中国计量科学研究院
National Institute of Metrology,China

Asia Pacific Metrology Programme

Time and frequency transfer methods based on GNSS

LIANG Kun, National Institute of Metrology(NIM), China

APMP DEC Workshop on GPS time-transfer and calibration techniques, Taipei, September 27-30, 2016

Outline

- Remote time and frequency transfer
- GNSS time and frequency transfer methods
- Data and results
- Characteristics, equipment and operation
- Application and extension
- Time link calibration

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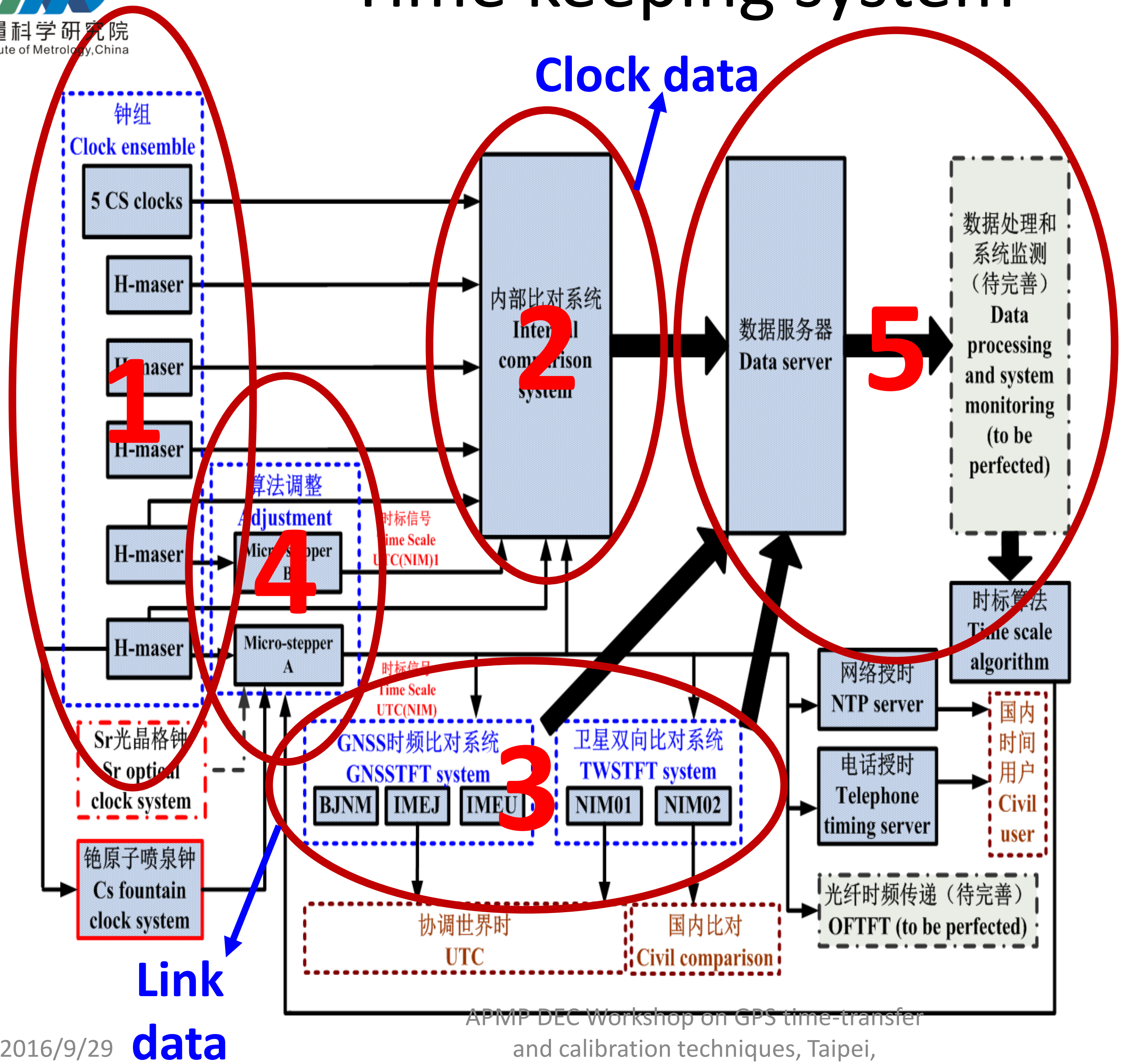
Time keeping system



1.Clock ensemble: generate the time and frequency signals continuously

2.Internal comparison system: compare the clocks in the ensemble(clock data)

3. Tracing and comparing system: trace to UTC, compare with the other time and frequency reference

4. Time scale algorithm

5. Data storage, transferring, processing and monitoring

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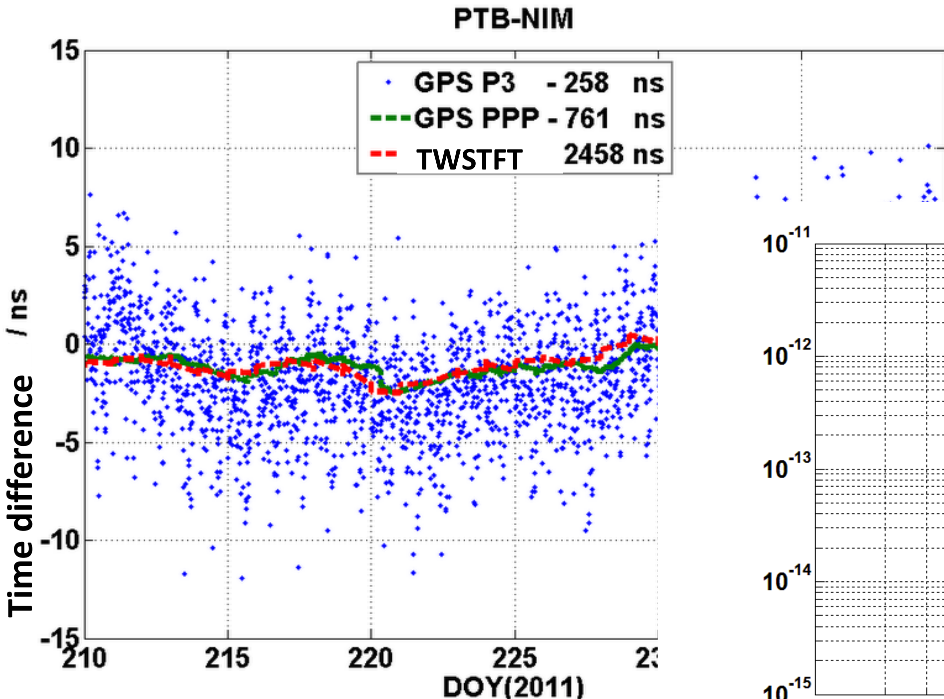
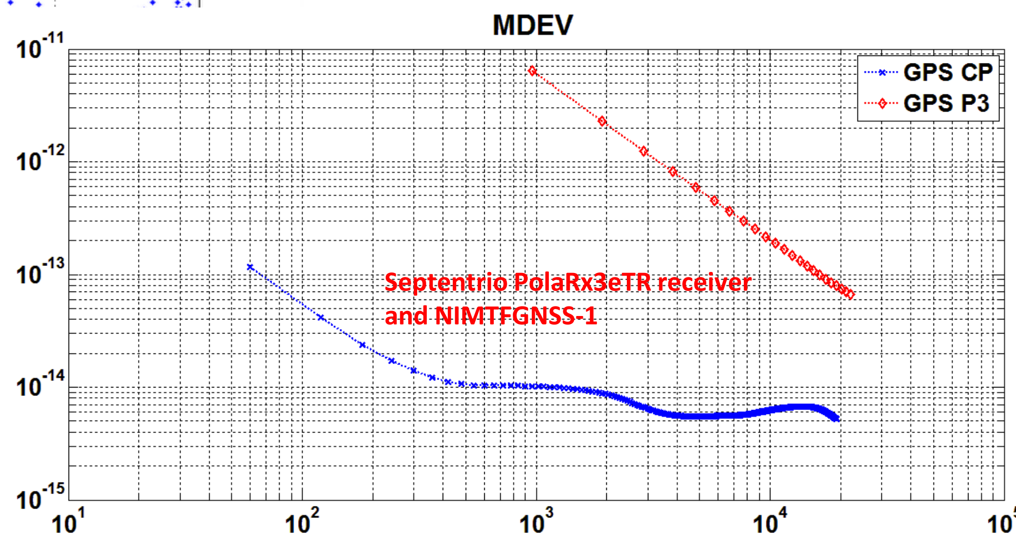
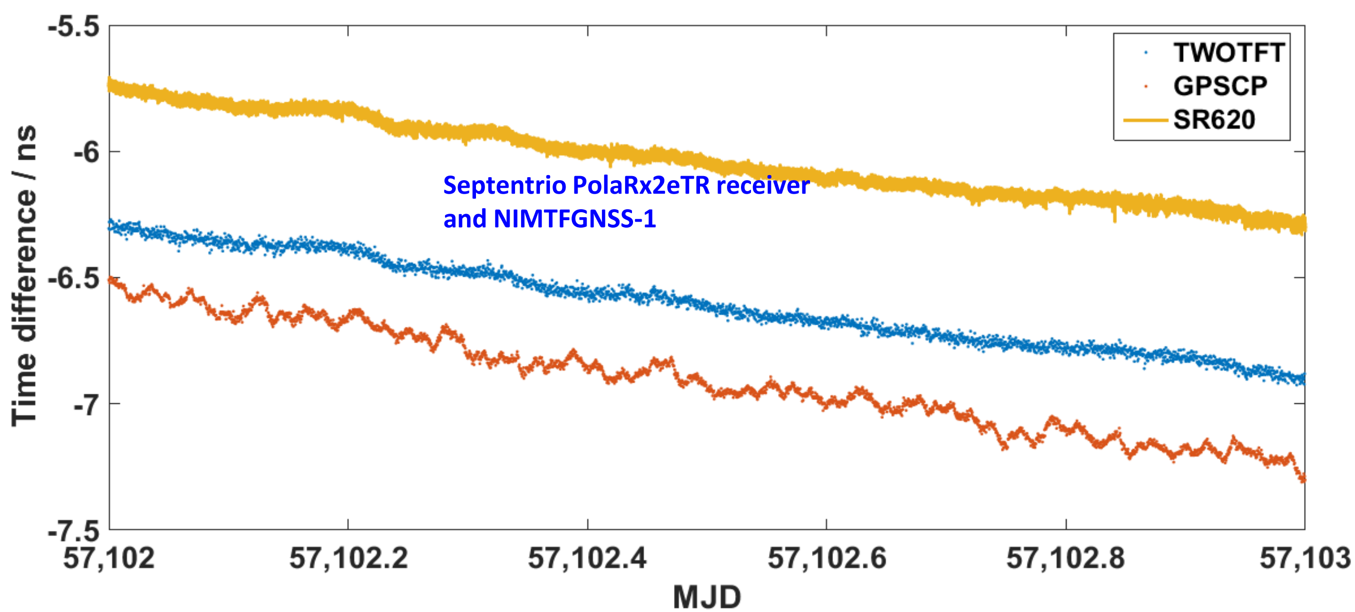
Remote time and frequency transfer

Methods	Uncertainty(A)	General features
GPS C/A code	1.0 ns ~1.5 ns	No sending signals, no big cost
GPS P3 code	0.7 ns	No sending signals, no big cost
GPS carrier phase	0.3 ns	No sending signals, no big cost
TWSTFT	0.3 ns ~ 0.5 ns	Need to rent satellite, expensive price for building TWSTFT earth station
Optical fiber	1 ps ~ tens of ps	Limited path, several hundreds kilometers

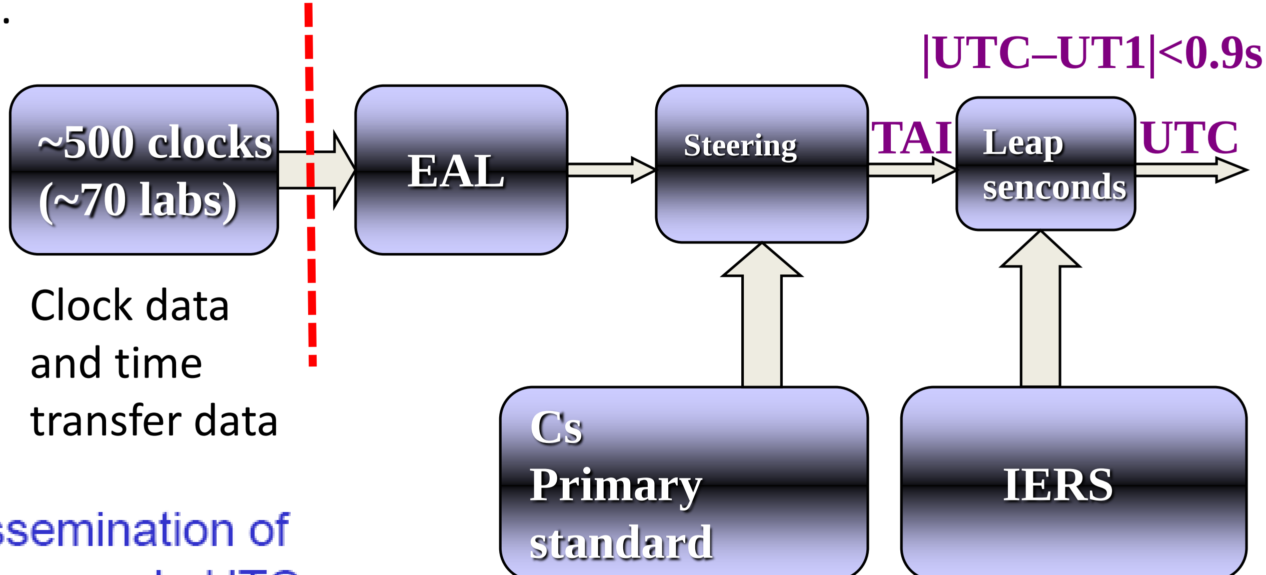

PTB-NIM
GPS P3 - 258 ns
GPS PPP - 761 ns
TWSTFT 2458 ns
Time difference / ns
15
10
5
0
-5
-10
-15
210
215
220
225
23
DOY(2011)


MDEV
GPS CP
GPS P3
Septentrio PolaRx3eTR receiver
and NIMTFGNSS-1
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}


TWOTFT
GPSCP
SR620
Septentrio PolaRx2eTR receiver
and NIMTFGNSS-1
Time difference / ns
-5.5
-6
-6.5
-7
-7.5
57,102
57,102.2
57,102.4
57,102.6
57,102.8
57,103
MJD

TAI corporation

The scale unit of TAI is kept as close as possible to the SI second by using data from those national laboratories which maintain the best primary caesium standards.



BIPM:

Maintenance and dissemination of the international time scale UTC whose unit interval is the SI second

ny laboratory wishing to contribute to the calculation of UTC at the BIPM must fulfil the ollowing conditions. It must:

(a) belong to a Member State of the BIPM or to an Associate of the CGPM;
(b) be equipped with atomic standards;
(c) operate equipment adapted for time transfer, producing data in a standard format as requested by the CCTF and the BIPM;
(d) have the capacity to report data to the BIPM on a continuous basis.

Participation in CCTF-K001.UTC is not limited to NMIs only, but other laboratories should request the authorization of the relevant NMI before applying to participate.

CCTF-K001.UTC key comparison

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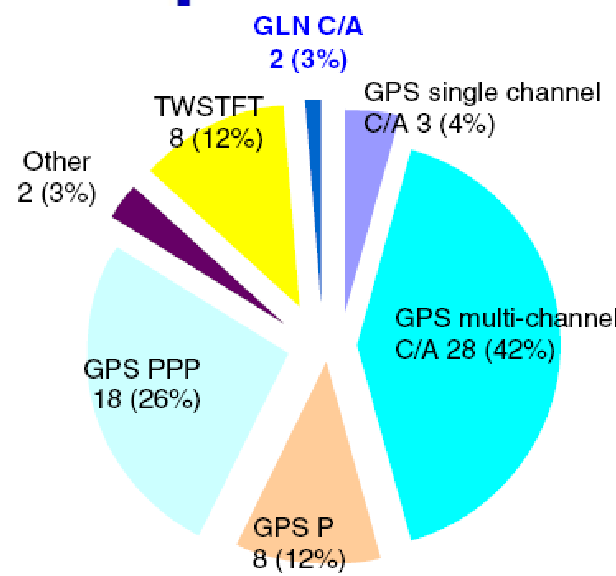
The BIPM organizes, for clock comparisons in TAI, an international network of time links:



Geographical distribution of the laboratories that contribute to TAI and time transfer equipment (April 2016)

In TAI， **the only key comparison is CCTF-K001.UTC**

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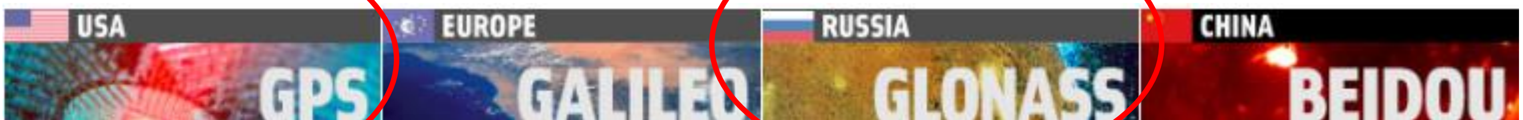
- Time link calibration(short introduction)

GNSS

B1&B2 signals

ICD 2.0 published officially



In building

Asia area coverage

More than 20 satellites and in 2020, global coverage

GPS constellation status, 27.05.14

Total satellites in constellation	32 SC
Operational	29 SC
In commissioning phase	2 SC
In maintenance	1 SC
In decommissioning phase	-

CDMA

GLONASS CONSTELLATION STATUS, 26.09.2016

Total satellites in constellation	27 SC
Operational	24 SC
In commissioning phase	-
In maintenance	-
Under check by the Satellite Prime Contractor	-
Spares	2 SC
In flight tests phase	1 SC

FDMA

GPS for examples

Pseudorange

C/A code

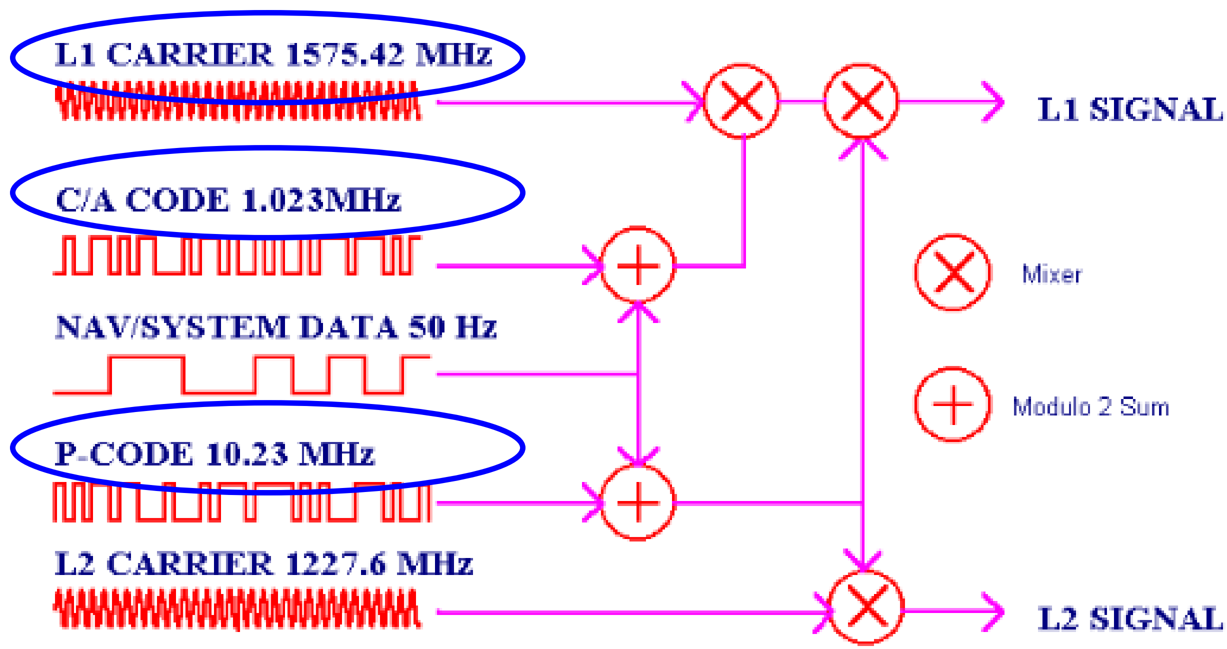
P code

Carrier phase

Carrier

Frequency& resolution

Precision



GPS SATELLITE SIGNALS

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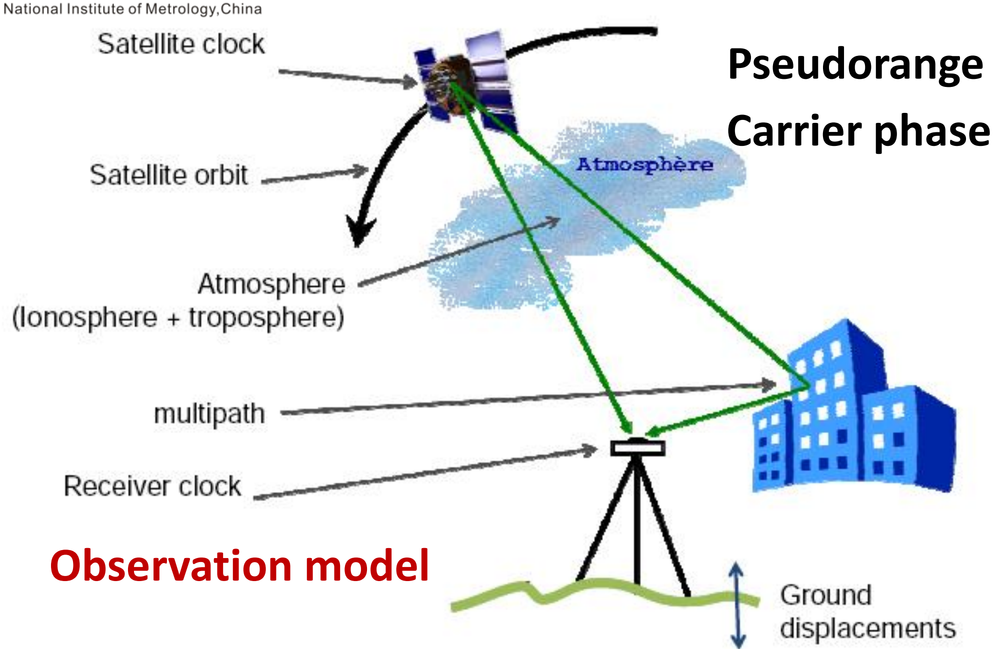
Some history for GPS time transfer

- Since 1985, GPS time transfer in common view has been used for the time tranfer/comparison and for the TAI calculation.
- Since 1990's， GPS time transfer in common view has been applied over the world.
- In 1994， CGGTTS format has been defined by CCTF for standard use in TAI corporation.
- Around 2000， GPS P3 code time transfer and GPS carrier phase time transfer was raised successively.

GPS time transfer methods



Observation model

1. Transfer by GPS C/A code

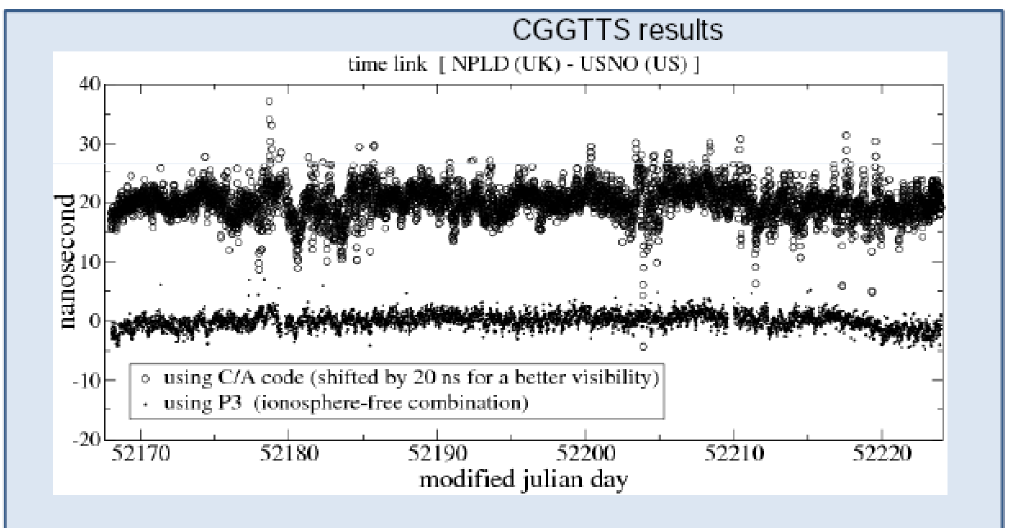
   Using navigation message for error correction and **modeled ionospheric correction**

2. Transfer by GPS P3 code

   Using navigation message for error correction and **iono-free combination of P1 code and P2 code**

3. Transfer by GPS carrier phase

   Using IGS precise ephemeris and complex **post-processing** with ambiguity fixing, precise error correction models and parameter estimation methods

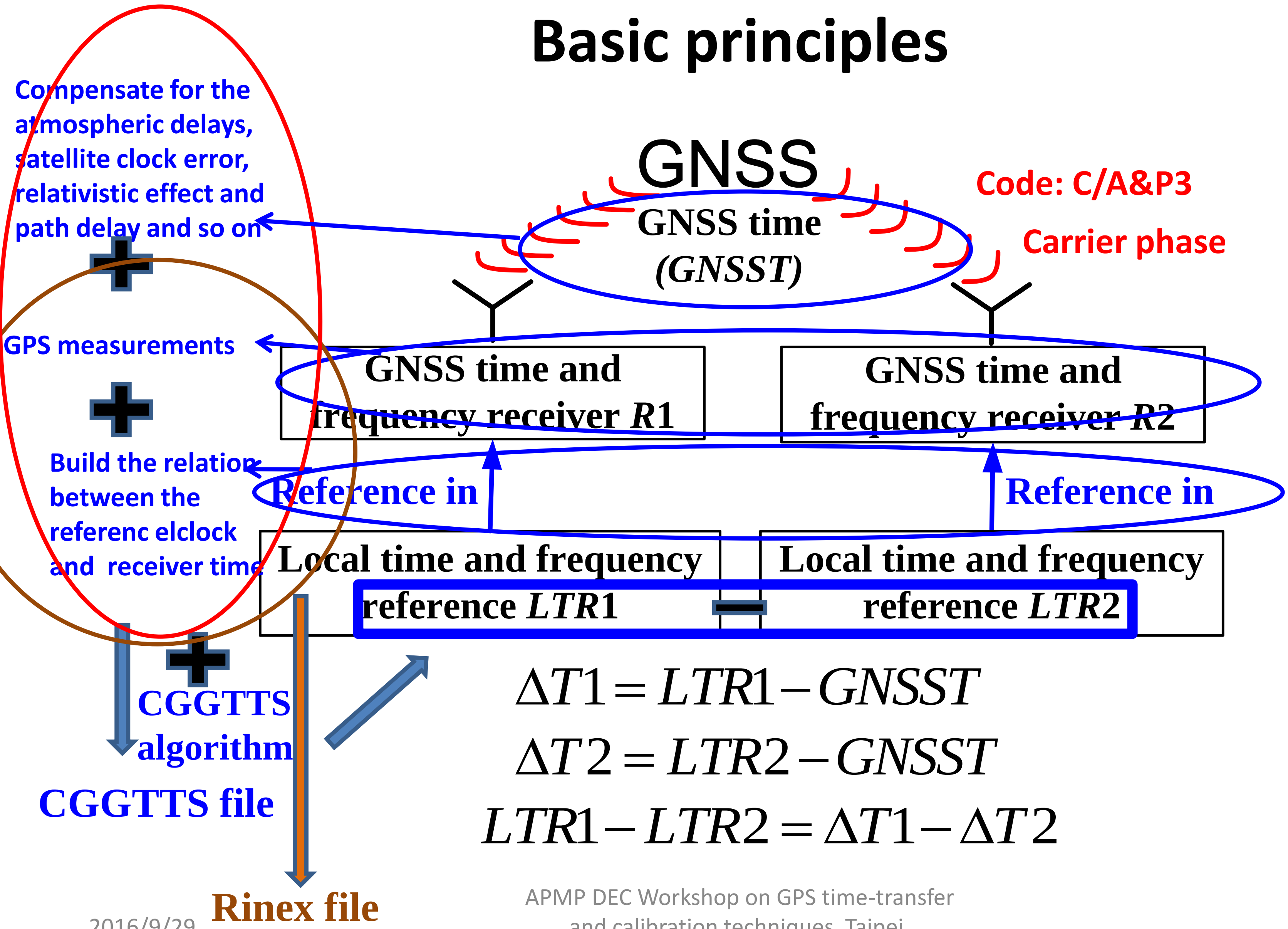


Ionospheric delay correction

P3 code will remove **99.9%** of the ionosphere delays and models like Klobuchar will remove only **60%**.

Pascale Defraigne. GNSS time transfer. TAI training of CCTF2012

Basic principles



$$\Delta T1 = LTR1 - GNSST$$

$$\Delta T2 = LTR2 - GNSST$$

$$LTR1 - LTR2 = \Delta T1 - \Delta T2$$

Observation equation for code

Based on pseudorange

To be determined

$$P_{1,2}^{sat} = \| \boxed{\mathbf{x}_{sat} - \mathbf{x}_{rec}} \| - c[\boxed{(t_{rec} - ref)} - (t_{sat} - ref)] + I_{1,2} + Tr + \delta_{1,2} + \varepsilon_{1,2}$$

Path between satellite position(calculated from navigation data) and position already known from geodetic measurement in advance

iono

tropo

Hardware delays

Known from calibration

Modeled with navigation data

Klonbuchar model from navigation data or dual frequency measurement

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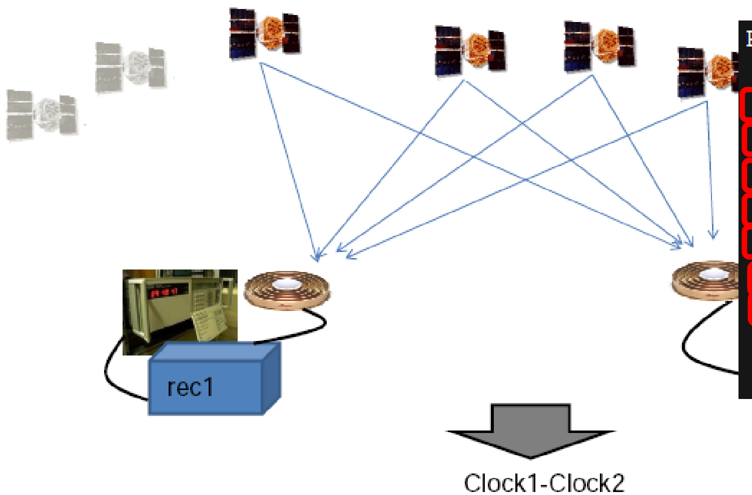
Common View(CV)



PRN	CL	MJD	STTIME hhmmss	TRKL s	ELV .1dg	AZTH .1dg	REFSV .1ns	SRSV .1ps/s	REFGPS .1ns	SRGPS .1ps/s
10	FF	57472	000200	780	221	3032	-194869	+20	-45	-74
13	FF	57472	000200	780	245	553	+59639	-1	+14	-29
15	FF	57472	000200	780	630	427	+3032963	-1	+9	-19
18	FF	57472	000200	780	568	3109	-4972674	+15	-1	+56
20	FF	57472	000200	780	542	1087	-4015107	-8	-21	+17
21	FF	57472	000200	780	569	2508	+5162835	+43	-9	+27
24	FF	57472	000200	780	611	1517	+144498	+17	+21	+10
10	FF	57472	001800	780	281	3062	-194765	+128	-31	+33
13	FF	57472	001800	780	186	588	+59625	-7	-27	-36

Pascale Defraigne. GNSS time transfer. TAI training of CCTF2012

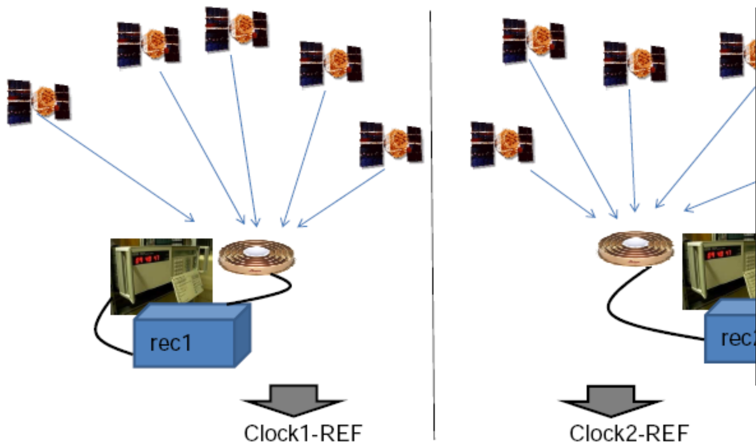
1. Get the difference between them
2. Average all the differences

Discarded

Get the difference between measurements from two sites by the same satellite and then combine the differences of all the satellites

PRN	CL	MJD	STTIME hhmmss	TRKL s	ELV .1dg	AZTH .1dg	REFSV .1ns	SRSV .1ps/s	REFSYS .1ns	SRSYS .1ps/s
13	FF	57472	000200	780	156	503	+59662	-25	38	-54
21	FF	57472	000200	780	658	2564	+5162872	+0	29	-16
20	FF	57472	000200	780	488	927	-4015055	-32	31	-7
18	FF	57472	000200	780	560	3232	-4972659	-19	14	+22
24	FF	57472	000200	780	623	1273	+144515	+14	38	+7
15	FF	57472	000200	780	527	393	+3032992	+3	37	-15
32	FF	57472	000200	780	77	2476	-93229	-65	27	-75
10	FF	57472	000200	780	235	3046	-194811	+106	13	+12
14	FF	57472	001800	780	189	2502	+44748	+113	44	+91
21	FF	57472	001800	780	634	2388	+5162887	+41	29	+26

All in View(AV)



Pascale Defraigne. GNSS time transfer. TAI training of CCTF2012

Average 1

PRN	CL	MJD	STTIME hhmmss	TRKL s	ELV .1dg	AZTH .1dg	REFSV .1ns	SRSV .1ps/s	REFGPS .1ns	SRGPS .1ps/s
10	FF	57472	000200	780	221	3032	-194869	+20	-45	-74
13	FF	57472	000200	780	245	553	+59639	-1	+14	-29
15	FF	57472	000200	780	630	427	+3032963	-1	+9	-19
18	FF	57472	000200	780	568	3109	-4972674	+15	-1	+56
20	FF	57472	000200	780	542	1087	-4015107	-8	-21	+17
21	FF	57472	000200	780	569	2508	+5162835	+43	-9	+27
24	FF	57472	000200	780	611	1517	+144498	+17	+21	+10
10	FF	57472	001800	780	281	3062	-194765	+128	-31	+33
13	FF	57472	001800	780	186	588	+59625	-7	-27	-36

1. Average all the measurements of two sites
2. Get one difference between two averaged measurements

Average 2

PRN	CL	MJD	STTIME hhmmss	TRKL s	ELV .1dg	AZTH .1dg	REFSV .1ns	SRSV .1ps/s	REFSYS .1ns	SRSYS .1ps/s
13	FF	57472	000200	780	156	503	+59662	-25	38	-54
21	FF	57472	000200	780	658	2564	+5162872	+0	29	-16
20	FF	57472	000200	780	488	927	-4015055	-32	31	-7
18	FF	57472	000200	780	560	3232	-4972659	-19	14	+22
24	FF	57472	000200	780	623	1273	+144515	+14	38	+7
15	FF	57472	000200	780	527	393	+3032992	+3	37	-15
32	FF	57472	000200	780	77	2476	-93229	-65	27	-75
10	FF	57472	000200	780	235	3046	-194811	+106	13	+12
14	FF	57472	001800	780	189	2502	+44748	+113	44	+91
21	FF	57472	001800	780	634	2388	+5162887	+41	29	+26

First combine the results of each site by all the satellites and then get the difference between the combined results two sites

GPS carrier phase time and frequency transfer

Code Wavelength :

P code : 29.3 m, C/A code : 293 m

Carrier wavelength: 19 cm (L1) and 24 cm (L2)

→Carrier phase measurements about 100 times more precise than codes measurements

BUT carrier phases ambiguous

→ only usable for frequency transfer, no time

→ need code data for time transfer

Carrier phase data will give the shape of the clock solution
Code data will give the numerical value of the clock solution.

In observation model, we need more precise error models for correction, ambiguity resolution and cycle slip detection …….

Pascale Defraigne. GNSS time transfer. TAI training of CCTF2012

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Codes :

$$P_3^{sat} = \| \mathbf{x}_{sat} - \mathbf{x}_{rec} \| - c\left[\boxed{(t_{rec} - ref)} - (t_{sat} - ref)\right] + Tr + \delta_3 + \varepsilon_3$$

Carrier Phases :

$$L_3^{sat} = \| \mathbf{x}_{sat} - \mathbf{x}_{rec} \| - c\left[\boxed{(t_{rec} - ref)} - (t_{sat} - ref)\right] + Tr + \lambda_3 N_3 + \varepsilon'_3$$

Pascale Defraigne. GNSS time transfer. TAI training of CCTF2012

-Needs precise satellite clocks/orbits like the ones delivered by the IGS
-No advantage of using precise carrier phases if broadcast orbits and clocks are used.

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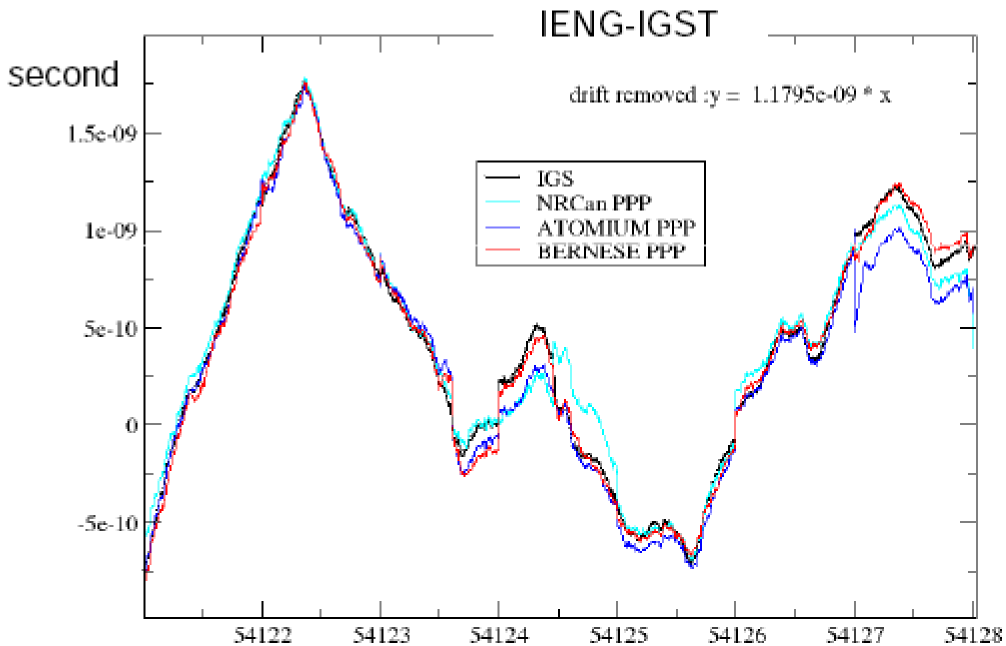
Available GPS CP processing tool

BIPM uses

Some professional geodetic software: NRCan-PPP, Bernese, GAMIT and GIPSY and some self-developed tool: Atomium and so on

Bernese, NRCan, Atomium, Gipsy, ...



Just as an example

T Feldmann, D Piester, A Bauch. GPS carrier-phase time and frequency transfer with different versions of precise point positioning software[C]. Proc. 40th Precise Time and Time Interval Meeting, 403-414, 2008.

Pascale Defraigne. GNSS time transfer. TAI training of CCTF2012

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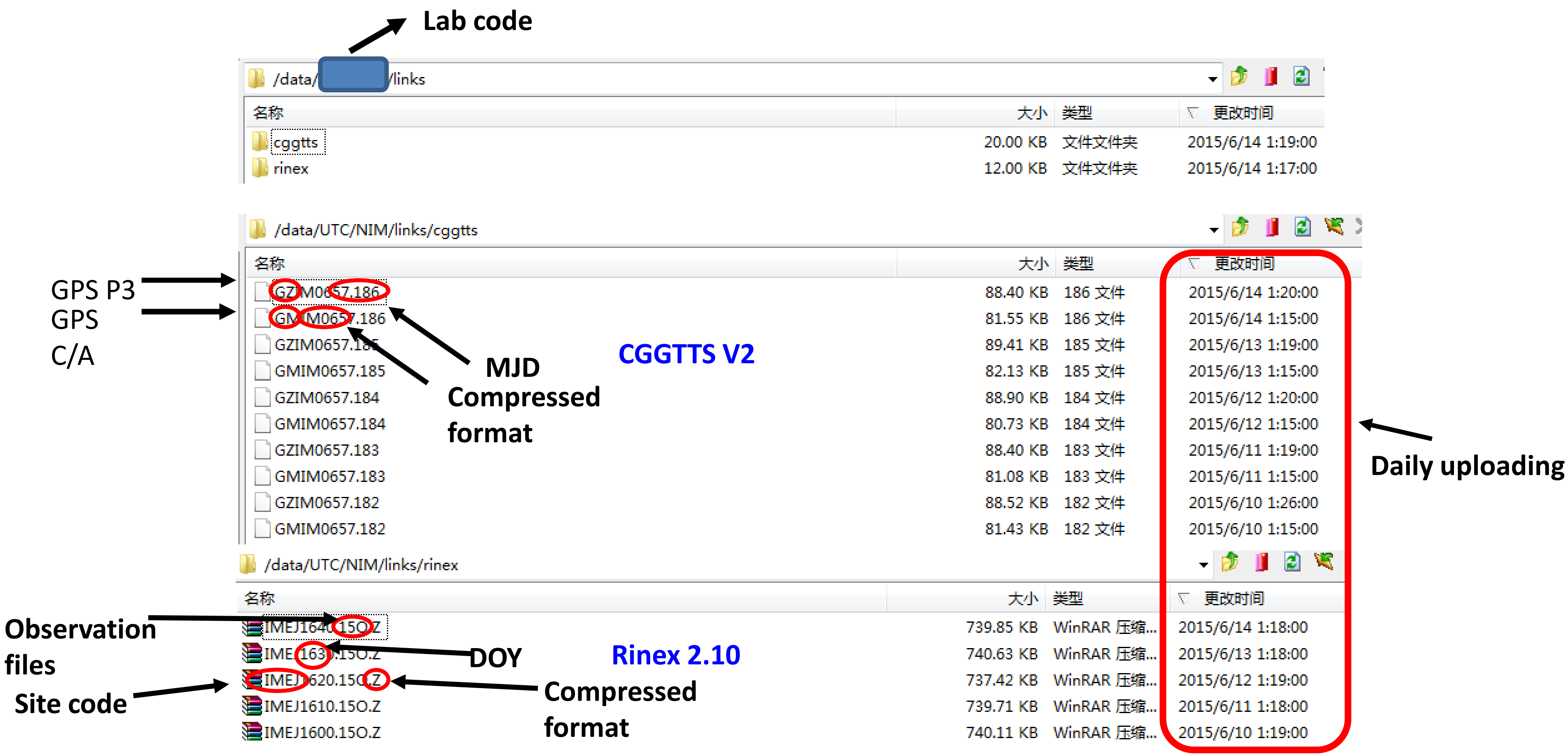
Data files


Lab code
/data/[redacted]/links
名称 大小 类型 更改时间
cggtts 20.00 KB 文件文件夹 2015/6/14 1:19:00
rinex 12.00 KB 文件文件夹 2015/6/14 1:17:00
/data/UTC/NIM/links/cggtts
名称 大小 类型 更改时间
GZIM0657.186 88.40 KB 186 文件 2015/6/14 1:20:00
GMIM0657.186 81.55 KB 186 文件 2015/6/14 1:15:00
GZIM0657.185 89.41 KB 185 文件 2015/6/13 1:19:00
GMIM0657.185 82.13 KB 185 文件 2015/6/13 1:15:00
GZIM0657.184 88.90 KB 184 文件 2015/6/12 1:20:00
GMIM0657.184 80.73 KB 184 文件 2015/6/12 1:15:00
GZIM0657.183 88.40 KB 183 文件 2015/6/11 1:19:00
GMIM0657.183 81.08 KB 183 文件 2015/6/11 1:15:00
GZIM0657.182 88.52 KB 182 文件 2015/6/10 1:26:00
GMIM0657.182 81.43 KB 182 文件 2015/6/10 1:15:00
GPS P3
GPS C/A
MJD
Compressed format
CGGTTS V2
Daily uploading
/data/UTC/NIM/links/rinex
名称 大小 类型 更改时间
IMEJ1640.15O.Z 739.85 KB WinRAR 压缩... 2015/6/14 1:18:00
IMEJ1630.15O.Z 740.63 KB WinRAR 压缩... 2015/6/13 1:18:00
IMEJ1620.15O.Z 737.42 KB WinRAR 压缩... 2015/6/12 1:19:00
IMEJ1610.15O.Z 739.71 KB WinRAR 压缩... 2015/6/11 1:18:00
IMEJ1600.15O.Z 740.11 KB WinRAR 压缩... 2015/6/10 1:19:00
Observation files
Site code
DOY
Rinex 2.10
Compressed format

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CGGTTS(CCTF Group on GPS Time Transfer Standards)

metrologia

International Reports

Technical Directives for Standardization of GPS Time Receiver Software

to be implemented for improving the accuracy of GPS common-view time transfer

D. W. Allan and C. Thomas

1. Introduction

The observation, using the common-view method [1], of satellites of the Global Positioning System (GPS), for the exchange of information between the military operators of GPS and the civil timing community [3].

The Group has identified two principal impediments to its objective of sub-nanosecond accuracy in GPS common-view time transfer:

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CGGTTS format

Annex III. GGTTS GPS Data Format Version 01

The GGTTS GPS Data Format Version 01 comprises:

(i) a *file header* with detailed information on the GPS equipment (lines 1 to 16);

(ii) a blank line (line 17);

1. Fil

Line

T
N
3.
Line :
R
p
Y
21 columns.

Line 3: "RCVR* = *" MAKER"*"TYPE"*"SERIAL NUMBER"*"YEAR"*" SOFTWARE

4. Data line

Line 20, column 1: space, ASCII value 20 (hexa-decimal).

Line 20,
Satel
No u

Line 20,
decimal).

Line 20,

Metrologia, 1994, **31**, 69-79

PRN	CL	MJD	STTIME	TRKL	ELV	AZTH	REFSV	SRSV	REFGPS	SRGPS
			hhmmss	s	.1dg	.1dg	.1ns	.1ps/s	.1ns	.1ps/s
10	FF	57472	000200	780	221	3032	-194869	+20	-45	-74
13	FF	57472	000200	780	245	553	+59639	-1	+14	-29
15	FF	57472	000200	780	630	427	+3032963	-1	+9	-19
18	FF	57472	000200	780	568	3109	-4972674	+15	-1	+56
20	FF	57472	000200	780	542	1087	-4015107	-8	-21	+17
21	FF	57472	000200	780	569	2508	+5162835	+43	-9	+27
24	FF	57472	000200	780	611	1517	+144498	+17	+21	+10
10	FF	57472	001800	780	281	3062	-194765	+128	-31	+33
13	FF	57472	001800	780	186	588	+59625	-7	-27	-36

Slope resulting from the treatment (vi-a) of Annex II.
In 0.1 ps/s.

ample
mated

value 20 (hexa-

7890" REFGPS

he treatment (vi-b)

/er, in

value 20 (hexa-

75 *ns"

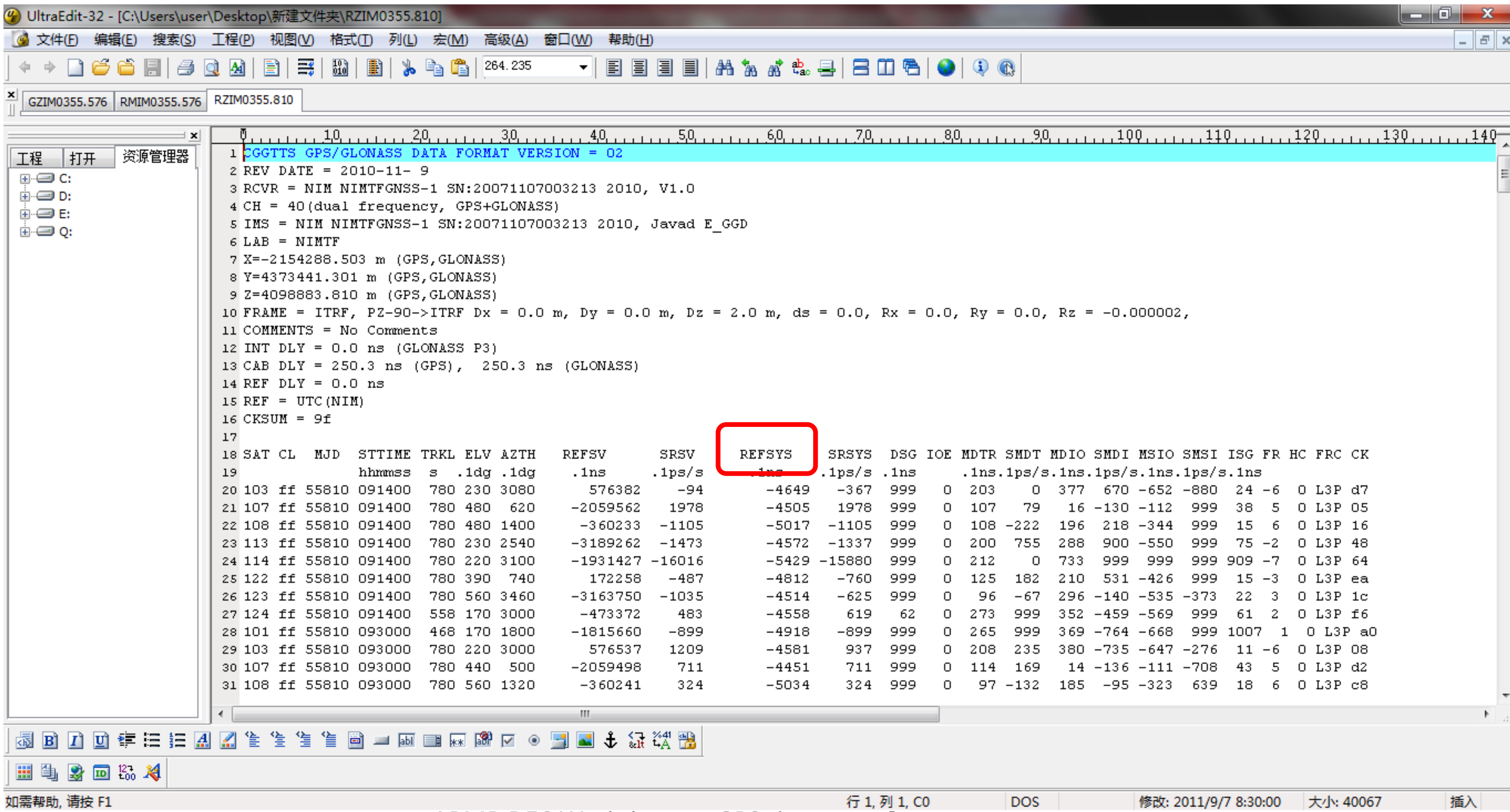
e GPS

antenna to the main unit, entered in the GPS time receiver, in ns and given with 1 decimal.
As many columns as necessary.

CGGTTS(Common GPS GLONASS Time Transfer Standards)

CGGTTS GPS/GLONASS Data Format Version

Include GLONASS



```
CGGTTS GPS/GLONASS DATA FORMAT VERSION = 02
REV DATE = 2010-11- 9
RCVR = NIM NIMTFGNSS-1 SN:20071107003213 2010, V1.0
CH = 40(dual frequency, GPS+GLONASS)
IMS = NIM NIMTFGNSS-1 SN:20071107003213 2010, Javad E_GGD
LAB = NIMTF
X=-2154288.503 m (GPS,GLONASS)
Y=4373441.301 m (GPS,GLONASS)
Z=4098883.810 m (GPS,GLONASS)
FRAME = ITRF, PZ-90->ITRF Dx = 0.0 m, Dy = 0.0 m, Dz = 2.0 m, ds = 0.0, Rx = 0.0, Ry = 0.0, Rz = -0.000002,
COMMENTS = No Comments
INT DLY = 0.0 ns (GLONASS P3)
CAB DLY = 250.3 ns (GPS),  250.3 ns (GLONASS)
REF DLY = 0.0 ns
REF = UTC(NIM)
CKSUM = 9f

SAT CL  MJD  STTIME TRKL ELV AZTH   REFSV      SRSV     REFSYS    SRSYS  DSG IOE MDTR SMDT MDIO SMDI MSIO SMSI ISG FR HC FRC CK
             hhmmss  s  .1dg .1dg   .1ns     .1ps/s      .1ns   .1ps/s .1ns     .1ns.1ps/s.1ns.1ps/s.1ns.1ps/s.1ns
103 ff 55810 091400  780 230 3080    576382     -94      -4649     -367  999   0  203    0  377  670 -652 -880  24 -6  0 L3P d7
107 ff 55810 091400  780 480  620  -2059562    1978      -4505     1978  999   0  107   79   16 -130 -112  999  38  5  0 L3P 05
108 ff 55810 091400  780 480 1400   -360233   -1105      -5017    -1105  999   0  108 -222  196  218 -344  999  15  6  0 L3P 16
113 ff 55810 091400  780 230 2540  -3189262   -1473      -4572    -1337  999   0  200  755  288  900 -550  999  75 -2  0 L3P 48
114 ff 55810 091400  780 220 3100  -1931427  -16016      -5429   -15880  999   0  212    0  733  999  999  999 909 -7  0 L3P 64
122 ff 55810 091400  780 390  740    172258    -487      -4812     -760  999   0  125  182  210  531 -426  999  15 -3  0 L3P ea
123 ff 55810 091400  780 560 3460  -3163750   -1035      -4514     -625  999   0   96  -67  296 -140 -535 -373  22  3  0 L3P 1c
124 ff 55810 091400  558 170 3000   -473372     483      -4558      619   62   0  273  999  352 -459 -569  999  61  2  0 L3P f6
101 ff 55810 093000  468 170 1800  -1815660    -899      -4918     -899  999   0  265  999  369 -764 -668  999 1007  1  0 L3P a0
103 ff 55810 093000  780 220 3000    576537    1209      -4581      937  999   0  208  235  380 -735 -647 -276  11 -6  0 L3P 08
107 ff 55810 093000  780 440  500  -2059498     711      -4451      711  999   0  114  169   14 -136 -111 -708  43  5  0 L3P d2
108 ff 55810 093000  780 560 1320   -360241     324      -5034      324  999   0   97 -132  185  -95 -323  639  18  6  0 L3P c8
```

CGGTTS(Common GNSS Generic Time Transfer Standard)

CGGTTS-Version 2E: an extended standard for GNSS Time Transfer

P. Defraigne, G. Petit

Abstract
The standard for GNSS time transfer was first defined in 1984, associated to the use of GPS signals, which were at that time degraded by the Selective Availability. It was updated at a few instances to follow the evolution of GPS, of the receivers, and the inclusion of GLONASS. With the emergence of additional navigation systems like Galileo, BeiDou, QZSS the standard has to be further adapted. This paper prepared by the CCTF Working Group on GNSS Time Transfer details the associated extended standard, named CGGTTS for Common GNSS Generic Time Transfer Standard, and the corresponding Version 2E of the format.

Examples of CGGTTS V2E files

Case 1: no ionospheric measurements available, single-fre

```
CGGTTS     GENERIC DATA FORMAT VERSION = 2E
REV DATE = 2014-02-20
RCVR = RRRRRRRR
CH = 12
IMS = 99999
LAB = ABC
X = +4027881.79 m (GPS)
Y =  +306998.67 m (GPS)
Z = +4919499.36 m (GPS)
FRAME = ITRF
COMMENTS = NO COMMENTS
SYS DLY =  237.0 ns (GPS C1)     CAL_ID = 1nnn-yyyy
REF DLY =  149.6 ns
REF = UTC(ABC)
CKSUM = 3B

SAT CL  MJD  STTIME TRKL ELV AZTH   REFSV      SRSV     REFSYS    SRSYS  DSG IOE MDTR SMDT MDIO SMDI FR HC FRC CK
             hhmmss  s  .1dg .1dg   .1ns     .1ps/s      .1ns    .1ps/s .1ns     .1ns.1ps/s.1ns.1ps/s
G 6 FF 57000 000600  780 185  754   -234764   -125           -36    -52   26  57  252  -36   64  +25  0  0 L1C E8
G17 FF 57000 000600  780  80  367  +1426632    -13           -34    -37   33   1  559 +393   67  +64  0  0 L1C D0
G25 FF 57000 000600  780 494 2568   -103408    +28           -35     +7    8  38  106  -11   57   -9  0  0 L1C A8
```

Important information

Example of header (GPS P3 data files).

```
CGGTTS GPS/GLONASS DATA FORMAT VERSION = 02
REV DATE = 2007-06-29
RCVR = NRL1 ASHTECH Z-XII3T RT9200102R2CGGTTS v4.0
CH = 12 (GPS)
IMS = NRL1 ASHTECH Z-XII3T RT9200102
LAB = NRL
X = +1117249.12 m (GPS)
Y = -4848758.67 m (GPS)
Z = +3976821.18 m (GPS)
FRAME = ITRF
COMMENTS = NO COMMENTS
INT DLY =  310.9 ns (GPS P1),  324.5 ns (GPS P2)
CAB DLY =  109.5 ns (GPS)
REF DLY =   14.4 ns
REF = UTC(NRL)
CKSUM = A2
```

PRN	CL	MJD	STTIME	TRKL	ELV	AZTH	REFSV	SRSV	REFGPS	SRGPS	DSG	IOE	MDTR	SMDT	MDIO	SMDI	MSIO	SMSI	ISG	FR	HC	FRC	CK
			hhmmss	s	.1dg	.1dg	.1ns	.1ps/s	.1ns	.1ps/s	.1ns		.1ns	.1ps/s	.1ns	.1ps/s	.1ns	.1ps/s	.1ns				
24	FF	54780	001400	780	424	3038	-1398240	-56	-105	-27	37	19	119	-13	68	+14	68	14	25	0	0	L3P	16
2	FF	54780	001400	780	521	841	-1742578	+4	-101	-21	25	20	101	+7	61	+24	61	24	19	0	0	L3P	A7
15	FF	54780	001400	780	266	1804	+2082940	+23	-90	-40	35	0	178	-47	118	+24	118	24	28	0	0	L3P	8
30	FF	54780	001400	780	156	2533	-1069545	+31	-126	+53	80	123	295	+75	85	-29	85	-29	62	0	0	L3P	3D
5	FF	54780	001400	780	90	2304	+3783014	+386	-69	+113	68	0	496	+246	106	-65	106	-65	56	0	0	L3P	3C
10	FF	54780	001400	780	743	203	+70469	+21	-75	+17	13	83	83	+3	48	-13	48	-13	9	0	0	L3P	95
4	FF	54780	001400	780	114	1006	+2273459	+304	-58	+184	88	4	397	+165	102	-140	102	-140	66	0	0	L3P	5B
29	FF	54780	001400	780	497	3017	+307365	-27	-80	-8	24	61	105	-9	59	+5	59	5	20	0	0	L3P	B0

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RINEX, Receiver Independent Exchange Format

RINEX v. 3.03	August 2015 release notes: ftp://igs.org/pub/data/format/RINEX_3.03_ReleaseNotes.pdf
RINEX v. 3.02	Enhanced 3.01 to include: a new header message to specify the GLONASS code-phase bias; the existing GLONASS frequency to slot header message has been specified as mandatory and a new RINEX file naming convention
RINEX v. 3.01	GPS, GLONASS, Galileo, BeiDou (Compass), QZSS and SBAS, however, structure of the data record has changed significantly with the addition to detailed characterization of actual signal generation
RINEX v. 2.11	GPS, GLONASS and Galileo observations, meteorological data, and navigation files. Additionally, the C2, L2C/L5 and Galileo codes have also been introduced
RINEX v. 2.10	GPS and GLONASS observations, meteorological data, and navigation files

- **3.01：include GPS, GLONASS, Galileo, BDS, SBAS, QZSS**

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Agree with the IGS antenna list for PPP processing

```
     2.11           OBSERVATION DATA    M                   RINEX VERSION / TYPE
sbf2rin-9.4.0                           11-JUN-14 08:03     PGM / RUN BY / DATE
bjnm                                                        MARKER NAME
21616M001                                                   MARKER NUMBER
LIANG Kun           NIM                                     OBSERVER / AGENCY
2001087             SEPT POLARX3ETR     2.1                 REC # / TYPE / VERS
NAE09190046         NOV702GG       NONE                     ANT # / TYPE
 -2154287.4861  4373437.9794  4098884.7010                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     6    C1    L1    L2    P2    P1    C2                  # / TYPES OF OBSERV
    30.000                                                  INTERVAL
  2014     6    10     0     0    0.0000000     GPS         TIME OF FIRST OBS
  2014     6    10    23    59   30.0000000     GPS         TIME OF LAST OBS
    58                                                      # OF SATELLITES
                                                            END OF HEADER
 14  6 10  0  0  0.0000000  0 17E19G31G14G24G32G01G18G25G12G22R07R11
                                R10R09R16R06R08
  27665893.830 5 145385272.02105
  
  22482103.041 7 118144279.19907  92060497.57905  22482106.553 5  22482102.925 5
  
  20687498.750 8 108713562.85108  84711890.50505  20687501.368 5  20687498.142 5
  
  23975809.996 6 125993728.17306  98176958.45003  23975817.714 3  23975809.992 3
  
  24320549.438 6 127805361.67006  99588629.09002  24320555.054 2  24320548.330 2
  
  25128209.476 6 132049633.01306 102895853.42202  25128218.988 2  25128209.498 2
  
```