GPS single point positioning algorithm

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1 Computation of receiver's position

This paper describes the computation of the position of a GPS receiver based on L1 pseudorange observations, here denoted by P. The algorithm is summarised in Table 1.
The GPS satellites continuously transmit signals on two bands: L1 and L2. Usually, only L1 is used for navigation purposes. There are three data streams modulated on L1: C/A ranging code, P ranging code and navigation message. The receiver correlates the received and generated ranging codes by shifting the generated ones with respect to the received ones. The amount of the shift is a measure of the travel time of the signal from satellite to the receiver. The travel time derived from the code correlation multiplied by the speed of light is called pseudorange. The mathematical definition of the pseudorange is given by the following equation:

$$P_A^s\left(\tilde{t}_A\right) = \left(\tilde{t}_A - \tilde{t}^s\right)c \tag{1}$$

where
$P_A^s\left(\tilde{t}_A\right)$ pseudorange measured at time $\tilde{t}_A$ by receiver A to satellite s
$\tilde{t}_A$ nominal time of the signal reception measured by the clock of receiver A
$\tilde{t}^s$ nominal time of signal transmission measured by the clock of satellite s
c   speed of light (see the value on page 9)

It is evident, that the pseudorange is directly affected by the satellite and receiver clock errors. The clock errors are defined by the following equations:

$$\begin{aligned} t_A &= \tilde{t}_A - \delta t_A \\ t^s &= \tilde{t}^s - \delta t^s \end{aligned} \tag{2}$$

where
δt_A receiver clock error
δt^s satellite clock error
t_A system time of the signal reception
t^s system time of the signal transmission
c   speed of light, numerical value is in Section 5.

By introducing (2) into Equation (1), we get:

$$P_A^s(\tilde{t}_A) = \rho_A^s(t_A) + c\,\delta t_A - c\,\delta t^s \tag{3}$$

where $\rho_A^s(t_A)$ is geometric distance between receiver A and satellite s at time t_A (also called topocentric distance):

$$\rho_A^s(t_A) = c\left(t_A - t^s\right) = c\Delta t_A^s \tag{4}$$

Where Δt_A^s is signal propagation time, which can be computed with sufficient accuracy by Equation (13).

Since the system (true) time t_A is unknown, the topocentric distance must be linearized around the known nominal receiver time $\tilde{t}_A$:

$$\rho_A^s(t_A) = \rho_A^s(\tilde{t}_A) - \dot{\rho}_A^s(\tilde{t}_A)\delta t_A \tag{5}$$

The second term in right side of equation (5) is at most about 0.8 m, therefore it can be neglected in case of code single point positioning (other error sources are larger).

We can relate the distance and the coordinates using Pythagoras' Theorem as follows:

$$\rho_A^s(\tilde{t}_A) = \sqrt{\left(X^s - x_A\right)^2 + \left(Y^s - y_A\right)^2 + \left(Z^s - z_A\right)^2} \tag{6}$$

where

X^s, Y^s, Z^s Cartesian coordinates of satellite s in WGS84

x_A, y_A, z_A Cartesian coordinates of receiver A expressed in rotated reference frame, due to the rotation of the Earth during the signal's travel time.

Please note that WGS84 is a terrestrial coordinate reference system, which rotates together with the Earth, so the measured distances are affected by the rotation, see Figure 1. The signal is transmitted from the satellite at time t_0 and arrives at the receiver at time t. The difference t minus t_0 is the signal's travel time Δt_A^s . The effect is different for different satellites, depending on the relative position with respect to the receiver.
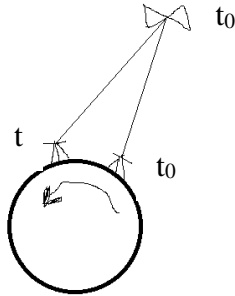

Figure 1. Effect of the rotation of the Earth on the measured distances.

To eliminate the effect of the rotation, also called as Sagnac effect, the measured distances must be expressed in a chosen position of the rotating system, e.g. for the time of transmission t_0. This intermediate coordinate system is called Earth–Centered Inertial Coordinate System (ECI). The receiver's coordinates in ECI are computed as:

$$\begin{aligned} x_A &= X_A - \dot{\Omega}_e Y_A \Delta t_A^s \\ y_A &= Y_A + \dot{\Omega}_e X_A \Delta t_A^s \\ z_A &= Z_A \end{aligned} \tag{7}$$

where X_A, Y_A, Z_A are WGS84 coordinates of the receiver, which are to be computed and $\dot{\Omega}_e$ is the rotation rate of the Earth; its numerical value is given in Table 3. The travel time Δt_A^s can be computed by Equation (13). Please note that theoretically, even the satellite coordinates should be expressed in ECI, but in practice, we can assume that t_0 is equal for all satellites: the maximum error in satellite-receiver distance caused by this assumption is 3 cm, which is negligible in code positioning.

Looking at Equations (3) - (7), we can see that there are four unknowns, namely three receiver coordinates X_A, Y_A, Z_A and receiver clock error δt_A. The satellite coordinates X^s, Y^s, Z^s can be computed using orbit parameters, satellite clock error δt^s can be computed using clock polynomial coefficients transmitted to the user in the navigation message, and the pseudorange $P_A^s(\tilde{t}_A)$ is measured by the GPS receiver.

Taking into account the tropospheric $T_A^s(\tilde{t}_A)$ and ionospheric $I_A^s(\tilde{t}_A)$ delays as well as Equation (5) neglecting term with δt_A, the observation equation (3) can be written as:

$$P_A^s(\tilde{t}_A) = \rho_A^s(\tilde{t}_A) + c\,\delta t_A - c\,\delta t_{L1}^s + I_A^s(\tilde{t}_A) + T_A^s(\tilde{t}_A) \tag{8}$$

If we insert Equation (7) into (6) and then linearize it using the Taylor's expansion, and neglecting higher order terms, we get:

$$\rho_A^s(\tilde{t}_A) = \rho_{A0}^s(\tilde{t}_A) + \frac{\partial\rho_{A0}^s(\tilde{t}_A)}{\partial X_{A0}}\Delta X + \frac{\partial\rho_{A0}^s(\tilde{t}_A)}{\partial Y_{A0}}\Delta Y + \frac{\partial\rho_{A0}^s(\tilde{t}_A)}{\partial Z_{A0}}\Delta Z \tag{9}$$

$$\frac{\partial\rho_{A0}^s(t_A)}{\partial X_{A0}} = a_X^s = -\frac{X^s - X_{A0} + Y^s\dot{\Omega}_e\Delta t_A^s - X_{A0}\dot{\Omega}_e^2\Delta t_A^{s\,2}}{\rho_{A0}^s}$$

$$\frac{\partial\rho_{A0}^s(t_A)}{\partial Y_{A0}} = a_Y^s = -\frac{Y^s - Y_{A0} - X^s\dot{\Omega}_e\Delta t_A^s - Y_{A0}\dot{\Omega}_e^2\Delta t_A^{s\,2}}{\rho_{A0}^s} \tag{10}$$

$$\frac{\partial\rho_{A0}^s(t_k)}{\partial Z_{A0}} = a_Z^s = -\frac{Z^s - Z_{A0}}{\rho_{A0}^s}$$

where

$$\rho_{A0}^s(\tilde{t}_A) = \sqrt{\left(X^s - X_{A0} + \dot{\Omega}_e Y_{A0}\Delta t_A^s\right)^2 + \left(Y^s - Y_{A0} - \dot{\Omega}_e X_{A0}\Delta t_A^s\right)^2 + \left(Z^s - Z_{A0}\right)^2} \tag{11}$$

The terms containing Δt_A^s in Equations (10) are negligible, so the coefficients can be computed by simplified equations:

$$\frac{\partial \rho_{A0}^{s}(t_A)}{\partial X_{A0}} = a_X^{s} = -\frac{X^{s} - X_{A0}}{\rho_{A0}^{s}}$$

$$\frac{\partial \rho_{A0}^{s}(t_A)}{\partial Y_{A0}} = a_Y^{s} = -\frac{Y^{s} - Y_{A0}}{\rho_{A0}^{s}} \qquad (12)$$

$$\frac{\partial \rho_{A0}^{s}(t_k)}{\partial Z_{A0}} = a_Z^{s} = -\frac{Z^{s} - Z_{A0}}{\rho_{A0}^{s}}$$

X_{A0}, Y_{A0} and Z_{A0} are approximate receiver coordinates, ΔX, ΔY, ΔZ are unknown corrections to the approximate coordinates and Δt_A^{s} is signal propagation time that can be computed with sufficient accuracy by:

$$\Delta t_A^{s} = \frac{P_A^{s}(\tilde{t}_A)}{c} \qquad (13)$$

$\dot{\Omega}_e$ is the rotation rate of the Earth, numerically given in Table 3.
X^{s}, Y^{s}, Z^{s} are WGS84 coordinates of satellite s computed at time of signal transmission t^{s}. The nominal transmission time $\tilde{t}^{s}$ is computed by:

$$\tilde{t}^{s} = \tilde{t}_A - \frac{P_A^{s}(\tilde{t}_A)}{c} \qquad (14)$$

The system transmission time t^{s} is computed as:

$$t^{s} = \tilde{t}^{s} - \delta t_{L1}^{s} \qquad (15)$$

Where δt_{L1}^{s} is satellite clock correction computed by Equation (27).

The observation equation (8) can be then rewritten as:

$$P_A^{s}(\tilde{t}_A) - \rho_{A0}^{s}(\tilde{t}_A) + c\,\delta t_{L1}^{s} - I_A^{s}(\tilde{t}_A) - T_A^{s}(\tilde{t}_A) = a_X^{s}\Delta X + a_Y^{s}\Delta Y + a_Z^{s}\Delta Z + c\delta t_A \qquad (16)$$

The left side of this equation contains the terms that are known (measured and computed), while the right side contains terms with unknown parameters ΔX, ΔY, ΔZ and δt_A. These parameters can be solved if at least 4 measurements are available. The parameters are solved by the least-squares (LSQ) method. This method is most conveniently expressed in matrix notation. Observation equations – system of equations to be solved:

$$\mathbf{L} - \mathbf{v} = \mathbf{A}\mathbf{X} \qquad (17)$$

where $\mathbf{v}$ is vector of unknown residuals (random errors of measurements). LSQ solution of (17) :

$$\hat{\mathbf{X}} = \mathbf{Q}_X \mathbf{A}^T \mathbf{L}$$
$$\mathbf{Q}_X = (\mathbf{A}^T \mathbf{A})^{-1}$$

(18)

$\mathbf{L}$ is the vector with n elements, where n is the number of observed satellites:

$$\mathbf{L} = \begin{bmatrix} P_A^1(\tilde{t}_A) - \rho_{A0}^1(\tilde{t}_A) + c\,\delta t_{L1}^1 - I_A^1(\tilde{t}_A) - T_A^1(\tilde{t}_A) \\ \vdots \\ P_A^n(\tilde{t}_A) - \rho_{A0}^n(\tilde{t}_A) + c\,\delta t_{L1}^n - I_A^n(\tilde{t}_A) - T_A^n(\tilde{t}_A) \end{bmatrix}$$

(19)

$\mathbf{A}$ is the design matrix containing the coefficients at unknown parameters. Its size is n x 4:

$$\mathbf{A} = \begin{bmatrix} a_X^1 & a_Y^1 & a_Z^1 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ a_X^n & a_Y^n & a_Z^n & 1 \end{bmatrix}$$

(20)

$\mathbf{X}$ is the vector of the four unknowns:

$$\mathbf{X} = \begin{bmatrix} \Delta X & \Delta Y & \Delta Z & c\delta t_A \end{bmatrix}^T$$

(21)

The estimated coordinates of the receiver are finally computed by:

$$X_A = X_{A0} + \Delta X$$
$$Y_A = Y_{A0} + \Delta Y$$
$$Z_A = Z_{A0} + \Delta Z$$

(22)

Please note that we estimate the receiver clock error multiplied by the velocity of light ($c\delta t_A$), rather than clock error (δt_A), to get better numerical stability of the solution.
Finally, we compute the standard uncertainties (standard deviations) of the estimated parameters as

$$\sigma_X = \sigma_0 \sqrt{Q_{x(1,1)}}$$
$$\sigma_Y = \sigma_0 \sqrt{Q_{x(2,2)}}$$
$$\sigma_Z = \sigma_0 \sqrt{Q_{x(3,3)}}$$
$$\sigma_{c\delta t} = \sigma_0 \sqrt{Q_{x(4,4)}}$$

(23)

where

$$\sigma_0 = \sqrt{\frac{\mathbf{v}^T \mathbf{v}}{n-k}}$$
$$\mathbf{v} = \mathbf{AX} - \mathbf{L}$$

(24)

n – number of satellites, k – number of parameters (k = 4).

PDOP can be computed as

$$PDOP = \sqrt{Q_x(1,1) + Q_x(2,2) + Q_x(3,3)} \tag{25}$$

Table 1. Algorithm for computation of receiver's position.

1. Compute signal propagation time by (13).
2. Compute signal transmission time $\tilde{t}^s$ by (14).
3. Compute satellite clock correction δt_{L1}^s by (27) and (28), neglect Δt_r.
4. Compute t^s by (15) using the correction from the step 3.
5. Compute eccentric anomaly (Table 2 - line 4-8)
6. Compute Δt_r by (29), Δt_{SV} by (28), δt_{L1}^s by (27) and t^s by (15).
7. Compute satellite coordinates X^s, Y^s, Z^s, for time t^s - Table 2 (line 4-19). Update the eccentric anomaly computed in step 5.
8. Compute satellite clock correction δt_{L1}^s by (27) - (30) using the updated eccentric anomaly.
9. Compute tropospheric correction $T_A^s(\tilde{t}_A)$.
10. Compute ionospheric correction $I_A^s(\tilde{t}_A)$.
11. Compute approximate distance $\rho_{A0}^s(\tilde{t}_A)$ by (11).
12. Compute elements of vector **L** (19).
13. Compute elements of matrix **A** (20); a_X^s, a_Y^s, a_Z^s by (12).
14. Estimate unknown parameters by (18).
15. Update receiver coordinates by (22).
16. Repeat steps 11 – 16 until the solution has converged. The solution has converged if the following condition is fulfilled: $\left|\left(\mathbf{v}^T\mathbf{v}\right)_i - \left(\mathbf{v}^T\mathbf{v}\right)_{i-1}\right| < \varepsilon$, where ε is a small number and depends on the numerical accuracy, ε = 1e-5 should suffice to preserve mm numerical precision of the computed coordinates; i is iteration number. The vector **v** is computed after step 13 by Equation (17).

2 Calculation of satellite coordinates

This section describes the computation of WGS84 coordinates of a GPS satellite for time of signal transmission t^s, computed by Equation (14) and (2). The coordinates are computed by the equations listed in Table 2. The necessary orbital parameters are found in the RINEX navigation file – see chapter 4.

During the coordinate computation, the Kepler's equation for eccentric anomaly must be solved. The following iterative solution is applied:

$$\begin{aligned} E_0 &= M_k \\ E_i &= M_k + e\sin E_{i-1}, \quad i = 1, 2, 3\ldots \end{aligned} \tag{26}$$

The iteration can be stopped if $\left| E_i - E_{i-1} \right| < \varepsilon$, where ε is a small number. We recommend $\varepsilon = $ 1e-13. Usually, 4 or 5 iterations suffice.

3   Satellite clock correction computation

The satellite clock correction δt_{L1}^s is needed for receiver position computation in Equation (19) For epoch $\tilde{t}^s$, it is computed by the following equation:

$$\delta t_{L1}^s = \Delta t_{SV} - T_{GD} \tag{27}$$

where

$$\Delta t_{SV} = a_{f0} + a_{f1}\left(\tilde{t}^s - t_{oc}\right) + a_{f2}\left(\tilde{t}^s - t_{oc}\right)^2 + \Delta t_r \tag{28}$$

Δt_r is the relativistic correction given by:

$$\Delta t_r = Fe\sqrt{A}\sin E_k \tag{29}$$

where F is a constant:

$$F = -4.442807633e - 10 \, \text{s}/\text{m}^{1/2} \tag{30}$$

e and A are orbit parameters and E_k is eccentric anomaly computed in course of satellite coordinates computation (see Table 2). Please note that $\left(\tilde{t}^s - t_{oc}\right)$ is the time difference expressed in seconds.

Table 2. Computation of satellite coordinates from orbital parameters. Source: Interface control document ICD-GPS-200.

1	$\mu = 3.986005 \times 10^{14}$ m^3/s^2	Earth' universal gravitational parameter
2	$\dot{\Omega}_e = 7.2921151467 \times 10^{-5}$ rad/s	Earth' rotation rate
3	$A = \left(\sqrt{A}\right)^2$	Semi-major axis
4	$n_0 = \sqrt{\dfrac{\mu}{A^3}}$	Computed mean motion
5	$t_k = t^s - t_{oe}$ $$t_k = \begin{cases} t_k - 604800 & \text{if} \quad t_k > 302400 \\ t_k + 604800 & \text{if} \quad t_k < -302400 \\ t_k & \text{otherwise} \end{cases}$$	Time from ephemeris reference epoch
6	$n = n_0 + \Delta n$	Corrected mean motion
7	$M_k = M_0 + n\, t_k$	Mean anomaly
8	$E_k = M_k + e \sin E_k$	Kepler's equation for eccentric anomaly. Solution by Eq. (26)
9	$\sin \nu_k = \dfrac{\sqrt{1 - e^2}\, \sin E_k}{1 - e \cos E_k}$ $\cos \nu_k = \dfrac{\cos E_k - e}{1 - e \cos E_k}$	True anomaly. Correct quadrant of ν_k must be determined. We recommend using atan2 function.
10	$\Phi_k = \nu_k + \omega$	Argument of latitude
11	$\delta u_k = c_{us} \sin 2\Phi_k + c_{uc} \cos 2\Phi_k$	Argument of latitude correction
12	$\delta r_k = c_{rs} \sin 2\Phi_k + c_{rc} \cos 2\Phi_k$	Radius correction
13	$\delta i_k = c_{is} \sin 2\Phi_k + c_{ic} \cos 2\Phi_k$	Inclination correction
14	$u_k = \Phi_k + \delta u_k$	Corrected argument of latitude
15	$r_k = A\left(1 - e \cos E_k\right) + \delta r_k$	Corrected radius
16	$i_k = i_0 + \delta i_k + (IDOT)\, t_k$	Corrected inclination
17	$x'_k = r_k \cos u_k$ $y'_k = r_k \sin u_k$	Position in orbital plane
18	$\Omega_k = \Omega_0 + \left(\dot{\Omega} - \dot{\Omega}_e\right) t_k - \dot{\Omega}_e t_{oe}$	Corrected longitude of ascending node
19	$x_k = x'_k \cos \Omega_k - y'_k \cos i_k \sin \Omega_k$ $y_k = x'_k \sin \Omega_k + y'_k \cos i_k \cos \Omega_k$ $z_k = y'_k \sin i_k$	WGS84 Cartesian coordinates, ($X^s = x_k$, $Y^s = y_k$, $Z^s = z_k$)

4   Identification of orbit parameters in RINEX format

RINEX format is defined in [2]. There are several types of RINEX files: observation, meteorological, message and navigation files. Only navigation files are relevant in this report. The name of a GPS navigation file is usually in form *ssssdddf.yyN*
where

ssss	4-character station name designator
ddd	day of the year of first record
f	file sequence number within day
yy	year
N	stands for "navigation"

If *f* = 0, file contains all the existing data of the current day.
Navigation file is a text file consisting of two parts: header and data records. The complete description of header is given in Table 5. Data records follow immediately after the header. One record contains data for one satellite and one reference epoch. Each record consists of 8 lines. The first line contains satellite number (PRN), reference epoch of clock parameters, and clock polynomial parameters. Lines 2 - 8 contain four numbers each. The meaning of the numbers is described in Table 4. Format of numbers is described by FORTRAN symbolism. The meaning of used symbols:

1X	one space
F9.2	floating number expressed by 9 digits (including decimal point and sign), 2 of them are reserved for decimals
A20	20 characters long string
D12.4	double-precision number expressed by 12 digits (including decimal point and sign), 4 of them are reserved for decimals
I6	integer, six digits long

Number before the type specifier (X, F, D, A, I) specifies number of repetitions. For example 4D12.4 specifies 4 double-precision numbers, each of them 12 digits long with four decimals.

5   Constants

The following constants are adopted by GPS exactly with given number of decimals.

Table 3. Constants according to the GPS interface document [1]

Constant	Numerical value	Unit
c	299792458	m/s
π	3.1415926535898	
μ	3.986005 x 10^{14}	m^3/s^2
$\dot{\Omega}_e$	7.2921151467 x 10^{-5}	rad/s

Table 4. GPS navigation message file - data record description

LINE OF RECORD	DESCRIPTION	FORMAT
1	Satellite PRN number	I2,
	Epoch: t_{oc} - Time of Clock	
	year (2 digits)	1X, I2
	month	1X, I2,
	day	1X, I2,
	hour	1X, I2,
	minute	1X, I2,
	second	F5.1
	SV clock bias a_{f0}	D19.12
	SV clock drift a_{f1}	D19.12
	SV clock drift rate a_{f2}	D19.12
2	IODE	3X, D19.12
	C_{rs}	D19.12
	Δn	D19.12
	M_0	D19.12
3	C_{uc}	3X, D19.12
	e	D19.12
	C_{us}	D19.12
	$\sqrt{A}$	D19.12
4	t_{oe}	3X, D19.12
	C_{ic}	D19.12
	(OMEGA)$_0$, Ω_0	D19.12
	C_{is}	D19.12
5	i_0	3X, D19.12
	C_{rc}	D19.12
	ω	D19.12
	OMEGADOT, $\dot{\Omega}$	D19.12
6	IDOT	3X, D19.12
	Code on L2	D19.12
	Week No. (to go with t_{oe})	D19.12
	L2 P data flag	D19.12
7	SV accuracy	3X, D19.12
	SV health	D19.12
	T_{GD}	D19.12
	IODC	D19.12
8	Transmission time of message	3X, D19.12
	Fit interval (Zero if not known)	D19.12
	Spare	D19.12
	Spare	D19.12

Table 5. GPS navigation message file - header section description, [2]

HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
RINEX VERSION / TYPE	- Format version (2.10) - File type ('N' for Navigation data)	F9.2, 11X, A1, 19X
PGM / RUN BY / DATE	- Name of program creating current file - Name of agency creating current file - Date of file creation	A20, A20, A20
COMMENT	Comment line(s)	A60
ION ALPHA	Ionosphere parameters α_0 - α_3	2X, 4D12.4
ION BETA	Ionosphere parameters β_0 - β_3	2X, 4D12.4
DELTA-UTC: A0,A1,T,W	Almanac parameters to compute time in UTC A0, A1: terms of polynomial T : reference time for UTC data W : UTC reference week number. Continuous number, not mod(1024)!	3X, 2D19.12, 2I9
LEAP SECONDS	Delta time due to leap seconds	I6
END OF HEADER	Last record in the header section.	60X

Table 6. Example of parameter identification in RINEX navigation file

```
    2.10              OBSERVATION DATA       G (GPS)              RINEX VERSION / TYPE
teqc  2002Mar14                              20040202 02:07:05UTCPGM / RUN BY / DATE
_OVO.0                                                           MARKER NAME
108638.0                                                         MARKER NUMBER
SWEPOS              LMU                                          OBSERVER / AGENCY
201                 ASHTECH UZ-12      UFB5                      REC # / TYPE / VERS
486                 ASH700936D_M       OSOD                      ANT # / TYPE
  3104219.4530    998383.9820   5463290.5080                    APPROX POSITION XYZ
       0.0710        0.0000        0.0000                        ANTENNA: DELTA H/E/N
      1     1                                                    WAVELENGTH FACT L1/2
      7  C1   L1   L2   P1   P2   D1   D2                        # / TYPES OF OBSERV
    15.0000                                                      INTERVAL
Forced Modulo Decimation to 15 seconds                          COMMENT
  2004     2     2    1                           GPS           TIME OF FIRST OBS
  2004     4     1   59                           GPS           TIME OF LAST OBS
MSWin2000|IAx86-PII|bcc3                          001|486/DX+   COMMENT
teqc  2002Mar14                                   02 02:07:00UTCCOMMENT
IMoS GFileSrv 3.32  LMU                           2004          COMMENT
                                                               END OF HEADER
 04  2  2  1  0   0.0000000  0 12G24G13G 8G21G29G26G10G17G 2G28G 3G27
   25001257.939 3  -3240782.381 3  -2477390.27041  25001256.67943  25001263.55241
      -3326.175       -2591.814
   23106629.672 3 -12188598.444 3   -9438884.30442  23106630.26943  23106632.40442
      -3249.560       -2532.122
   20664230.640 4 -27083620.911 4  -21043552.60142  20664230.28544  20664233.24942
       1668.628        1300.232
   24835458.607 3  -1852700.687 3   -1409814.31741  24835459.14243  24835461.18641
       2256.893        1758.620
```

Observation epoch (y m d h m s)

number of satellites for the epoch followed by list of them

P1 code pseudorange towards satellite 13

Table 7. Example of observation identification in RINEX observation file.

6 References

[1]   GPS Interface Control Document IS-GPS-200M, file IS-GPS-200M.pdf

[2]   Werner Gurtner: RINEX: The Receiver Independent Exchange Format Version 2.10, Astronomical Institute, University of Berne, January 2002. File rinex.format.

[3]   Hofmann-Wellenhof, B., H. Lichtenegger and J. Collins, 2001: GPS, Theory and Practice. Springer Verlag, (Fifth, revised edition).

[4]   Leick, A., 1995: GPS satellite surveying. John Wiley and Sons.