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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

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- old ONRJ campus

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- ONRJ campus

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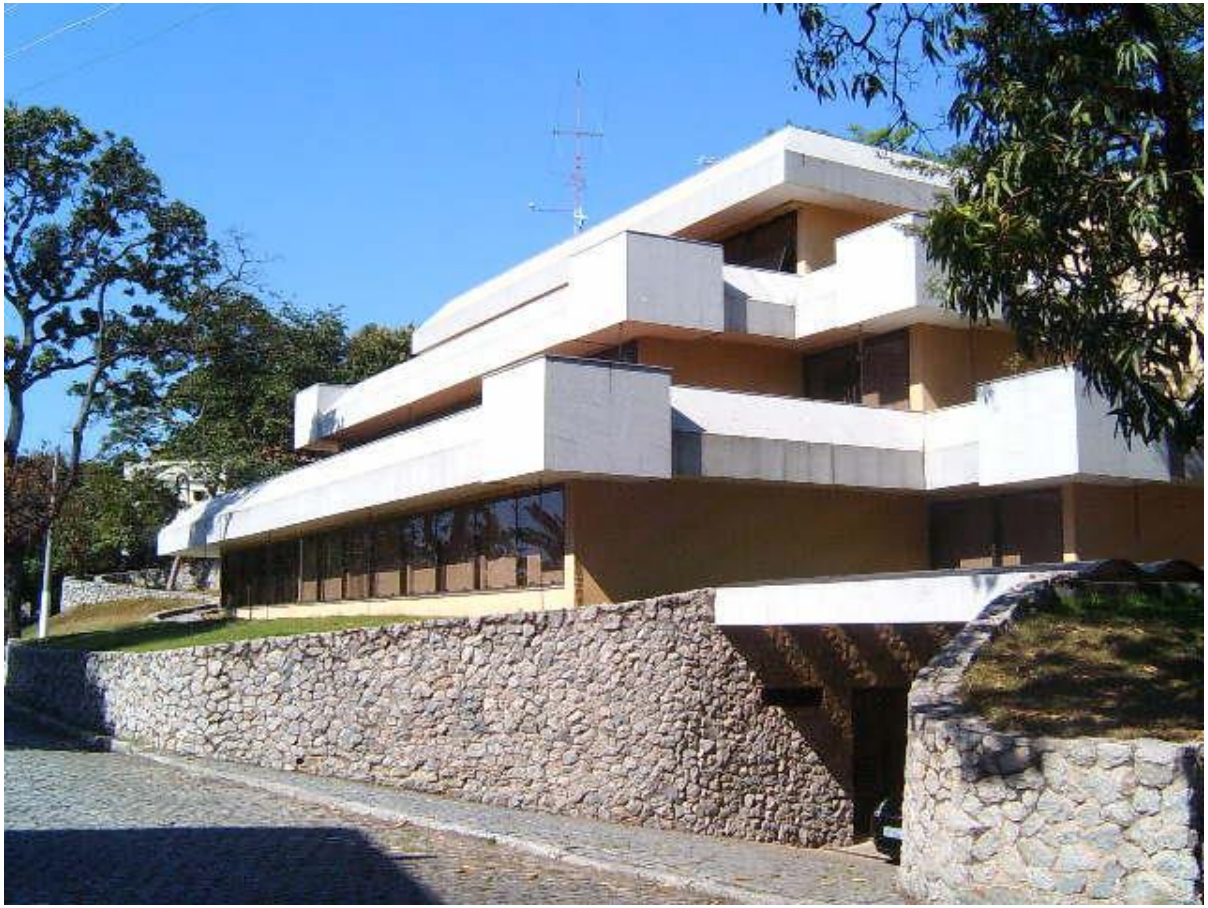
DSHO

- Brazilian LPTF - 1983



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DSHO

- HLB is generated from a set of:

  7 Cs clocks

  2 H Masers

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DSHO

- Calibration services

- Speaking clock (internet, phone)

- Synchronization

- Timestamping

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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

- 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.

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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.

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TIME TRANSFER USING GNSS

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

Geodetic GNSS Receivers

+

Common View comparison

+

P3 and PPP methods

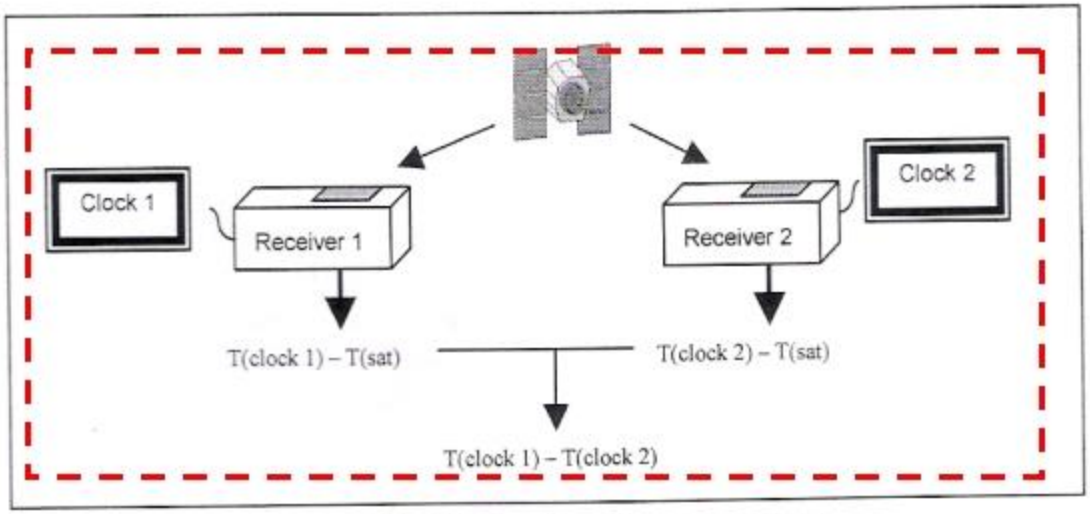

Fig. 1. Principle of common view.

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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.)

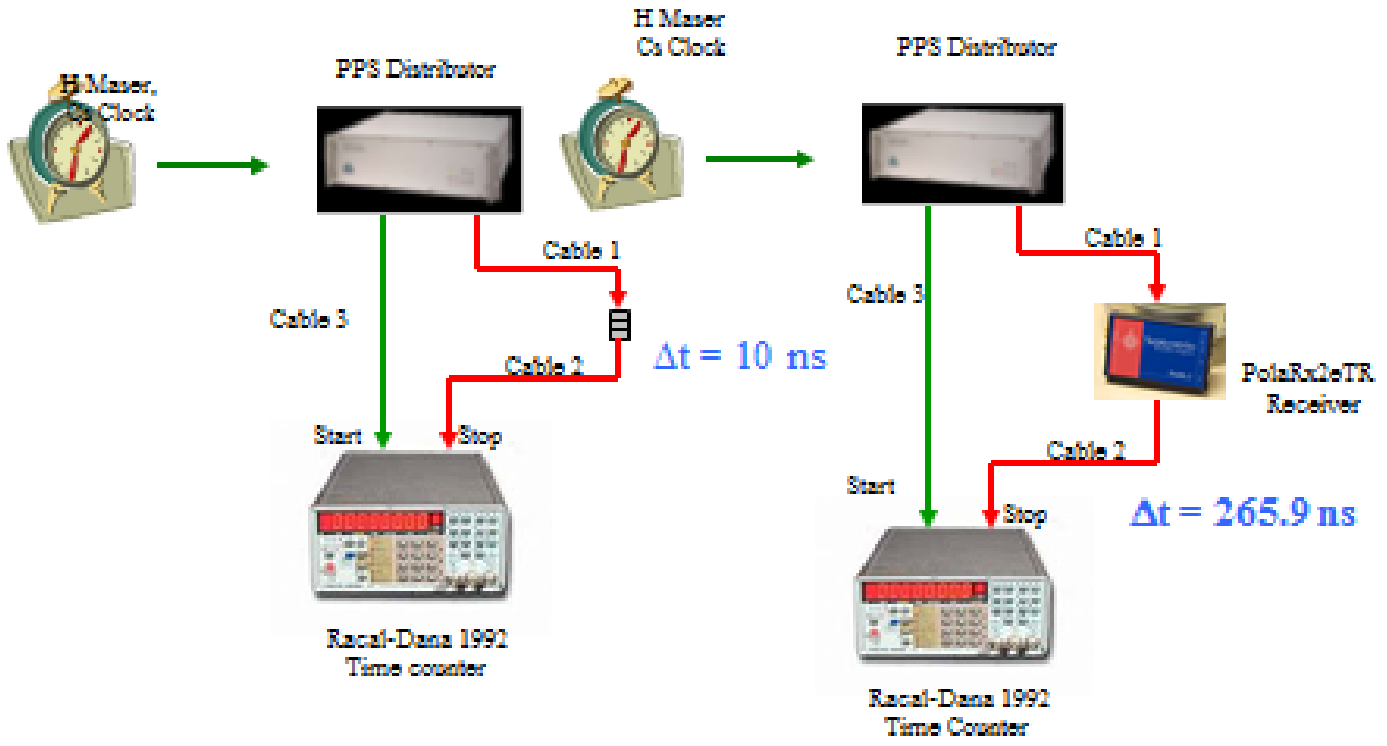
Observation	Noise
C/A code	0,15m
P1, P2 code	0,10m
L1 phase	0,2mm
L2 phase	0,4mm

Antenna

L = 25 m

Δt = 126.0 ns

Receiver and cables calibration



GPS P1 and P2 calibration

Definitions

XR: From external reference to 1PPS in

XD: From 1PPS in to internal reference (i.e. 20 MHz in inverted, delayed by 15.6 ns (Meas 3.1) or 20 MHz out advanced by 2.4 ns (Meas 3.2)).
first positive zero crossing). XC, XD: Cables etc... from antenna to receiver (typicaly XC is long cable, XD is short cable(s) + splitter if needed)

XR: receiver internal delay; XS: antenna delay

BIPC values (TM118: June 2002): XR1=281.1 ns; XR2=295.4 ns; XR1+XS1=305.6 ns; XR2+XS2=321.9 ns)

Set-up at BIPM May-June 2009

ITRF 2005 (epoch 2008.67)

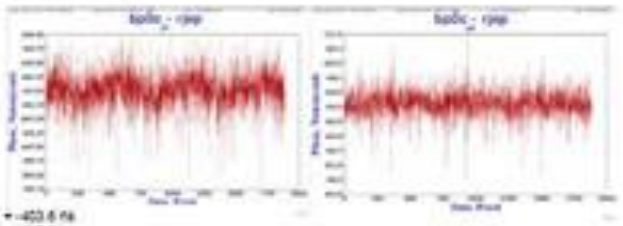
	5071A to 1PPS in	Mseas 3.1 (3.3) / ns	Meas 3.2 / ns	Ant. Cable / ns
BIPC	54.7 ns XP = 54.7 ns	20.0 int ref - 1PPSin (XD) = 36.6 ns (using 3.1)	N/A	XC = 234.4 ns; XD = 0 Short base: XC+XD = 234.4 ns
RJEP (PolaRx2)	XP = 46.7 ns	287.2 int ref - 1PPSin (XD) = 265.9 ns		Short base: XC+XD = 126.7 ns

Observations

Short baseline: doy 149-152 (29 May-2 June 2009, MJD 54980.7-54983.9)

Measurement results

02/06/2009 (L. Tisserand) via R2CGGTTS



Short baseline: MJD: 54980.7-54983.9

Delta [-XP-XD+XR1+XC+XD+XS1] (MBRG - BIPC) = -403.6 ns

Delta [-XP-XD+XR2+XC+XD+XS2] (MBRG - BIPC) = -417.2 ns

Calibration results

17/06/2009 (G. Petit)

Short baseline

BIPC: -XP-XD+XR1+XC+XD+XS1 = 448.7 ns

BIPC: -XP-XD+XR2+XC+XD+XS2 = 465.0 ns

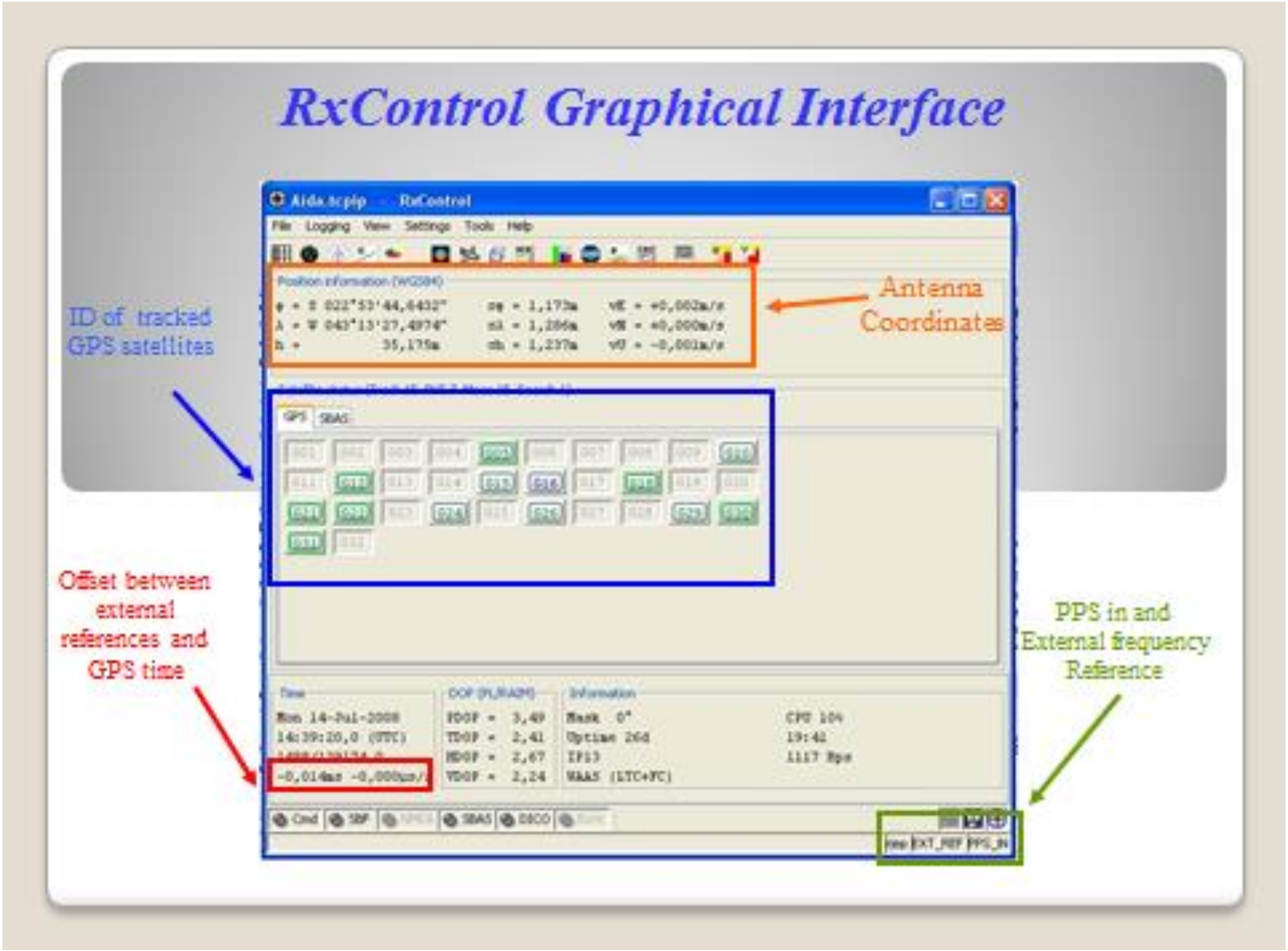
MBRG: -XP-XD+XC+XD = -183.9 ns

Therefore

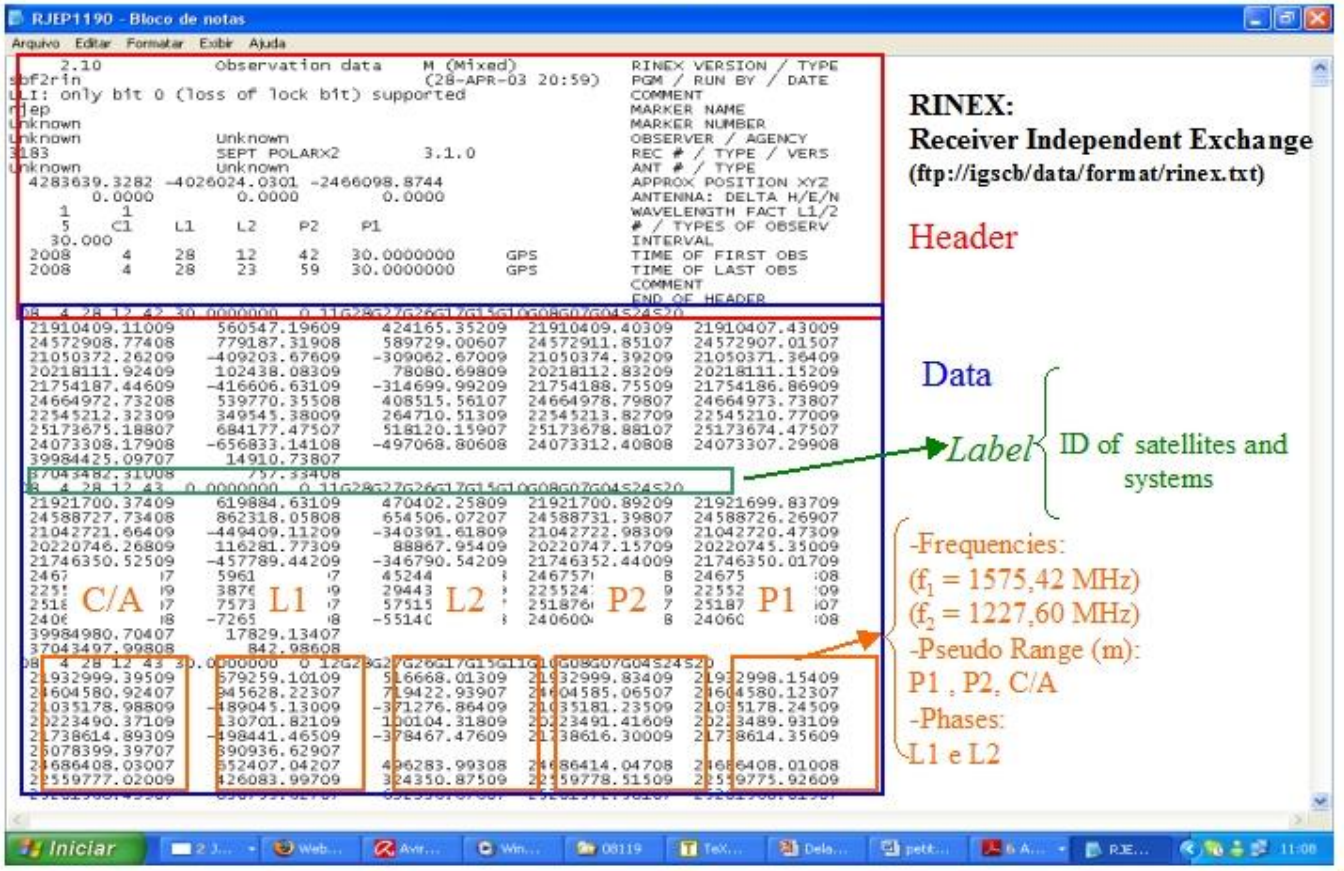
MBRG: XR1+XS1 = 229.0 ns (GPS –P1)

MBRG: 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
ID of tracked GPS satellites
Antenna Coordinates
Offset between external references and GPS time
PPS in and External frequency Reference

Time transfer data



Rinex to CGGTTS format

CGGTTS → CCTF Group on GNSS Time Transfer Standards

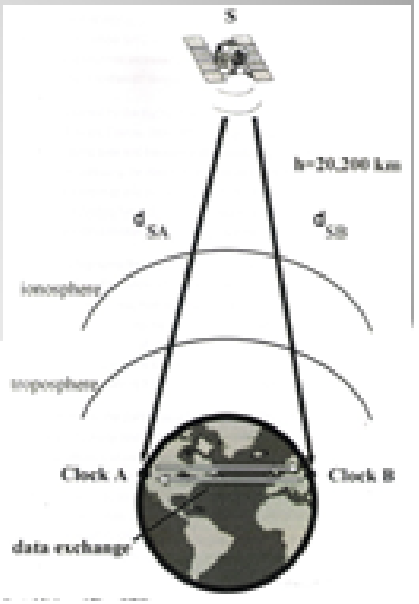
```
REV DATE = 2011-5-13
RCVR = SEPT POLARX2 v3.2.0 SN:3183    RINCGGTTS v4.2
CH = 16 (GPS)
ANT = SEPT POLARX2 v3.2.0 SN:3183
APC = OBS
X = -4420544.42 m (GPS)
Y = -4024029.01 m (GPS)
Z = -2466102.31 m (GPS)
FRAME = ITRF
COMMENTS = ReControl Auto-Generated File
INT DLY =  128.9 ns (GPS P1),  131.0 ns (GPS P2)
CAB DLY =  126.0 ns (GPS)
REF DLY =  476.4 ns
REF = UTC(ONRJ)
REMARK = GL
```

Antenna position

Delays

External reference

PRN	CL	MJD	STTIME	TRKL	ELV	AZTH	REFSV	SRSV	REFGPS	SRGPS	DSG	IOE	MDTR
			hhmmss	s	.1dg	.1dg	.1ns	.1ps/s	.1ns	.1ps/s	.1ns		.1ns
7	FF	55733	000200	780	438	2903	-150797	-27	-341	-14	43	21	
24	FF	55733	000200	780	168	3568	-4002346	-83	-396	-51	39	80	
11	FF	55733	000200	780	60	49	+1612348	+72	-427	+39	51	87	
4	FF	55733	000200	780	175	2450	-1499488	-179	-381	-72	60	67	
8	FF	55733	000200	780	188	3048	-82995	+51	-366	+52	44	41	
13	FF	55733	000200	780	415	2071	-2646762	+66	-332	+49	39	118	
32	FF	55733	000200	780	423	499	+2770090	-30	-284	-102	21	50	
20	FF	55733	000200	780	731	410	-500830	+144	-234	+147	24	85	
23	FF	55733	000200	780	481	1574	-2977273	+46	-250	+17	30	67	
16	FF	55733	000200	780	366	1319	+1803088	+109	-335	+84	38	97	
7	FF	55733	001800	780	480	2802	-150761	+29	-294	+41	32	21	
24	FF	55733	001800	780	113	4	-4002397	+147	-416	+179	45	80	
4	FF	55733	001800	780	185	2512	-1499633	-163	-414	-57	47	67	
8	FF	55733	001800	780	240	3009	-82933	+9	-303	+4	33	41	
3	FF	55733	001800	780	63	766	-7314730	-52	-392	-1	23	34	
13	FF	55733	001800	780	437	1980	-2646709	+104	-296	+87	53	118	
32	FF	55733	001800	780	359	438	+2770102	+91	-341	+19	30	50	
10	FF	55733	001800	780	134	2193	+462561	-124	-483	-135	35	21	
20	FF	55733	001800	780	655	309	-500865	-75	-266	-72	27	85	
31	FF	55733	001800	780	499	1464	-1979949	+91	-356	-9	38	49	



P3 code:

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

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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
G    9 C1C L1C C1W C2W L2W C2L L2L C5Q L5Q                  SYS / # / OBS TYPES
E    8 C1C L1C C5Q L5Q C7Q L7Q C8Q L8Q                      SYS / # / OBS TYPES
R    6 C1C L1C C2P L2P C2C L2C                              SYS / # / OBS TYPES
C    4 C1I L1I C7I L7I                                      SYS / # / OBS TYPES
G L1C  0.00000                                             SYS / PHASE SHIFT
G L2W  0.00000                                             SYS / PHASE SHIFT
G L2L  0.00000                                             SYS / PHASE SHIFT
G L5Q  0.00000                                             SYS / PHASE SHIFT
E L1C  0.00000                                             SYS / PHASE SHIFT
E L5Q  0.00000                                             SYS / PHASE SHIFT
E L7Q  0.00000                                             SYS / PHASE SHIFT
E L8Q  0.00000                                             SYS / PHASE SHIFT
R L1C  0.00000                                             SYS / PHASE SHIFT
R L2P  0.00000                                             SYS / PHASE SHIFT
R L2C  0.00000                                             SYS / PHASE SHIFT
C L1I  0.00000                                             SYS / PHASE SHIFT
C L7I  0.00000                                             SYS / PHASE SHIFT
    30.000                                                 INTERVAL
  2015     3    10     0     0    0.0000000      GPS        TIME OF FIRST OBS
……                                                            END OF HEADER
> 2015 03 10 17 44 30.0000000  0 22
G15  23173636.432 7 121778380.26207  23173636.445 5  23173649.041 5
94892318.35605  23173649.456 6  94892349.36506
G31  25261218.401 6 132748453.18606  25261218.245 2  25261236.248 2
103440355.34002  25261237.447 5 103440349.36005
G18  20137469.344 8 105823248.41908  20137468.674 7  20137475.913 7
82459764.88807
G29  21232435.015 8 111577127.75808  21232434.926 6  21232443.791 6
86943217.00606  21232444.021 7  86943216.99407
G25  23113635.067 7 121462726.92907  23113634.580 4  23113657.408 4
94646254.10004  23113657.030 6  94646249.05406  23113662.891 7  90702652.15807
G22  22507677.836 7 118278689.59507  22507676.871 5  22507689.601 5
92165265.92405
G16  24172146.635 6 127025527.47406  24172146.050 3  24172159.865 3
98980988.19103
G21  20804022.064 8 109325970.82108  20804021.269 6  20804028.503 6
85189128.17506
G08  25589623.448 6 134474268.34006  25589622.661 2  25589644.765 2
104785177.10602
C14  26553321.328 6 138270105.19306  26553337.950 6 106919283.72906
C12  22046892.948 8 114803977.70508  22046899.622 8  88773758.64408
C11  25404680.098 6 132288880.66306  25404694.475 7 102294231.68607
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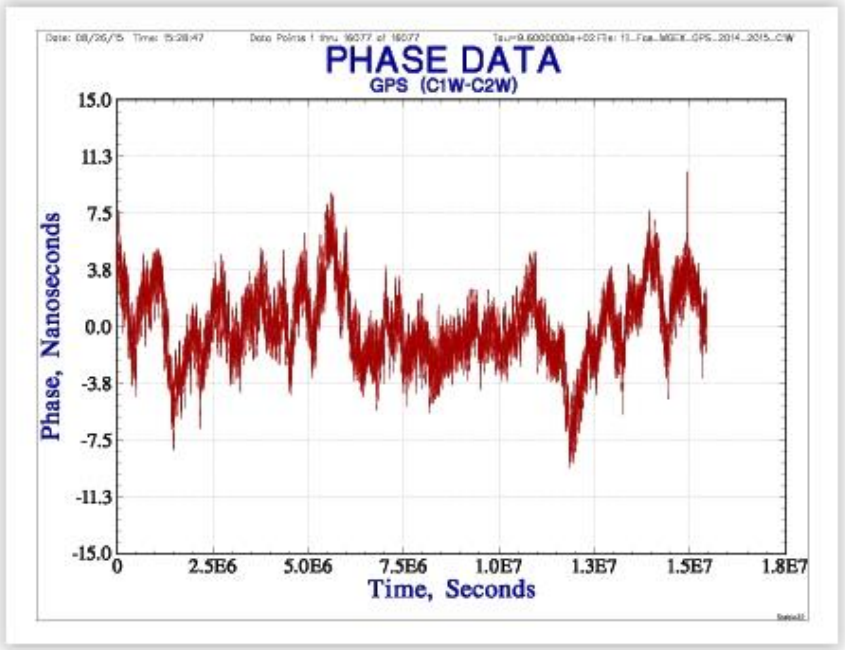
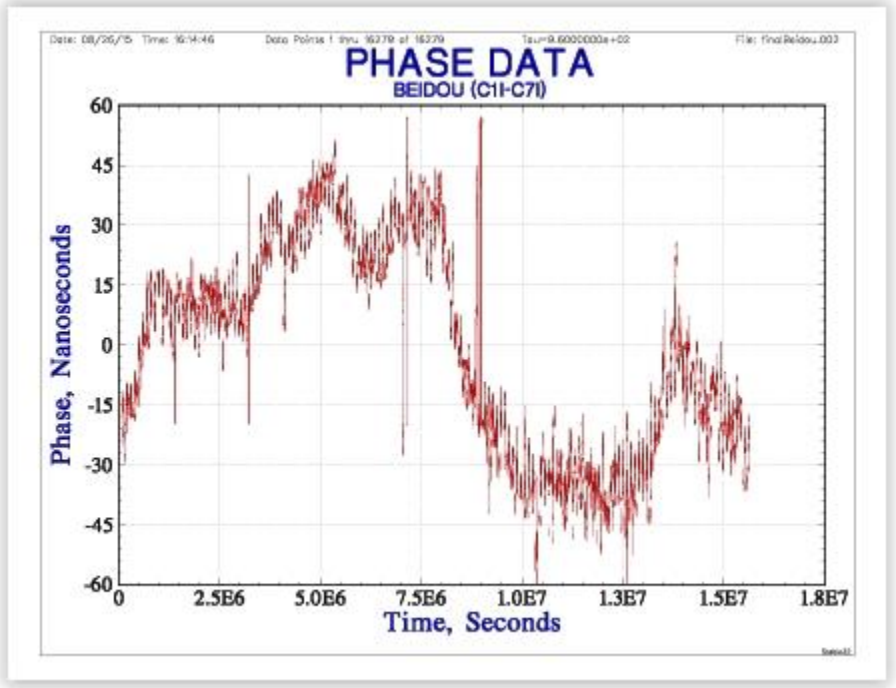
BEIDOU and GPS Data





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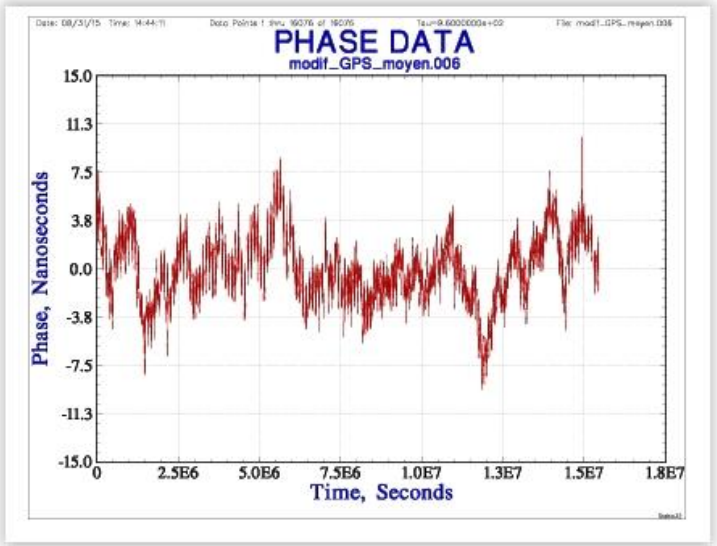

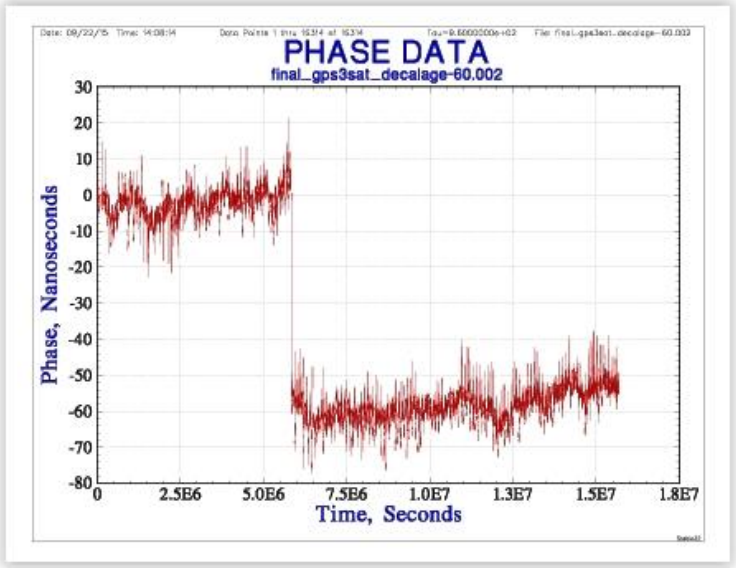

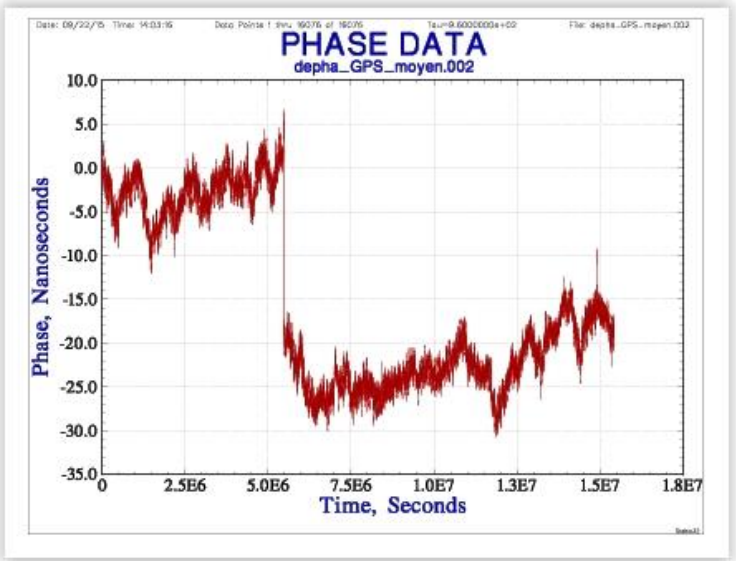

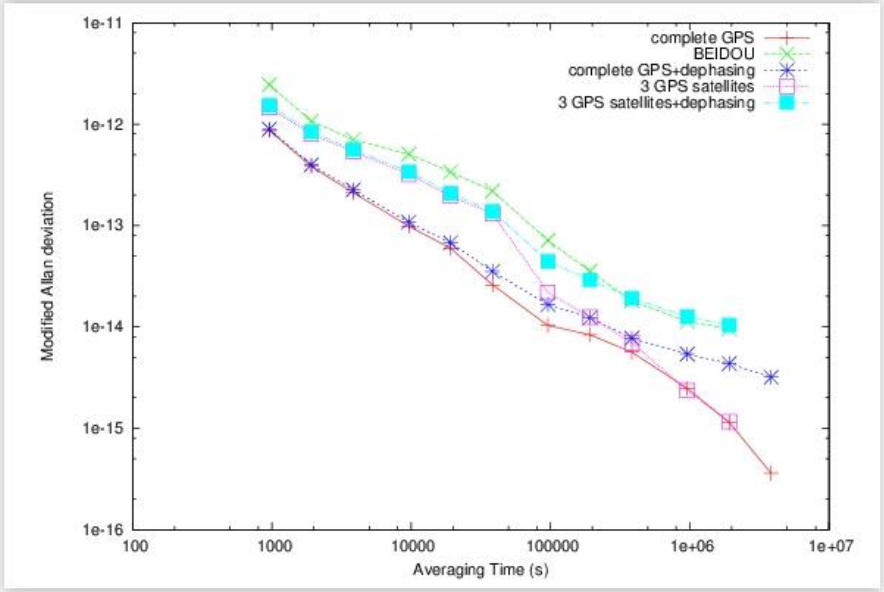

ICG Experts Meeting - 2015

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Thank you