

**IMPLEMENTATION OF A STANDARD FORMAT
FOR GPS COMMON VIEW DATA***

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ABSTRACT

A new format for standardizing common view time transfer data, recommended by the Consultative Committee for the Definition of the Second, is being implemented in receivers commonly used for contributing data for the generation of International Atomic Time. We discuss three aspects of this new format that potentially improve GPS common-view time transfer: (1) the standard specifies the method for treating short term data, (2) it presents data in consistent formats including needed terms not previously available, and (3) the standard includes a header of parameters important for the GPS common-view process. In coordination with the release of firmware conforming to this new format the Bureau International des Poids et Mesures will release future international track schedules consistent with the new standard.

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INTRODUCTION

A new format for standardizing common view time transfer data, recommended by the Consultative Committee for the Definition of the Second (CCDS), is being implemented in receivers commonly used for contributing data for the generation of International Atomic Time (TAI). The primary means of remote clock comparison for generating TAI is common-view GPS time transfer [1]. The global accuracy for this type of time transfer is currently less than 10 ns [2]. Understanding the sources of inaccuracy, the BIPM initiated an effort to standardize data-taking methods used in receivers and data transfer methods used for reporting to the BIPM. By combining this effort with the use of good coordinates, precise GPS satellite ephemerides, and measured local ionospheric delays, we hope to increase the accuracy for common-view time transfer [3].

One of the major motivations for standardization is the implementation of Selective Availability (SA) in GPS satellites. With SA, GPS timing is degraded as a way of limiting the navigation accuracy available to the standard positioning service (SPS) user. This follows since navigation in GPS is accomplished using measurements of time as received from satellites. If common-view time transfer is performed strictly, that is, with measurements taken on identical seconds, and with receivers which process the signals and the data identically, then the GPS satellite clocks cancel completely. SA makes this need for strict common-view even more important. We include in this paper some direct satellite data with SA and predict the effects on common-view time transfer due to differences in receivers. Thus, a standard can improve time transfer by allowing common-view time transfer to be done with different receivers and still cancel the effects of the satellite clock.

The new format has potential to improve GPS common-view time transfer due to a number of elements: (1) the standard specifies the method for treating short term data, (2) it presents data in consistent formats including needed terms not previously available, and (3) includes a header of parameters important for the GPS common-view process. Essential to common-view time transfer is that stations track satellites according to a common schedule. In coordination with the release of firmware conforming to this new format the Bureau International des Poids et Mesures (BIPM) will release future international track schedules consistent with the new standard. In this paper we summarize information about the short-term data processing, the header and the data format. When developing the standard for a receiver, one should obtain all the detailed information as reported in the Technical Directives [4].

SHORT TERM DATA PROCESSING

Data processing is performed as follows:

- (1) Pseudo-range data are recorded for times corresponding to successive dates at intervals of 1 s. 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.

(2) Least-squares quadratic fits are applied on successive and nonoverlapping sets of 15 pseudo-range measurements taken every second. The quadratic fit results are estimated at the date corresponding to the midpoint of each set.

(3) Corrections are applied to the results of (2) to obtain estimates of the local reference minus the Satellite Vehicle (SV) clock (REFSV) and of the local reference minus GPS time (REFGPS) for each 15 second interval.

(4) The nominal track length corresponds to the recording of 780 short-term measurements. The number of successive and nonoverlapping data sets treated according to (2) and (3) is then equal to 52. For full tracks, the track length TRKL will thus equal 780 s.

(5) At the end of the track, least-squares linear fits are performed to obtain and store the midpoint value and slope for both REFSV and REFGPS. Since these two are related deterministically by nearly a straight line they will have the same rms deviation around the fit, which is also stored as DSG. In addition, least-squares linear regression gives the midpoint and slope of the ionospheric and tropospheric model values, and the ionospheric measurements if they exist.

THE EFFECTS OF SA

We investigate the effects of SA by taking measurements every 15 s of GPS - UTC(NIST) tracking different satellites from horizon to horizon. We took data sequentially from three different satellites on two consecutive days, November 21-22, 1994. The satellites had pseudo-random code numbers (PRN's) 20, 22, and 25. Figures 1-3 show the data from the three satellites, and Figures 4-6 show the time deviation TDEV of the three, respectively.

The new standard will cancel all the clock dither when used for common-view GPS time transfer, provided that each of the two receivers involved track the same satellites over the same time periods. If there is a difference of 15 s in the tracking, for example if one receiver tracks 15 s less than the other, then the clock dither of SA will corrupt the common-view time transfer. We can estimate this by looking at the expected dispersion in time at due to SA at 15 s. The rms of the three TDEV values for $\tau=15$ s is 11 ns. From the TDEV plots we see that the slope on the log-log plots starts consistent with a model of τ^0 from 15-30 s. If we assume a model of flicker phase modulation (PM) for $\tau=15$ s this implies an expected time dispersion of 13 ns [5]. Over a 13 min track there are 52 estimates of REFGPS and REFSV each from a quadratic fit over 15 s

of data. Let us consider the case where one track is a full-length track and the matching track in another receiver is 15 s short. If we can assume that the effects of one 15 s point average down in the linear fit as the square root of the total number of points, then we can expect the effect on the common-view time transfer to be

$$\frac{13 \text{ ns}}{\sqrt{52}} = 1.8 \text{ ns}. \quad (1)$$

Thus SA could add approximately 2 ns to a common-view uncertainty budget with only a mismatch of 15 s from exact common-view. With a goal of 1 ns we see the reason why a standard for data taking can help common-view time transfer.

Many users receive GPS time directly from the satellites without using the common-view method to compare with another lab. From considering the TDEV of SA, we can design a filter that averages SA optimally, to allow users to obtain the best possible restitution of GPS time [6]. From the three TDEV analyses we see a bump rising from 1 min and dropping at 16 min. This effect could be due in part to a periodic behavior with a period of approximately 16 min [7,8]. Averaging can improve the GPS restitution if the TDEV values drop with increasing τ . Yet there is no indication in these data that the TDEV values drop significantly beyond 16 min. This may be due to effects at the beginning and end of the tracks when the elevation is low. This suggests limitations on the potential for filtering SA. Yet our data were taken using a single channel receiver. A multi-channel receiver could improve on filtering. It may be that the combination of SA signals still drop in TDEV, allowing improvement from averaging.

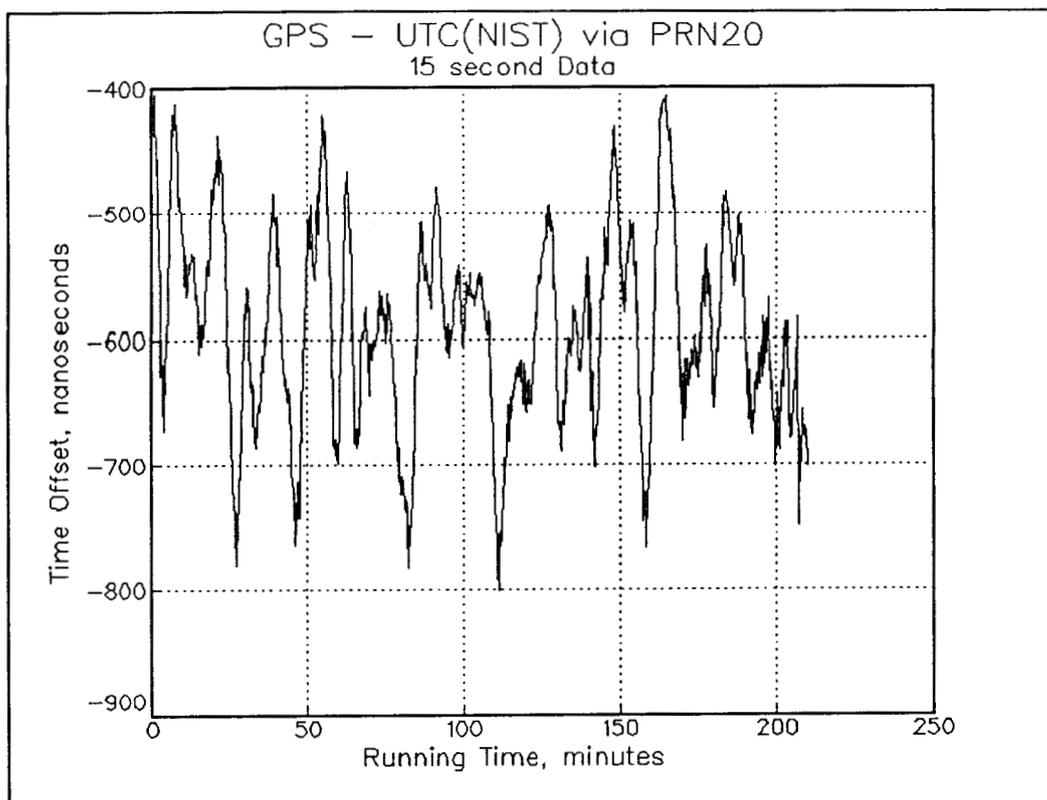


Figure 1. GPS time from PRN#20 time against UTC(NIST) every 15 s. The data start at 19:16:00 UT on November 21, 1994.

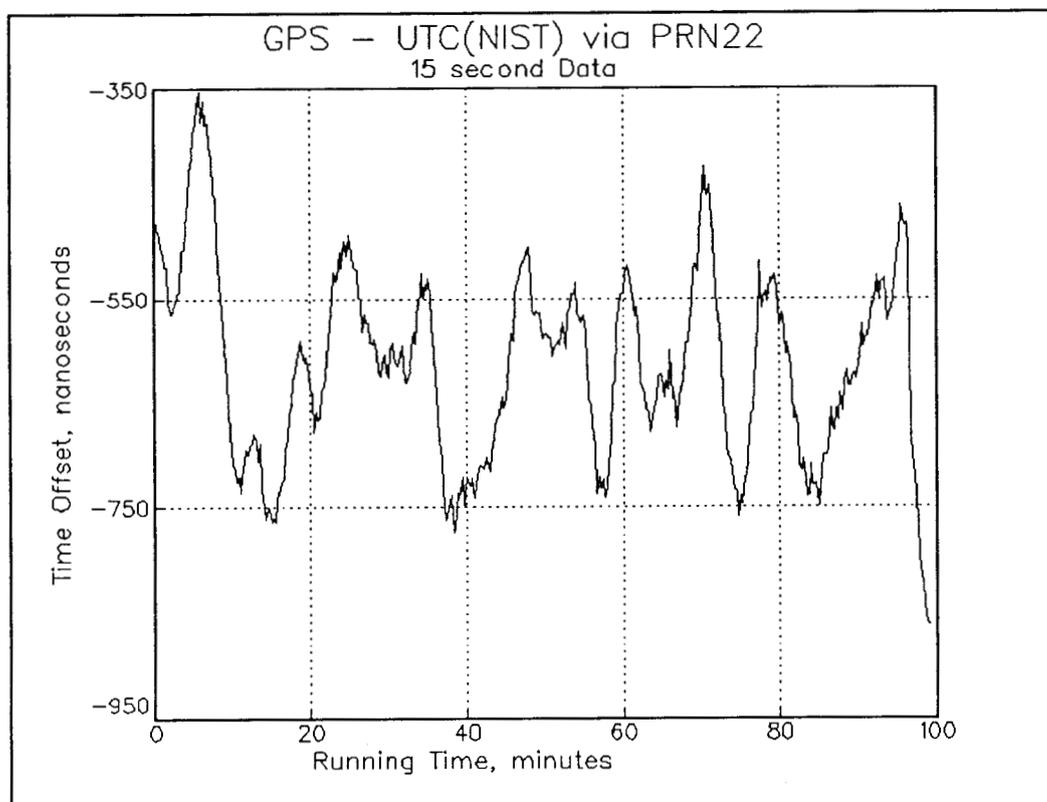


Figure 2 GPS time from PRN#22 measured against UTC(NIST) every 15 s. The data start at 01:05:15 UT on November 22, 1994.

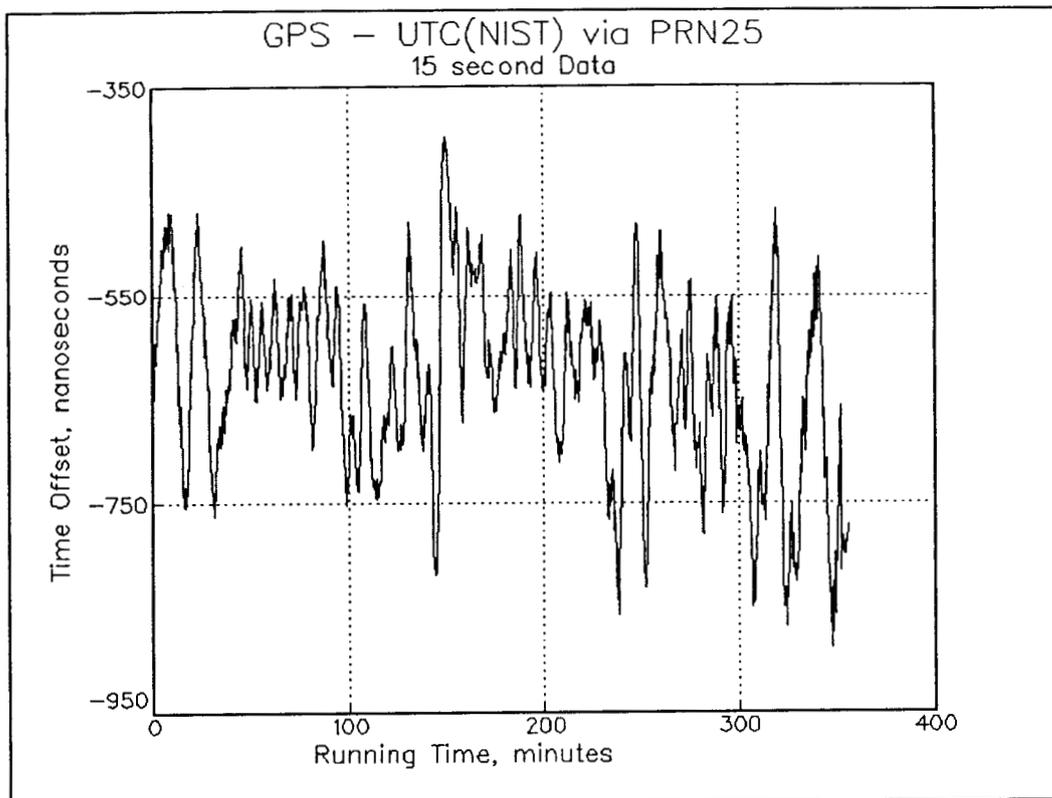


Figure 3 GPS time from PRN#25 measured against UTC(NIST) every 15 s. The data start at 18:52:45 UT on November 21, 1994.

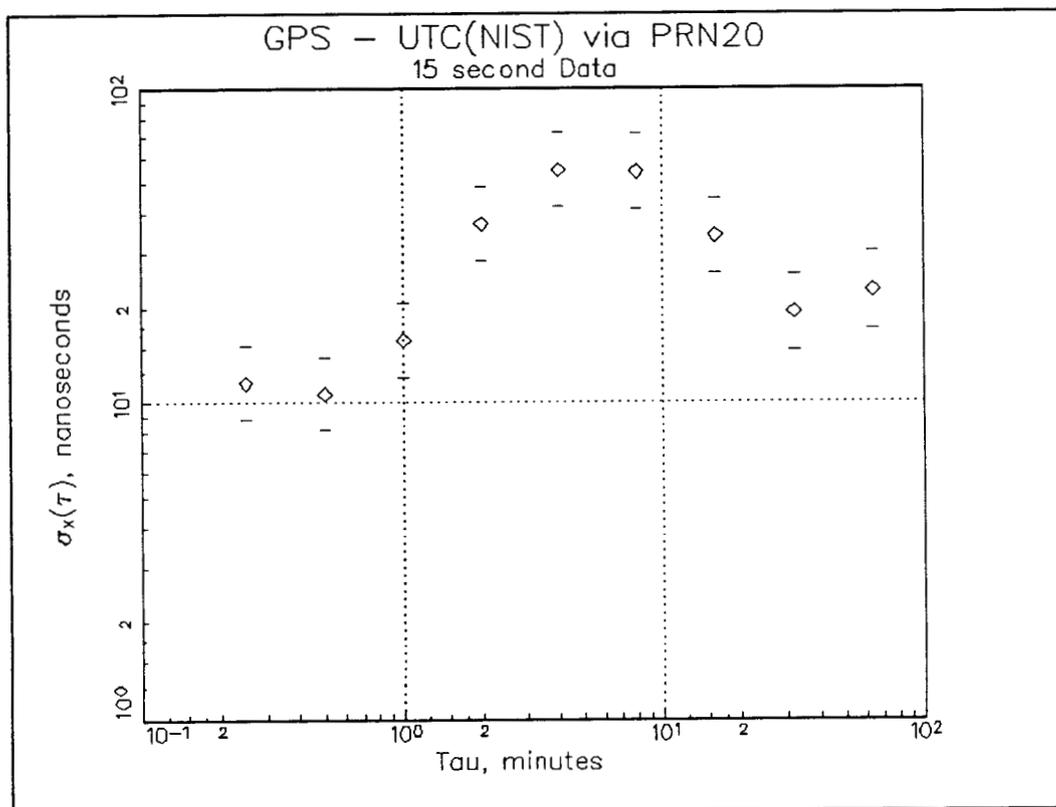


Figure 4 Time Deviation of data from figure 1.

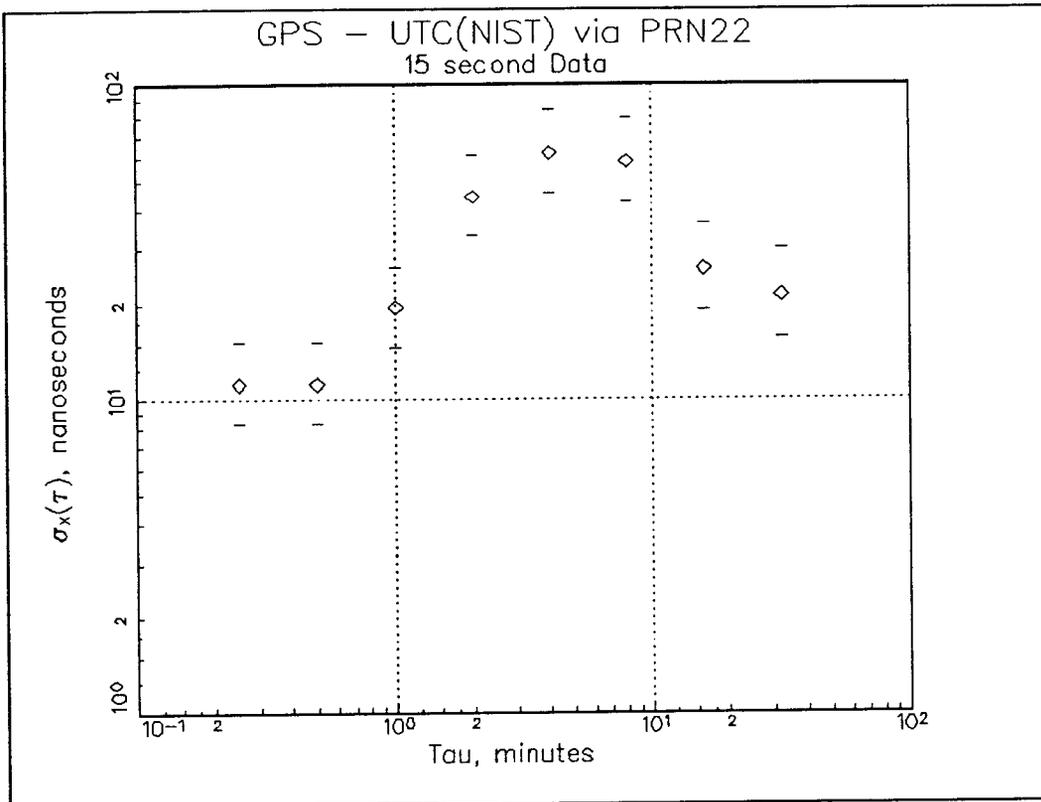


Figure 5. Time Deviation of data from figure 2.

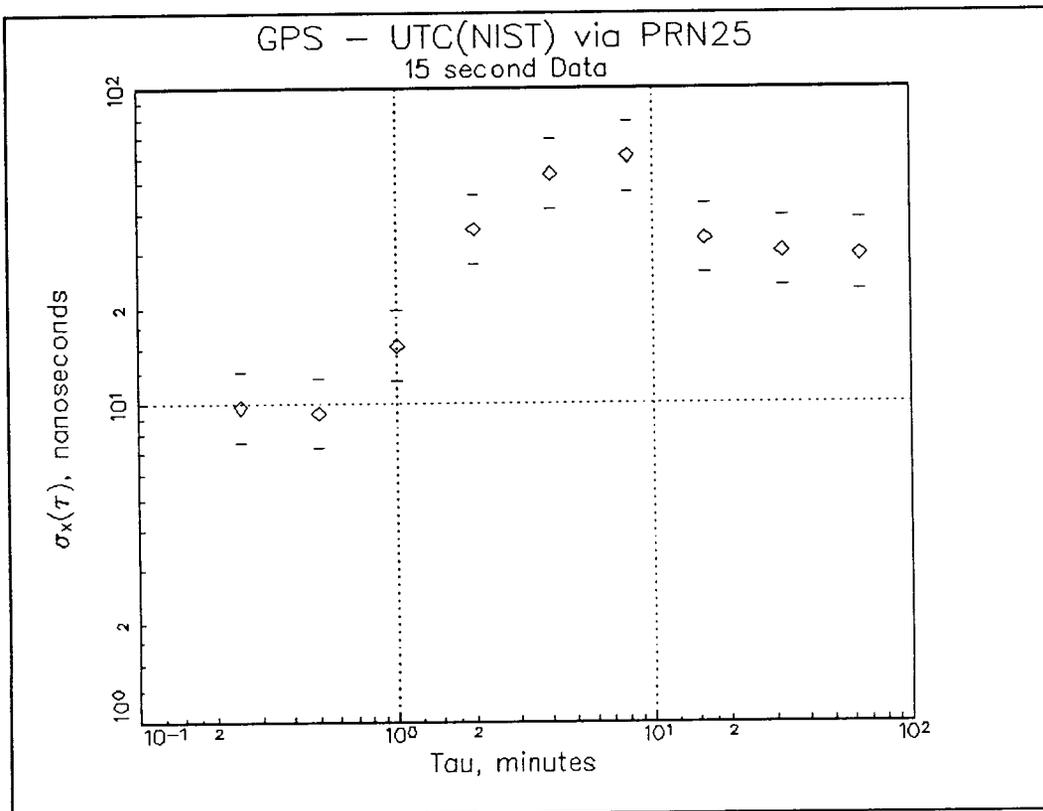


Figure 6. Time deviation of data from figure 3.

Example (fictitious data)

```

GGTTS GPS DATA FORMAT VERSION = 01
REV DATE = 1993-05-28
RCVR = AOA TTR7A 12405 1987 14
CH = 15
IMS = 99999 or 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 = C3 or CKSUM = 49
    
```

No measured ionospheric delays available

```

PRN CL MJD STTIME TRKL ELV AZTH REFSV SRSV REFGPS SRGPS DSG IOE MDTR SMDT MDIO SMDI CK
      hhmms s .ldg .ldg .lns .lps/s .lps/s .lps/s .lps/s .lps/s .lps/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
    
```

Measured ionospheric delays available

```

PRN CL MJD STTIME TRKL ELV AZTH REFSV SRSV REFGPS SRGPS DSG IOE MDTR SMDT MDIO MSIO SMSI ISG CK
      hhmms s .ldg .ldg .lns .lps/s .lps/s .lps/s .lps/s .lps/s .lps/s
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
    
```

The definitions of the acronyms used in the data format follow. Note that a * stands for a space, ASCII value 20 (hexadecimal). Text to be written in the data file is indicated by ' '.

File header

Line 1: 'GGTTS*GPS*DATA*FORMAT*VERSION*='*01, title to be written.

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.

Line 3: 'RCVR*='* 'MAKER'*'TYPE'*'SERIAL NUMBER'*'YEAR'*', maker acronym, type, serial number, first year of operation, and eventually software number of the GPS time receiver.

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.

Line 5: 'IMS*='* 'MAKER'*'TYPE'*'SERIAL NUMBER'*'YEAR'*', maker acronym, type, serial number, first year of operation, and eventually software number of the Ionospheric Measurement System. IMS = 99999 if none.

Line 6: 'LAB*='* 'LABORATORY, acronym of the laboratory where observations are performed.

Line 7: 'X*='* 'X COORDINATE '*m', X coordinate of the GPS antenna, in m and given with at least 2 decimals.

Line 8: 'Y*='* 'Y COORDINATE '*m', Y coordinate of the GPS antenna, in m and given with at least 2 decimals.

Line 9: 'Z*='* 'Z COORDINATE '*m', Z coordinate of the GPS antenna, in m and given with at least 2 decimals.

Line 10: 'FRAME*='* 'FRAME, designation of the reference frame of the GPS antenna coordinates.

Line 11: 'COMMENTS*='* 'COMMENTS, Any comments about the coordinates, for example the method of determination or the estimated uncertainty.

Line 12: 'INT*DLY*='* 'INTERNAL DELAY '*ns', internal delay entered in the GPS time receiver, in ns and given with 1 decimal.

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.

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.

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.

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.

Line 17: blank line.

Acronyms

The following are the definitions of the acronyms

- PRN: Satellite vehicle PRN number.
- CL: Common-view hexadecimal class byte.
- MJD: Modified Julian Day.
- STTIME: Date of the start time of the track in hour, min and second referenced to UTC.
- TRKL: Track length, 780 for full tracks, in s.
- ELV: Satellite elevation at the date corresponding to the midpoint of the track in 0.1 degree.
- AZTH: Satellite azimuth at the date corresponding to the midpoint of the track in 0.1 degree.
- REFSV: Estimate of the time difference of local reference minus SV clock at the middle of track from the linear fit, in 0.1 ns.
- SRSV: Slope of the linear fit for REFSV 0.1 ps/s.
- REFGPS: Estimate of the time difference of local reference minus GPS time at the middle of the track from the linear fit, in 0.1 ns.
- SRGPS: Slope of the linear fit for REFGPS 0.1 ps/s.
- DSG: [Data Sigma] Root mean square of the residuals to the linear fit for REFGPS in 0.1 ns.
- IOE: [Index of Ephemeris] Three digit decimal code (0-255) indicating the ephemeris used for the computation.
- MDTR: Modelled tropospheric delay at the middle of the track from the linear fit, in 0.1 ns.
- SMDT: Slope of the modelled tropospheric delay resulting from the linear fit in 0.1 ps/s.
- MDIO: Modelled ionospheric delay resulting from the linear in 0.1 ns.
- SMDI: Slope of the modelled ionospheric delay resulting from the linear fit in 0.1 ps/s.
- MSIO: Measured ionospheric delay resulting from the linear fit in 0.1 ns.
- SMSI: Slope of the measured ionospheric delay resulting from the linear in 0.1 ps/s.
- ISG: [Ionospheric Sigma] Root mean square of the residuals to the linear fit in 0.1 ns.
- 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 space preceding the check-sum. (both included).

There can be optional comments on the data line after the check sum out to the 128 character line length. These characters are not included in the line check-sum.

CONCLUSIONS

The new GPS data format, along with the prescription for processing short term data, can help improve common-view time transfer. Especially with the implementation of SA, common-view tracks can be significantly degraded if the two receivers tracking in common view do not work identically. The new standard can help us move toward a goal of 1 ns time transfer accuracy across intercontinental distances using GPS time transfer in common-view.

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