10 Dec 2007 (original)
26-June 2012 (minor clarifications)

RINEX: The Receiver Independent Exchange Format Version 2.11

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Contents:
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0. REVISION HISTORY

0.1 Revision Summary

First Revision, April 1993
Clarification December 1993
Doppler Definition: January 1994
PR Clarification: October 1994
Wlfact Clarification: February 1995
Event Time Frame Clarification: May 1996
Minor errors in the examples A7/A8: May 1996
Naming convention for compressed met files; January 1997
Continuation line clarifications: April 1997
GLONASS Extensions: April 1997
Met sensor description and position records: April 1997
Wavelength factor clarifications: April 1997
Error in example A12: CORR TO SYSTEM TIME, April 1997
Redefinition of sv clock params in GLONASS Nav Mess Files: March 1998
Naming conventions for compressed RINEX obs files: March 1998
GPS week: No roll-over, continuous number: March 1998
Error in compressed DOS file naming convention: July 1998
Table A13 contained blank satellite identifiers: Sept 1998
Discrepancy between Tables A5 and A9 removed: Sept 1998
Phase data format overflow: Clarification: Oct 1998
Message frame time Table A11: Clarification: Oct 1998
RINEX Version 2.10 Modifications: July 1999
Typo in paragraph 0.4 (epoch flag >1): Nov 1999
Clarification regarding trailing blanks: Dec 1999
Clarification regarding units of ZD,ZT, URA(GEO)
Clarification regarding time system identifier of GEO obs files
Clarification regarding time system identifier in TIME OF LAST record: Feb 2000
Addition of GEO examples: February 2000
Clarification of epoch field for event flag records: May 2000
Table A6: Typos in format definition of epoch: May 2000

Clarification of the GLONASS satellite identifier: June 2001
Clarification of the floating point exponent format: January 2002
RINEX Version 2.11 modifications: October 2004
Some clarifications in the GEO D-UTC A0,A1,T,W,S,U record November 2005
Wind, rain and hail observables in met files: December 2005
Unknown/undefined observation types and header records: December 2005
References to clock and SBAS RINEX files. Extended filenames: December 2005
Header continuation lines have to include the respective header label
Glonass frequency numbers -7 ... +13: December 2007 |
Changed 2.10 to 2.11 in Appendix files and as specified in Revision 0.7 below: June 26,2012

0.2 First Revision

The first documentation of the RINEX Version 2 Format was published by W. Gurtner and G. Mader in the CSTG GPS Bulletin of September/October 1990. The main reason for a revision is the new treatment of antispoofing data by the RINEX format (see chapter 7). Chapter 4 gives a recommendation for data compression procedures, especially useful when large amounts of data are exchanged through computer networks. In Table A3 in the original paper the definition of the "PGM / RUN BY / DATE" navigation header record was missing, although the example showed it. The redefinition of AODE/AODC to IODE/IODC also asked for an update of the format description. For consistency reasons we also defined a Version 2 format for the Meteorological Data files (inclusion of a END OF HEADER record and an optional MARKER NUMBER record).

The slight modification (or rather the definition of a bit in the Loss of Lock Indicator unused so far) to flag AS data is so small a change that we decided to NOT increase the version number!

0.3 Later Revisions

* URA Clarification (10-Dec-93):

  The user range accuracy in the Navigation Message File did not contain a definition of the units: There existed two ways of interpretation: Either the 4 bit value from the original message or the converted value in meters according to GPS ICD-200. In order to simplify the interpretation for the user of the RINEX files I propose the bits to be converted into meters prior to RINEX file creation.

* GLONASS Extensions:

  In March 1997 a proposal for extensions to the current RINEX definitions based on experiences collected with GLONASS only and mixed GPS/GLONASS data files was circulated among several instrument manufacturers and software developers.

  The results of the call for comments have been worked into this document. A separate document (glonass.txt) summarizes just the necessary extensions.

* A blank satellite identifier is allowed in pure GPS files only

* Met sensor description and position records were added to facilitate the precise use of met values.

* Description and examples for wavelength factors and their temporary changes (bit 1 of LLI) clarified.

* The RINEX documentation distributed in spring 1997 contained definitions for the GLONASS satellite clock offset and drift with the intention to have them defined identically to the GPS values. Unfortunately the GLONASS Interface Document consulted had a sign error in one of the formulae.

  The values should be stored into the RINEX file as -TauN, +GammaN, -TauC. The original definition asked for -TauN, -GammaN, +TauC. See paragraph 8.2.

  To avoid problems with files created with the original definitions a real

to avoid problems with files created with the original definitions a real valued version number (2.01) has been introduced for GLONASS nav mess files.

* IGS decided to use the Hatanaka compression scheme for RINEX observation files. Below the corresponding RINEX file name conventions are included as recommendations. The DOS naming (extension .yyE) was wrongly set to .yyY in the March 1998 version of the document.

* GPS week: The GPS week number in all RINEX files is a continuous number not affected by the 1024 roll-over, it runs from 1023 over 1024 to 1025 etc.

* A discrepancy between the definition of the header line fields of met sensor description and position in Table A5 and the example in Table A9 was removed. The latter was correct.

* Clarification for phase data format overflows: Add or subtract a suitable number of cycles, set LLI flag.

* Clarification for the GLONASS satellite identifier: "Almanac number" was somewhat ambiguous. It has been replaced by "slot number" within the satellite constellation.

0.4 Version 2.10 Modifications

The modifications leading to Version 2.10 include:

- Fractional version number
- Zero padding of 2-digit year values (years 2000-2009 --> 00-09)
- Field length of time of first obs (1/10 microsecond resolution)
- Non-integer sampling rate (INTERVAL header record)
- Header records now allowed after all epoch flags >1
- Additional obs types in obs files: S1, S2 (raw signal strength values)
- Receiver clock offset header line to clarify applied corrections
- Default wavelength factor header line mandatory
- Inmarsat GPS payloads: New satellite system definition, new nav mess files
- Curve fit interval in GPS nav mess file
- Redefinition of SV health value in GPS nav mess file
- Additional obs types in met files (ZD, ZT)

0.5 Version 2.10 Revisions

* "Header records now allowed after all epoch flags >2" in paragraph 0.4 should read ">1"

* The original intention of the RINEX format was to allow for variable record lengths of the ASCII files to minimize the file size. Empty fields or unknown values can either be represented by zeroes or blank space. Most RINEX converters removed trailing blank to further reduce the file size. The documentation was not clear enough to explicitly allow for this practice (paragraphs 2, 5.3, 9.1).

* The time system identifier of GPS observations generated by GEO payloads defaults to GPS (explicitly stated now in paragraph 9.1)

* The time system identifier in the TIME OF LAST OBS header record has to be identical to the one in the TIME OF FIRST OBS record

* Clarification of Table A2 to be compatible with examples of Table A7: For event flags without significant epoch the epoch fields can be left blank. Table A6: Format for epoch contained obvious errors

* Clarification of the floating point exponent format in navigation message files (two digits, E,e,D,d letters)

0.6 Version 2.11

The modifications of 2.10 leading to Version 2.11 include

- Definition of the Galileo satellite system code
- Definition of the code for Galileo System Time (GAL)
- Definition of the frequency numbers for Galileo and new GPS observables
- Observation code for L2C pseudorange (C2)
- Some clarifications in the GEO NAV Message files
  - Transmission time of message
  - Health
  - URA
  - CORR TO SYSTEM TIME replaced by more general D-UTC A0,A1,T,W,S,U record
- Introduction of wind speed and direction, rain fall increment, hail indicator
- Recommendation regarding unknown/undefined observation types and header records
- Recommendations for extended filenames for high-rate observation files

0.7 Version 2.11 June 26,2012

Minor edits to the Version 2.11 release:

- Updated revision Summary
- Changed Table of Contents, Appendix reference to 2.11 from 2.10
- Updated Section 4 to reflect new links to Hatanaka compression information.
- Changed Section 6.7 Satelite Health (Version 2.10 to Version 2.11)
- Changed Section 9.
  From: RINEX Version 2.10 defines the necessary extensions to handle
        such data in RINEX files for data exchange and postprocessing purposes.
  To : The necessary extensions to handle data exchange and post-processing
       were originally defined in RINEX Version 2.10 and apply in 2.11 as well."
- Changed the Format label for GPS Navigation File in Table A3 from 2.10 to 2.11
- Changed the Format label for Meteo Data in Table A5 from 2.10 to 2.11
- Changed the Format label for the GPS Observation File - Example in Table A7 from 2.10 to 2.11
- Changed the Format label for the GPS Navigation File - Example in Table A8 from 2.10 to 2.11
- Changed the COMMENT for the GPS Navigation File - Example in Table A8 from 2.10 to 2.11
- Changed the Format label for the Meteo Data File - Example in Table A9 from 2.10 to 2.11
- Changed the Format label for GLONASS Navigation File in Table A10 from 2.10 to 2.11
- Changed the COMMENT for the GLONASS Navigation File - Example in Table A12 from 2.10 to 2.11
- Changed the Format label for the GLONASS Observation File - Example in Table A13 from 2.10 to 2.11
- Changed the Format label for the Mixed GPS/GLONASS Observation File - Example in Table A14 from 2.10 to 2.11
- Changed the Format label for the Mixed GPS/GEO Observation File - Example in Table A17 from 2.10 to 2.11

Clarifications:

- Continuation records in RINEX headers: They also have to include the respective header label in colums 61-80.
- The newer GLONASS satellites started using frequency numbers in the 0 to -7 range. Table A11 BROADCAST ORBIT - 2 was modified accordingly.

1. THE PHILOSOPHY OF RINEX

The first proposal for the "Receiver Independent Exchange Format" RINEX has been developed by the Astronomical Institute of the University of Berne for the easy exchange of the GPS data to be collected during the large European GPS campaign EUREF 89, which involved more than 60 GPS receivers of 4 different manufacturers. The governing aspect during the development was the following fact:

Most geodetic processing software for GPS data use a well-defined set of observables:

- the carrier-phase measurement at one or both carriers (actually being a measurement on the beat frequency between the received carrier of the satellite signal and a receiver-generated reference frequency).

- the pseudorange (code) measurement, equivalent to the difference of the time of reception (expressed in the time frame of the receiver) and the time of transmission (expressed in the time frame of the satellite) of a distinct satellite signal.

- the observation time being the reading of the receiver clock at the instant of validity of the carrier-phase and/or the code measurements.

Usually the software assumes that the observation time is valid for both the phase AND the code measurements, AND for all satellites observed.

Consequently all these programs do not need most of the information that is usually stored by the receivers: They need phase, code, and time in the above mentioned definitions, and some station-related information like station name, antenna height, etc.

2. GENERAL FORMAT DESCRIPTION

Currently the format consists of seven ASCII file types:

1. Observation Data File
2. Navigation Message File
3. Meteorological Data File
4. GLONASS Navigation Message File
5. GEO Navigation Message File
6. Satellite and Receiver Clock Date File
7. SBAS Broadcast Data File

The format definition of the clock files has been published in 1998 in a separate document by Jim Ray and Werner Gurtner, available at the IGS Central Bureau Information System:
ftp://igscb.jpl.nasa.gov/igscb/data/format/rinex_clock.txt

The format definition of the Space-based augmentation system (SBAS) broadcast data file has been published in 2004 by Norbert Suard, Werner Gurtner and Lou Estey, available at the IGS Central Bureau Information System:
ftp://igscb.jpl.nasa.gov/igscb/data/format/geo_sbas.txt

Each file type consists of a header section and a data section. The header section contains global information for the entire file and is placed at the beginning of the file. The header section contains header labels in columns 61-80 for each line contained in the header section. These labels are mandatory and must appear exactly as given in these descriptions and examples.

The format has been optimized for minimum space requirements independent from the number of different observation types of a specific receiver by indicating in the header the types of observations to be stored. In computer systems allowing variable record lengths the observation records may be kept as short as possible. Trailing blanks can be removed from the records. The maximum record length is 80 bytes per record.

Each Observation file and each Meteorological Data file basically contain the data from one site and one session. RINEX Version 2 also allows to include observation data from more than one site subsequently occupied by a roving receiver in rapid static or kinematic applications. Although Version 2 allows to insert header records into the data field we do not recommend to concatenate data of more than one receiver (or antenna) into the same file,

even if the data do not overlap in time.

If data from more than one receiver has to be exchanged it would not be economical to include the identical satellite messages collected by the different receivers several times. Therefore the Navigation Message File from one receiver may be exchanged or a composite Navigation Message File created containing non-redundant information from several receivers in order to make the most complete file.

The format of the data records of the RINEX Version 1 Navigation Message file is identical to the former NGS exchange format.

The actual format descriptions as well as examples are given in the Tables at the end of the paper.

3. DEFINITION OF THE OBSERVABLES

GPS observables include three fundamental quantities that need to be defined: Time, Phase, and Range.

TIME:

The time of the measurement is the receiver time of the received signals. It is identical for the phase and range measurements and is identical for all satellites observed at that epoch. It is expressed in GPS time (not Universal Time).

PSEUDO-RANGE:

The pseudo-range (PR) is the distance from the receiver antenna to the satellite antenna including receiver and satellite clock offsets (and other biases, such as atmospheric delays):

```
PR  =  distance +
       c * (receiver clock offset - satellite clock offset +
            other biases)
```

so that the pseudo-range reflects the actual behavior of the receiver and satellite clocks. The pseudo-range is stored in units of meters.

See also clarifications for pseudoranges in mixed GPS/GLONASS files in chapter 8.1.

PHASE:

The phase is the carrier-phase measured in whole cycles. The half-cycles measured by squaring-type receivers must be converted to whole cycles and flagged by the wavelength factor in the header section (GPS only).

The phase changes in the same sense as the range (negative doppler). The phase observations between epochs must be connected by including the integer number of cycles. The phase observations will not contain any systematic drifts from intentional offsets of the reference oscillators.

The observables are not corrected for external effects like atmospheric refraction, satellite clock offsets, etc.

If the receiver or the converter software adjusts the measurements using the real-time-derived receiver clock offsets dT(r), the consistency of the 3 quantities phase / pseudo-range / epoch must be maintained, i.e. the receiver clock correction should be applied to all 3 observables:

```
Time(corr)  = Time(r)  -  dT(r)
PR(corr)    =  PR(r)   -  dT(r)*c
phase(corr) = phase(r) -  dT(r)*freq
```

DOPPLER:

The sign of the doppler shift as additional observable is defined as usual:
Positive for approaching satellites.

4. THE EXCHANGE OF RINEX FILES:

We recommend using the following naming convention for RINEX files:

```
   ssssdddf.yyt

   |    |  | | |
   |    |  | | +--  t:  file type:
   |    |  | |          O: Observation file
   |    |  | |          N: GPS Navigation file
   |    |  | |          M: Meteorological data file
   |    |  | |          G: GLONASS Navigation file
   |    |  | |          L: Future Galileo Navigation file
   |    |  | |          H: Geostationary GPS payload nav mess file
   |    |  | |          B: Geo SBAS broadcast data file
   |    |  | |                      (separate documentation)
   |    |  | |          C: Clock file (separate documentation)
   |    |  | |          S: Summary file (used e.g., by IGS, not a standard!)
   |    |  | |
   |    |  | +---  yy:  two-digit year
   |    |  |
   |    |  +-----   f:  file sequence number/character within day
   |    |               daily file: f = 0
   |    |               hourly files:
   |    |               f = a:  1st hour 00h-01h; f = b: 2nd hour 01h-02h; ...
   |    |               f = x: 24th hour 23h-24h
   |    |
   |    +-------  ddd:  day of the year of first record
   |
   +------------ ssss:  4-character station name designator
```

For 15-minutes high-rate tracking data we recommend the following extended
filenames:

```
   ssssdddhmm.yyo

   |    |  ||  | |
   |    |  ||  | +-  o: observation file
   |    |  ||  |
   |    |  ||  +--- yy: two-digit year
   |    |  ||
   |    |  |+------ mm: starting minute within the hour (00, 15, 30, 45)
   |    |  |
   |    |  +-------  h: character for the n-th hour in the day
   |    |               (a= 1st hour: 00h-01h, b= 2nd hour: 1h to 2h,...,
   |    |               x=24th hour: 23h-24h. 0= one-day file)
   |    |
   |    +---------- ddd: day of the year
   |
   +------------ ssss: 4-character ID for the LEO receiver/antenna
```

When data transmission times or storage volumes are critical we recommend
compressing the files prior to storage or transmission using the UNIX
"compress" und "uncompress" programs. Compatible routines are available on
VAX/VMS and PC/DOS systems, as well.

Proposed file name extensions for the compressed files:

```
  +-------------------------------------------------------------------+
```

File Types	All platforms uncompressed	UNIX compressed	VMS compressed	DOS
Obs Files	.yyO	.yyO.Z	.yyO_Z	.yyY
Obs Files (Hatanaka compressed)	.yyD	.yyD.Z	.yyD_Z	.yyE
GPS Nav Files	.yyN	.yyN.Z	.yyN_Z	.yyX
GLONASS Nav File	.yyG	.yyG.Z	.yyG_Z	.yyV
Galileo Nav File	.yyL	.yyL.Z	.yyL_Z	.yyT
GEO Nav Files	.yyH	.yyH.Z	.yyH_Z	.yyU
GEO SBAS Broadcast Files (sep. doc.)	.yyB	.yyB.Z	.yyB_Z	.yyA
Met Data Files	.yyM	.yyM.Z	.yyM_Z	.yyW
Clock Files (see sep.doc.)	.yyC	.yyC.Z	.yyC_Z	.yyK

References for the Hatanaka compression scheme: See e.g.

- http://terras.gsi.go.jp/ja/crx2rnx.html
- Hatanaka, Y. (2008): A Compression Format and Tools for GNSS Observation Data, Bulletin of the Geographical Survey Institute, 55, 21-30, available at http://www.gsi.go.jp/ENGLISH/Bulletin55.html.
- IGSMails 1525,1686,1726,1763,1785,4967,4969,4975

5. RINEX VERSION 2 FEATURES

The following section contains features that have been introduced for RINEX Version 2:

5.1 Satellite Numbers:

Version 2 has been prepared to contain GLONASS or other satellite systems' observations. Therefore we have to be able to distinguish the satellites of the different systems: We precede the 2-digit satellite number with a system identifier.

snn

s: satellite system identifier
- G or blank : GPS
- R : GLONASS
- S : Geostationary signal payload
- E : Galileo

nn:
- PRN (GPS, Galileo), slot number (GLONASS)
- PRN-100 (GEO)

Note: G is mandatory in mixed GPS/GLONASS/Galileo files

(blank default modified in April 1997)

5.2 Order of the Header Records:

As the record descriptors in columns 61-80 are mandatory, the programs reading a RINEX Version 2 header are able to decode the header records with formats according to the record descriptor, provided the records have been first read into an internal buffer.

We therefore propose to allow free ordering of the header records, with the following exceptions:

- The "RINEX VERSION / TYPE" record must be the first record in a file

- The default "WAVELENGTH FACT L1/2" record must precede all records defining wavelength factors for individual satellites

- The "# OF SATELLITES" record (if present) should be immediately followed

by the corresponding number of "PRN / # OF OBS" records. (These records may be handy for documentary purposes. However, since they may only be created after having read the whole raw data file we define them to be optional.

5.3 Missing Items, Duration of the Validity of Values

Items that are not known at the file creation time can be set to zero or blank or the respective record may be completely omitted. Consequently items of missing header records will be set to zero or blank by the program reading RINEX files. Trailing blanks may be truncated from the record.

Each value remains valid until changed by an additional header record.

5.4 Event Flag Records

The "number of satellites" also corresponds to the number of records of the same epoch followed. Therefore it may be used to skip the appropriate number of records if certain event flags are not to be evaluated in detail.

5.5 Receiver Clock Offset

A large number of users asked to optionally include a receiver-derived clock offset into the RINEX format. In order to remove uncertainties if the data (epoch, pseudorange, phase) have been previously corrected or not by the reported clock offset, RINEX Version 2.10 requests a clarifying (new) header record.

It would then be possible to reconstruct the original observations if necessary.

As the output format for the receiver-derived clock offset is limited to nanoseconds the offset should be rounded to the nearest nanosecond before it is used to correct the observables in order to guarantee correct reconstruction.

6. ADDITIONAL HINTS AND TIPS

6.1 Versions

Programs developed to read RINEX files have to verify the version number. Files of newer versions may look different even if they do not use any of the newer features

6.2 Leading Blanks in CHARACTER fields

We propose that routines to read RINEX Version 2 files automatically delete leading blanks in any CHARACTER input field. Routines creating RINEX Version 2 files should also left-justify all variables in the CHARACTER fields.

6.3 Variable-length Records

DOS, and other, files may have variable record lengths, so we recommend to first read each observation record into a 80-character blank string and decode the data afterwards. In variable length records, empty data fields at the end of a record may be missing, especially in the case of the optional receiver clock offset.

6.4 Blank Fields

6.4 Blank Fields

In view of future modifications we recommend to carefully skip any fields currently defined to be blank (Format fields nX), because they may be assigned to new contents in future versions.

6.5 2-Digit Years

RINEX version 2 stores the years of data records with two digits only. The header of observation files contains a TIME OF FIRST OBS record with the full four-digit year, the GPS nav messages contain the GPS week numbers. From these two data items the unambiguous year can easily be reconstructed.

A hundred-year ambiguity occurs in the met data and GLONASS and GEO nav messages: Instead of introducing a new TIME OF FIRST OBS header line it is safe to stipulate that any two-digit years in RINEX Version 1 and Version 2.xx files are understood to represent

```
80-99:  1980-1999
00-79:  2000-2079
```

Full 4-digit year fields could then be defined by a future RINEX version 3.

6.6 Fit Interval

Bit 17 in word 10 of subframe 2 is a "fit interval" flag which indicates the curve-fit interval used by the GPS Control Segment in determining the ephemeris parameters, as follows (see ICD-GPS-200, 20.3.3.4.3.1):

```
0 = 4 hours
1 = greater than 4 hours.
```

Together with the IODC values and Table 20-XII the actual fit interval can be determined. The second value in the last record of each message shall contain the fit interval in hours determined using IODC, fit flag, and Table 20-XII, according to the Interface Document ICD-GPS-200.

6.7 Satellite Health

The health of the signal components (bits 18 to 22 of word three in subframe one) are now (Version 2.11) included into the health value reported in the second field of the sixth nav mess records.

A program reading RINEX files could easily decide if bit 17 only or all bits (17-22) have been written:

```
RINEX Value:   0    Health OK
RINEX Value:   1    Health not OK (bits 18-22 not stored)
RINEX Value: >32    Health not OK (bits 18-22 stored)
```

6.8 Transmission Time of Message (Navigation message file)

The transmission time of message can be shortly before midnight Saturday/Sunday, the TOE and TOC of the message already in the next week. As the reported week in the RINEX nav message (BROADCAST ORBIT - 5 record) goes with ToE (this is different from the GPS week in the original satellite message!), the transmission time of message should be reduced by 604800 (i.e., will become negative) to also refer to the same week.

6.9 Unknown / Undefined Observation Types and Header Records

It is a good practice for a program reading RINEX files to make sure that it does not crash if it encounters unknown observation types or header records

does not crash if it encounters unknown observation types or header records by properly skipping them and optionally reporting them to the user.

7. RINEX UNDER ANTISPOOFING (AS)

Some receivers generate code delay differences between the first and second frequency using cross-correlation techniques when AS is on and may recover the phase observations on L2 in full cycles. Using the C/A code delay on L1 and the observed difference it is possible to generate a code delay observation for the second frequency.

Other receivers recover P code observations by breaking down the Y code into P and W code.

Most of these observations may suffer from an increased noise level. In order to enable the postprocessing programs to take special actions, such AS-infected observations are flagged using bit number 2 of the Loss of Lock Indicators (i.e. their current values are increased by 4).

8. GLONASS Extensions

8.1 RINEX Observation File

8.1.1 Time System Identifier

The original RINEX Version 2 needed one major supplement, the explicit definition of the time system:

GLONASS is basically running on UTC (or, more precisely, GLONASS system time linked to UTC(SU)), i.e. the time tags are given in UTC and not GPS time. In order to remove possible misunderstandings and ambiguities, the header records "TIME OF FIRST OBS" and (if present) "TIME OF LAST OBS" in GLONASS and GPS observation files _can_, in mixed GLONASS/GPS observation files _must_ contain a time system identifier defining the system that all time tags in the file are referring to: "GPS" to identify GPS time, "GLO" to identify the GLONASS UTC time system. Pure GPS files default to GPS and pure GLONASS files default to GLO.

Format definitions see Table A1.

Hence, the two possible time tags differ by the current number of leap seconds.

In order to have the current number of leap seconds available we recommend to include a LEAP SECOND line into the RINEX header.

If there are known non-integer biases between the "GPS receiver clock" and "GLONASS receiver clock" in the same receiver, they should be applied. In this case the respective code and phase observations have to be corrected, too (c * bias if expressed in meters).

Unknown such biases will have to be solved for during the post processing

The small differences (modulo 1 second) between GLONASS system time, UTC(SU), UTC(USNO) and GPS system time have to be dealt with during the post-processing and not before the RINEX conversion. It may also be necessary to solve for remaining differences during the post-processing.

8.1.2 Pseudorange Definition

The pseudorange (code) measurement is defined to be equivalent to the difference of the time of reception (expressed in the time frame of the receiver) and the time of transmission (expressed in the time frame of the satellite) of a distinct satellite signal.

If a mixed-mode GPS/GLONASS receiver refers all pseudorange observations to

one receiver clock only,

- the raw GLONASS pseudoranges will show the current number of leap seconds between GPS time and GLONASS time if the receiver clock is running in the GPS time frame

- the raw GPS pseudoranges will show the negative number of leap seconds between GPS time and GLONASS time if the receiver clock is running in the GLONASS time frame

In order to avoid misunderstandings and to keep the code observations within the format fields, the pseudoranges must be corrected in this case as follows:

```
PR(GPS) := PR(GPS) + c * leap_seconds   if generated with a receiver clock
                                        running in the GLONASS time frame

PR(GLO) := PR(GLO) - c * leap_seconds   if generated with a receiver clock
                                        running in the GPS time frame
```

to remove the contributions of the leap seconds from the pseudoranges.

"leap_seconds" is the actual number of leap seconds between GPS and GLONASS (UTC) time, as broadcast in the GPS almanac and distributed in Circular T of BIPM.

8.1.3 More Than 12 Satellites per Epoch

The format of the epoch / satellite line in the observation record part of the RINEX Observation files has only been defined for up to 12 satellites per epoch. We explicitly define now the format of the continuation lines, see Table A2.

8.2 RINEX Navigation Files for GLONASS

As the GLONASS navigation message differs in contents from the GPS message too much, a special GLONASS navigation message file format has been defined.

The header section and the first data record (epoch, satellite clock information) is similar to the GPS navigation file. The following records contain the satellite position, velocity and acceleration, the clock and frequency biases as well as auxiliary information as health, satellite frequency (channel), age of the information.

The corrections of the satellite time to UTC are as follows:

```
GPS    : Tutc = Tsv - af0  -  af1  *(Tsv-Toc) - ... -  A0  - ... - leap_sec
GLONASS: Tutc = Tsv + TauN - GammaN*(Tsv-Tb)        + TauC
```

*** In order to use the same sign conventions for the GLONASS corrections as in the GPS navigation files, the broadcast GLONASS values are stored as:

-TauN, +GammaN, -TauC.

The time tags in the GLONASS navigation files are given in UTC (i.e. _not_ Moscow time or GPS time).

File naming convention: See above.

9. RINEX Extensions for Geostationary Satellites (GPS Signal Payloads)

With the implementation of GNSS programs, GPS-like ranging measurements can be performed on geostationary navigation payloads.

The necessary extensions to handle data exchange and post-processing were originally defined in RINEX Version 2.10 and apply in 2.11 as well.

9.1 RINEX Observation Files for GEO Satellites

A new satellite system identifier has been defined for the geostationary GPS signal payloads: "S", to be used in the RINEX VERSION / TYPE header line and in the satellite identifier 'snn', nn being the GEO PRN number minus 100.

e.g.: PRN = 120 --> 'snn' = "S20"

In mixed dual frequency GPS satellite / single frequency GEO payload observation files the fields for the second frequency observations of GEO satellites remain blank, are set to zero values or (if last in the record) can be truncated.

The time system identifier of GEO satellites generating GPS signals defaults to GPS time.

9.2 RINEX Navigation Message Files for GEO Satellites

As the GEO broadcast orbit format differs from the GPS message a special GEO navigation message file format has been defined which is nearly identical with the GLONASS nav mess file format.

The header section contains informations about the generating program, comments, and the difference between the GEO system time and UTC.

The first data record contains the epoch and satellite clock information, the following records contain the satellite position, velocity and acceleration and auxiliary information such as health, age of the data, etc.

The time tags in the GEO navigation files are given in the GPS time frame, i.e. not UTC.

The corrections of the satellite time to UTC are as follows:

GEO : Tutc = Tsv - aGf0 - aGf1 *(Tsv-Toe) - W0 - leap_sec

W0 being the correction to transform the GEO system time to UTC. Toe, aGf0, aGf1 see below in the format definition tables.

The "Transmission Time of Message" (PRN / EPOCH / SV CLK header record) is expressed in GPS seconds of the week. It marks the beginning of the message transmission. It has to refer to the same GPS week as the "Epoch of Ephemerides". It has to be adjusted by - or + 604800 seconds, if necessary (which would make it lower than zero or larger than 604800, respectively). It is a redefinition of the Version 2.10 "Message frame time".

"Health" shall be defined as follows:

- Bits 0 to 3 equal to Health in Message Type 17 (MT17)
- bit 4 is set to 1 if MT17 health is unavailable
- bit 5 is set to 1 if the URA index is equal to 15

In the SBAS message definitions bit 3 of the health is currently marked as 'reserved'.

In case of bit 4 set to 1, it is recommended to set bits 0,1,2,3 to 1, too.

"User Range Accuracy" (URA):

The same convention for converting the URA index to meters is used as with GPS. Set URA = 32767 meters if URA index = 15.

"IODN" (Issue Of Data Navigation)

The IODN is defined as the 8 first bits after the message type 9,

called IODN in RTCA DO229, Annex A and Annex B and called "spare" in Annex C.

The "CORR TO SYSTEM" TIME header record has been replaced by the more general record "D-UTC A0,A1,T,W,S,U" in Version 2.11.

10. Version 2.11 Modifications

The main driver for version 2.11 was the easy inclusion of Galileo and new GPS observables into the RINEX format. As these modifications are VERY MINOR (no changes in the actual formats) many RINEX readers will not have to be modified at all or to a small amount (accept version number 2.11), only.

After the first introduction of the "GEO navigation message file" in Version 2.10 feedback from the SBAS community lead to a number of clarifications/ redefinitions that were included in the Version 2.11 modifications.

10.1 Galileo and New GPS Observables

10.1.1 New Observation Codes

In Version 2.10 only the observation codes for two frequencies were define (Table A1).

The new codes for GPS L2C/L5 and Galileo codes are introduced as follows:

System	Freq.Band	Frequency	RINEX 2-character Code			
			Ps.Range	Carr.Phase	Doppler	Sign.Strength
GPS	L1	1575.42	C1,P1	L1	D1	S1
	L2	1227.60	C2,P2	L2	D2	S2
	L5	1176.45	C5	L5	D5	S5
Glonass	G1	1602+k*9/16	C1,P1	L1	D1	S1
	G2	1246+k*7/16	C2,P2	L2	D2	S2
Galileo	E2-L1-E1	1575.42	C1	L1	D1	S1
	E5a	1176.45	C5	L5	D5	S5
	E5b	1207.140	C7	L7	D7	S7
	E5a+b	1191.795	C8	L8	D8	S8
	E6	1278.75	C6	L6	D6	S6
SBAS	L1	1575.42	C1	L1	D1	S1
	L5	1176.45	C5	L5	D5	S5

The current two-character observation code does not easily allow a further refinement of the code to account for the different possibilities how to generate a specific observable, e.g., with respect to the underlying code (P,Y,M code in GPS) or the channels (I,Q, A,B,C in Galileo, I,Q in the new GPS L5 frequency, GPS L2C). The next RINEX version (3.0) will increase the length of the observation codes to allow a more detailed definition.

The definition of observations for Transit Doppler is obsolete and has been removed from Version 2.11

10.1.2 Wavelength Factors

The WAVELENGTH FACT L1/2 header record defining the factor, the carrier wavelength has to be divided with for ambiguity resolution, has been introduced because of receivers generating GPS phase observations under antispoofing with one cycle corresponding to half the carrier wavelength only (squaring technique). Galileo observables will not be generated by squaring. We therefore define the WAVELENGTH FACT L1/2 header record to be valid for L1 and L2 GPS phase observables only. All wavelength factors default to 1. This header record can therefore be declared to be optional.

10.1.3 Code for Galileo Satellite System

Use "E" to indicate the Galileo Satellite System in the header of RINEX observation files.

10.1.4 Galileo System Time

Include GAL as Galileo System Time into TIME OF FIRST OBS and TIME OF LAST OBS header records.

10.2 Clarifications in the GEO Navigation Message File

The following clarifications/modifications were introduced (see chapter 9.2):

- Health word
- Issue of Data (Navigation) IODN
- Correction to system time
- Transmission time of message

10.3 New observables for RINEX met files

Wind speed (ms), wind direction (from where the wind blows), and an incremental rain fall value (1/10 mm): rain accumulation since the last recording, hail indicator

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Document RTCA DO 229, Appendix A

APPENDIX: RINEX VERSION 2.11 FORMAT DEFINITIONS AND EXAMPLES

TABLE A1
GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION

GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION

HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
RINEX VERSION / TYPE	- Format version (2.11) - File type ('O' for Observation Data) - Satellite System: blank or 'G': GPS 'R': GLONASS 'S': Geostationary signal payload 'E': Galileo 'M': Mixed	F9.2,11X, A1,19X, 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 *
MARKER NAME	Name of antenna marker	A60
* MARKER NUMBER	Number of antenna marker	A20 *
OBSERVER / AGENCY	Name of observer / agency	A20,A40
REC # / TYPE / VERS	Receiver number, type, and version (Version: e.g. Internal Software Version)	3A20
ANT # / TYPE	Antenna number and type	2A20
APPROX POSITION XYZ	Approximate marker position (WGS84)	3F14.4
ANTENNA: DELTA H/E/N	- Antenna height: Height of bottom surface of antenna above marker - Eccentricities of antenna center relative to marker to the east and north (all units in meters)	3F14.4
* WAVELENGTH FACT L1/2	- Default wavelength factors for L1 and L2 (GPS only) 1: Full cycle ambiguities 2: Half cycle ambiguities (squaring) 0 (in L2): Single frequency instrument - zero or blank The wavelength factor record is optional for GPS and obsolete for other systems. Wavelength factors default to 1. If the record exists it must precede any satellite-specific records (see below).	* 2I6, I6
* WAVELENGTH FACT L1/2	- Wavelength factors for L1 and L2 (GPS) 1: Full cycle ambiguities 2: Half cycle ambiguities (squaring) 0 (in L2): Single frequency instrument - Number of satellites to follow in list for which these factors are valid. - List of PRNs (satellite numbers with system identifier) These optional satellite specific lines may follow, if they identify a state different from the default values. Repeat record if necessary.	2I6, * I6, 7(3X,A1,I2)
# / TYPES OF OBSERV	Number of different observation types	I6

# / TYPES OF OBSERV	- Number of different observation types stored in the file	I6,	
	- Observation types		
	- Observation code	9(4X,A1,	
	- Frequency code	A1)	
	If more than 9 observation types:		
	Use continuation line(s) (including the header label in cols. 61-80!)	6X,9(4X,2A1)	
	The following observation types are defined in RINEX Version 2.11:		
	Observation code (use uppercase only):		
	C: Pseudorange GPS: C/A, L2C; Glonass: C/A; Galileo: All		
	P: Pseudorange GPS and Glonass: P code		
	L: Carrier phase		
	D: Doppler frequency		
	S: Raw signal strengths or SNR values as given by the receiver for the respective phase observations		
	Frequency code		
	GPS: 1: L1, 2: L2, 5: L5, 6: --, 7: --, 8: --		
	Glonass: G1, G2, --, --, --, --		
	Galileo: E2-L1-E1, --, E5a, E6, E5b, E5a+b		
	SBAS: L1, --, L5, --, --, --		
	Observations collected under Antispoofing are converted to "L2" or "P2" and flagged with bit 2 of loss of lock indicator (see Table A2).		
	Units : Phase : full cycles; Pseudorange : meters; Doppler : Hz; SNR etc : receiver-dependent		
	The sequence of the types in this record has to correspond to the sequence of the observations in the observation records		
* INTERVAL	Observation interval in seconds	F10.3	*
TIME OF FIRST OBS	- Time of first observation record (4-digit-year, month,day,hour,min,sec)	5I6,F13.7,	
	- Time system: GPS (=GPS time system); GLO (=UTC time system); GAL (=Galileo System Time)	5X,A3	
	Compulsory in mixed GPS/GLONASS files		
	Defaults: GPS for pure GPS files; GLO for pure GLONASS files; GAL for pure Galileo files		
* TIME OF LAST OBS	- Time of last observation record (4-digit-year, month,day,hour,min,sec)	5I6,F13.7,	*
	- Time system: Same value as in TIME OF FIRST OBS record	5X,A3	
* RCV CLOCK OFFS APPL	Epoch, code, and phase are corrected by applying the realtime-derived receiver clock offset: 1=yes, 0=no; default: 0=no. Record required if clock offsets are	I6	*

	reported in the EPOCH/SAT records	
*|LEAP SECONDS	Number of leap seconds since 6-Jan-1980 Recommended for mixed files	I6 |*
*|# OF SATELLITES	Number of satellites, for which observations are stored in the file	I6 |*
*|PRN / # OF OBS	PRN (sat.number), number of observations for each observation type indicated in the "# / TYPES OF OBSERV" - record. If more than 9 observation types: Use continuation line(s) including the header label in cols. 61-80! This record is (these records are) repeated for each satellite present in the data file	3X,A1,I2,9I6 |* 6X,9I6
END OF HEADER	Last record in the header section.	60X

Records marked with * are optional

TABLE A2

GNSS OBSERVATION DATA FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
EPOCH/SAT or EVENT FLAG	- Epoch : - year (2 digits, padded with 0 if necessary) - month,day,hour,min, - sec	1X,I2.2, 4(1X,I2), F11.7,
	- Epoch flag 0: OK 1: power failure between previous and current epoch >1: Event flag	2X,I1,
	- Number of satellites in current epoch	I3,
	- List of PRNs (sat.numbers with system identifier, see 5.1) in current epoch	12(A1,I2),
	- receiver clock offset (seconds, optional)	F12.9
	If more than 12 satellites: Use continuation line(s)	32X, 12(A1,I2)
	If epoch flag 2-5:	
	- Event flag: 2: start moving antenna 3: new site occupation (end of kinem. data) (at least MARKER NAME record follows) 4: header information follows 5: external event (epoch is significant, same time frame as observation time tags)	[2X,I1,]
	- "Number of satellites" contains number of special records to follow. Maximum number of records: 999	[I3]
	- For events without significant epoch the epoch fields can be left blank	
	If epoch flag = 6:	

	6: cycle slip records follow to optionally report detected and repaired cycle slips (same format as OBSERVATIONS records; slip instead of observation; LLI and signal strength blank or zero)		
OBSERVATIONS	- Observation - LLI - Signal strength	rep. within record for each obs.type (same seq as given in header)	m(F14.3, I1, I1)
	If more than 5 observation types (=80 char): continue observations in next record.		
	This record is (these records are) repeated for each satellite given in EPOCH/SAT - record.		
	Observations: Phase : Units in whole cycles of carrier Code : Units in meters Missing observations are written as 0.0 or blanks.		
	Phase values overflowing the fixed format F14.3 have to be clipped into the valid interval (e.g. add or subtract 10**9), set LLI indicator.		
	Loss of lock indicator (LLI). Range: 0-7 0 or blank: OK or not known Bit 0 set : Lost lock between previous and current observation: cycle slip possible Bit 1 set : Opposite wavelength factor to the one defined for the satellite by a previous WAVELENGTH FACT L1/2 line or opposite to the default. Valid for the current epoch only. Bit 2 set : Observation under Antispoofing (may suffer from increased noise) Bits 0 and 1 for phase only.		
	Signal strength projected into interval 1-9: 1: minimum possible signal strength 5: threshold for good S/N ratio 9: maximum possible signal strength 0 or blank: not known, don't care		

TABLE A3

GPS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION

HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT	
RINEX VERSION / TYPE	- Format version (2.11) - 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 A0-A3 of almanac (page 18 of subframe 4)	2X,4D12.4	*

* ION BETA	Ionosphere parameters B0-B3 of almanac	2X,4D12.4 *
* DELTA-UTC: A0,A1,T,W	Almanac parameters to compute time in UTC (page 18 of subframe 4) 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

Records marked with * are optional

TABLE A4
GPS NAVIGATION MESSAGE FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
PRN / EPOCH / SV CLK	- Satellite PRN number	I2,
	- Epoch: Toc - Time of Clock	
	year (2 digits, padded with 0	
	if necessary)	1X,I2.2,
	month	1X,I2,
	day	1X,I2,
	hour	1X,I2,
	minute	1X,I2,
	second	F5.1,
	- SV clock bias (seconds)	3D19.12
	- SV clock drift (sec/sec)	
	- SV clock drift rate (sec/sec2)	*)
BROADCAST ORBIT - 1	- IODE Issue of Data, Ephemeris	3X,4D19.12
	- Crs (meters)	
	- Delta n (radians/sec)	
	- M0 (radians)	
BROADCAST ORBIT - 2	- Cuc (radians)	3X,4D19.12
	- e Eccentricity	
	- Cus (radians)	
	- sqrt(A) (sqrt(m))	
BROADCAST ORBIT - 3	- Toe Time of Ephemeris	3X,4D19.12
	(sec of GPS week)	
	- Cic (radians)	
	- OMEGA (radians)	
	- CIS (radians)	
BROADCAST ORBIT - 4	- i0 (radians)	3X,4D19.12
	- Crc (meters)	
	- omega (radians)	
	- OMEGA DOT (radians/sec)	
BROADCAST ORBIT - 5	- IDOT (radians/sec)	3X,4D19.12
	- Codes on L2 channel	
	- GPS Week # (to go with TOE)	
	Continuous number, not mod(1024)!	
	- L2 P data flag	
BROADCAST ORBIT - 6	- SV accuracy (meters)	3X,4D19.12
	- SV health (bits 17-22 w 3 sf 1)	
	- TGD (seconds)	

	- IODC Issue of Data, Clock	
BROADCAST ORBIT - 7	- Transmission time of message **) (sec of GPS week, derived e.g. from Z-count in Hand Over Word (HOW) - Fit interval (hours) (see ICD-GPS-200, 20.3.4.4) Zero if not known - spare - spare	3X,4D19.12

**) Adjust the Transmission time of message by -604800 to refer to the reported week, if necessary.

*) In order to account for the various compilers, E,e,D, and d are allowed letters between the fraction and exponent of all floating point numbers in the navigation message files.
Zero-padded two-digit exponents are required, however.

TABLE A5
METEOROLOGICAL DATA FILE - HEADER SECTION DESCRIPTION

HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT	
RINEX VERSION / TYPE	- Format version (2.11) - File type ('M' for Meteorological 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)	A60	*
MARKER NAME	Station Name (preferably identical to MARKER NAME in the associated Observation File)	A60	
MARKER NUMBER	Station Number (preferably identical to MARKER NUMBER in the associated Observation File)	A20	*
# / TYPES OF OBSERV	- Number of different observation types stored in the file - Observation types The following meteorological observation types are defined in RINEX Version 2: PR : Pressure (mbar) TD : Dry temperature (deg Celsius) HR : Relative humidity (percent) ZW : Wet zenith path delay (mm) (for WVR data) ZD : Dry component of zenith path delay (mm) ZT : Total zenith path delay (mm) WD : Wind azimuth (deg) from where the wind blows WS : Wind speed (m/s) RI : "Rain increment" (1/10 mm): Rain accumulation since last measurement HI : Hail indicator: 1 = Hail detected since last measurement	I6, 9(4X,A2)	

	The sequence of the types in this record must correspond to the sequence of the measurements in the data records If more than 9 observation types are being used, use continuation lines including header label in cols. 61-80!	6X,9(4X,A2)
SENSOR MOD/TYPE/ACC	Description of the met sensor - Model (manufacturer) - Type - Accuracy (same units as obs values) - Observation type Record is repeated for each observation type found in # / TYPES OF OBSERV record	 A20, A20,6X, F7.1,4X, A2,1X
SENSOR POS XYZ/H	Approximate position of the met sensor - Geocentric coordinates X,Y,Z (ITRF - Ellipsoidal height H or WGS-84) - Observation type Set X,Y,Z to zero if not known. Make sure H refers to ITRF or WGS-84! Record required for barometer, recommended for other sensors.	 3F14.4, 1F14.4, 1X,A2,1X
END OF HEADER	Last record in the header section.	60X

Records marked with * are optional

TABLE A6
METEOROLOGICAL DATA FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
EPOCH / MET	- Epoch in GPS time (not local time!) year (2 digits, padded with 0 if necessary) month,day,hour,min,sec The 2-digit years in RINEX Version 1 and 2.xx files are understood to represent 80-99: 1980-1999 and 00-79: 2000-2079 - Met data in the same sequence as given in the header More than 8 met data types: Use continuation lines	 1X,I2.2, 5(1X,I2), mF7.1 4X,10F7.1,3X

TABLE A7
GPS OBSERVATION DATA FILE - EXAMPLE

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

     2.11           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
BLANK OR G = GPS,  R = GLONASS,  E = GALILEO,  M = MIXED    COMMENT
XXRINEXO V9.9       AIUB                24-MAR-01 14:43     PGM / RUN BY / DATE
EXAMPLE OF A MIXED RINEX FILE (NO FEATURES OF V 2.11)       COMMENT
A 9080                                                      MARKER NAME
```

```
A 9080                                                      MARKER NAME
9080.1.34                                                   MARKER NUMBER
BILL SMITH          ABC INSTITUTE                           OBSERVER / AGENCY
X1234A123           XX                  ZZZ                 REC # / TYPE / VERS
234                 YY                                      ANT # / TYPE
  4375274.       587466.      4589095.                      APPROX POSITION XYZ
        .9030         .0000         .0000                   ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     1     2     6   G14   G15   G16   G17   G18   G19      WAVELENGTH FACT L1/2
     0                                                      RCV CLOCK OFFS APPL
     5    P1    L1    L2    P2    L5                        # / TYPES OF OBSERV
    18.000                                                  INTERVAL
  2005     3    24    13    10   36.0000000                 TIME OF FIRST OBS
                                                            END OF HEADER
 05  3 24 13 10 36.0000000  0  4G12G09G06E11                        -.123456789
  23629347.915            .300 8         -.353    23629364.158
  20891534.648           -.120 9         -.358    20891541.292
  20607600.189           -.430 9          .394    20607605.848
                          .324 8                                  .178 7
 05  3 24 13 10 50.0000000  4  4
     1     2     2   G 9   G12                                   WAVELENGTH FACT L1/2
  *** WAVELENGTH FACTOR CHANGED FOR 2 SATELLITES ***            COMMENT
      NOW 8 SATELLITES HAVE WL FACT 1 AND 2!                    COMMENT
                                                                COMMENT
 05  3 24 13 10 54.0000000  0  6G12G09G06R21R22E11                 -.123456789
  23619095.450      -53875.632 8    -41981.375    23619112.008
  20886075.667      -28688.027 9    -22354.535    20886082.101
  20611072.689       18247.789 9     14219.770    20611078.410
  21345678.576       12345.567 5
  22123456.789       23456.789 5
                     65432.123 5                              48861.586 7
 05  3 24 13 11  0.0000000  2  1
           *** FROM NOW ON KINEMATIC DATA! ***                  COMMENT
 05  3 24 13 11 48.0000000  0  4G16G12G09G06                        -.123456789
  21110991.756       16119.980 7     12560.510    21110998.441
  23588424.398     -215050.557 6   -167571.734    23588439.570
  20869878.790     -113803.187 8    -88677.926    20869884.938
  20621643.727       73797.462 7     57505.177    20621649.276
                           3  4
A 9080                                                      MARKER NAME
9080.1.34                                                   MARKER NUMBER
        .9030         .0000         .0000                   ANTENNA: DELTA H/E/N
         --> THIS IS THE START OF A NEW SITE <--            COMMENT
 05  3 24 13 12  6.0000000  0  4G16G12G06G09                        -.123456987
  21112589.384       24515.877 6     19102.763 3  21112596.187
  23578228.338     -268624.234 7   -209317.284 4  23578244.398
  20625218.088       92581.207 7     72141.846 4  20625223.795
  20864539.693     -141858.836 8   -110539.435 5  20864545.943
 05  3 24 13 13  1.2345678  5  0
                           4  1
       (AN EVENT FLAG WITH SIGNIFICANT EPOCH)               COMMENT
 05  3 24 13 14 12.0000000  0  4G16G12G09G06                        -.123456012
  21124965.133       89551.30216     69779.62654  21124972.2754
  23507272.372     -212616.150 7   -165674.789 5  23507288.421
  20828010.354     -333820.093 6   -260119.395 5  20828017.129
  20650944.902      227775.130 7    177487.651 4  20650950.363
                           4  1
          *** ANTISPOOFING ON G 16 AND LOST LOCK             COMMENT
 05  3 24 13 14 12.0000000  6  2G16G09
                123456789.0      -9876543.5
                       0.0            -0.5
                           4  2
          ---> CYCLE SLIPS THAT HAVE BEEN APPLIED TO        COMMENT
               THE OBSERVATIONS                             COMMENT
 05  3 24 13 14 48.0000000  0  4G16G12G09G06                        -.123456234
  21128884.159      110143.144 7     85825.18545  21128890.7764
  23487131.045     -318463.297 7   -248152.72824  23487146.149
  20817844.743      387242.571 6    301747.22925  20817851.322
```

```
 20617844.743     -387242.371 6   -301747.22925  20617851.522
 20658519.895      267583.67817    208507.26234  20658525.869
                         4  3
        ***   SATELLITE G 9   THIS EPOCH ON WLFACT 1 (L2)  COMMENT
        *** G 6 LOST LOCK AND THIS EPOCH ON WLFACT 2 (L2)  COMMENT
              (OPPOSITE TO PREVIOUS SETTINGS)             COMMENT

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

TABLE A8
GPS NAVIGATION MESSAGE FILE - EXAMPLE

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

     2.11           N: GPS NAV DATA                         RINEX VERSION / TYPE
XXRINEXN V2.10      AIUB                 3-SEP-99 15:22     PGM / RUN BY / DATE
EXAMPLE OF VERSION 2.11 FORMAT                              COMMENT
     .1676D-07   .2235D-07  -.1192D-06  -.1192D-06          ION ALPHA
     .1208D+06   .1310D+06  -.1310D+06  -.1966D+06          ION BETA
     .133179128170D-06  .107469588780D-12   552960     1025 DELTA-UTC: A0,A1,T,W
    13                                                      LEAP SECONDS
                                                            END OF HEADER
 6 99  9  2 17 51 44.0 -.839701388031D-03 -.165982783074D-10  .000000000000D+00
     .910000000000D+02  .934062500000D+02  .116040547840D-08  .162092304801D+00
     .484101474285D-05  .626740418375D-02  .652112066746D-05  .515365489006D+04
     .409904000000D+06 -.242143869400D-07  .329237003460D+00 -.596046447754D-07
     .111541663136D+01  .326593750000D+03  .206958726335D+01 -.638312302555D-08
     .307155651409D-09  .000000000000D+00  .102500000000D+04  .000000000000D+00
     .000000000000D+00  .000000000000D+00  .000000000000D+00  .910000000000D+02
     .406800000000D+06  .000000000000D+00
13 99  9  2 19  0  0.0  .490025617182D-03  .204636307899D-11  .000000000000D+00
     .133000000000D+03 -.963125000000D+02  .146970407622D-08  .292961152146D+01
    -.498816370964D-05  .200239347760D-02  .928156077862D-05  .515328476143D+04
     .414000000000D+06 -.279396772385D-07  .243031939942D+01 -.558793544769D-07
     .110192796930D+01  .271187500000D+03 -.232757915425D+01 -.619632953057D-08
    -.785747015231D-11  .000000000000D+00  .102500000000D+04  .000000000000D+00
     .000000000000D+00  .000000000000D+00  .000000000000D+00  .389000000000D+03
     .410400000000D+06  .000000000000D+00

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

TABLE A9
METEOROLOGICAL DATA FILE - EXAMPLE

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

     2.11           METEOROLOGICAL DATA                     RINEX VERSION / TYPE
XXRINEXM V9.9       AIUB                 3-APR-96 00:10     PGM / RUN BY / DATE
EXAMPLE OF A MET DATA FILE (NO FEATURES OF V 2.11)          COMMENT
A 9080                                                      MARKER NAME
     3    PR    TD    HR                                   # / TYPES OF OBSERV
PAROSCIENTIFIC      740-16B                  0.2    PR SENSOR MOD/TYPE/ACC
HAENNI                                       0.1    TD SENSOR MOD/TYPE/ACC
ROTRONIC            I-240W                   5.0    HR SENSOR MOD/TYPE/ACC
       0.0            0.0           0.0    1234.5678 PR SENSOR POS XYZ/H
                                                            END OF HEADER
 96  4  1  0  0 15  987.1   10.6   89.5
 96  4  1  0  0 30  987.2   10.9   90.0
 96  4  1  0  0 45  987.1   11.6   89.0

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

TABLE A10

GLONASS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION

	HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	RINEX VERSION / TYPE	- Format version (2.11) - File type ('G' = GLONASS nav mess 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 (dd-mmm-yy hh:mm)	A20, A20, A20
*	COMMENT	Comment line(s)	A60
*	CORR TO SYSTEM TIME	- Time of reference for system time corr (year, month, day) - Correction to system time scale (sec) to correct GLONASS system time to UTC(SU) (-TauC)	3I6, 3X,D19.12 *)
*	LEAP SECONDS	Number of leap seconds since 6-Jan-1980	I6
	END OF HEADER	Last record in the header section.	60X

Records marked with * are optional

TABLE A11

GLONASS NAVIGATION MESSAGE FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
PRN / EPOCH / SV CLK	- Satellite number: Slot number in sat. constellation - Epoch of ephemerides (UTC) - year (2 digits, padded with 0, if necessary) - month,day,hour,minute, - second - SV clock bias (sec) (-TauN) - SV relative frequency bias (+GammaN) - message frame time (tk) (0 .le. tk .lt. 86400 sec of day UTC) The 2-digit years in RINEX 1 and 2.xx files are understood to represent 80-99: 1980-1999 and 00-79: 2000-2079	I2, 1X,I2.2, 4(1X,I2), F5.1, D19.12, D19.12, D19.12 *)
BROADCAST ORBIT - 1	- Satellite position X (km) - velocity X dot (km/sec) - X acceleration (km/sec2) - health (0=OK) (Bn)	3X,4D19.12
BROADCAST ORBIT - 2	- Satellite position Y (km) - velocity Y dot (km/sec) - Y acceleration (km/sec2) - frequency number (-7 ... +13)	3X,4D19.12
BROADCAST ORBIT - 3	- Satellite position Z (km) - velocity Z dot (km/sec)	3X,4D19.12

```
 |                    | -           Z acceleration  (km/sec2)    |            |
 |                    | - Age of oper. information  (days)   (E) |            |
 +--------------------+------------------------------------------+------------+
```

*) In order to account for the various compilers, E,e,D, and d are allowed letters between the fraction and exponent of all floating point numbers in the navigation message files.
Zero-padded two-digit exponents are required, however.

TABLE A12
GLONASS NAVIGATION MESSAGE FILE - EXAMPLE

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

     2.11           GLONASS NAV DATA                         RINEX VERSION / TYPE
ASRINEXG V1.1.0 VM  AIUB                 19-FEB-98 10:42     PGM / RUN BY / DATE
STATION ZIMMERWALD                                           COMMENT
  1998     2    16    0.379979610443D-06                     CORR TO SYSTEM TIME
                                                             END OF HEADER
 3 98  2 15  0 15  0.0 0.163525342941D-03 0.363797880709D-11 0.108000000000D+05
    0.106275903320D+05-0.348924636841D+00 0.931322574615D-09 0.000000000000D+00
   -0.944422070313D+04 0.288163375854D+01 0.931322574615D-09 0.210000000000D+02
    0.212257280273D+05 0.144599342346D+01-0.186264514923D-08 0.300000000000D+01
 4 98  2 15  0 15  0.0 0.179599039257D-03 0.636646291241D-11 0.122400000000D+05
    0.562136621094D+04-0.289074897766D+00-0.931322574615D-09 0.000000000000D+00
   -0.236819248047D+05 0.102263259888D+01 0.931322574615D-09 0.120000000000D+02
    0.762532910156D+04 0.339257907867D+01 0.000000000000D+00 0.300000000000D+01
11 98  2 15  0 15  0.0-0.559808686376D-04-0.272848410532D-11 0.108600000000D+05
   -0.350348437500D+04-0.255325126648D+01 0.931322574615D-09 0.000000000000D+00
    0.106803754883D+05-0.182923507690D+01 0.000000000000D+00 0.400000000000D+01
    0.228762856445D+05 0.447064399719D+00-0.186264514923D-08 0.300000000000D+01
12 98  2 15  0 15  0.0 0.199414789677D-04-0.181898940355D-11 0.108900000000D+05
    0.131731816406D+05-0.143945598602D+01 0.372529029846D-08 0.000000000000D+00
    0.171148715820D+05-0.118937969208D+01 0.931322574615D-09 0.220000000000D+02
    0.135737919922D+05 0.288976097107D+01-0.931322574615D-09 0.300000000000D+01

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

TABLE A13
GLONASS OBSERVATION FILE - EXAMPLE

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

     2.11           OBSERVATION DATA    R (GLONASS)          RINEX VERSION / TYPE
XXRINEXO V1.1       AIUB                27-AUG-93 07:23      PGM / RUN BY / DATE
TST1                                                         MARKER NAME
VIEWEG              BRAUNSCHWEIG                             OBSERVER / AGENCY
100                 XX-RECEIVER         1.0                  REC # / TYPE / VERS
101                 XX-ANTENNA                               ANT # / TYPE
  3844808.114    715426.767   5021804.854                   APPROX POSITION XYZ
        1.2340         .0000         .0000                   ANTENNA: DELTA H/E/N
     1     1                                                 WAVELENGTH FACT L1/2
     2    C1    L1                                          # / TYPES OF OBSERV
    10.000                                                   INTERVAL
  1993     8    23    14    24   40.0490000     GLO         TIME OF FIRST OBS
                                                             END OF HEADER
 93  8 23 14 24 40.0490000  0  3  2R01R21
  23986839.824       20520.565 5
  23707804.625       19937.231 5
  23834065.096       -9334.581 5
```

```
 93  8 23 14 24 50.0490000  0  3  2R01R21
  23992341.033       49856.525 5
  23713141.002       48479.290 5
  23831189.435      -24821.796 5
 93  8 23 14 25   .0490000  0  3  2R01R21
  23997824.854       79217.202 5
  23718494.110       77092.992 5
  23828329.946      -40219.918 5
 93  8 23 14 25 10.0490000  0  5  2R05R17R01R21
  24003328.910      108602.422 5
  24933965.449      -19202.780 5
  22203326.578       -2987.327 5
  23723851.686      105777.849 5
  23825485.526      -55529.205 5
 93  8 23 14 25 20.0490010  0  5  2R05R17R01R21
  24008828.023      138012.178 5
  24927995.616      -51188.500 5
  22202547.907       -7213.298 5
  23729236.758      134533.636 5
  23822662.277      -70749.590 5
 93  8 23 14 25 30.0490000  0  5  2R05R17R01R21
  24014330.779      167446.477 5
  24922041.288      -83151.666 5
  22201767.457      -11388.909 5
  23734633.024      163360.131 5
  23819848.894      -85881.102 5

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

TABLE A14

MIXED GPS/GLONASS OBSERVATION FILE - EXAMPLE

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

     2.11           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
YYRINEXO V2.8.1 VM  AIUB                 6-FEB-00 13:59     PGM / RUN BY / DATE
TST2                                                        MARKER NAME
001-02-A                                                    MARKER NUMBER
JIM                 Y-COMPANY                               OBSERVER / AGENCY
1                   YY-RECEIVER         2.0.1               REC # / TYPE / VERS
1                   GEODETIC L1                             ANT # / TYPE
  3851178.1849   -80151.4072  5066671.1013                  APPROX POSITION XYZ
        1.2340        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     0                                                WAVELENGTH FACT L1/2
     2    C1    L1                                          # / TYPES OF OBSERV
    10.000                                                  INTERVAL
    11                                                      LEAP SECONDS
  2000     2     6    11    53    0.0000000     GPS         TIME OF FIRST OBS
                                                            END OF HEADER
 00  2  6 11 53  0.0000000  0 14G23G07G02G05G26G09G21R20R19R12R02R11
                              R10R03
  22576523.586   -11256947.60212
  22360162.704   -16225110.75413
  24484865.974    14662682.882 2
  21950524.331   -13784707.24912
  22507304.252     9846064.848 2
  20148742.213   -20988953.712 4
  22800149.591   -16650822.70012
  19811403.273   -25116169.741 3
  23046997.513    -3264701.688 2
  22778170.622  -821857836.745 1
  22221283.991  -988088156.884 2
  19300913.475   -83282658.19013
  20309075.579  -672668843.84713
```

```
 23397403.484  -285457101.34211
 00  2  6 11 53 10.0000000  0 14G23G07G02G05G26G09G21R20R19R12R02R11
                              R10R03
 22578985.016   -11244012.910 2
 22359738.890   -16227337.841 2
 24490324.818    14691368.710 2
 21944376.706   -13817012.849 2
 22512598.731     9873887.580 2
 20147322.111   -20996416.338 4
 22798942.949   -16657163.594 2
 19812513.509   -25110234.795 3
 23053885.702    -3227854.397 2
 22770607.029  -821898566.774 1
 22222967.297  -988079145.989 2
 19297913.736   -83298710.38413
 20313087.618  -672647337.04113
 23392352.454  -285484291.40311

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

TABLE A15

GEOSTATIONARY NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION

	HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	RINEX VERSION / TYPE	- Format version (2.11) - File type ('H' = GEO nav mess 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 (dd-mmm-yy hh:mm)	A20, A20, A20
*	COMMENT	Comment line(s)	A60
*	CORR TO SYSTEM TIME Obsolete in RINEX Version 2.11	- Time of reference for system time corr (year, month, day) - Correction to transform the GEO system time to UTC (W0)	3I6, 3X,D19.12 *)
*	D-UTC A0,A1,T,W,S,U	Corrections to transform the system time to UTC A0,A1 Coefficients of 1-deg polynomial A0 sec, A1 sec/sec CORR(s) = A0 + A1*DELTAT T Reference time for polynomial (Seconds into GPS week) W Reference week number (GPS week, continuous number) S EGNOS, WAAS, or MSAS ... (left-justified) Derived from MT17 service provider. If not known: Use Snn with nn = PRN-100 of satellite broadcasting the MT12 U UTC Identifier (0 if unknown) 1=UTC(NIST), 2=UTC(USNO), 3=UTC(SU), 4=UTC(BIPM), 5=UTC(Europe Lab), 6=UTC(CRL), >6 = reserved for future Omit record if corrections not provided. Replaces CORR TO SYSTEM TIME !	 2D19.12, I7, I5, X,A5,X I2,2X
*	LEAP SECONDS	Number of leap seconds since 6-Jan-1980	I6

LEAP SECONDS	Number of leap seconds since 6-Jan-1980	10
END OF HEADER	Last record in the header section.	60X

Records marked with * are optional

TABLE A16

GEOSTATIONARY NAVIGATION MESSAGE FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
PRN / EPOCH / SV CLK	- Satellite number (PRN - 100)	I2,
	- Epoch of ephemerides (GPS) (Toe)	
	- year (2 digits, padded with 0 if necessary)	1X,I2.2,
	- month,day,hour,minute,	4(1X,I2),
	- second	F5.1,
	- SV clock bias (sec) (aGf0)	D19.12,
	- SV relative frequency bias (aGf1)	D19.12,
	- Transmission time of message (start of the message) in GPS seconds of the week	D19.12
BROADCAST ORBIT - 1	- Satellite position X (km)	3X,4D19.12
	- velocity X dot (km/sec)	
	- X acceleration (km/sec2)	*)
	- health (0=OK)	
BROADCAST ORBIT - 2	- Satellite position Y (km)	3X,4D19.12
	- velocity Y dot (km/sec)	
	- Y acceleration (km/sec2)	
	- Accuracy code (URA, meters)	
BROADCAST ORBIT - 3	- Satellite position Z (km)	3X,4D19.12
	- velocity Z dot (km/sec)	
	- Z acceleration (km/sec2)	
	- IODN (Issue of Data Navigation, DO229, 8 first bits after Message Type if MT9)	

*) In order to account for the various compilers, E,e,D, and d are allowed letters between the fraction and exponent of all floating point numbers in the navigation message files.

Zero-padded two-digit exponents are required, however.

TABLE A17

MIXED GPS/GEO OBSERVATION FILE - EXAMPLE

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

     2.11           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
RinExp V.2.0.2      TESTUSER            00-02-04 09:30      PGM / RUN BY / DATE
                                                            COMMENT
The file contains L1 pseudorange and phase data of the      COMMENT
geostationary AOR-E satellite (PRN 120 = S20)               COMMENT
                                                            COMMENT
TLSE D                                                      MARKER NAME
ESTB                TESTAGENCY                              OBSERVER / AGENCY
SGL98030069         Novatel Millennium  HW3-1 SW 4.45/2.3   REC # / TYPE / VERS
                    ASH701073.1                             ANT # / TYPE
  4620365.0750   112100.1700  4371610.4160                  APPROX POSITION XYZ
```

```
 4629365.0750   112100.1790  4371619.4160                  APPROX POSITION XYZ
       0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
    1     1                                                WAVELENGTH FACT L1/2
    4    C1    L1    L2    P2                              # / TYPES OF OBSERV
    1                                                      INTERVAL
 2000     1    13    14    45    0.000000      GPS         TIME OF FIRST OBS
 2000     1    13    15     0    0.000000      GPS         TIME OF LAST OBS
    0                                                      RCV CLOCK OFFS APPL
                                                           END OF HEADER
 00 01 13 14 45  0.0000000  0  8G25G17G06G05G24G29G30S20             0.000535140
  21839900.207     -236148.877 9   -184047.71049  21839901.4384
  25151926.413     -161002.900 9   -125509.72447  25151935.8274
  20531103.515      763336.059 9    594797.53149  20531105.0114
  23001624.801     -432989.642 9   -337436.50348  23001628.1684
  23610349.510     -384890.728 9   -299952.38848  23610354.3504
  23954474.398     -151982.173 9   -118480.96847  23954481.1994
  20622367.016     -332628.466 9   -259214.55249  20622367.8754
  38137559.506      335849.135 9
 00 01 13 14 45  1.0000000  0  8G25G17G06G05G24G29G30S20             0.000535144
  21839500.278     -238250.743 9   -185685.52549  21839501.4814
  25151246.148     -164576.503 9   -128294.33947  25151256.2614
  20531084.382      763235.849 9    594719.44849  20531085.8784
  23002123.430     -430369.237 9   -335394.62748  23002126.7114
  23610670.127     -383205.864 9   -298639.51048  23610674.9834
  23955051.773     -148948.417 9   -116117.00748  23955058.5034
  20622558.579     -331621.765 9   -258430.11049  20622559.4574
  38137558.783      335846.284 9
 00 01 13 14 45  2.0000000  0  8G25G17G06G05G24G29G30S20             0.000535144
  21839100.418     -240352.173 9   -187323.00449  21839101.6534
  25150565.890     -168150.148 9   -131078.97647  25150576.2144
  20531065.378      763136.116 9    594641.73549  20531066.8984
  23002622.082     -427748.683 9   -333352.63648  23002625.3444
  23610990.819     -381520.461 9   -297326.20848  23610995.8424
  23955629.062     -145914.531 9   -113752.94748  23955636.5544
  20622750.161     -330614.723 9   -257645.40149  20622751.0554
  38137558.365      335843.457 9

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

TABLE A18

GEO NAVIGATION MESSAGE FILE - EXAMPLE

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

     2.11           H: GEO NAV MSG DATA                    RINEX VERSION / TYPE
SBAS2RINEX 2.0      CNES                20-Oct-03 14:01    PGM / RUN BY / DATE
0.133179128170D-06-0.107469588780D-12 518400 1240 EGNOS  5 D-UTC A0,A1,T,W,S,U
    13                                                     LEAP SECONDS
This file contains navigation message data from a SBAS     COMMENT
(geostationary) satellite, here AOR-W (PRN 122 = # 22)     COMMENT
                                                           END OF HEADER
22 03 10 18  0  1  4.0-1.005828380585D-07 6.366462912410D-12 5.184420000000D+05
    2.482832392000D+04-3.593750000000D-04-1.375000000000D-07 0.000000000000D+00
   -3.408920872000D+04-1.480625000000D-03-5.000000000000D-08 4.000000000000D+00
   -1.650560000000D+01 8.360000000000D-04 6.250000000000D-08 2.300000000000D+01
22 03 10 18  0  5 20.0-9.872019290924D-08 5.456968210638D-12 5.186940000000D+05
    2.482822744000D+04-3.962500000000D-04-1.375000000000D-07 0.000000000000D+00
   -3.408958936000D+04-1.492500000000D-03-5.000000000000D-08 4.000000000000D+00
   -1.628960000000D+01 8.520000000000D-04 6.250000000000D-08 2.400000000000D+01
22 03 10 18  0  9 36.0-9.732320904732D-08 4.547473508865D-12 5.189510000000D+05
    2.482812152000D+04-4.325000000000D-04-1.375000000000D-07 0.000000000000D+00
   -3.408997304000D+04-1.505000000000D-03-5.000000000000D-08 4.000000000000D+00
   -1.606960000000D+01 8.800000000000D-04 6.250000000000D-08 2.500000000000D+01
22 03 10 18  0 13 52.0-9.592622518539D-08 4.547473508865D-12 5.192110000000D+05
    2.482800632000D+04-4.681250000000D-04-1.375000000000D-07 0.000000000000D+00
   -3.409035992000D+04-1.518125000000D-03-3.750000000000D-08 4.000000000000D+00
```

```
   -1.584240000000D+01 8.960000000000D-04 6.250000000000D-08 2.600000000000D+01

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