighting of the clocks is based on the measured frequency stability only [Metrologia 40 (2003) S252–S256]. However, UTC has to be linked to a local realization UTC(k) for any practical purposes and the main part of the uncertainty on UTC-UTC(k) is due to the link between the lab k and PTB [Metrologia 43 (2006) 278–286]. Assuming that the delays in laboratory k are properly calibrated, the calibration error (type B) of the link is the main contribution to that uncertainty. It can range from 1 ns for calibrated TWSTFT to 20 ns for uncalibrated GPS receivers.

At the CCTF 2006 it was pointed out by the BIPM that with the increasing number of types of GNSS receivers in use in the laboratories contributing to TAI, it becomes more and more difficult for the BIPM to run all calibration trips for the different receiver models. It was suggested that RMOs take over the task to organize and run calibration trips with GNSS receivers.

The TC T&F of EUROMET has run a restricted calibration trip with a GPS receiver among 4 timing laboratories (EUROMET project 529). However, it has no expertise in organizing a wider campaign with the result to be included in the computation of TAI. Nor does it have a clear picture of the GNSS receivers installed in every lab. This information is however necessary, as the details of the calibration procedure depend also on the receiver type.

This project aims at gaining an overview of the receivers used in the labs, especially in those which have not yet participated in a BIPM calibration campaign. The survey was carried out by Email. A form was sent in January 2008 to the participants to be filled.

We present here a summary of the responses received until March 2008. A compilation of calibration values for different GPS receivers is also presented.

Results

The form has been returned by 16 NMIs and the results of each NMI are included in annex 2.

The survey covers 35 receivers which can be classified in three categories (the shortcuts used for the receivers types are listed in annex 1):

Single frequency single channel receivers

- TTR6 (4 receivers in 4 NMIs)

Single frequency multi channel receivers

- TTS2 (10 in 8 NMIs)
- TSC2214 (1)
- TFSTT (2 in 1 NMI)

Dual frequency (geodetic) receivers

- AZ12T (7 in 4 NMIs)
- GTR50 (2 in 1 NMI)
- JLE (2 in 2 NMIs)
- JLGGD (1)
- PRx2 (3 in 3 NMIs)
- TTS3 (3 in 3 NMIs)

Calibration values

18 receivers have been directly calibrated versus a traveling receiver from the BIPM. 5 NMIs do not possess any receivers calibrated by this method, however 5 of them have been calibrated indirectly. Almost all NMIs are interested in participating to new calibration campaigns, but none is able to provide a receiver which could be used as a travelling reference.

Using the values of the calibration constants given by the BIPM calibrations, it is possible to compare different receivers from a similar type. In order to improve the statistics we have included the calibration value of receivers from laboratories participating to TAI but not to this survey (DLR, IFAG, KRISS, NICT, NMIJ, NRC, ONRJ, ORB, ROA, SP, TL).
The distribution of the calibration values P1, P2 and P3=2.54 P1-1.54 P2 are plotted in figures 1-3 for the AZ12T, PRx2 and TTS2 receivers. One observe a broad spreading of the values, in accordance to the arbitrary uncertainty of 20 ns chosen by the BIPM for uncalibrated receivers.

Some AZ12T receivers have been calibrated several times over the years (PTBB 5 times, OPMT 5 times, IT3 2 times). From those calibrations one can compute for each detector *j* the difference δ_i between each P3 calibration value $D_{i,j}$ and the mean value of the delay $\langle D_j \rangle$: $\delta_{i,j} = D_{i,j} - \langle D_j \rangle$. An histogram plot of the $\delta_{i,j}$ is shown on figure 4. The standard deviation is 1.8 ns, showing a good reproducibility of the calibrations.

Conclusion

There is certainly an interest for more calibration of GPS receivers because the uncertainty on the links UTC-UTC(k) are mainly limited by the calibration uncertainties. However there is no traveling equipment available within EURAMET, a close collaboration with the BIPM is hence always needed. Nevertheless punctual calibrations between labs are always possible and a protocol may be created in order to standardize the procedure.

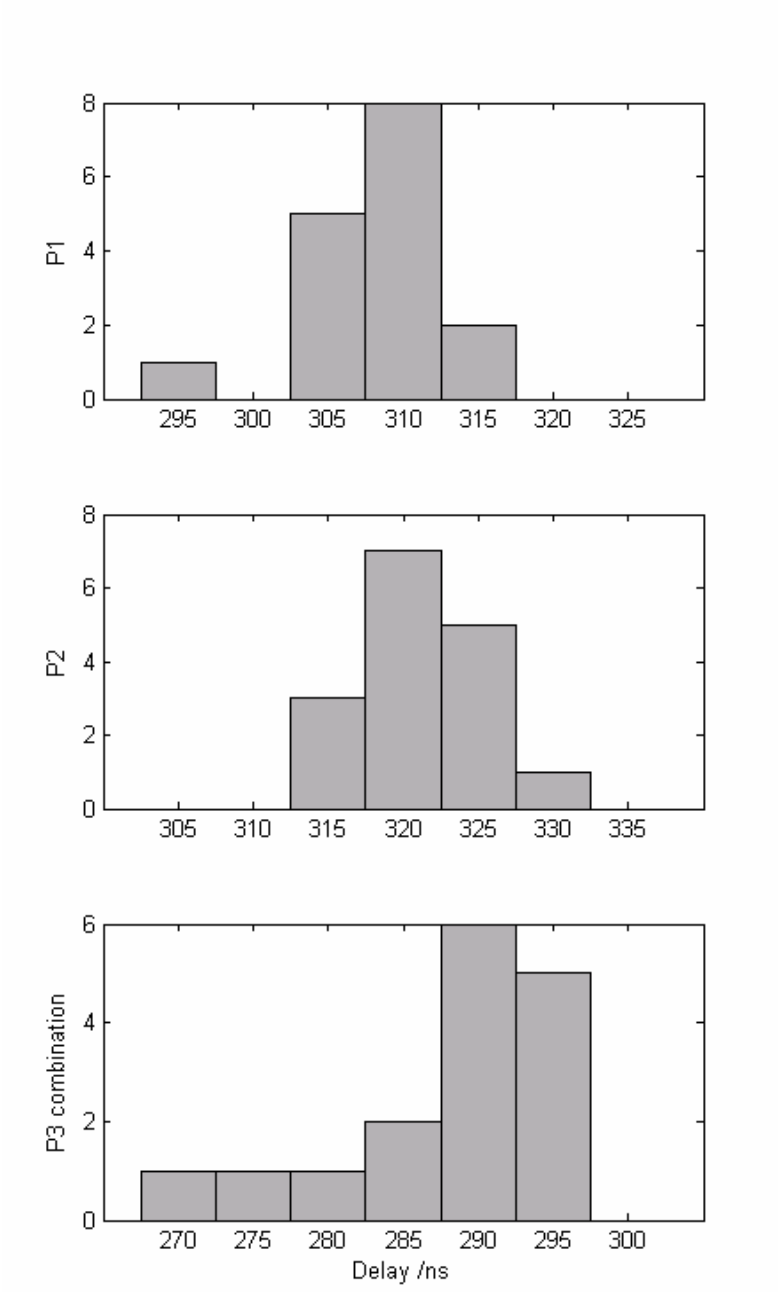

Figure 1 Distribution of calibration constants for 16 AZ12T receivers

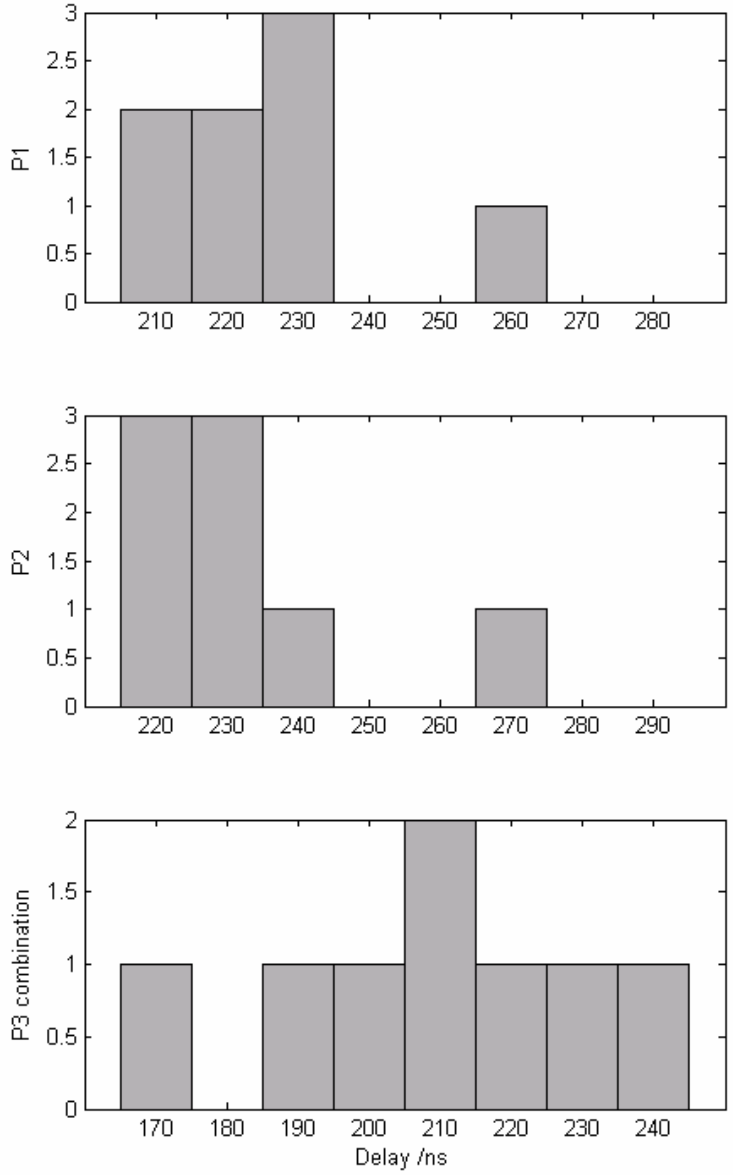

Figure 2 Distribution of calibration constants for 8 PRx2 receivers

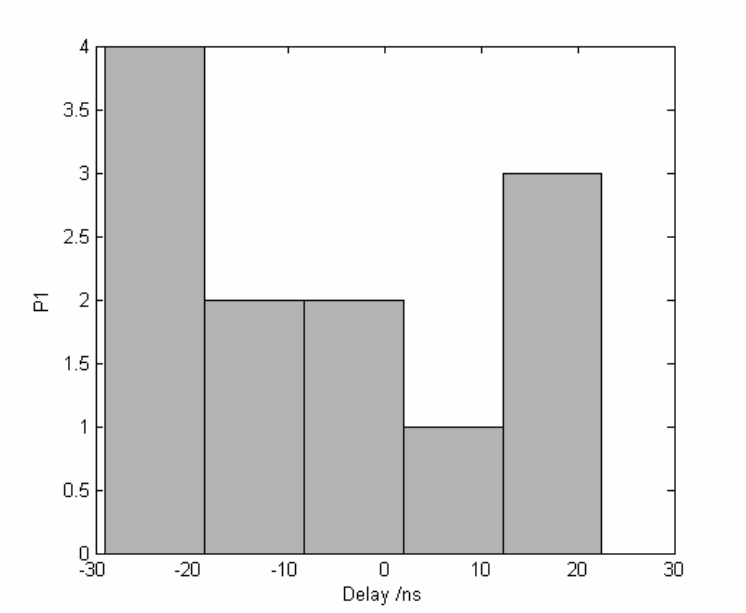

Figure 3 Distribution of calibration constants for 12 TTS2 receivers

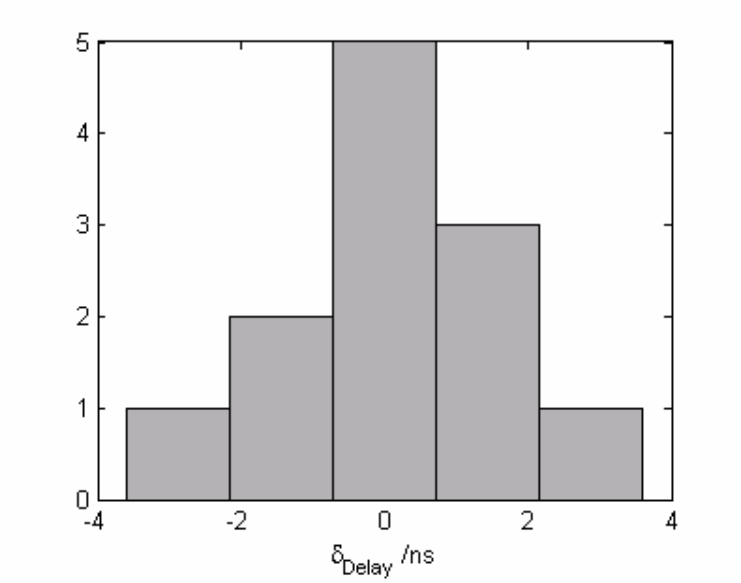

Figure 4 Distribution of the P3 calibration constant for repeated calibration of the same receiver

Annex 1

List of GPS receivers types for time and frequency transfer used in EURAMET T&F laboratories

Dual frequency receivers

AZ12T: Ashtech Z12-T, *discontinued*, Company not existing anymore
GTR50 : Dicom GTR50, http://www.dicom.cz/en/product/873-time-frequency-transfer-receiver
JLE: Javad Legacy-E, *discontinued*, http://www.javad.com
JLGGD: Javad Lexon GGD, *discontinued*, http://www.javad.com
PRx2 : Septentrio PolaRx2 TR, http://www.septentrio.com/products_gps.htm
TTS3 : Piktime Systems TTS-3, http://piktime.com/receivers.php

Single frequency, multichannel receivers

TFSTT: Time&Frequency Solutions TimeTrace,
http://www.timefreq.com/pages/default.aspx?pageID=764
TSC2214 : Timing Solutions TSC 2214, *discontinued*, company absorbed by Symmetricom
TTS2 : Piktime Systems TTS-2, http://piktime.com/receivers.php

Single frequency, single channel receivers

TTR6 : Allen Osborne Associate TTR-6, *discontinued*, Company not existing anymore

List of GPS antennas types used in EURAMET T&F laboratories

No702: Novatel GPS-702, http://www.novatel.com/products/gps_701_702GG.htm
TCR: Thales Ashtech choke ring antenna:
http://www.ppmgmbh.de/ppm%20ov/pages_e/produkt_e/GPS%20Antennen/GPS_Antennen_Thales_Choke_Ring_e.html
Allen Osborne, Associates: discontinued
Ashtech SNOW: conical radome http://pro.magellangps.com/fr/support/antennaspecs.asp
Javad, Javad Mar Ant: http://javad.com/jgnss/products/antennas/
TCR3 : Topcon CR-3, dicontinued : http://www.topconpositioning.com/products/gps/antennas/
TSA: 3S Navigation TSA-100, http://3snavigation.com/TSA-100.html
M20A3A: Motorola GCNTM 20A3A, discontinued?
MOT: Motorola Oncore Timing antenna http://home.planet.nl/~niess153/gps/timing2000.pdf

For a list of antennas see: http://www.gps-solutions.com/ant_info.html#AOAD/M_T

Annex 2: Results of the survey

BEV (Austria)

Receiver	BEV1	BEV2	BEV3
Receiver local ID	s/n: 024	s/n: 054	410
Type of receiver	TTS2	TTS2	TTR6
Type of antenna			
S/N receiver/antenna	024/	054/	410/
public data	www.metrologie.at/GPSData_BEV	no	no
Calibrated	yes	yes	no
Date of last calibration	25.10.2006 - 31.10.2006 10.10.2007 – 11.10.2007	25.10.2006 - 31.10.2006 10.10.2007 – 11.10.2007	
Calibrated by	BIPM/TUG-Joanneum Research	BIPM/TUG-Joanneum Research	
Calibration procedure	BIPM document Joanneum Research report, BEV calibration report	BIPM document Joanneum Research report, BEV calibration report	
interest in campaign	yes	yes	yes
used for travelling reference	no	no	no
Point of contact	anton.niessner@bev.gv.at		

BIM (Bulgaria)

Receiver	BIM1	BIM2
Receiver/Antenna ID	SN :467 / SN : 583	SN : 057, 005 2007
Type of receiver	TTR6	TTS2
Type of antenna	Allen Osborne	Active micro strip patch Antenna Module
S/N receiver/antenna	467/583	057
public data		no
Calibrated	yes	no
Date of last calibration	24.11.2006-1.12.2006	
Calibrated by	BIPM	
Calibration procedure	Calibration of a GPS Receiver using the traveling TTS2 receiver, Version 3.0	
interest in campaign	no	yes
used for raveling reference	no	no
Point of contact	ts.aleksandrova@bim.government.bg	

DMDM (Serbia)

Receiver ID	ZMDM1
Receiver/Antenna ID	043 / AN08960115
Type of receiver	TTS2
Type of antenna	Motorola Oncore Timing 2000
S/N receiver/antenna	AN08960115/
public data	no
Calibrated	yes
Date of last calibration	14.12.2006

Calibrated by	BIPM
Calibration procedure	guide-bp0n-v4
interest in campaign	yes
used for travelling reference	no
Point of contact	marendic@dmdm@rs

EIM (Greece)

Receiver ID	EIM1
Receiver/Antenna ID	TSC 2214 s/n SP00191
Type of receiver	TSC2214
Type of antenna	
S/N receiver/antenna	SP00191/
public data	ftp2.bipm.org/pub/tai/data/
Calibrated	yes
Date of last calibration	25.05.2007
Calibrated by	NIST
Calibration procedure	In site comparison with UTC(NIST) through 1 PPS output with a time interval counter
interest in campaign	yes
used for travelling reference	no
Point of contact	hsara@eim.gr

GUM (Poland)

Receiver ID	GUM1	GUM2
Receiver/Antenna ID	Main system (SN 023/ no SN)	Reserve system
Type of receiver	TTS2	TTS2
Type of antenna	TSA-100, Temperature stabilized	GPS Timing 2000, Temperature stabilized
S/N receiver/antenna	023/	
public data	ftp:/212.244.160.69/gps_cv	no
Calibrated	yes	yes
Date of last calibration	2-6 October 2006	2-6 October 2006
Calibrated by	BIPM	GUM
Calibration procedure	BIPM document	According to BIPM document
interest in campaign	yes	yes
used for travelling reference	no	no
Point of contact	timegum@gum.gov.pl	

INM (Romania)

Receiver ID	NIMB1	NIMB2
Receiver/Antenna ID	TTS-2	PolaRx 2/ sn 5581
Type of receiver	TTS2	PRx2
Type of antenna	thermo stabilized antenna	choke ring antenna
S/N receiver/antenna		5481/
public data	bipm	no
Calibrated	yes	no
Date of last calibration	09-12.2006	
Calibrated by	BIPM	
Calibration procedure	Travelling receiver	

interest in campaign	no	yes
used for travelling reference	no	no
Point of contact	anca.niculescu@inm.ro	

IT (Italy)

Receiver ID	IT1	IT2	IT3
Receiver/Antenna ID	s/n 033 37.1	s/n 022 200	s/n RT 920010203
Type of receiver	TTS2	TTS3	AZ12T
Type of antenna	Temperature stabilized antenna Motorola GCNTM 20°3A	Javad Mar Ant	Choke Ring Antenna p.n. 701945-01
S/N receiver/antenna	033 37.1/AN 16N00218	022 200/MA#2426	RT 920010203/CR 520010512
public data	BIPM	no	IGS
Calibrated	yes	no	yes
Date of last calibration	11.2004		11.2007
Calibrated by	BIPM		BIPM
Calibration procedure	Travelling receiver		Travelling receiver
interest in campaign	yes	yes	yes
used for raveling reference	no	no	no
Point of contact	d.calonico@inrim.it		

LNE-SYRTE (France)

Receiver ID	LNE1	LNE2	LNE3
Receiver/Antenna ID	OPMT / 3S-02-TSADM S/N 00019	OMP2 / 3S-02-TSADM S/N 00019	TTR01
Type of receiver	AZ12T	AZ12T	TTR6
Type of antenna	TSA	TSA	Allan Osborne
S/N receiver/antenna			
public data	no	no	http://opdaf1.obspm.fr/utfic/gpsop.res
Calibrated	yes	yes	yes
Date of last calibration	2006	2006	2007
Calibrated by	BIPM	BIPM	BIPM
Calibration procedure	Travelling receiver	Travelling receiver	Travelling receiver
interest in campaign	yes	yes	yes
used for raveling reference	not yet		
Point of contact	Pierre.Uhrich@obspm.fr		

LATMB - SAMC (Latvia)

Receiver ID	LV1
Receiver/Antenna ID	O13 / 2161
Type of receiver	TTS3
Type of antenna	JAVAD MarAnt+
S/N receiver/antenna	013/2161
public data	
Calibrated	yes
Date of last calibration	06.03.2006
Calibrated by	SRC AOS , Poland

Calibration procedure	Differential calibration of the C/A code part of TTS-3 based on Rapport BIPM-95/12 and Rapport BIPM-2004/06
interest in campaign	yes
used for travelling reference	no
Point of contact	sergeijs.kasnajenko@latmb.lv

METAS (Switzerland)

Receiver ID	METAS1	METAS2	METAS3
Receiver/Antenna ID	WAB1(CH00)	WAB2(CH01)	WAB4(CH03)
Type of receiver	AZ12T	AZ12T	PRx2
Type of antenna	Ash 700936(D)	Ash 700936(F)	Ash 700936(E)
S/N receiver/antenna	3397/CR14345	RT91993201/CR1998390144	3289/CR14349
public data	BIPM ftp	BIPM ftp	BIPM ftp
Calibrated	yes	yes	yes
Date of last calibration	11/2004	12/2004	08/2008
Calibrated by	BIPM	BIPM	BIPM
Calibration procedure	Portable receiver	Portable receiver	Portable receiver
interest in campaign	yes	yes	yes
used for travelling reference	no	no	no
Point of contact	andre.stefanov@metas.ch		

MIKES (Finland)

Receiver ID	MIKES1
Receiver/Antenna ID	sn 235-0598/sn 2170204
Type of receiver	JLE
Type of antenna	Topcon CR-3
S/N receiver/antenna	235-0598/2170204
public data	ftp://62.161.69.5/pub/tai/data/200x/time_transfer
Calibrated	no
Date of last calibration	
Calibrated by	
Calibration procedure	
interest in campaign	yes
used for travelling reference	no
Point of contact	mikko.merimaa@mikes.fi

NPL (UK)

Receiver ID	NPL1	NPL2	NPL3
Receiver/Antenna ID	NPL Javad	NPL TFS101	NPL TFS102
Type of receiver	JLE	TFSTT	TFSTT
Type of antenna			
S/N receiver/antenna			
public data	no	ftp.npl.co.uk/pub/time/gpsmulti/	no
Calibrated	no	yes	yes
Date of last calibration		06.2002	2004
Calibrated by		BIPM	NPL Internal Calibration
Calibration procedure		Travelling receiver	comparison with

			TFS101 receiver
interest in campaign	yes	yes	yes
used for raveling reference	no	no	no
Point of contact	peter.whibberley@npl.co.uk		

ORB

Receiver	SMD1	SMD2
Receiver/Antenna ID	TTS-2	Septentrio
Type of receiver	TTS2	PRx2
Type of antenna	Temperature regulated	Choke ring antenna (Thales)
S/N receiver/antenna		
public data		
Calibrated	yes	
Date of last calibration	2005 and 2007	
Calibrated by	Poland	Septentrio
Calibration procedure	Comparison	Manufacturer
interest in campaign		
used for travelling reference	no	no

PTB (Germany)

Receiver ID	PTB1	PTB2	PTB3	PTB4
Receiver/Antenna ID	PTB04	PTB05	PTBB	PTBG
Type of receiver	TTS2	TTS3	AZ12T	AZ12T
Type of antenna		Javad	Ashtech Snow	Ashtech Snow
S/N receiver/antenna				
public data	ftp.ptb.de/pub/time/gps_multi	ftp.ptb.de/pub/time/TTS-3	BIPM ftp	BIPM ftp
Calibrated	yes	Factory	yes	no
Date of last calibration	10.2005		06.2006	
Calibrated by	BIPM		BIPM	
Calibration procedure	Portable receiver		Portable receiver	
interest in campaign	yes	yes	yes	yes
used for travelling reference	no	no	no	no
Point of contact	andreas.bauch@ptb.de			

SP (Sweden)

Receiver ID	SP1
Receiver/Antenna ID	SP01 SNR:0212/GPS antenna 1 SNR:258
Type of receiver	JLGGD
Type of antenna	Dorne-Margolin Choke ring
S/N receiver/antenna	0212/258
public data	no
Calibrated	yes
Date of last calibration	11.2005
Calibrated by	BIPM
Calibration procedure	LC(TWSTFT)
interest in campaign	yes

used for raveling reference	no
Point of contact	Kenneth.jaldehag@sp.se

UFE (Czech Republic)

Receiver	IPE1	IPE2	IPE3
Receiver/Antenna ID	TP04/A04	TP03/A03	TP02/A02
Type of receiver	GTR50	GTR50	TTR6
Type of antenna	Novatel GPS-702 dual frequency temperature stabilized	Novatel GPS-702 dual frequency temperature stabilized	AOA antenna
S/N receiver/antenna	02/NVH03400007	01/NVH03400034	412/639
public data	BIPM ftp and http://www.ufe.cz/dpt130/gps/	no	BIPM ftp
Calibrated	yes	no	no
Date of last calibration	January 2008		
Calibrated by	BIPM		
Calibration procedure	calibrated against the GTR-50 S/N0801068 of BIPM and afterwards at BIPM the GTR-50 S/N..68 against BP0C (P3) and BP0N (CGGTTS)	At IPE against TP04/A04 using MC CV GPS (both CGGTTS and P3)	At IPE against TP04/A04 using SC CV GPS
interest in campaign	yes		
used for raveling reference	no	no	no
Point of contact	kuna@ufe.cz		