RINEX: The Receiver Independent Exchange Format Version 2

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(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)

0. INTRODUCTION

0.1 First Revision

This paper is a revised version of the one 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 definiton 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 asks 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!                     *
```

0.2 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 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 descrepancy 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.

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 four ASCII file types:

1. Observation Data File
2. Navigation Message File
3. Meteorological Data File
4. GLONASS Navigation Message File

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 mimimum 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 then be kept as short as possible. 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.

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 at both L1 and L2. The half-cycles measured by sqaring-type receivers must be converted to whole cycles and flagged by the wavelength factor in the header section.

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      ssss:    4-character station 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
                             t:    file type:
                                   O: Observation file
                                   N: Navigation file
                                   M: Meteorological data file
                                   G: GLONASS Navigation file
```

To exchange RINEX files on magnetic tapes we recommend using the following tape format:

- Non-label; ASCII; fixed record length: 80 characters;
  block size: 8000

- First file on tape contains list of files using above-mentioned
  naming conventions

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 naming conventions for the compressed files:

System	Obs files	GPS Nav Files	GLONASS Nav Files	Met Files
UNIX	ssssdddf.yyO.Z	ssssdddf.yyN.Z	ssssdddf.yyG.Z	ssssdddf.yyM.Z
VMS	ssssdddf.yyO_Z	ssssdddf.yyN_Z	ssssdddf.yyG_Z	ssssdddf.yyM_Z
DOS	ssssdddf.yyY	ssssdddf.yyX	ssssdddf.yyV	ssssdddf.yyW

Proposed naming conventions for observation files compressed using the Hatanaka file compression scheme:

System	Obs files
UNIX	ssssdddf.yyD.Z
VMS	ssssdddf.yyD_Z
DOS	ssssdddf.yyE

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

ftp://igscb.jpl.nasa.gov/igscb/software/rnxcmp/docs/
IGSMails 1525,1686,1726,1763,1785

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
                                  T          : Transit
                           nn:    PRN (GPS), almanac number (GLONASS)
```

or two-digit Transit satellite number

Note: G is mandatory in mixed GPS/GLONASS 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 (if present) should 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. 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 prevent confusion and redundancy, the receiver clock offset (if present) should report the value that has been used to correct the observables according to the formulae under item 1. 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

Programs developed to read RINEX Version 1 files have to verify the version number. Version 2 files may look different (version number, END OF HEADER record, receiver and antenna serial number alphanumeric) even if they do not use any of the new features

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.

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.

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

RINEX Version 2 needs 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).

Filenaming convention: See above.

9. REFERENCES

Evans, A. (1989): "Summary of the Workshop on GPS Exchange Formats." Proceedings of the Fifth International Geodetic Symposium on Satellite Systems, pp. 917ff, Las Cruces.

Gurtner, W., G. Mader, D. Arthur (1989): "A Common Exchange Format for GPS Data." CSTG GPS Bulletin Vol.2 No.3, May/June 1989, National Geodetic Survey, Rockville.

Gurtner, W., G. Mader (1990): "The RINEX Format: Current Status, Future Developments." Proceedings of the Second International Symposium of Precise Positioning with the Global Positioning system, pp. 977ff, Ottawa.

Gurtner, W., G. Mader (1990): "Receiver Independent Exchange Format Version 2." CSTG GPS Bulletin Vol.3 No.3, Sept/Oct 1990, National Geodetic Survey, Rockville.

10. RINEX VERSION 2 FORMAT DEFINITIONS AND EXAMPLES

TABLE A1

OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION

HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
RINEX VERSION / TYPE	- Format version (2)	I6,14X,
	- File type ('O' for Observation Data)	A1,19X,
	- Satellite System: blank or 'G': GPS	A1,19X
	'R': GLONASS	

		'T': NNSS Transit	
		'M': Mixed	
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	- Wavelength factors for L1 and L2 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. 0 or blank: Default wavelength factors for all satellites not contained in such a list. - List of PRNs (satellite numbers with system identifier) Repeat record if necessary	2I6, I6, 7(3X,A1,I2)	
# / TYPES OF OBSERV	- Number of different observation types stored in the file - Observation types If more than 9 observation types: Use continuation line(s) The following observation types are defined in RINEX Version 2: L1, L2: Phase measurements on L1 and L2 C1 : Pseudorange using C/A-Code on L1 P1, P2: Pseudorange using P-Code on L1,L2 D1, D2: Doppler frequency on L1 and L2 T1, T2: Transit Integrated Doppler on 150 (T1) and 400 MHz (T2) 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 Transit : cycles The sequence of the types in this record has to correspond to the sequence of the observations in the observation records	I6, 9(4X,A2) 6X,9(4X,A2)	
*INTERVAL	Observation interval in seconds	I6	*
TIME OF FIRST OBS	- Time of first observation record	5I6,F12.6,	

	(4-digit-year, month,day,hour,min,sec)		
	- Time system: GPS (=GPS time system)	6X,A3	
	GLO (=UTC time system)		
	Compulsory in mixed GPS/GLONASS files		
	Defaults: GPS for pure GPS files		
	GLO for pure GLONASS files		
*|TIME OF LAST OBS	- Time of last observation record	5I6,F12.6,	*
	(4-digit-year, month,day,hour,min,sec)		
	- Time system: GPS (=GPS time system)	6X,A3	
	GLO (=UTC time system)		
	Compulsory in mixed GPS/GLONASS files		
	Defaults: GPS for pure GPS files		
	GLO for pure GLONASS files		
*|LEAP SECONDS	Number of leap seconds since 6-Jan-1980	I6	*
	Recommended for mixed GPS/GLONASS files		
*|# OF SATELLITES	Number of satellites, for which	I6	*
	observations are stored in the file		
*|PRN / # OF OBS	PRN (sat.number), number of observations	3X,A1,I2,9I6	*
	for each observation type indicated		
	in the "# / TYPES OF OBSERV" - record.		
	If more than 9 observation types:		
	Use continuation line(s)	6X,9I6	
	This record is (these records are)		
	repeated for each satellite present in		
	the data file		
|END OF HEADER	Last record in the header section.	60X	

Records marked with * are optional

TABLE A2
OBSERVATION DATA FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
EPOCH/SAT	- Epoch :	5I3,F11.7,
or	year (2 digits), month,day,hour,min,sec	
EVENT FLAG	- Epoch flag 0: OK	I3,
	1: power failure between	
	previous and current epoch	
	>1: Event flag	
	- Number of satellites in current epoch	I3,
	- List of PRNs (sat.numbers with system	12(A1,I2),
	identifier, see 5.1) in current epoch	
	- receiver clock offset (seconds, optional)	F12.9
	If more than 12 satellites: Use continuation	32X,
	line(s)	12(A1,I2)
	If EVENT FLAG record (epoch flag > 1):	
	- 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)	
	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)	
	- "Number of satellites" contains number of	
	records to follow (0 for event flags 2,5)	
OBSERVATIONS	- Observation | rep. within record for	m(F14.3,
	- LLI | each obs.type (same seq	I1,

	- Signal strength	as given in header)	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. 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. 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
NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION

	HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	RINEX VERSION / TYPE	- Format version (2) - File type ('N' for Navigation data)	I6,14X, 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
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)	5I3,
	month	
	day	
	hour	
	minute	
	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 (MSB only)	
	- TGD (seconds)	
	- IODC Issue of Data, Clock	
BROADCAST ORBIT - 7	- Transmission time of message	3X,4D19.12
	(sec of GPS week, derived e.g.	
	from Z-count in Hand Over Word (HOW)	
	- spare	
	- spare	
	- spare	

TABLE A5
METEOROLOCICAL DATA FILE - HEADER SECTION DESCRIPTION

HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT	
RINEX VERSION / TYPE	- Format version (2)	I6,14X,	
	- File type ('M' for Meteorological Data)	A1,39X	
PGM / RUN BY / DATE	- Name of program creating current file	A20,	
	- Name of agency creating current file	A20,	
	- Date of file creation	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	A20	*

	the associated Observation File)	
# / 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 (millimeters) (for WVR data) 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 with format (6X,9(4X,A2))	I6, 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

TABLE A6
METEOROLOGICAL DATA FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
EPOCH / MET	- Epoch in GPS time (not local time!) year (2 digits), month,day,hour,min,sec	6I3,
	- Met data in the same sequence as given in the header	mF7.1
	More than 8 met data types: Use continuation lines	4X,10F7.1,3X

TABLE A7
OBSERVATION DATA FILE - EXAMPLE

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

     2             OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
BLANK OR G = GPS,  R = GLONASS,  T = TRANSIT,  M = MIXED    COMMENT
XXRINEXO V9.9       AIUB               22-APR-93 12:43     PGM / RUN BY / DATE
EXAMPLE OF A MIXED RINEX FILE                              COMMENT
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
     4    P1    L1    L2    P2                              # / TYPES OF OBSERV
    18                                                       INTERVAL
  1990     3    24    13    10   36.000000                  TIME OF FIRST OBS
                                                           END OF HEADER
 90  3 24 13 10 36.0000000  0  3G12G 9G 6                            -.123456789
  23629347.915            .300 8         -.353    23629364.158
  20891534.648           -.120 9         -.358    20891541.292
  20607600.189           -.430 9          .394    20607605.848
 90  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
 90  3 24 13 10 54.0000000  0  5G12G 9G 6R21R22                      -.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
 90  3 24 13 11  0.0000000  2
                           4  1
           *** FROM NOW ON KINEMATIC DATA! ***                COMMENT
 90  3 24 13 11 48.0000000  0  4G16G12G 9G 6                         -.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
 90  3 24 13 12  6.0000000  0  4G16G12G 6G 9                         -.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
 90  3 24 13 13  1.2345678  5  0
                           4  1
        (AN EVENT FLAG WITH SIGNIFICANT EPOCH)                COMMENT
 90  3 24 13 14 12.0000000  0  4G16G12G 9G 6                         -.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
 90  3 24 13 14 12.0000000  6  2G16G 9
                123456789.0      -9876543.5
                        0.0            -0.5
                           4  2
          ---> CYCLE SLIPS THAT HAVE BEEN APPLIED TO          COMMENT
               THE OBSERVATIONS                               COMMENT
 90  3 24 13 14 48.0000000  0  4G16G12G 9G 6                         -.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
  20658519.895      267583.67817    208507.26234  20658525.869
                           4  4
         ***   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

NAVIGATION MESSAGE FILE - EXAMPLE

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

     2              N: GPS NAV DATA                         RINEX VERSION / TYPE
XXRINEXN V2.0       AIUB                12-SEP-90 15:22     PGM / RUN BY / DATE
EXAMPLE OF VERSION 2 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       39 DELTA-UTC: A0,A1,T,W
     6                                                      LEAP SECONDS
                                                            END OF HEADER
 6 90  8  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  .551000000000D+03  .000000000000D+00
     .000000000000D+00  .000000000000D+00  .000000000000D+00  .910000000000D+02
     .406800000000D+06
13 90  8  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  .551000000000D+03  .000000000000D+00
     .000000000000D+00  .000000000000D+00  .000000000000D+00  .389000000000D+03
     .410400000000D+06

----|---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              METEOROLOGICAL DATA                     RINEX VERSION / TYPE
XXRINEXM V9.9       AIUB                3-APR-96 00:10      PGM / RUN BY / DATE
EXAMPLE OF A MET DATA FILE                                  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 (2.01) - 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	 3I6, 3X,D19.12	*

	UTC(SU)	(-TauC)	
*|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 almanac number		I2,
	- Epoch of ephemerides	(UTC)	
	- year (2 digits)		5I3,
	- month		
	- day		
	- hour		
	- minute		
	- second		F5.1,
	- SV clock bias (sec)	(-TauN)	D19.12,
	- SV relative frequency bias	(+GammaN)	D19.12,
	- message frame time (sec of day UTC)		D19.12
BROADCAST ORBIT - 1	- Satellite position X (km)		3X,4D19.12
	- velocity X dot (km/sec)		
	- X acceleration (km/sec2)		
	- health (0=OK)	(Bn)	
BROADCAST ORBIT - 2	- Satellite position Y (km)		3X,4D19.12
	- velocity Y dot (km/sec)		
	- Y acceleration (km/sec2)		
	- frequency number (1-24)		
BROADCAST ORBIT - 3	- Satellite position Z (km)		3X,4D19.12
	- velocity Z dot (km/sec)		
	- Z acceleration (km/sec2)		
	- Age of oper. information (days)	(E)	

TABLE A12

GLONASS NAVIGATION MESSAGE FILE - EXAMPLE

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

     2.01           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              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                                                      INTERVAL
  1993     8    23    14    24   40.049000      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              OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
YYRINEXO V2.8.1 VM  AIUB                19-FEB-97 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                                                      INTERVAL
    11                                                      LEAP SECONDS
  1997     2     6    11    53    0.000000      GPS         TIME OF FIRST OBS
```

```
                                                            END OF HEADER
 97  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
 97  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|
```