International Reports

Technical Directives for Standardization of GPS Time Receiver Software

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

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1. Introduction

The observation, using the common-view method [1], of satellites of the Global Positioning System (GPS), is one of the most precise and accurate methods for time comparison between remote clocks on the Earth or in its close vicinity. It has already been shown that this method is capable of providing accuracy at the level of a few nanoseconds when using accurate GPS antenna coordinates, post-processed precise satellite ephemerides, measured ionospheric delays and results derived from differential calibrations of receivers [2].

Improvement of the common-view method to sub-nanosecond accuracy may be limited by:

(a) the effects of Selective Availability (SA), an intentional degradation of GPS satellite signals currently implemented on Block II satellites; and

(b) the lack of standardization in commercial GPS time receiver software, which does not treat short-term data by a unified procedure.

A group of experts has been formed to draw up standards to be observed by the users and manufacturers concerned with the use of GPS time receivers for common-view time transfer. This group, the Group on GPS Time Transfer Standards (GGTTS) operates under the auspices of the permanent Working Group on improvements to TAI, chaired by Dr G.M.R. Winkler, of the Comité Consultatif pour la Définition de la Seconde (CCDS). Its membership is drawn from key experts from some of the principal timing centres along with some representation from the GPS manufacturing community. The Group is complementary to the Subcommittee on Time of the Civil GPS Service Interface Committee (CGSIC) which is mainly a forum 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:

(a) limitations in the software and hardware of the different GPS receiver manufacturers; and

(b) limitations in past procedures imposed by the data format and the methods used to acquire data.

Following extended discussions at an open forum (2 December 1991, Pasadena, California, USA) and three formal meetings (5 December 1991, Pasadena, 11 June 1992, Paris, France, and 23 March 1993 at the BIPM, Sèvres, France), conclusions from the Group were presented during the 12th Session of the CCDS (24-26 March 1993 at the BIPM). In turn, the CCDS adopted Recommendation S 6, for presentation to the Comité International des Poids et Mesures.

GPS time transfer standardization

Recommendation S 6 (1993)

The Comité Consultatif pour la Définition de la Seconde,

considering

that the common-view method for the observation of satellites of the Global Positioning System (GPS), is one of the most precise and accurate methods for time comparison between remote clocks on the Earth or in its close vicinity,

that this method has the potential for reaching an accuracy approaching 1 ns,

the need for removing the effects of Selective Availability (SA),

the lack of standardization in GPS timing receiving equipment,

the need for absolute as well as relative calibration of GPS timing receiving equipment,

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recommends

that GPS timing receiver manufacturers proceed towards the implementation of the technical directives produced by the Group on GPS Time Transfer Standards,

that methods be developed and implemented for frequent and systematic calibration of GPS timing receiving equipment.

This recommendation is addressed to GPS timing receiver manufacturers and recommends them to implement the decisions of the Group on GPS Time Transfer Standards. It also emphasizes the need for both absolute and relative calibration methods.

The present document lists explicit technical directives for software standardization of single frequency C/A-Code GPS time receivers, possibly operating in tandem with an ionospheric measurement system, with a view to improving the accuracy of GPS common-view time transfer performed with such devices. It lists the final conclusions of the Group: a more detailed account of its work is given in [3-9].

2. Technical Directives

The directives issued by the Group on GPS Time Transfer Standards are designed to improve the accuracy of GPS common-view time transfer. They take the form of nine general technical directives for the standardization of GPS time receiver software and are supplemented by three detailed annexes: Structure of Short-term Observations; Processing of GPS Short-term Data Taken over a Full Track; and GGTTS GPS Data Format Version 01.

The general technical directives are:

Technical Directive 1

The sole reference time scale to be used for monitoring GPS satellite tracks is Universal Coordinated Time, UTC, as produced and distributed by the BIPM.

Technical Directive 2

Each GPS common-view track is characterized by the date of the first observation, given as a Modified Julian Date (MJD) together with a UTC hour, minute and second. The length of each track corresponds to the recording of 780 successive short-term observations, at intervals of 1 second, as described in Annex I.

Technical Directive 3

The regular International GPS Tracking Schedule, for observation of GPS satellites in common view, is prepared by the BIPM. The time of a track given in the BIPM International GPS Tracking Schedule is the date of the first observation.

Note
A period of order 2 minutes is usually required to lock the receiver onto the satellite signal. The characteristic date of a track, as defined by Technical Directive 2, is not given as the date of the beginning of the lock-on procedure, but as the date of the first actual observation used in short-term data reduction as explained in Annex I and Annex II. Following the practical implementation of the technical directives given in the present document, the dates given in the BIPM International GPS Tracking Schedule thus have a different meaning from that of earlier schedules.

Technical Directive 4

The sole method approved for short-term data processing is that detailed in Annex II.

Technical Directive 5

All modelled procedures, parameters and constants needed in short-term data processing are deduced from the information given in the Interface Control Document of the US Department of Defense or in the NATO Standardization Agreement (STANAG). These are updated at each new issue.

Technical Directive 6

The receiver software allows local antenna coordinates to be entered in the form X, Y and Z.

Technical Directive 7

An option in the operation of the receiver allows short-term data taken every second, data resulting from the standard treatment over 15 seconds detailed in Annex II, parameters and constants used in the software for the GPS time receiver to be output at the choice of the individual user.

Technical Directive 8

The GPS time receiver should have the capability to cover the twenty-four hours of a day with regular tracks, the number of daily tracks not being subject to artificial limitation.

Note
A full-length track lasts 13 minutes, the receiver usually needs about 2 minutes for locking onto the signal and an additional 1 minute is helpful for data-processing and preparation for a new track, so that two consecutive tracks are reasonably distant by 16 minutes. The twenty-four hours of a day correspond to 90 successive intervals of 16 minutes and are then covered with 89 full-length

tracks, taking into account the 4 minute day-to-day recurrence of the satellite observation which prevents observation of a 90th full-length track.

Technical Directive 9

The GPS data are recorded and transmitted in data files arranged according to the data file format given in Annex III, which comprises in particular:

(a) a file header with detailed information concerning the receiver operation;
(b) a check-sum parameter for each data line in order to minimize errors in data transmission;
(c) most of the quantities reported at the actual mid-time of tracks; and
(d) optional additional columns, not included in the value of the check-sum, for comments and additional data.

Each line of the data file is terminated by a carriage-return and a line feed. For multichannel GPS time receivers, one data file is created for each channel.

3. Conclusions

The technical directives listed in this document have been established by the members of the Group on GPS Time Transfer Standards after careful studies and numerous discussions. The Group is well aware of the volume of work which is requested of the receiver manufacturers and also of consequential changes for national laboratories.

The implementation of these directives, however, will unify GPS time receiver software and avoid any misunderstandings concerning the content of GPS data files. Immediate consequences will be an improvement in the accuracy and precision of GPS time links computed through strict common views, as used by the BIPM for the computation of TAI, and improvement in the short-term stability of reference time scales like UTC.

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Annex I. Structure of Short-term Observations

The GPS short-term observations are pseudo-range data taken every second. The pseudo-range data are measurements of a laboratory reference 1 pps (1 pulse-per-second) signal against the 1 pps signal received from the satellite, obtained using a time-interval counter or some equivalent method. Each pseudo-range measurement includes a value of the received signal integrated over a time which depends on the receiver hardware. This integration time should be 1 second or less.

In the following, one given pseudo-range data is characterized by its date, i.e. by a label with MJD and UTC hour, minute and second, corresponding to the date of the laboratory 1 pps. The start time of a track, as given in the International GPS Tracking Schedule according to Technical Directive 3, is thus the date of the first pseudo-range data, which corresponds, in reality, to a received signal integrated over a time interval ending on this date. The International GPS Tracking Schedule is thus composed of a list of satellites to observe at a nominal start time referenced to UTC. Additional hexadecimal numbers, called common-view classes (CL) are added to characterize the common views between different regions of the Earth.

Here, for simplification, the start time of a track is designed as second 0. The successive pseudo-range data can be represented as in Figure AI.1.

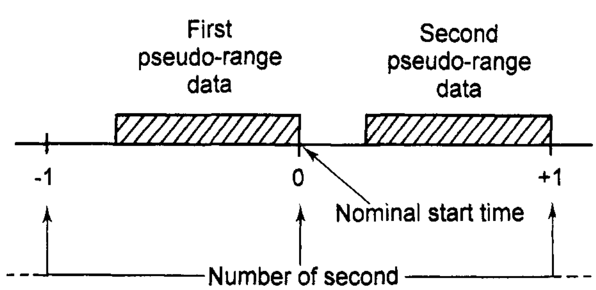

Figure AI.1. Successive pseudo-range data.

According to Annex II, the pseudo-range data are first processed through quadratic fits applied to successive and non-overlapping sets of 15 pseudo-range data. The first quadratic fit is thus applied to the pseudo-range data dated at seconds 0, 1, …, 14. The result of this first quadratic fit is given for the date corresponding to the midpoint, i.e. to second 7.

The second quadratic fit is applied to the 15 following pseudo-range data, dated at seconds 15, 16, …, 29, thus each pseudo-range data is used once and only once. The result of this second quadratic fit is estimated at second 22.

The first dates of quadratic fits are thus seconds 0 [mod 15], the last dates of quadratic fits are seconds 14 [mod 15] and the dates of quadratic fit results are seconds 7 [mod 15]. This can be represented as shown in Figure AI.2.

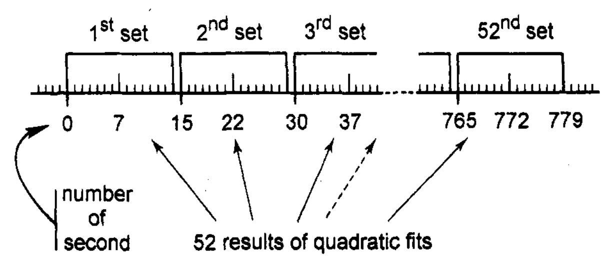

Figure AI.2. First dates of quadratic fits and dates of the results of quadratic fits.

According to Technical Directive 2, each full track corresponds to the recording of 780 pseudo-range data, which are dated from second 0 to second 779. The process thus uses 52 sets of 15 data and performs 52 quadratic fits, whose results are dated at second 7, 22, …, 772. A linear fit is then applied to these results (see Annex II).

Notes

- *From the above, it appears that the duration of a full-length track is equal to 779 s and not to 780 s, as is usually said. In fact, this is not true: as pseudo-range measurements are integrated over a time interval, the first begins before second 0 and the last ends at second 779. For simplification, the track length, appearing under the acronym TRKL, is taken to be 780 s for full-length tracks, or to be the number of pseudo-range measurements for shorter tracks.*
- *Several linear fits are performed to further reduce the quadratic fit results. The results of these linear fits are then estimated at the date corresponding to the middle of the actual track (see Annex III). This particular date does not appear in the data file, as only the starting date is reported. Rigorously it should be labelled second 389,5 for full-length tracks and does not corrrespond to an even second.*

Annex II. Processing of GPS Short-term Data Taken over a Full Track

Data processing is performed as follows:

(i) Pseudo-range data are recorded for times corresponding to successive dates at intervals of 1 second. The date of the first pseudo-range data is the nominal starting time of the track. It is referenced to UTC and appears in the data file under the acronyms MJD and STTIME.

(ii) Least-squares quadratic fits are applied on successive and non-overlapping sets of 15 pseudo-range measurements dated according to Annex I. The quadratic fit results are estimated at the date corresponding to the midpoint of each set.

(iii) Corrections listed below are evaluated at the dates corresponding to the results of (ii) (see Annex I) and applied to these results:

(iii-1) geometric delay from ground-antenna coordinates and broadcast ephemerides (fixed for a track);
(iii-2) ionospheric delay from broadcast parameters;
(iii-3) tropospheric delay;
(iii-4) Sagnac correction;
(iii-5) periodic relativistic correction due to the eccentricity of the GPS satellite's orbit; *
(iii-6) L_1-L_2 broadcast correction;
(iii-7) receiver delay;
(iii-8) antenna and local-clock cable delays.

(iv) Clock corrections for access to GPS time, as derived from a second-order polynomial (usually written as $a_0 + a_1t + a_2t^2$) whose coefficients are contained in the GPS message, are evaluated at the dates corresponding to the results of (ii) and applied to the results of (iii).

(v) The nominal track length corresponds to the recording of 780 short-term measurements. The number of successive and non-overlapping data sets treated according to (ii), (iii) and (iv) is then equal to 52 (see Annex I). For full tracks, the track length, TRKL, is taken equal to 780 s (see Annex I).

(vi) At the end of the track, a number of least-squares linear fits are performed.

(vi-a) One linear fit treats all the data resulting from (iii); the result of this linear fit takes the form of an estimate of the quantity to be measured, REFSV, reported at the date corresponding to the midpoint of the actual track, and a slope, SRSV, given in the GPS data file.
(vi-b) One linear fit treats all the data resulting from (iv); the result of this linear fit takes the form of an estimate of the quantity to be measured, REFGPS, reported at the date corresponding to the midpoint of the actual track, a slope, SRGPS, and a rms, DSG, given in the GPS data file.
(vi-c) One linear fit treats the modelled ionospheric corrections evaluated in (iii-2); the result of this linear fit takes the form of an estimate of the modelled ionospheric delay, MDIO, reported at the date corresponding to the midpoint of the actual track, and a slope, SMDI, given in the GPS data file.
(vi-d) One linear fit treats the modelled tropospheric corrections evaluated in (iii-3); the result of this linear fit takes the form of an estimate of the modelled tropospheric delay, MDTR, reported at the date corresponding to the midpoint of the actual track, and a slope, SMDT, given in the GPS data file.
(vi-e) One linear fit treats the measured ionospheric corrections obtained from an Ionospheric Measurement System, if available, at the dates corresponding to the results of (ii); the result of this linear fit takes the form of an estimate of the measured ionospheric delay, MSIO, reported at the date corresponding to the midpoint of the actual track, a slope, SMSI, and a rms, ISG, given in the GPS data file.

Note
The Group on GPS Time Transfer Standards gives a tolerance for data which is not in the form of pseudo-ranges at intervals of 1 second if the hardware of the GPS time receiver currently in operation does not generate such data.
For existing receivers which take short-term observations every 0,6 s, the data processing could closely copy that given in this Annex, with quadratic fits over durations of about 15 s followed by a linear fit.
For existing receivers which take short-term observations every 6 seconds, it is reasonable to process the 6 second data directly through a linear fit.
It is expected that new receivers will operate in accordance with the basic 1 second pseudo-range data.

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);

(iii) a *line header* with the acronyms of the reported quantities (line 18);

(iv) a *unit header* with the units used for the reported quantities (line 19); and

(v) a series of *data lines* (lines 20, 21, 22, ..., (n-1), n, ..., etc.), each line corresponding to one GPS track. The GPS tracks are ordered in chronological order, the track reported in line n occurring after the track reported in line (n-1).

Each line of the data file is limited to 128 columns and is terminated by a carriage-return and a line feed.

* The constant part of the relativistic correction to the frequency, consisting of the gravitational red shift and the second-order Doppler effect, is applied before launch to the satellite oscillators as a frequency offset.

Notes
- ** stands for a space, ASCII value 20 (hexadecimal). Text to be written in the data file is indicated by " ".*
- *The line order described in (v) does not correspond to the line order output by most current receivers.*

1. File header

Line 1: `"GGTTS*GPS*DATA*FORMAT*VERSION* = *" N`
Title to be written.
`N = 01.`
34 columns (as long as N < 100).

Line 2: `"REV*DATE* = *" YYYY"-"MM"-"DD`
Revision date of the header data, changed when 1 parameter given in the header is changed.
`YYYY-MM-DD` for year, month and day.
21 columns.

Line 3: `"RCVR* = *" MAKER"*"TYPE"*"SERIAL NUMBER"*"YEAR"*" SOFTWARE NUMBER`
Maker acronym, type, serial number, first year of operation, and eventually software number of the GPS time receiver.
As many columns as necessary.

Line 4: `"CH* = *" CHANNEL NUMBER`
Number of the channel used to produce the data included in the file, `CH = 01` for a one-channel receiver.
7 columns (as long as CH < 100).

Line 5: `"IMS* = *" MAKER"*"TYPE"*"SERIAL NUMBER"*"YEAR"*" SOFTWARE NUMBER`
Maker acronym, type, serial number, first year of operation, and eventually software number of the Ionospheric Measurement System.
`IMS = 99999` if none.
Similar to line 3 if included in the time receiver.
As many columns as necessary.

Line 6: `"LAB* = *" LABORATORY`
Acronym of the laboratory where observations are performed.
As many columns as necessary.

Line 7: `"X* = *" X COORDINATE "*m"`
X coordinate of the GPS antenna, in m and given with at least 2 decimals.
As many columns as necessary.

Line 8: `"Y* = *" Y COORDINATE "*m"`
Y coordinate of the GPS antenna, in m and given with at least 2 decimals.
As many columns as necessary.

Line 9: `"Z* = *" Z COORDINATE "*m"`
Z coordinate of the GPS antenna, in m and given with at least 2 decimals.
As many columns as necessary.

Line 10: `"FRAME* = *" FRAME`
Designation of the reference frame of the GPS antenna coordinates.
As many columns as necessary.

Line 11: `"COMMENTS* = *" COMMENTS`
Any comments about the coordinates, for example the method of determination or the estimated uncertainty.
As many columns as necessary.

Line 12: `"INT*DLY* = *" INTERNAL DELAY "*ns"`
Internal delay entered in the GPS time receiver, in ns and given with 1 decimal.
As many columns as necessary.

Line 13: `"CAB*DLY* = *" CABLE DELAY "*ns"`
Delay coming from the cable length from the GPS antenna to the main unit, entered in the GPS time receiver, in ns and given with 1 decimal.
As many columns as necessary.

Line 14: `"REF*DLY* = *" REFERENCE DELAY "*ns"`
Delay coming from the cable length from the reference output to the main unit, entered in the GPS time receiver, in ns and given with 1 decimal.
As many columns as necessary.

Line 15: `"REF* = *" REFERENCE`
Identifier of the time reference entered in the GPS time receiver. For laboratories contributing to TAI it can be the 7-digit code of a clock or the 5-digit code of a local UTC, as attributed by the BIPM.
As many columns as necessary.

Line 16: `"CKSUM* = *" XX`
Header check-sum: hexadecimal representation of the sum, modulo 256, of the ASCII values of the characters which constitute the complete header, beginning with the first letter "G" of "GGTTS" in line 1, including all spaces indicated as * and corresponding to the ASCII value 20 (hexadecimal), ending with the space after " = " of line 16 just preceding the actual check sum value, and excluding all carriage returns or line feeds.
10 columns.

Line 17: blank line.

2. Line header

2.1 No measured ionospheric delays available

Line 5 of the header indicates: `IMS = 99999`

No ionospheric measurements are available, the specific format of the line header is as follows:

Line 18.1: "PRN*CL**MJD**STTIME*TRKL*ELV*AZTH***REFSV******SRSV*****REFGPS****SRGPS**DSG*IOE*MDTR*SMDT*MDIO*SMDI*CK"
Line to be written.
The acronyms are explained in Section 4 below.
103 columns.

2.2 Measured ionospheric delays available

Line 5 of the header indicates, for instance:

IMS = AIR NIMS 003 1992
(Example with fictitious data, see Section 6 below).

Ionospheric measurements are available, the specific format of the line header is as follows:

Line 18.2: "PRN*CL**MJD**STTIME*TRKL*ELV*AZTH***REFSV******SRSV*****REFGPS****SRGPS**DSG*IOE*MDTR*SMDT*MDIO*SMDI*MSIO*SMSI*ISG*CK"
Line to be written.
The acronyms are explained in Section 4 below.
117 columns.

3. Unit header

3.1 No measured ionospheric delays available

Line 19.1: "*************hhmmss**s**.1dg*.1dg****.1ns*****.1ps/s*****.1ns****.1ps/s*.1ns*****.1ns.1ps/s.1ns.1ps/s**"
Line to be written.
103 columns.

3.2 Measured ionospheric delays available

Line 19.2: "*************hhmmss**s**.1dg*.1dg****.1ns*****.1ps/s*****.1ns****.1ps/s*.1ns*****.1ns.1ps/s.1ns.1ps/s.1ns.1ps/s.1ns**"
Line to be written.
117 columns.

4. Data line

Line 20, column 1: space, ASCII value 20 (hexadecimal).

Line 20, columns 2-3: "12" PRN
Satellite vehicle PRN number.
No unit.

Line 20, column 4: space, ASCII value 20 (hexadecimal).

Line 20, columns 5-6: "12" CL
Common-view hexadecimal class byte.
No unit.

Line 20, column 7: space, ASCII value 20 (hexadecimal).

Line 20, columns 8-12: "12345" MJD
Modified Julian Day.
No unit.

Line 20, column 13: space, ASCII value 20 (hexadecimal).

Line 20, columns 14-19: "121212" STTIME
Date of the start time of the track (see Annex I).
In hour, minute and second referenced to UTC.

Line 20, column 20: space, ASCII value 20 (hexadecimal).

Line 20, columns 21-24: "1234" TRKL
Track length, 780 for full tracks (see Annex I).
In s.

Line 20, column 25: space, ASCII value 20 (hexadecimal).

Line 20, columns 26-28: "123" ELV
Satellite elevation at the date corresponding to the midpoint of the track.
In 0.1 degree.

Line 20, column 29: space, ASCII value 20 (hexadecimal).

Line 20, columns 30-33: "1234" AZTH
Satellite azimuth at the date corresponding to the midpoint of the track.
In 0.1 degree.

Line 20, column 34: space, ASCII value 20 (hexadecimal).

Line 20, columns 35-45: "+1234567890" REFSV
Time difference resulting from the treatment (vi-a) of Annex II.
In 0.1 ns.

Line 20, column 46: space, ASCII value 20 (hexadecimal).

Line 20, columns 47-52: "+12345" SRSV
Slope resulting from the treatment (vi-a) of Annex II.
In 0.1 ps/s.

Line 20, column 53: space, ASCII value 20 (hexadecimal).

Line 20, columns 54-64: "+1234567890" REFGPS
Time difference resulting from the treatment (vi-b) of Annex II.
In 0.1 ns.

Line 20, column 65: space, ASCII value 20 (hexadecimal).

Line 20, columns 66-71: `"+12345"` SRGPS
Slope resulting from the treatment (vi-b) of Annex II.
In 0.1 ps/s.

Line 20, column 72: space, ASCII value 20 (hexadecimal).

Line 20, columns 73-76: `"1234"` DSG
[Data Sigma] Root-mean-square of the residuals to the linear fit (vi-b) of Annex II.
In 0.1 ns.

Line 20, column 77: space, ASCII value 20 (hexadecimal).

Line 20, columns 78-80: `"123"` IOE
[Index of Ephemeris] Three-digit decimal code (0-255) indicating the ephemeris used for the computation.
No unit.

Line 20, column 81: space, ASCII value 20 (hexadecimal).

Line 20, columns 82-85: `"1234"` MDTR
Modelled tropospheric delay resulting from the linear fit (vi-d) of Annex II.
In 0.1 ns.

Line 20, column 86: space, ASCII value 20 (hexadecimal).

Line 20, columns 87-90: `"+123"` SMDT
Slope of the modelled tropospheric delay resulting from the linear fit (vi-d) of Annex II.
In 0.1 ps/s.

Line 20, column 91: space, ASCII value 20 (hexadecimal).

Line 20, columns 92-95: `"1234"` MDIO
Modelled ionospheric delay resulting from the linear fit (vi-c) of Annex II.
In 0.1 ns.

Line 20, column 96: space, ASCII value 20 (hexadecimal).

Line 20, columns 97-100: `"+123"` SMDI
Slope of the modelled ionospheric delay resulting from the linear fit (vi-c) of Annex II.
In 0.1 ps/s.

Line 20, column 101: space, ASCII value 20 (hexadecimal).

4.1 No measured ionospheric delays available

Line 20.1, columns 102-103: `"12"` CK
Data line check-sum: hexadecimal representation of the sum, modulo 256, of the ASCII values of the characters which constitute the data line from column 1 to column 101 (both included).

Line 20.1, columns 104-128:
`"1234567890123456789012345"`
Optional comments on the data line, constituted of characters which are not included in the line check-sum CK.

4.2 Measured ionospheric delays available

Line 20.2, columns 102-105: `"1234"` MSIO
Measured ionospheric delay resulting from the linear fit (vi-e) of Annex II.
In 0.1 ns.

Line 20.2, column 106: space, ASCII value 20 (hexadecimal).

Line 20.2, columns 107-110: `"+123"` SMSI
Slope of the measured ionospheric delay resulting from the linear fit (vi-e) of Annex II.
In 0.1 ps/s.

Line 20.2, column 111: space, ASCII value 20 (hexadecimal).

Line 20.2, columns 112-114: `"123"` ISG
[Ionospheric Sigma] Root-mean-square of the residuals to the linear fit (vi-e) of Annex II.
In 0.1 ns.

Line 20.2, column 115: space, ASCII value 20 (hexadecimal).

Line 20.2, columns 116-177: `"12"` CK
Data line check-sum: hexadecimal representation of the sum, modulo 256, of the ASCII values of the characters which constitute the data line, from column 1 to column 115 (both included).

Line 20.2, columns 118-128: `"12345678901"`
Optional comments on the data line, constituted of characters which are not included in the line check-sum.

Notes

- *Any missing data should be replaced by series of 9.*
- *When the number of columns reserved for reporting a quantity is too large, the value of the corresponding quantity must be preceded by spaces, ASCII value 20 in hexadecimal (see Section 6 below).*

5. Conclusions

The format for one data line can be represented as follows:

5.1 No measured ionospheric delays available

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000011111111111111111111111111111
00000000011111111112222222222333333333344444444445555555555666666666677777777778888888888999999999900000000001111111111222222222
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678
PRN*CL**MJD**STTIME*TRKL*ELV*AZTH***REFSV******SRSV*****REFGPS****SRGPS**DSG*IOE*MDTR*SMDT*MDIO*SMDI*CK
************hhmmss**s**.1dg*.1dg****.1ns*****.1ps/s*****.1ns****.1ps/s*.1ns*****.1ns.1ps/s.1ns.1ps/s**
*12*12*12345*121212*1234*123*1234*+1234567890*+12345*+1234567890*+12345*1234*123*1234*+123*1234*+123*12optionalcommentsoptionalc
```

5.2 Measured ionospheric delays available

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000011111111111111111111111111111
00000000011111111112222222222333333333344444444445555555555666666666677777777778888888888999999999900000000001111111111222222222
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678
PRN*CL**MJD**STTIME*TRKL*ELV*AZTH***REFSV******SRSV*****REFGPS****SRGPS**DSG*IOE*MDTR*SMDT*MDIO*SMDI*MSIO*SMSI*ISG*CK
************hhmmss**s**.1dg*.1dg****.1ns*****.1ps/s*****.1ns****.1ps/s*.1ns*****.1ns.1ps/s.1ns.1ps/s.1ns.1ps/s.1ns**
*12*12*12345*121212*1234*123*1234*+1234567890*+12345*+1234567890*+12345*1234*123*1234*+123*1234*+123*1234*+123*123*12optcomments
```

6. Example (fictitious data)

6.1 No measured ionospheric delays available

```
GGTTS GPS DATA FORMAT VERSION = 01
REV DATE = 1993-05-28
RCVR = AOA TTR7A 12405 1987 14
CH = 15
IMS = 99999
LAB = XXXX
X = +4327301.23 m
Y = +568003.02 m
Z = +4636534.56 m
FRAME = ITRF88
COMMENTS = NO COMMENTS
INT DLY = 85.5 ns
CAB DLY = 232.0 ns
REF DLY = 10.3 ns
REF = 10077
CKSUM = C3

PRN CL  MJD  STTIME TRKL ELV AZTH   REFSV      SRSV     REFGPS    SRGPS  DSG IOE MDTR SMDT MDIO SMDI CK
             hhmmss  s  .1dg .1dg   .1ns      .1ps/s     .1ns    .1ps/s .1ns     .1ns.1ps/s.1ns.1ps/s
  3 8D 48877  20400  780 251 3560   -3658990   +100       +4520   +100    21 221   64  +90  452  -27 BBhello
 18 02 48877  35000  780 650  910  +56987262  -5602       +5921  -5602   350 123  102  +61  281  +26 52
 15 11 48878 110215  765 425 2700     +45893  +4892       +4269  +4890   306  55   54  -32  620  +15 A9
 15 88 48878 120000  780 531 2850     +45992  +4745       +4290  +4745   400  55   57  -29  627  +16 18receiv. out of operation
```

6.2 Measured ionospheric delays available

```
GGTTS GPS DATA FORMAT VERSION = 01
REV DATE = 1993-05-28
RCVR = AOA TTR7A 12405 1987 14
CH = 15
IMS = AIR NIMS 003 1992
LAB = XXXX
X = +4327301.23 m
Y = +568003.02 m
Z = +4636534.56 m
FRAME = ITRF88
COMMENTS = NO COMMENTS
INT DLY = 85.5 ns
CAB DLY = 232.0 ns
REF DLY = 10.3 ns
REF = 10077
CKSUM = 49

PRN CL  MJD  STTIME TRKL ELV AZTH   REFSV      SRSV     REFGPS    SRGPS  DSG IOE MDTR SMDT MDIO SMDI MSIO SMSI ISG CK
             hhmmss  s   .1dg .1dg   .1ns      .1ps/s    .1ns     .1ps/s .1ns     .1ns.1ps/s.1ns.1ps/s.1ns.1ps/s.1ns
  3 8D 48877  20400  780 251 3560   -3658990    +100       +4520    +100   21 221   64  +90  452  -27  480  -37  18 F4hello
 18 02 48877  35000  780 650  910  +56987262   -5602       +5921   -5602  350 123  102  +61  281  +26 9999 9999 999 89no meas ion
 15 11 48878 110215  765 425 2700     +45893   +4892       +4269   +4890  306  55   54  -32  620  +15  599  +16  33 29
 15 88 48878 120000  780 531 2850     +45992   +4745       +4290   +4745  400  55   57  -29  627  +16  601  +17  29 00rec out
```