

RINEX Extensions to Handle Clock Information  
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(Error in example data formats corrected, 28 August 1998)

(Add SV antenna offsets in comment, PRN list in headers, 19 March 1999)

(Add provision for broadcast GPS time as clock reference, 22 March 1999)

(Allow clock reference changes, 23 March 1999)

(Clarify "Note" under ANALYSIS CLK REF and COMMENT, 03 June 1999)

(Add station coordinates to header "SOLN STA NAME / NUM", 15 June 1999)

## 0. INTRODUCTION

Thus far, the IGS has produced clock results only for the GPS satellites and these are tabulated and distributed at the 15-minute intervals used in the sp3 orbit ephemerides files. There is much interest in increasing the satellite clock interval to 30 seconds (e.g., to overcome SA effects on interpolation) and also in producing station clock results (at some appropriate interval, probably 5 minutes). In principle, the sp3 format could continue to be used for both of these extensions, but it would be wasteful considering that the vast majority of the file space is set aside for orbit information. Also, the variety of other clock information that also needs to be exchanged does not lend itself to the sp3 format.

Alternatively, the IGS could devise a new format specifically for distributing clock information. It does not appear that the timing community already uses a standard data format that is well suited for the IGS needs.

## 1. CLOCK DATA TYPES

At the level of monitoring and reporting data from a specific GPS station (or more generally, a "receiver", which could include low Earth-orbiting satellites and other non-stationary platforms) the following types of observations can be expected:

- calibration data (CR): time delay measurements between a GPS receiver and some external reference point (e.g., local master clock)
- discontinuity data (DR): a phase-tracking GPS receiver (e.g., AOA TurboRogue) maintains an internal clock that sometimes will reset itself; in principle, there may be methods to monitor such changes which could then be logged as a relative change in clock state

From analysis of GPS data, the results for an ensemble of receiver and satellite clocks can be determined differentially. Normally, all clock values are estimated relative to a single clock being held fixed as a reference. Alternatively, a linear combination of the estimated clocks can be held fixed to some a priori value (normally, zero). Either way, all the clock values can be re-aligned after estimation to remove the

effect of the particular choice of reference clock, which can change for each data analysis arc. Such re-alignment is most commonly done using broadcast GPS time for the satellites as an underlying timescale, typically fitted to a low-order polynomial. In any case, the data are:

analysis data (AR,AS): results from GPS phase/pseudorange data analysis for a network of station/receiver (AR) and satellite (AS) clocks, all relative to a fixed reference clock (or ensemble) adopted in the analysis

If a timescale re-alignment has been applied (e.g., to GPS time), then the analysis reference clock will have non-zero values (but should still be reported as the reference in the header records) and these must be reported together with all other estimated clocks in the clock data records. In this case, the method of re-alignment should be described in the header comment records.

In addition, the broadcast clocks of the satellites can be monitored and compared to a laboratory standard:

monitor data (MS): broadcast values for satellite clocks as compared with a laboratory standard via monitor receivers (usually timing receivers)

## 2. FORMAT TYPES AND FILE NAMING

Following established practice, the receiver-specific data ("CR" and "DR") could be reported using an extension of the RINEX format while the analysis data ("Ax" and "MS") could be reported using an extension to a standard product format, such as SINEX. However, since all of these data types are related and probably need similar format requirements, it seems more economical to consider a single file format type suitable for all.

RINEX seems the most appropriate file type, even though it is not normally used for analysis products. When it becomes feasible and necessary to include clock estimates with other analysis products, then suitable formats can be incorporated into SINEX. Until then, it is suggested that a RINEX format extension be used for all clock/timing results. Normally, "CR" and "DR" data types would be collected at the stations, files would be prepared at the data centers, and the files would flow to the Global Data Centers named as:

```
for calibration data (CR) & discontinuity data (DR)
-----
ssssddf.yyC      ssss:    4-character station/receiver name
                    designator
                    ddd:    day of the year of first record
                    f:      file sequence number within day
                    0:      file contains all the existing
                            data of the current day
                    yy:     year
                    C:      file type "C" for clock information
```

The suffix "C" would be a new RINEX file type. Normally, data would be compiled into files by each 24-hour day (GPS time).

The analysis results "AR", "AS", and "MS" would be formed at IGS Analysis Centers or by IGS/BIPM Pilot Project analysis groups and would normally include results for a number of stations/receivers and/or satellites.

These files would be named as:

```
for analysis data (Ax) & monitor data (MS)
-----
cccwwwwd.clk      ccc:      3-character analysis center name
                  designator
                  wwwww:   GPS week number
                  d:       day within GPS week (0 - 7)
                  clk:     suffix to identify clock information
                           product files
```

Files could be either daily (d = 0,...,6) or weekly (d = 7).

However, despite the file names, a single format for the contents would apply for all data types.

### 3. NUMERICAL PRECISION

All timing quantities (units sec, sec/sec, sec/sec\*\*2) are reported in exponential format with a precision of 12 decimal places.

### 4. CLOCK DISCONTINUITIES

Clock discontinuities (in bias, rate, and/or acceleration) could be reported in either of two ways. If monitored in situ and logged, these could be reported as "DR" data types in .yyC station files. If detected in data analysis, these can be reported in .clk files as two "AR" data records for the same station at the same epoch but with two different sets of clock values.

### 5. RECEIVER AND SATELLITE NAMES

Since the clock data are normally used in conjunction with data analysis results (even for the calibration and discontinuity data types), it is most convenient to use naming conventions for the receivers and satellites which correspond to the same names used in analyses. In order to ensure uniqueness and complete identification, it is also necessary to supply the receiver ID number (for fixed terrestrial receivers, the DOMES number issued by the Terrestrial Frame Section of the IERS). Thus, receivers should be identified by:

```
Station names:    IGS official 4-character receiver name designator
Station number:   DOMES number (or other unique identifier)
```

For satellite names, the following designations are used in RINEX:

```
Satellite names: 3-character string:
"Gnn":   nn is the PRN number for GPS
          satellites
"Rnn":   nn is the almanac number for
          GLONASS satellites
```

If other satellite transmitters become available with suitable GPS- or GLONASS-like signals, such as the geostationary platforms currently being considered, then they can also be included using future RINEX naming conventions.

## 6. RINEX CLOCK FORMAT DEFINITIONS AND EXAMPLES

The header records should be included in the order indicated, when required. The records below marked with \* are optional.

It is recommended that each record be read into a blank buffer string and then the information can be decoded afterwards from the buffer. Header and data records are limited to 80 characters. If more than bias and bias sigma are reported, a continuation line must be used.

A data file must begin with the header records. Data records begin immediately after the "END OF HEADER" record and complete the remainder of the data file.

TABLE A15 CLOCK DATA FILE - HEADER SECTION DESCRIPTION			
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT	
RINEX VERSION / TYPE	- Format version (2.00) - File type ("C" for Clock Data)	F9.2,11X, A1,39X	
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)  While comments are generally optional, they must be included for the following information:  SATELLITE ANTENNA PHASE CENTER OFFSETS ----- The vector offset used in data analysis for the separation of the satellite antenna phase centers and the satellite centers of mass must be known. A change in the Z-direction will appear as a shift in the satellite clock estimates. By agreement among the IGS Analysis Centers, the IGS Z-offsets are given below and a COMMENT record of this type should always be included:  CLK ANT Z-OFFSET(M): II/IIA 1.023; IIR 0.000  * REQUIRED for data types "Ax"  TIMESCALE RE-ALIGNMENT ----- If estimated clock values have been uniformly shifted in timescale, e.g., to GPS time, the method applied should be noted here. In addition, non-zero clock values should be reported in the clock data records for the analysis reference	A60	*

	<p>clock, corresponding to the alignment correction applied to all the receiver and satellite clocks. The analysis reference clock should still be listed as "ANALYSIS CLK REF" even though it will have non-zero values.</p> <p>* REQUIRED for data types "Ax", if applicable</p>		
* LEAP SECONDS	<p>Number of leap seconds since 6-Jan-1980 Recommended as an aid to convert from GPS time to UTC</p>	I6	*
# / TYPES OF DATA	<p>- Number of different clock data types stored in the file - List of clock data types</p> <p>The following clock data types are defined in RINEX Version 2:</p> <p>"AR": Data analysis results for receiver clocks derived from a set of network receivers and satellites wrt to a reference clock fixed in the analysis "AS": Data analysis results for satellite clocks derived from a set of network receivers and satellites wrt to a reference clock fixed in the analysis "CR": Calibration measurements for a single GPS receiver wrt an external local reference clock "DR": Discontinuity measurements for a single GPS receiver "MS": Monitor measurements for the broadcast satellite clocks wrt a standard timescale</p>	I6, 5(4X,A2)	
STATION NAME / NUM	<p>- 4-character receiver name designator - Unique receiver identifier, preferably the DOMES number for fixed stations</p> <p>* REQUIRED for data types "CR" &amp; "DR"</p>	A4,1X, A20,35X	
STATION CLK REF	<p>Unique identifier for external reference clock being used as the standard for calibration</p> <p>* REQUIRED for data type "CR"</p>	A60	
ANALYSIS CENTER	<p>Name of Analysis Center - 3-character IGS AC designator - Full name of Analysis Center</p>	A3,2X, A55	

	* REQUIRED for data types "Ax" & "MS"	
# OF CLK REF	<ul style="list-style-type: none"> <li>- Number of analysis clock references (satellite or receiver clocks) listed under "ANALYSIS CLK REF"</li> <li>- Start epoch (in GPS time): year (4 digits),month,day,hour,min,second [default: blank start and stop times imply single "ANALYSIS CLK REF" applies for entire file]</li> <li>- Stop epoch (in GPS time): year (4 digits),month,day,hour,min,second [default: blank start and stop times imply single "ANALYSIS CLK REF" applies for entire file]</li> </ul> <p>NOTE: Multiple groups of "# OF CLK REF" "ANALYSIS CLK REF" records can be used for changes in analysis clock reference within a single analysis file.</p> <p>* REQUIRED for data types "Ax"</p>	I6,1X,  I4,4I3, F10.6,  1X, I4,4I3, F10.6
ANALYSIS CLK REF	<p>List of the analysis clock references (repeat for each reference clock enumerated in the previous record)</p> <ul style="list-style-type: none"> <li>- Name of the receiver or satellite used as the fixed reference in data analysis</li> <li>- Unique identifier for reference clock (if a receiver), preferably the DOMES number for fixed stations</li> <li>- Optionally a non-zero value for the the apriori clock constraint can be provided (unit: seconds).</li> </ul> <p>NOTE: If all analysis clock estimates are re-aligned (e.g., to broadcast GPS time) then the fixed analysis clock will have non-zero values corresponding to the alignment corrections applied to all other clocks. The non-zero clock values for the reference must be reported in the clock data records together with the other clock values, but the reference clock should still be listed here. The method of re-alignment should be described in header comment records.</p> <p>* REQUIRED for data types "Ax"</p>	A4,1X,  A20,15X,  E19.12,1X
# OF SOLN STA / TRF	- Number of receivers included in the clock data records (including the analysis reference clock even if it has zero values and is not given in the data records) and listed in the	I6,4X,

	<p>following header records</p> <ul style="list-style-type: none"> <li>- Terrestrial reference frame or SINEX solution for the station/receiver coordinates which match the clock solution</li> </ul> <p>* REQUIRED for data types "Ax"</p>	A50
SOLN STA NAME / NUM	<p>For each station/receiver included in the clock data records, as well as the analysis reference clock even if it has zero values and is not included in the data records (number given in the previous header record), include one record with the following information:</p> <ul style="list-style-type: none"> <li>- 4-character station/receiver name designator</li> <li>- Unique station/receiver identifier, preferably the DOMES number for fixed stations</li> <li>- Geocentric XYZ station coordinates corresponding to the analysis clock values reported (in millimeters!)</li> </ul> <p>* REQUIRED for data types "Ax"</p>	A4,1X, A20, I11,X, I11,X, I11
# OF SOLN SATS	<ul style="list-style-type: none"> <li>- Number of different satellites in the clock data records and listed in following header records</li> </ul> <p>* REQUIRED for data types "Ax"</p>	I6,54X
PRN LIST	<p>List of all satellites reported in this file. Each satellite name is a 3-character string:</p> <ul style="list-style-type: none"> <li>- "Gnn" where nn is the PRN number for GPS satellite</li> <li>- "Rnn" where nn is the almanac number for GLONASS satellite</li> </ul> <p>* REQUIRED for data types "Ax"</p>	15(A1,I2,1X)
END OF HEADER	Last record in the header section.	60X

Records marked with \* are optional

TABLE A16 CLOCK DATA FILE - DATA RECORD DESCRIPTION		
OBS. RECORD	DESCRIPTION	FORMAT
TYP/EPOCH/CLK	- Clock data type (AR, AS, CR, DR, MS)	A2,1X,
	- Receiver or satellite name	A4,1X,

	<ul style="list-style-type: none"> <li>- Receiver name is the IGS 4-character designator</li> <li>- Satellite name is a 3-character string: <ul style="list-style-type: none"> <li>- "Gnn" where nn is the PRN number for GPS satellite</li> <li>- "Rnn" where nn is the almanac number for GLONASS satellite</li> </ul> </li> <li>- Epoch in GPS time (not local time!): <ul style="list-style-type: none"> <li>year (4 digits), month, day, hour, min, second</li> </ul> </li> <li>- Number of data values to follow</li> <li>- Clock data in the following sequence: <ul style="list-style-type: none"> <li>- Clock bias (seconds)</li> <li>- Clock bias sigma [optional] (seconds)</li> </ul> </li> </ul>	          I4,4I3, F10.6, I3,3X,  E19.12,X E19.12
TYP/EPOCH/CLK (CONT)	<ul style="list-style-type: none"> <li>- Clock rate [optional] (dimensionless)</li> <li>- Clock rate sigma [optional] (dimensionless)</li> <li>- Clock acceleration [optional] (per second)</li> <li>- Clock acceleration sigma [optional] (per second)</li> </ul> <p>The continuation line is necessary for more than 2 data values</p> <p>NB: For data types "Ax", "CR", and "MS", clock data are in the sense of reported station/satellite clock *minus* reference clock value. For data type "DR", clock data are the sense of clock value after discontinuity *minus* before.</p> <p>Clock data apart from bias values are optional. However, if any optional values are included, then all lower order values must be supplied even if optional (although zero values may be given)</p>	E19.12,X, E19.12,X, E19.12,X, E19.12

TABLE A17  
CLOCK DATA FILE - EXAMPLE FOR ANALYSIS DATA

```

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
2.00          CLOCK DATA          RINEX VERSION / TYPE
TORINEXC V9.9  USNO                 3-APR-96 00:10  PGM / RUN BY / DATE
CLK ANT Z-OFFSET(M): II/IIA 1.023; IIR 0.000  COMMENT
EXAMPLE OF A CLOCK DATA FILE  COMMENT
IN THIS CASE ANALYSIS RESULTS ARE INCLUDED  COMMENT
No re-alignment of the clocks has been applied.  COMMENT
10  LEAP SECONDS
2   AS   AR  # / TYPES OF DATA
USN  USNO USING GIPSY/OASIS-II  ANALYSIS CENTER
1 1994 07 14 0 0 0.000000 1994 07 14 20 59 0.000000# OF CLK REF
USNO 40451S003  -.123456789012E+00 ANALYSIS CLK REF
1 1994 07 14 21 0 0.000000 1994 07 14 21 59 0.000000# OF CLK REF

```



```

TIDB 50103M108          -0.123456789012E+00 ANALYSIS CLK REF
  4      ITRF96                      # OF SOLN STA / TRF
GOLD 40405S031          1234567890 -1234567890 -1234567890SOLN STA NAME / NUM
AREQ 42202M005          -1234567890 1234567890 -1234567890SOLN STA NAME / NUM
TIDB 50103M108          1234567890 -1234567890 1234567890SOLN STA NAME / NUM
HARK 30302M007          -1234567890 1234567890 -1234567890SOLN STA NAME / NUM
USNO 40451S003          1234567890 -1234567890 -1234567890SOLN STA NAME / NUM
  27                      # OF SOLN SATS
G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G13 G14 G15 G16 G17 PRN LIST
G18 G19 G21 G22 G23 G24 G25 G26 G27 G29 G30 G31          PRN LIST
                                END OF HEADER
AR AREQ 1994 07 14 20 59 0.000000 6 -0.123456789012E+00 -0.123456789012E+01
-0.123456789012E+02 -0.123456789012E+03 -0.123456789012E+04 -0.123456789012E+05
AS G16 1994 07 14 20 59 0.000000 2 -.123456789012E+00 -.123456789012E-01
AR GOLD 1994 07 14 20 59 0.000000 4 -.123456789012E-01 -.123456789012E-02
-.123456789012E-03 -.123456789012E-04
AR HARK 1994 07 14 20 59 0.000000 2 .123456789012E+00 .123456789012E+00
AR TIDB 1994 07 14 20 59 0.000000 6 .123456789012E+00 .123456789012E+00
.123456789012E+00 .123456789012E+00 .123456789012E+00 .123456789012E+00

```

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

```

+-----+
|                                     TABLE A18                                     |
|                                     CLOCK DATA FILE - EXAMPLE FOR CALIBRATION/DISCONTINUITY DATA |
+-----+

```

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

```

      2.00          CLOCK DATA          RINEX VERSION / TYPE
TORINEXC V9.9      USNO          3-APR-96 00:10      PGM / RUN BY / DATE
EXAMPLE OF A CLOCK DATA FILE          COMMENT
IN THIS CASE CALIBRATION/DISCONTINUITY DATA GIVEN      COMMENT
      10          LEAP SECONDS
      2      CR      DR          # / TYPES OF DATA
USNO 40451S003          STATION NAME / NUM
UTC(USNO) MASTER CLOCK VIA CONTINUOUS CABLE MONITOR      STATION CLK REF
                                END OF HEADER
CR USNO 1994 07 14 20 59 50.000000 2 .123456789012E+00 .123456789012E-01
CR USNO 1994 07 14 22 19 30.000000 2 -.123456789012E+00 .123456789012E-02
DR USNO 1994 07 14 22 23 14.500000 2 -.123456789012E+01 .123456789012E+00
CR USNO 1994 07 14 23 44 50.000000 2 -.123456789012E+02 .123456789012E+00

```

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|