

# **TIME TRANSFER USING GNSS**

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## Brazilian Time and Frequency Reference Laboratory ONRJ - DSHO

- National Observatory ONRJ >> 1827 D. Pedro I
- To conduct geographical, astronomical and geodetic studies to support maritime navigation and to contribute to the training of Brazilian Navy Academy officers
- To generate, maintain and disseminate the HLB Brazilian Legal Time (june/1913)  
TA(ONRJ) and UTC(ONRJ)



- old ONRJ campus

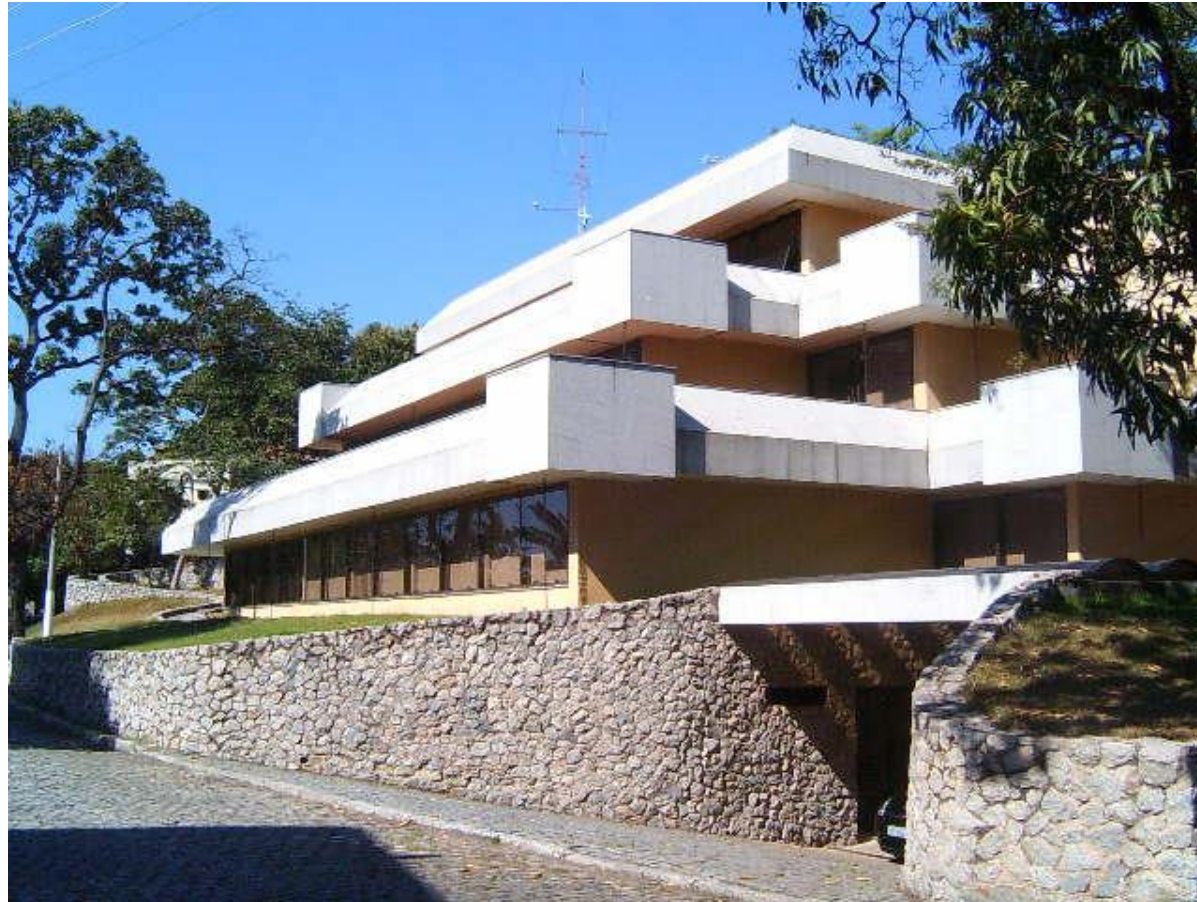


- ONRJ campus



# DSHO

- Brazilian LPTF - 1983



# DSHO

- HLB is generated from a set of:
  - 7 Cs clocks
  - 2 H Masers



# DSHO

- Calibration services
- Speaking clock (internet, phone)
- Synchronization
- Timestamping

**Bureau**  
↑ **International des**  
↑ **Poids et**  
↓ **Mesures**

- the intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards.

## The role and objectives of the BIPM

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- To coordinate the realization and improvement of the world-wide measurement system to ensure it delivers accurate and comparable measurement results.
- To undertake selected scientific and technical activities that are more efficiently carried out in its own laboratories on behalf of Member States.
- To promote the importance of metrology to science, industry and society, in particular through collaboration with other intergovernmental organizations and international bodies and in international forums.

The unique role of the BIPM enables it to achieve its mission by developing the technical and organizational infrastructure of the International System of Units (SI) as the basis for the world-wide traceability of measurement results. This is achieved both through technical activities in its laboratories and through international coordination.



# Time and Frequency Metrology

The BIPM organizes, for clock comparisons in TAI, an international network of time links:



Geographical distribution of the laboratories that contribute to TAI and time transfer equipment as of April 2013.

# TIME TRANSFER USING GNSS

## Remote Traceability to UTC (BIPM) and to UTC(ONRJ)

**Geodetic GNSS Receivers**  
+  
**Common View comparison**  
+  
**P3 and PPP methods**

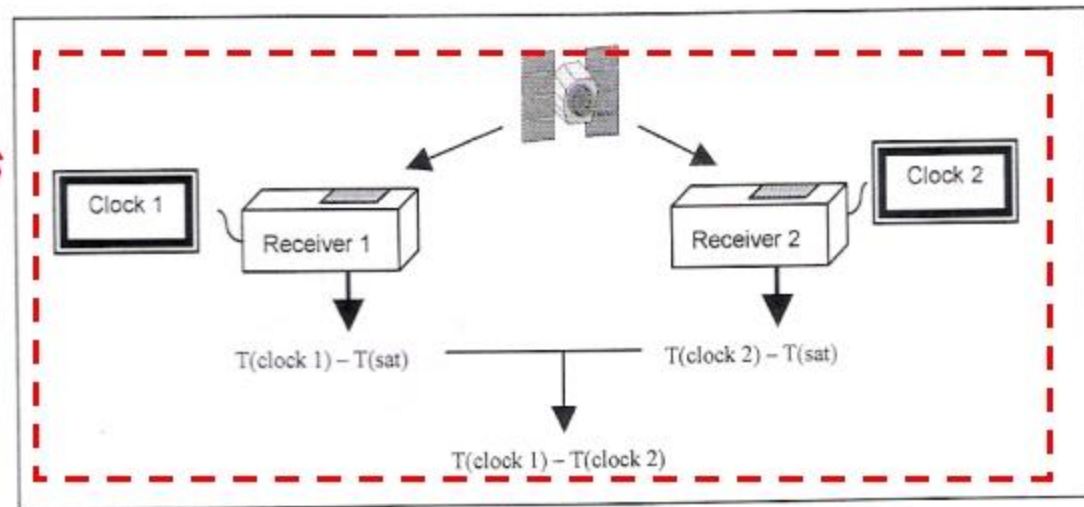


Fig. 1. Principle of common view.


## National Network of T&F Reference Stations

### *PolaRx2eTR Receiver* *PolaNT Antenna*

**GNSS Geodetic Receiver**  
(Septentrio Satellite Navigation) → > 12 GPS sats.

UTC (H maser) reference signal {  
 -10 MHz (precise frequency ref.)  
 -1PPS (precise time ref.)


Observation	Noise
C/A code	0,15m
P1, P2 code	0,10m
L1 phase	0,2mm
L2 phase	0,4mm



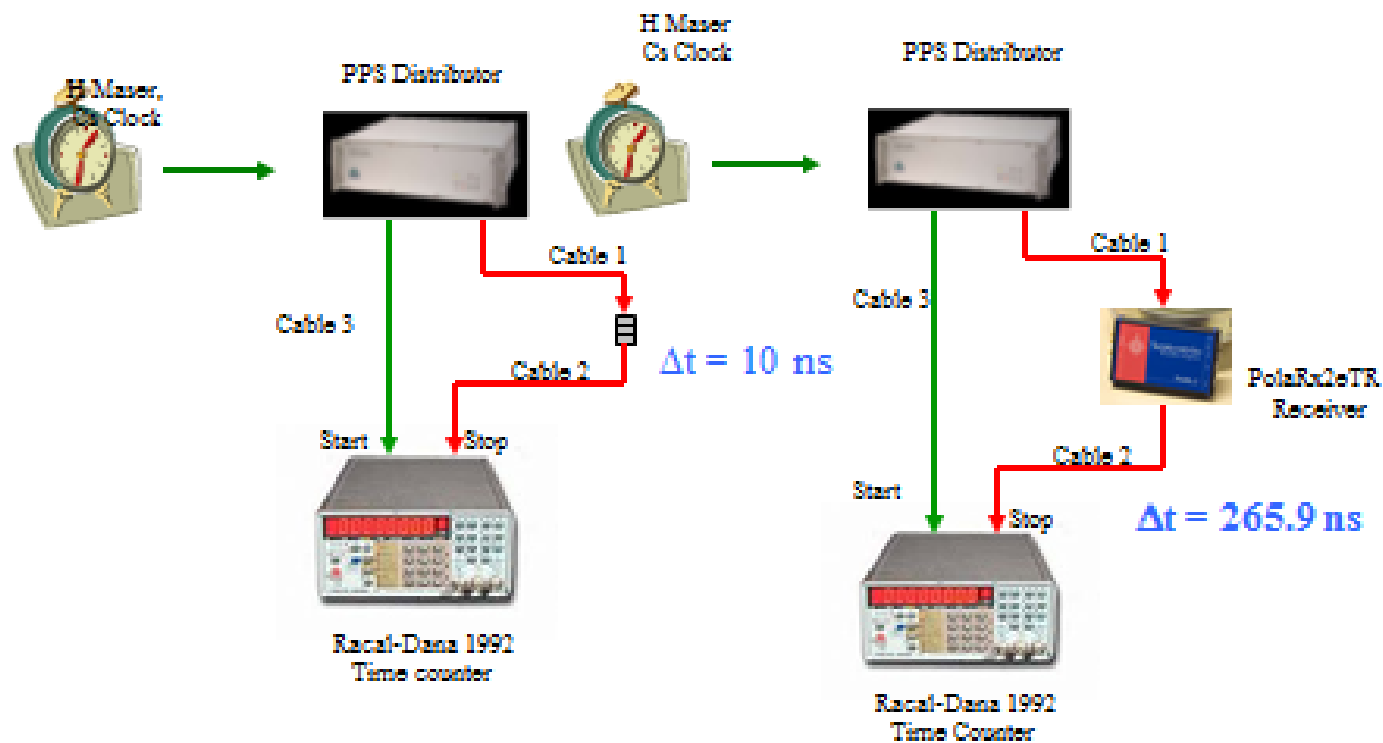
**Antenna**

L = 25 m

$\Delta t = 126.0$  ns



## *Receiver and cables calibration*





## GPS P1 and P2 calibration

### Definitions

XR: From external reference to 1PPS in

KD: From 1PPS in to internal reference (i.e. 20 MHz in inverter, delayed by 15.8 ns (Meas 3.1) or

20 MHz out advanced by 2.4 ns (Meas 3.2)

Not positive (anti-floating) XC, XD: Cables etc., from antenna to receiver (typically XC is long cable, XD is short cable(s) + splitter if needed)

XR: receiver internal delay, XD: antenna delay

BPC values (TM18, June 2002): XR1=281.1 ns, XR2=286.4 ns, XR1+XD1=308.6 ns, XR2+XD2=321.8 ns

### Set-up at BIPM May-June 2009

ITRF 2008 (epoch 2008.67)

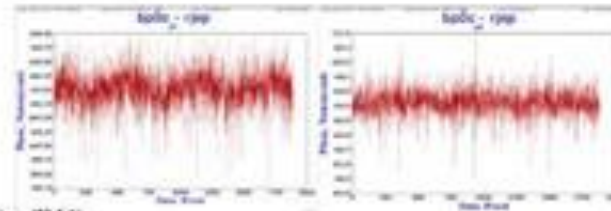
	XP081A to 1PPS in	Meas 3.1 (3.3) / ns	Meas 3.2 / ns	Ant. Cable / ns
BPC	54.7 ns	26.8	N/A	XC = 234.4 ns; XD = 0
	XP = 54.7 ns	ref ref - 1PPS in (XC) = 36.8 ns (using 3.1)		Short case: XC+XD = 234.4 ns
RJEP (PolaRx2)	XP = 45.7 ns	257.2		Short case: XC+XD = 126.7 ns
		ref ref - 1PPS in (XC) = 265.9 ns		

### Observations

Short baseline: day 149-152 (28 May-2 June 2009, MJD 54992.7-54992.8)

### Measurement results

0206/2009 (L. Tisserand) via RDC-DTTTS



Short baseline: MJD 54992.7-54992.8

Delta (-XR-KD+XR1+XC+XD+XD1) (MBRD - BPC) = -403.6 ns

Delta (-XR-KD+XR2+XC+XD+XD2) (MBRD - BPC) = -417.2 ns

### Calibration results

1306/2009 (G. Petit)

Short baseline

BPC: -XR-KD+XR1+XC+XD+XD1 = 448.7 ns

BPC: -XR-KD+XR2+XC+XD+XD2 = 455.3 ns

MBRD: -XR-KD+KD+XD = -183.9 ns

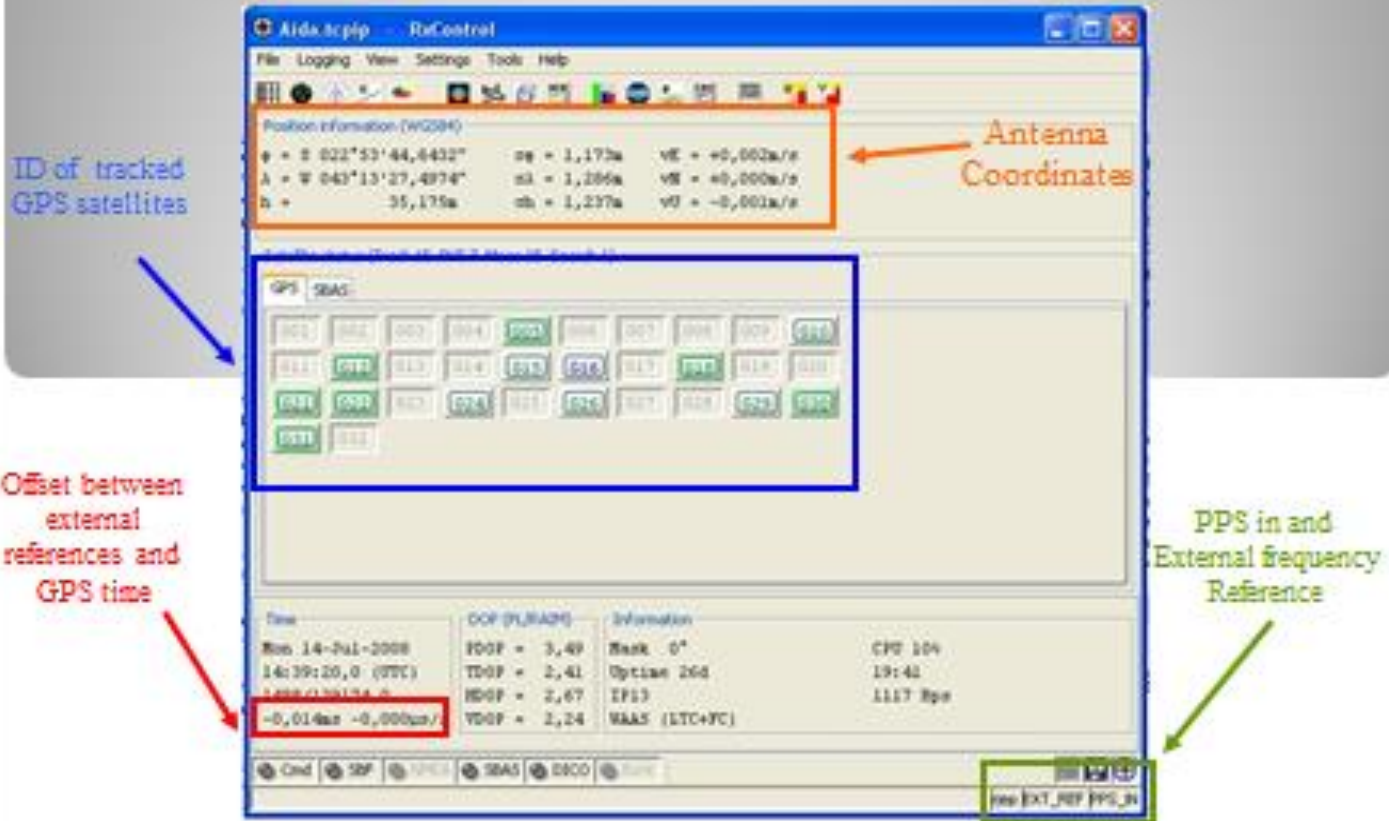
Therefore

**MBRD: XR1+XS1 = 229.0 ns (GPS -P1)**

**MBRD: XR2+XS2 = 231.7 ns (GPS -P2)**

$$\Delta t = \begin{cases} \text{GPS P1} = 229.0 \text{ ns} \\ \text{GPS P2} = 231.7 \text{ ns} \end{cases}$$

## RxControl Graphical Interface



**Antenna Coordinates**

**ID of tracked GPS satellites**

**Offset between external references and GPS time**

**PPS in and External frequency Reference**

Position Information (WGS84)

$\phi = 0\ 022^{\circ}53'44,6432''$	$eg = 1,172m$	$ve = +0,002m/s$
$\lambda = W\ 043^{\circ}13'27,4974''$	$sl = 1,286m$	$vs = +0,000m/s$
$b = 35,175m$	$sh = 1,237m$	$vf = -0,003m/s$

GPS SBAS

ID	HDOP	PDOP	SDOP	GDOP	Age	Use	Track	Alt	Vel	Acc
001	000	000	000	000	000	000	000	000	000	000
002	000	000	000	000	000	000	000	000	000	000
003	000	000	000	000	000	000	000	000	000	000
004	000	000	000	000	000	000	000	000	000	000
005	000	000	000	000	000	000	000	000	000	000
006	000	000	000	000	000	000	000	000	000	000
007	000	000	000	000	000	000	000	000	000	000
008	000	000	000	000	000	000	000	000	000	000
009	000	000	000	000	000	000	000	000	000	000
010	000	000	000	000	000	000	000	000	000	000
011	000	000	000	000	000	000	000	000	000	000
012	000	000	000	000	000	000	000	000	000	000
013	000	000	000	000	000	000	000	000	000	000
014	000	000	000	000	000	000	000	000	000	000
015	000	000	000	000	000	000	000	000	000	000
016	000	000	000	000	000	000	000	000	000	000
017	000	000	000	000	000	000	000	000	000	000
018	000	000	000	000	000	000	000	000	000	000
019	000	000	000	000	000	000	000	000	000	000
020	000	000	000	000	000	000	000	000	000	000

Time	DOF (PL/BAOP)	Information	
Mon 14-Jul-2008	EDOF = 3,49	Mask 0*	CPU 10%
14:39:20,0 (UTC)	TDOP = 2,41	Optim 26d	19:42
143920100.0	HDOP = 2,67	IF13	1117 Rps
	VDOP = 2,24	MAAS (LTC+PC)	

see EXT\_REF PPS\_IN

# Time transfer data

RJEP1190 - Bloco de notas

Arquivo Editar Formatar Exibir Ajuda

```

2.10 Observation data M (Mixed) RINEX VERSION / TYPE
sf2rjn (28-APR-03 20:59) PGM / RUN BY / DATE
COMMENT
L1: only bit 0 (loss of lock bit) supported
MARKER NAME
rjep MARKER NUMBER
Unknown OBSERVER / AGENCY
Unknown SEPT POLARX2 3.1.0 REC # / TYPE / VERS
3183 ANT # / TYPE
Unknown APPROX POSITION XYZ
4283639.3282 -4026024.0301 -2466098.8744 ANTENNA: DELTA H/E/N
0.0000 0.0000 0.0000 WAVELENGTH FACT L1/2
1 1 # / TYPES OF OBSERV
5 C1 L1 L2 P2 P1 INTERVAL
30.000 TIME OF FIRST OBS
2008 4 28 12 42 30.0000000 GPS TIME OF LAST OBS
2008 4 28 23 59 30.0000000 GPS COMMENT
END OF HEADER

```

**RINEX:**  
Receiver Independent Exchange  
(ftp://igsceb/data/format/rinex.txt)

**Header**

```

# 4 28 12 42 30.000000 0.11628627626617615610608607604524520
21910409.11009 560547.19609 424165.35209 21910409.40309 21910407.43009
24572908.77408 779187.31908 589729.00607 24572911.85107 24572907.01507
21050372.26209 -409203.67609 -309082.67009 21050374.39209 21050371.36409
20218111.92409 102438.08309 78080.69809 20218112.83209 20218111.15209
21754187.44609 -416606.63109 -314699.99209 21754188.75509 21754186.86909
24664972.73208 539770.35508 408515.56107 24664978.79807 24664973.73807
22545212.32309 349545.38009 264710.51309 22545213.82709 22545210.77009
25173675.18807 684177.47507 518120.15907 25173678.88107 25173674.47507
24073308.17908 -656833.14108 -497068.80608 24073312.40808 24073307.29908
39984425.09707 14910.73807
#7043482.31008 737.33408
# 4 28 12 43 30.000000 0.11628627626617615610608607604524520
21921700.37409 619884.63109 470402.25809 21921700.89209 21921699.83709
24588727.73408 862318.05808 654506.07207 24588731.39807 24588726.26907
21042721.66409 -449409.11209 -340391.61809 21042722.98309 21042720.47309
20220746.26809 116281.77309 88867.95409 20220747.15709 20220745.35009
21746350.52509 -457789.44209 -346790.54209 21746352.44009 21746350.01709
2467 17 5961 7 45244 2467571 8 24675 :08
2251 19 3876 9 29443 225524 9 22552 :09
2518 17 7573 7 57515 251876 7 25187 :07
2406 18 -7265 8 -55144 240600 8 24060 :08
39984980.70407 17829.13407
37043497.99808 842.98608
# 4 28 12 43 30.000000 0.11628627626617615610608607604524520
21932999.39509 579259.10109 516668.01309 21932999.83409 21932998.15409
24604580.92407 945628.22307 719422.93907 24604585.06507 24604580.12307
21035178.98809 -489045.13009 -371276.86409 21035181.23509 21035178.24509
20223490.37109 130701.82109 100104.31809 20223491.41609 20223489.93109
21738614.89309 -498441.46509 -378467.47609 21738616.30009 21738614.35609
25078399.39707 390936.62907
24686408.03007 552407.04207 406283.99308 24686414.04708 24686408.01008
2559777.02009 426083.99709 324350.87509 2559778.51509 2559775.92609

```

**Data**

**Label** ID of satellites and systems

**Frequencies:**  
 $f_1 = 1575,42$  MHz  
 $f_2 = 1227,60$  MHz

**Pseudo Range (m):**  
P1, P2, C/A

**Phases:**  
L1 e L2

## Rinex to CGGTTS format

CGGTTS → CCTF Group on GNSS Time Transfer Standards

```

RINEX OBSERVATION DATA FORMAT VERSION # 02
SV DATE = 2011-0-12
CVR = SEPT POLARIS V3.2.0 SM:0100 R000GTTT v4.2
N = 16 (GPS)
RS = SEPT POLARIS V3.2.0 SM:0100
AB = 08

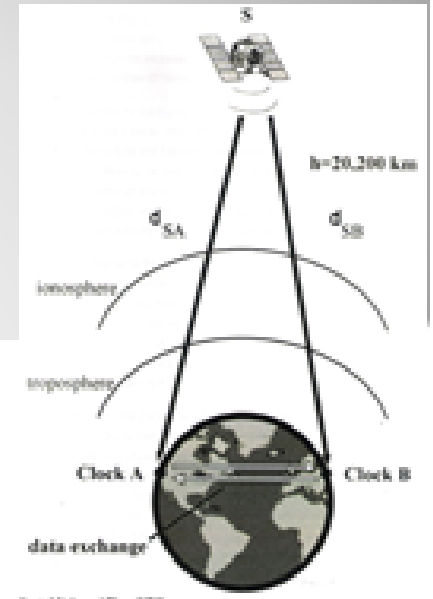
# -4200044.47 m (GPS)
# -6026029.01 m (GPS)
# -2466100.31 m (GPS)
PAMA = 1190
COMMENTS = ReConical Auto-Generated File
MT DLT = 126.9 ns (GPS P1), 131.0 ns (GPS P2)
AB DLT = 126.0 ns (GPS)
EP DLT = 478.4 ns
EP = UTC(OHBJ)
RCON = 01
  
```

FRN CL	SJD	STTIME	RK1	ELV	ASTH	REFSV	SRSV	REFGPS	RGPS	DOO	DOE	#
		hhmmss	m	ddg	ddg	mm	mm/m	mm	mm/m	mm	mm	
7	P1	000100	700	438	2803	-150797	-27	-341	-24	43	21	
24	P1	000200	700	168	3548	-6002348	-83	-396	-51	39	80	
11	P1	000300	700	60	49	+1612348	+72	-427	+39	51	87	
4	P1	000400	700	175	2480	-1489488	-179	-381	-71	60	87	
8	P1	000500	700	188	3048	-82995	+51	-366	+52	44	41	
13	P1	000600	700	415	2071	-2646762	+66	-332	+49	39	118	
32	P1	000700	700	423	489	+2770090	-30	-284	-100	21	50	
20	P1	000800	700	791	410	-500800	+144	-234	+147	24	88	
23	P1	000900	700	481	1574	-2977273	+66	-150	+17	30	87	
16	P1	001000	700	366	1119	+1803088	+109	-335	+84	38	97	
7	P1	001800	700	480	2802	-150761	+29	-294	+41	32	51	
24	P1	001900	700	113	4	-6002397	+167	-416	+179	45	80	
4	P1	001900	700	185	2522	-1489433	-163	-414	-57	47	87	
8	P1	001900	700	240	3009	-82993	+3	-303	+4	33	41	
3	P1	001900	700	63	766	-7314730	-52	-392	-1	23	34	
13	P1	001900	700	437	1980	-2646709	+104	-296	+87	53	118	
32	P1	001900	700	359	438	+2770102	+91	-261	+39	30	50	
10	P1	001900	700	134	2193	+62561	-124	-483	-135	35	21	
20	P1	001900	700	655	309	-500845	-75	-266	-71	27	88	
24	P1	001900	700	499	1464	-1507997	+71	-314	-9	38	87	

Antenna position

Delays

External reference



P3 code:

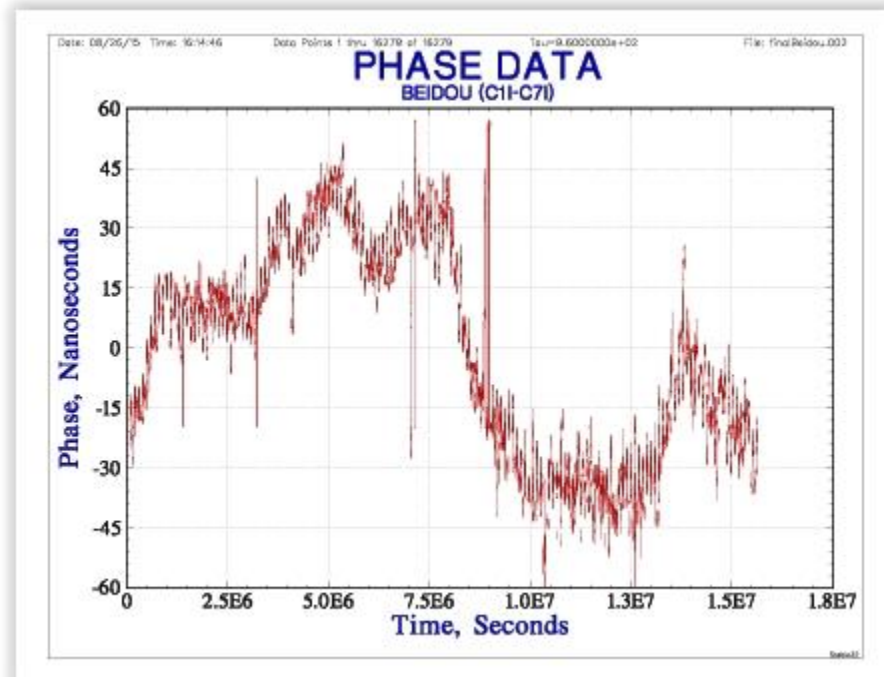
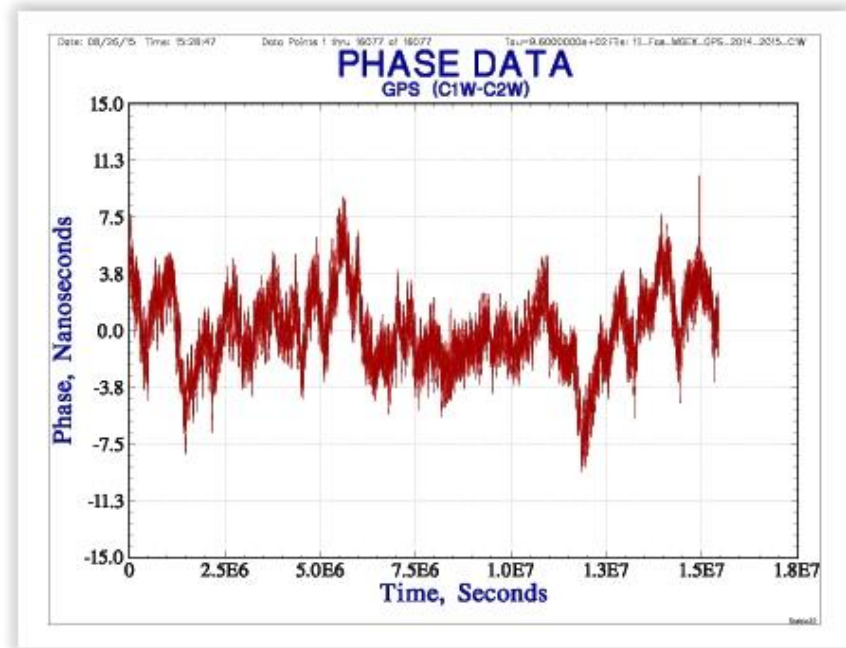
$$P3 = \frac{(f_1^2 * P1 - f_2^2 * P2)}{(f_1^2 - f_2^2)}$$

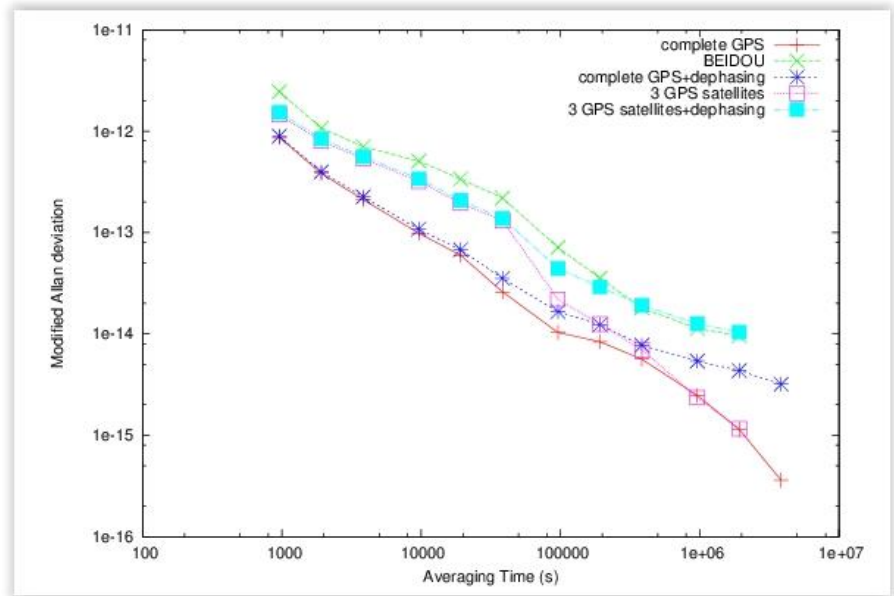
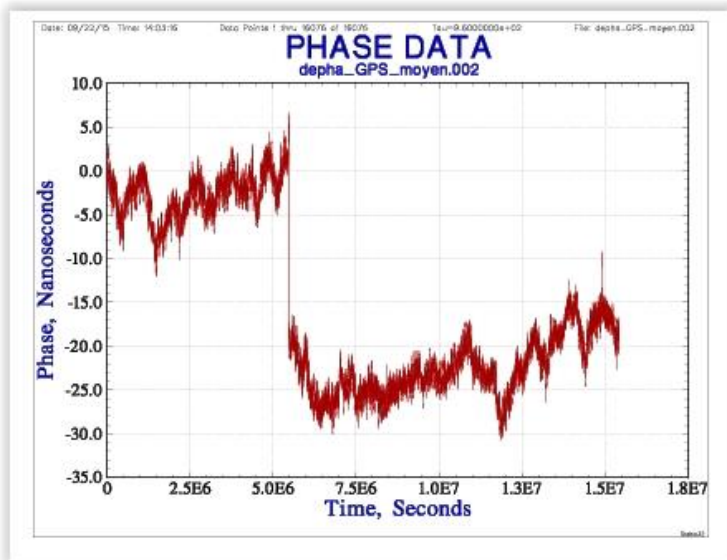
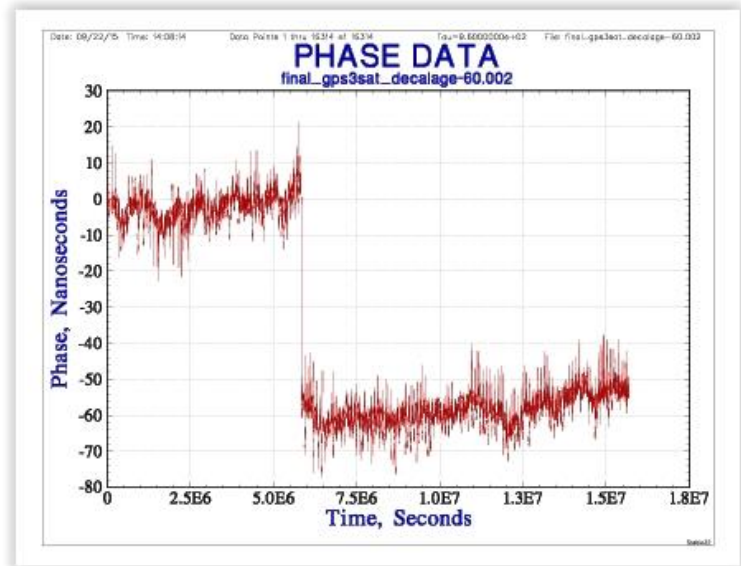
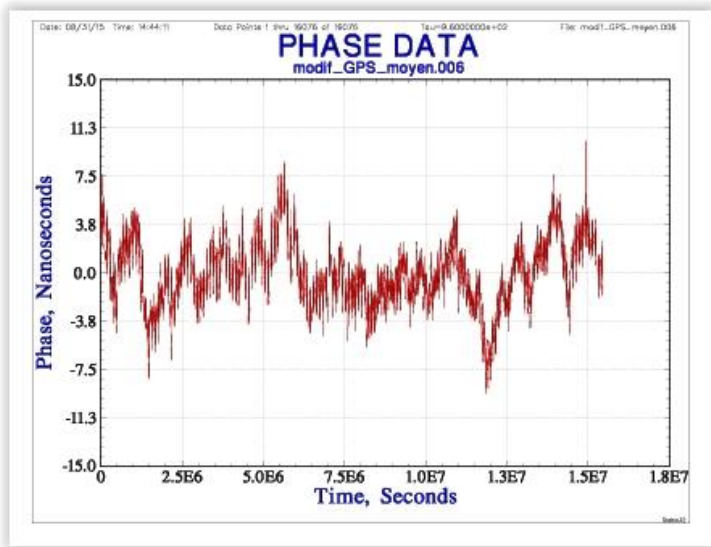


# BEIDOU and GPS Data

3.02		OBSERVATION DATA				M	RINEX VERSION / TYPE				
sbf2rin-9.4.0						20150310 210556 LCL	PGM / RUN BY / DATE				
rjep						MARKER NAME					
Unknown						MARKER NUMBER					
SJ		ONRJ				OBSERVER / AGENCY					
3001290		SEPT POLARX4TR				2.6-BDS-Beta		REC # / TYPE / VERS			
Unknown		Unknown				ANT # / TYPE					
4283631.4054		-4025962.5718 -2466126.1688				APPROX POSITION XYZ					
0.0000		0.0000 0.0000				ANTENNA: DELTA H/E/N					
<b>G</b>	<b>9</b>	<b>C1C</b>	<b>L1C</b>	<b>C1W</b>	<b>C2W</b>	<b>L2W</b>	<b>C2L</b>	<b>L2L</b>	<b>C5Q</b>	<b>L5Q</b>	<b>SYS / # / OBS TYPES</b>
E	8	C1C	L1C	C5Q	L5Q	C7Q	L7Q	C8Q	L8Q		SYS / # / OBS TYPES
R	6	C1C	L1C	C2P	L2P	C2C	L2C				SYS / # / OBS TYPES
<b>C</b>	<b>4</b>	<b>C1I</b>	<b>L1I</b>	<b>C7I</b>	<b>L7I</b>						<b>SYS / # / OBS TYPES</b>
G	L1C	0.000000									SYS / PHASE SHIFT
G	L2W	0.000000									SYS / PHASE SHIFT
G	L2L	0.000000									SYS / PHASE SHIFT
G	L5Q	0.000000									SYS / PHASE SHIFT
E	L1C	0.000000									SYS / PHASE SHIFT
E	L5Q	0.000000									SYS / PHASE SHIFT
E	L7Q	0.000000									SYS / PHASE SHIFT
E	L8Q	0.000000									SYS / PHASE SHIFT
R	L1C	0.000000									SYS / PHASE SHIFT
R	L2P	0.000000									SYS / PHASE SHIFT
R	L2C	0.000000									SYS / PHASE SHIFT
C	L1I	0.000000									SYS / PHASE SHIFT
C	L7I	0.000000									SYS / PHASE SHIFT
30.000											INTERVAL
2015		3	10	0	0	0.0000000	<b>GPS</b>				TIME OF FIRST OBS
											END OF HEADER
> 2015 03 10 17 44 30.0000000 0 22											
<b>G15</b>	23173636.432	7	121778380.26207	23173636.445	5	23173649.041	5				
94892318.35605	23173649.456	6	94892349.36506								
<b>G31</b>	25261218.401	6	132748453.18606	25261218.245	2	25261236.248	2				
103440355.34002	25261237.447	5	103440349.36005								
<b>G18</b>	20137469.344	8	105823248.41908	20137468.674	7	20137475.913	7				
82459764.88807											
<b>G29</b>	21232435.015	8	111577127.75808	21232434.926	6	21232443.791	6				
86943217.00606	21232444.021	7	86943216.99407								
<b>G25</b>	23113635.067	7	121462726.92907	23113634.580	4	23113657.408	4				
94646254.10004	23113657.030	6	94646249.05406	23113662.891	7	90702652.15807					
<b>G22</b>	22507677.836	7	118278689.59507	22507676.871	5	22507689.601	5				
92165265.92405											
<b>G16</b>	24172146.635	6	127025527.47406	24172146.050	3	24172159.865	3				
98980988.19103											
<b>G21</b>	20804022.064	8	109325970.82108	20804021.269	6	20804028.503	6				
85189128.17506											
<b>G08</b>	25589623.448	6	134474268.34006	25589622.661	2	25589644.765	2				
104785177.10602											
<b>C14</b>	26553321.328	6	138270105.19306	26553337.950	6	106919283.72906					
<b>C12</b>	22046892.948	8	114803977.70508	22046899.622	8	88773758.64408					
<b>C11</b>	25404680.098	6	132288880.66306	25404694.475	7	102294231.68607					

# BEIDOU and GPS Data





**Thank you**