# RINEX

# The Receiver Independent Exchange Format

## Version 3.00

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# 0. REVISION HISTORY

None so far.

# 1. THE PHILOSOPHY AND HISTORY OF RINEX

The first proposal for the ***Receiver Independent Exchange Format RINEX*** was developed by the Astronomical Institute of the University of Berne for the easy exchange of the GPS data to be collected during the first 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.

Up till now two major format versions have been developed and published:

- The original RINEX Version 1 presented at and accepted by the 5th International Geodetic Symposium on Satellite Positioning in Las Cruces, 1989. [Gurtner et al. 1989], [Evans 1989]
- RINEX Version 2 presented at and accepted by the Second International Symposium of Precise Positioning with the Global Positioning system in Ottawa, 1990, mainly adding the possibility to include tracking data from different satellite systems (Glonass, SBAS). [Gurtner and Mader 1990a, 1990b], [Gurtner 1994].

Several subversions of RINEX Version 2 have been defined:

- Version 2.10: Among other minor changes allowing for sampling rates other than integer seconds and including raw signal strengths as new observables. [Gurtner 2002]
- Version 2.11: Includes the definition of a two-character observation code for L2C pseudoranges and some modifications in the GEO NAV MESS files [Gurtner and Estey 2005]
- Version 2.20: Unofficial version used for the exchange of tracking data from spaceborne receivers within the IGS LEO pilot project [Gurtner and Estey 2002]

As spin-offs of this idea of a receiver-independent GPS exchange format other RINEX-like exchange file formats have been defined, mainly used by the International GNSS Service IGS:

- Exchange format for **satellite and receiver clock offsets** determined by processing data of a GNSS tracking network [Ray and Gurtner 1999]

- Exchange format for the complete **broadcast data of space-based augmentation systems** SBAS. [Suard et al. 2004]
- IONEX: Exchange format for **ionosphere models** determined by processing data of a GNSS tracking network [Schaer et al. 1998]
- ANTEX: Exchange format for **phase center variations** of geodetic GNSS antennae [Rothacher and Schmid 2005]

The upcoming European Navigation Satellite System Galileo and the enhanced GPS with new frequencies and observation types, especially the possibility to track frequencies on different channels, ask for a more flexible and more detailed definition of the observation codes.

To improve the handling of the data files in case of "mixed" files, i.e. files containing tracking data of more than one satellite system, each one with different observation types, the record structure of the data record has been modified significantly and, following several requests, the limitation to 80 characters length has been removed.

As the changes are quite significant, they lead to a new RINEX Version 3. The new version also includes the unofficial Version 2.20 definitions for space-borne receivers.

***The current RINEX definition version 3.00 keeps the format of the existing navigation and meteorological files as they were in version 2.10 (or 2.11, respectively). The Galileo navigation message file definition can only be done when the Galileo broadcast message contents is made available to the public. It is possible that adjustments to the GPS RINEX navigation message file will have to be performed to account for the GPS enhancements.***

## 2. GENERAL FORMAT DESCRIPTION

Currently the RINEX format consists of five ASCII file types:

1. Observation Data File
2. GPS Navigation Message File
3. Meteorological Data File
4. GLONASS Navigation Message File
5. SBAS[1] Geostationary Navigation Message File

The Galileo Navigation Message File will be defined as soon as the contents of the Galileo Navigation Message has been published.

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 or satellite system by indicating in the header the types of observations to be stored for this receiver and the satellite systems having been observed. 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. There is no maximum record length limitation for the observation records.

Each Observation file and each Meteorological Data file basically contain the data from one site and one session. Starting with Version 2 RINEX also allows to include observation data from more than one site

[1] SBAS: Satellite-Based Augmentation System

subsequently occupied by a roving receiver in rapid static or kinematic applications. Although Version 2 and higher allow to insert header records into the data field it is not recommended 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 have 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 was 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. BASIC DEFINITIONS

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

### 3.1 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. By default it is expressed in GPS time for GPS data files (i.e., not Universal Time). For Glonass files or mixed files the actual time system can be indicated in the Start Time header record.

### 3.2 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.

### 3.3 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.

Phase shifts between phases of the same frequency but tracked on a different carrier channel (I vs. Q, or A vs. B vs. C, Galileo, modernized GPS) are not corrected.

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 |

### 3.4 Doppler

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

### 3.5 Satellite numbers

Starting with RINEX Version 2 the former two-digit satellite numbers **nn** are preceded by a one-character system identifier **s**:

```
snn

||
|+--  nn:  PRN          (GPS, Galileo)
|          slot number (GLONASS)
|          PRN-100     (SBAS Geostationary)
|
+---   s:  satellite system identifier
           G : GPS
           R : GLONASS
           S : SBAS payload
           E : Galileo

SBAS: Satellite-Based Augmentation System
```

**Table 1:** Satellite numbers

The same satellite system identifiers are also used in all header records when appropriate.

## 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: SBAS payload navigation message file
|   |  | |          B: 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 (zero)
|   |               hourly files:
|   |               a =  1st hour: 00h-01h; b =  2nd hour: 01h-02h;
|   |                           . . .       x = 24th hour: 23h-24h
|   +-------  ddd:  day of the year of first record
+----------- ssss:  4-character station name designator
```

**Table 2:** Recommended filenames: General, daily, hourly files

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: 01h-02h;
|   |                         . . .        x = 24th hour: 23h-24h.
|   +--------- ddd: day of the year
+------------ ssss: 4-char station ID or ID for the LEO
                    receiver/antenna
```

**Table 3:** Recommended filenames: High-rate data files

When data transmission times or storage volumes are critical we recommend compressing the files prior to storage or transmission. IGS currently uses 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 compressed |
|---|---|---|---|---|
| Obs Files | .yy**O** | .yy**O.Z** | .yy**O_Z** | .yy**Y** |
| Obs Files (Hatanaka compressed) | .yy**D** | .yy**D.Z** | .yy**D_Z** | .yy**E** |
| GPS Nav Message Files | .yy**N** | .yy**N.Z** | .yy**N_Z** | .yy**X** |
| GLONASS Nav Message File | .yy**G** | .yy**G.Z** | .yy**G_Z** | .yy**V** |
| Galileo Nav Message File | .yy**L** | .yy**L.Z** | .yy**L_Z** | .yy**T** |
| GEO SBAS Nav Message Files | .yy**H** | .yy**H.Z** | .yy**H_Z** | .yy**U** |
| GEO SBAS Broadcast Files (sep. doc.) | .yy**B** | .yy**B.Z** | .yy**B_Z** | .yy**A** |
| Met Data Files | .yy**M** | .yy**M.Z** | .yy**M_Z** | .yy**W** |
| Clock Files (see sep.doc.) | .yy**C** | .yy**C.Z** | .yy**C_Z** | .yy**K** |

**Table 4:** Recommended filename extensions for compressed files

In order to additionally reduce the size of observation files Yuki Hatanaka developed a special compression scheme that takes advantage of the structure of the RINEX observation data by forming higher-order differences in time between observations of the same type and satellite. This compressed file is also an ASCII file that is subsequently compressed again using the above mentioned standard compression programs.

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

- ftp://terras.gsi.go.jp/software

- IGSMails 1525,1686,1726,1763,1785,4967,4969,4975

The file naming and compression recommendations are strictly speaking not part of the RINEX format definition. However, they significantly facilitate the exchange of RINEX data in large user communities like IGS.

# 5. RINEX VERSION 3 FEATURES

The following section contains features that have been introduced for RINEX Version 3:

## 5.1 Observation codes

The new signal structures for GPS and Galileo make it possible to generate code and phase observations based on one or a combination of several channels: Two-channel signals are composed of I and Q components, three-channel signals of A, B, and C components. Moreover a wideband tracking of a combined E5a + E5b frequency tracking is possible. In order to keep the observation codes short but still allow for a detailed characterization of the actual signal generation the length of the codes is increased from two (Version 1 and 2) to three by adding a signal generation attribute:

The observation code **`tna`** consists of three parts:

- **`t`** : observation type: **`C`** = pseudorange, **`L`** = carrier phase, **`D`** = doppler, **`S`** = signal strength)
- **`n`** : band / frequency: **`1`**, **`2`**,…,**`8`**
- **`a`** : attribute: tracking mode or channel, e.g., **`I`**, **`Q`**, etc

Examples:

- **`L1C:`** C/A code-derived L1 carrier phase (GPS, Glonass)
  Carrier phase on E2-L1-E1 derived from C channel (Galileo)
- **`C2L:`** L2C pseudorange derived from the L channel (GPS)

For Galileo the band/frequency number **`n`** does not necessarily agree with the official frequency numbers: **`n`** = 7 for E5b, **`n`** = 8 for E5a+b.

| System | Freq. Band | Frequency | Channel or Code | Observation Codes | | | |
|---|---|---|---|---|---|---|---|
| | | | | Pseudo Range | Carrier Phase | Doppler | Signal Strength |
| **GPS** | L1 | 1575.42 | C/A | C1C | L1C | D1C | S1C |
| | | | P | C1P | L1P | D1P | S1P |
| | | | Z-tracking and similar (AS on) | C1W | L1W | D1W | S1W |
| | | | Y | C1Y | L1Y | D1Y | S1Y |
| | | | M | C1M | L1M | D1M | S1M |
| | | | codeless | -- | L1N | D1N | S1N |
| | L2 | 1227.60 | C/A | C2C | L2C | D2C | S2C |
| | | | L1(C/A)+(P2-P1) (semi-codeless) | C2D | L2D | D2D | S2D |
| | | | L2C (M) | C2S | L2S | D2S | S2S |
| | | | L2C (L) | C2L | L2L | D2L | S2L |
| | | | L2C (M+L)[2] | C2X | L2X | D2X | S2X |

[2] **Example:** Trimble NetRS and Septentrio PolaRx2C track L2C on the combined code M+L, therefore attribute **X** has to be used for these observables.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | P | C2P | L2P | D2P | S2P |
| | | | Z-tracking and similar (AS on) | C2W | L2W | D2W | S2W |
| | | | Y | C2Y | L2Y | D2Y | S2Y |
| | | | M | C2M | L2M | D2M | S2M |
| | | | codeless | -- | L2N | D2N | S2N |
| | L5 | 1176.45 | I | C5I | L5I | D5I | S5I |
| | | | Q | C5Q | L5Q | D5Q | S5Q |
| | | | I+Q | C5X | L5X | D5X | S5X |
| **Glonass** | G1 | 1602+k*9/16 k=0…13 or -7...+6 | C/A | C1C | L1C | D1C | S1C |
| | | | P | C1P | L1P | D1P | S1P |
| | G2 | 1246+k*7/16 | C/A (Glonass M) | C2C | L2C | D2C | S2C |
| | | | P | C2P | L2P | D2P | S2P |
| **Galileo** | E2-L1-E1 | 1575.42 | A PRS | C1A | L1A | D1A | S1A |
| | | | B OS/CS/SoL | C1B | L1B | D1B | S1B |
| | | | C no data | C1C | L1C | D1C | S1C |
| | | | B+C | C1X | L1X | D1X | S1X |
| | | | A+B+C | C1Z | L1Z | D1Z | S1Z |
| | E5a | 1176.45 | I OS | C5I | L5I | D5I | S5I |
| | | | Q no data | C5Q | L5Q | D5Q | S5Q |
| | | | I+Q | C5X | L5X | D5X | S5X |
| | E5b | 1207.140 | I OS/CS/SoL | C7I | L7I | D7I | S7I |
| | | | Q no data | C7Q | L7Q | D7Q | S7Q |
| | | | I+Q | C7X | L7X | D7X | S7X |
| | E5a+b (AltBOC) | 1191.795 | I | C8I | L8I | D8I | S8I |
| | | | Q | C8Q | L8Q | D8Q | S8Q |
| | | | I+Q | C8X | L8X | D8X | S8X |
| | E6 | 1278.75 | A PRS | C6A | L6A | D6A | S6A |
| | | | B CS | C6B | L6B | D6B | S6B |
| | | | C no data | C6C | L6C | D6C | S6C |
| | | | B+C | C6X | L6X | D6X | S6X |
| | | | A+B+C | C6Z | L6Z | D6Z | S6Z |
| **SBAS** | L1 | 1575.42 | C/A | C1C | L1C | D1C | S1C |
| | L5 | 1176.45 | I | C5I | L5I | D5I | S5I |
| | | | Q | C5Q | L5Q | D5Q | S5Q |
| | | | I+Q | C5X | L5X | D5X | S5X |

**Table 5:** RINEX Version 3 observation codes

**Antispoofing (AS) of GPS:** True codeless GPS receivers (squaring-type receivers) use the attribute N. Semi-codeless receivers tracking the first frequency using C/A code and the second receiver using some codeless options use attribute **N**. Z-tracking under AS or similar techniques to recover pseudorange and phase on the "P-code" band use attribute **W**. Y-code tracking receivers use attribute **Y**.

*As all observations affected by "AS on" get now their own attribute (codeless, semi-codeless, Z-tracking and similar) the Antispoofing flag introduced into the observation data records of RINEX Version 2 has become obsolete.*

**Unknown tracking mode:** In case of unknown tracking mode or channel the attribute **a** can be left blank. However, a mixture of blank and non-blank attributes within the same observation type of the same frequency band and of the same satellite system has to be avoided: **L2S** and **L2** is not allowed, **L2S** and **C2** is OK.

## 5.2 Satellite system-dependent list of observables

The order of the observations stored per epoch and satellite in the observation records is given by a list of observation codes in a header record. As the types of the observations actually generated by a receiver may heavily depend on the satellite system RINEX Version 3 requests system-dependent observation code list (header record type **SYS / # / OBS TYPES**).

## 5.3 Marker type

In order to indicate the nature of the marker a **MARKER TYPE** header record has been defined:

| | |
|---|---|
| **GEODETIC** | Earth-fixed, high-precision monumentation |
| **NON_GEODETIC** | Earth-fixed, low-precision monumentation |
| **SPACEBORNE** | Orbiting space vehicle |
| **AIRBORNE** | Aircraft, balloon, etc. |
| **WATER_CRAFT** | Mobile water craft |
| **GROUND_CRAFT** | Mobile terrestrial vehicle |
| **FIXED_BUOY** | "Fixed" on water surface |
| **FLOATING_BUOY** | Floating on water surface |
| **FLOATING_ICE** | Floating ice sheet, etc. |
| **GLACIER** | "Fixed" on a glacier |
| **BALLISTIC** | Rockets, shells, etc |
| **ANIMAL** | Animal carrying a receiver |
| **HUMAN** | Human being |

**Table 6:** Proposed marker type keywords

The record is required except for **GEODETIC** and **NON_GEODETIC** marker types.

Attributes other than **GEODETIC** and **NON_GEODETIC** will tell the user program that the data were collected by a moving receiver. The inclusion of a "start moving antenna" record (event flag 2) into the data body of the RINEX file is therefore not necessary. Event flags 2 and 3 are still necessary to flag alternating kinematic and static phases of a receiver visiting multiple earth-fixed monuments, however.

Users may define other project-dependent keywords

## 5.4 Half-wavelength observations

Half-wavelength observations (collected by **codeless** squaring techniques) get their own observation codes. A special wavelength factor header line and bit 1 of the LLI flag in the observation records are not necessary anymore. If a receiver changed between squaring and full cycle tracking within the time period of a RINEX file, observation codes for both types of observations have to be inserted into the respective **SYS / # / OBS TYPES** header record.

Half-wavelength phase observations are stored in full cycles. Ambiguity resolution however has to account for half wavelengths!.

## 5.5 Scale factor

The *optional* **SYS / SCALE FACTOR** record allows e.g., to store phase data with 0.0001 cycles resolution if the data was multiplied by a scale factor of 10 before being stored into RINEX file. Used to increase resolution by 10, 100, etc only. It is a modification of the Version 2.20 **OBS SCALE FACTOR** record.

## 5.6 Information about receivers on a vehicle

For the processing of data collected by receivers on a vehicle the following additional information can be provided by special header records:

- Antenna position (position of the antenna reference point) in a body-fixed coordinate system: **ANTENNA: DELTA X/Y/Z**
- Bore-sight of antenna: The unit vector of the direction of the antenna axis towards the GNSS satellites. It corresponds to the vertical axis on earth-bound antenna: **ANTENNA: B.SIGHT XYZ**
- Antenna orientation: Zero-direction of the antenna. Used for the application of "azimuth"-dependent phase center variation models (see 6.14 below). **ANTENNA: ZERODIR XYZ**
- Current center of mass of the vehicle (for spaceborne receivers): **CENTER OF MASS: XYZ**
- Average phase center position: **ANTENNA: PHASECENTER (**see below)

All three quantities have to be given in the same body-fixed coordinate system. The attitude of the vehicle has to be provided by separate attitude files in the same body-fixed coordinate system.

## 5.7 Signal strengths

The generation of the RINEX signal strength indicators sn_rnx in the data records (1 = very weak,…,9 = very strong) are standardized in case the raw signal strength[3] sn_raw is given in **dbHz**:

**sn_rnx = MIN(MAX(INT(sn_raw/6),1),9)**

| S/N (dbHz) | S/N (RINEX) |
|---|---|
| <12 | 1 |
| 12-17 | 2 |
| 18-23 | 3 |
| 24-29 | 4 |
| 30-35 | 5 |
| 36-41 | 6 |
| 42-47 | 7 |
| 48-53 | 8 |
| ≥54 | 9 |

**Table 7**: Standardized S/N indicators

The raw signal strengths optionally stored as **Sna** observations in the data records should be stored in dbHz if possible. The new **SIGNAL STRENGTH UNIT** header record can be used to indicate the units of these observations.

## 5.8 Date/time format in the PGM / RUN BY / DATE header record

The format of the generation time of the RINEX files stored in the second header record **PGM / RUN BY / DATE** is now defined to be

**yyyymmdd hhmmss zone**

**zone:** 3 – 4 character code for the time zone

It is recommended to use **UTC** as time zone. Set **zone** to **LCL** if local time was used with unknown local time system code.

[3] S/N is the raw S/N at the output of the correlators, without attempting to recover any correlation losses

## 5.9 Antenna phase center header record

An *optional* header record for antenna phase center positions **ANTENNA: PHASECENTER** is defined to allow for higher precision positioning without need of additional external antenna information. It can be useful in well-defined networks or applications. It contains the position of an *average* phase center relative to the antenna reference point for a specific frequency and satellite system. On vehicles the phase center position can be reported in the body-fixed coordinate system. See 6.14 below.

## 5.10 Antenna orientation

Header records have been defined to report the orientation of the antenna zero-direction as well as the direction of its vertical axis (bore-sight) if mounted tilted on a fixed station. The header records can also be used for antennas on vehicles. See 6.14 below.

## 5.11 Observation data records

Apart from the new observation code definitions the most conspicuous modification of the RINEX format concerns the observation records. As the types of the observations and their order within a data record are depending on the satellite system a new format should make it easier for programs as well as human beings to read the data records. Each observation record begins with the satellite number **snn**, the epoch record starts with special character **>**. It is now also much easier to synchronize the reading program with the next epoch record in case of a corrupted data file or when streaming observation data in a RINEX-like format.

For the following list of observation types for the four satellite systems **G,S,E,R**

```
G    5 C1P L1P L2C C2C S2C                                  SYS / # / OBS TYPES
R    2 C1C L1C                                              SYS / # / OBS TYPES
E    2 L1B L5I                                              SYS / # / OBS TYPES
S    2 C1C L1C                                              SYS / # / OBS TYPES
```

**Table 8:** Example for a list of observation types

the epoch and observation records look as follows:

```
> 2006 03 24 13 10 54.0000000  0  7      -0.123456789210
G06  23619095.450      -53875.632 8    -41981.375 5  23619112.008          24.158
G09  20886075.667      -28688.027 9    -22354.535 6  20886082.101          38.543
G12  20611072.689       18247.789 9     14219.770 8  20611078.410          32.326
R21  21345678.576       12345.567 5
R22  22123456.789       23456.789 5
E11     65432.123 5     48861.586 7
S20  38137559.506      335849.135 9
```

**Table 9:** Example for observation data records

The receiver clock correction in the epoch record has been placed such that it could be preceded by an identifier to make it system-dependent in a later format revision, if necessary.

## 5.12 Ionosphere delay as pseudo-observables

RINEX files could also be used to make available additional information linked to the actual observations. One such element is the ionosphere delay having been determined or derived from a ionosphere model.
We add the ionosphere phase delay expressed in full cycles of the respective satellite system-dependent wavelength as pseudo-observable to the list of the RINEX observables.

- **t** : observation type: **I** = Ionosphere phase delay

- **n** : band / frequency: **1**, **2**,…,**8**
- **a** : attribute: blank

The ionosphere pseudo-observable has to be included into the list of observables of the respective satellite system. Only one ionosphere observable per satellite has to be included.

The user adds the ionosphere delay to the raw phase observation of the same wavelength and converts it to other wavelengths and to pseudorange corrections in meters:

$$corr\_phase(f_i) = raw\_phase(f_i) + d\_ion(f_i)$$
$$corr\_prange(f_i) = raw\_prange(f_i) - d\_ion(f_i) \cdot c/f_i$$
$$d\_ion(f_k) = d\_ion(f_i) \cdot (f_i/f_k)^2 \quad \text{(accounting for 1st order effects only)}$$

$d\_ion(f_i)$: Given ionospheric phase correction for frequency $f_i$

### 5.13 Channel numbers as pseudo-observables

For special applications it might be necessary to know the receiver channel numbers having been assigned by the receiver to the individual satellites. We may include this information as another pseudo-observable:

- **t** : observation type: **X** = Receiver channel number
- **n** : band / frequency : **0**
- **a** : attribute: blank

Lowest channel number allowed is 1 (re-number channels beforehand, if necessary). In case of a receiver using multiple channels for one satellite the channels could be packed with two digits each right-justified into the same data field, order corresponding to the order of the observables concerned. Format `F14.3` according to `(<5-nc>(2X),<nc>I2.2,'.000')`, `nc` being the number of channels.

*Restriction:* Not more than 5 channels and channel numbers <100.

*Examples:*

```
     0910.000     for channels 9 and 10
   010203.000     for channels 1, 2, and 3
-----F14.3----
```

### 5.14 Corrections of differential code biases (DCBs)

For high-precision applications there are programs available to correct the observations in RINEX files for differential code biases (e.g., **cc2noncc**, J. Ray 2005). We introduce a header record **SYS / DCBS APPLIED** to flag files with corrected observations.

## 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 reading files automatically delete leading blanks in any CHARACTER input field. Routines creating RINEX files should also left-justify all variables in the CHARACTER fields.

## 6.3 Variable-length records

ASCII files usually have variable record lengths, so we recommend to first read each observation record into a blank string long enough to accommodate the larges possible observation record 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

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 Order of the header records, order of data records

As the record descriptors in columns 61-80 are mandatory, the programs reading a RINEX Version 3 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 **`SYS / # / OBS TYPES`** record(s) should precede any **`SYS / DCBS APPLIED`** and **`SYS / SCALE FACTOR`** records.
- 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.
- The **`END OF HEADER`** of course is the last header in the record

## 6.6 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.

## 6.7 Unknown / Undefined observation types and header records

It is a good practice for a program reading RINEX files to make sure that it properly deals with unknown observation types, header records or event flags by skipping them and/or reporting them to the user. The program should also check the RINEX version number in the header record and take proper action if it cannot deal with it.

## 6.8 Event flag records

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

## 6.9 Receiver clock offset

A receiver-derived clock offset can optionally be reported in the RINEX observation files. In order to remove uncertainties if the data (epoch, pseudorange, phase) have been previously corrected or not by the reported clock offset, RINEX Versions 2.10 onwards requests a clarifying header record: **`RCV CLOCK OFFS APPL`**. 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 were used to correct the observables in order to guarantee correct reconstruction.

## 6.10 Two-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 are/will be defined in the RINEX version 3 files.

## 6.11 Fit interval (GPS navigation message file)

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.

## 6.12 Satellite health (GPS navigation message file)

The health of the signal components (bits 18 to 22 of word three in subframe one) are included from version 2.10 on 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) |

## 6.13 Transmission time of message (GPS 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.

### 6.14 Antenna references

We distinguish between

- The ***marker***, i.e. the geodetic reference monument, on which an antenna is mounted directly with forced centering or on a tripod.

- The ***antenna reference point*** (ARP), i.e., a well-defined point on the antenna, e.g., the center of the bottom surface of the preamplifier. The antenna height is measured from the marker to the ARP and reported in the **ANTENNA: DELTA H/E/N** header record. Small horizontal eccentricities of the ARP w/r to the marker can be reported in the same record. On vehicles the position of the ARP is reported in the body-fixed coordinate system in an **ANTENNA: DELTA X/Y/Z** header record.

- The ***average phase center***: A frequency- and minimum elevation-dependent position of the average phase center above the antenna reference point. It's position is important to know in mixed-antennae networks. It can be given in an absolute sense or relative to a reference antenna. Optional header record: **ANTENNA: PHASECENTER**. For fixed stations the components are in north/east/up direction, on vehicles the position is reported in the body-fixed system X,Y,Z.

  For more precise applications an elevation- or elevation and azimuth-dependent phase center variation model for the antenna (referring to the agreed-upon ARP) should be used.

- The ***orientation*** of the antenna: The "zero direction" is usually oriented towards north on fixed stations. Deviations from the north direction can be reported with the azimuth of the zero-direction in an **ANTENNA: ZERODIR AZI** header record. On vehicles the zero-direction is reported as a unit vector in the body-fixed coordinate system in an **ANTENNA: ZERODIR XYZ** header record. The zero direction of a tilted antenna on a fixed station can be reported as unit vector in the left-handed north/east/up local coordinate system in an **ANTENNA: ZERODIR XYZ** header record.

- The ***bore-sight direction*** of an antenna on a vehicle: The "vertical" symmetry axis of the antenna pointing towards the GNSS satellites. It can be reported as unit vector in the body-fixed coordinated system in the **ANTENNA: B.SIGHT XYZ** record. A tilted antenna on a fixed station could be reported as unit vector in the left-handed north/east/up local coordinate system in the same header record.

To be able to interpret the various positions correctly it is important that the **MARKER TYPE** record is included in the RINEX header.

## 7. RINEX UNDER ANTISPOOFING (AS)

Some receivers generate code (pseudorange) 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 post-processing programs to take special actions, such AS-infected observations have been flagged in RINEX Version 2 using bit number 2 of the Loss of Lock Indicators (i.e. their current values are increased by 4). In Version 3 there are special attributes for the observation type to more precisely characterize the observable (codeless, semi-codeless, Z-tracking or similar techniques when AS on, L2C, P-code when AS off, Y-code tracking), making the AS flag obsolete.

# 8. DEALING WITH DIFFERENT SATELLITE SYSTEMS

## 8.1 RINEX observation files

### 8.1.1 Time system identifier

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. Galileo runs on Galileo System Time, which is, apart from small differences < 50ns, identical to TAI (International Atomic Time).

In order to remove possible misunderstandings and ambiguities, the header records **`TIME OF FIRST OBS`** and (if present) **`TIME OF LAST OBS`** in pure GPS, GLONASS or Galileo observation files **can**, in mixed GPS/GLONASS/Galileo 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
- **`GAL`** to identify Galileo system time.

Pure GPS files default to **`GPS`**, pure GLONASS files default to **`GLO`**, pure Galileo files default to **`GAL.`**

Format definitions see Table A1.

Apart from the small errors in the realizations of the different time systems, the relations between the systems are:

$$GLO = UTC = GPS - \Delta t_{LS}$$
$$GAL = TAI = GPS + 19$$
$$GAL = TAI = UTC + \Delta t_{LS} + 19 = UTC + n_{leap}$$
$$n_{leap} = \Delta t_{LS} + 19$$

$\Delta t_{LS:}$ Delta time between GPS and UTC due to leap seconds, as transmitted by the GPS satellites in the almanac

$n_{leap}$: Number of leap seconds introduced between UTC and TAI (2005: $n_{leap}$ =32, 2006: $n_{leap}$ =33)

In order to have the current number of leap seconds available we recommend to include $\Delta t_{LS}$ by a **`LEAP SECOND`** line into the RINEX file headers.

If there are known non-integer biases between "GPS receiver clock", "GLONASS receiver clock" or “Galileo receiver clock” in the same receiver, they should be applied in the process of RINEX conversion. 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 Galileo system time, TAI, 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/Galileo 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

- the raw Galileo pseudoranges will show an offset of – 19 seconds if the receiver clock is running in the GPS rime frame

- etc.

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 * $\Delta t_{LS}$ | if generated with a receiver clock running in the GLONASS time frame |
| PR(GLO) := PR(GLO) - c * $\Delta t_{LS}$ | if generated with a receiver clock running in the GPS time frame |
| PR(GAL) := PR(GAL) + 19 s | if generated with a receiver clock running in the GPS time frame |
| etc. | |

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

$\Delta t_{LS}$ 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.

## 8.2 RINEX navigation message 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 - ... - $\Delta t_{LS}$
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<br>-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.

## 8.3 RINEX navigation message files for Galileo

Currently the format and the contents of the Galileo broadcast navigation message are unknown. A Galileo RINEX navigation file definition will follow later.

## 8.4 RINEX observation files for GEO satellites

A separate satellite system identifier has been defined for the Space-Based Augmentation System (SBAS) 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 SBAS 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.

## 8.5 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 navigation message file format.

The header section contains information 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 - $\Delta t_{LS}$

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.

*Issue Of Data Navigation* (IODN)

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.

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Document RTCA DO 229, Appendix A

# APPENDIX: RINEX FORMAT DEFINITIONS AND EXAMPLES

## A 1 GNSS Observation Data File - Header Section Description

**TABLE A1**
**GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION**

| **HEADER LABEL** (Columns 61-80) | **DESCRIPTION** | **FORMAT** |
|---|---|---|
| **RINEX VERSION / TYPE** | - Format version : **3.00**<br>- File type: **O** for Observation Data<br>- Satellite System: **G**: GPS<br>**R**: GLONASS<br>**E**: Galileo<br>**S**: SBAS payload<br>**M**: Mixed | F9.2,11X,<br>A1,19X,<br>A1,19X |
| **PGM / RUN BY / DATE** | - Name of program creating current file<br>- Name of agency creating current file<br>- Date and time of file creation<br>Format: yyyymmdd hhmmss zone<br>zone: 3-4 char. code for time zone.<br>**UTC** recommended!<br>**LCL** if local time with unknown local time system code | A20,<br>A20,<br><br>A20 |
| * **COMMENT** | Comment line(s) | A60 * |
| **MARKER NAME** | Name of antenna marker | A60 |
| * **MARKER NUMBER** | Number of antenna marker | A20 * |
| **MARKER TYPE** | - Type of the marker.<br><br>**GEODETIC** : Earth-fixed, high-precision monumentation<br>**NON_GEODETIC** : Earth-fixed, low-precision monumentation<br>**SPACEBORNE** : Orbiting space vehicle<br>**AIRBORNE** : Aircraft, balloon, etc.<br>**WATER_CRAFT** : Mobile water craft<br>**GROUND_CRAFT** : Mobile terrestrial vehicle<br>**FIXED_BUOY** : "Fixed" on water surface<br>**FLOATING_BUOY**: Floating on water surface<br>**FLOATING_ICE** : Floating ice sheet, etc.<br>**GLACIER** : "Fixed" on a glacier<br>**BALLISTIC** : Rockets, shells, etc<br>**ANIMAL** : Animal carrying a receiver<br>**HUMAN** : Human being<br><br>Record required except for **GEODETIC** and **NON_GEODETIC** marker types.<br><br>Users may define other project-dependent keywords. | A20,40X |
| **OBSERVER / AGENCY** | Name of observer / agency | A20,A40 |
| **REC # / TYPE / VERS** | Receiver number, type, and version<br>(Version: e.g. Internal Software Version) | 3A20 |
| **ANT # / TYPE** | Antenna number and type | 2A20 |
| **APPROX POSITION XYZ** | Geocentric approximate marker position<br>(Units: Meters, System: ITRS recommended)<br>Optional for moving platforms | 3F14.4 |

| | | | | |
|---|---|---|---|---|
| | **ANTENNA: DELTA H/E/N** | - Antenna height: Height of the antenna<br>reference point (ARP) above the marker<br>- Horizontal eccentricity of ARP<br>relative to the marker (east/north)<br>All units in meters | F14.4,<br><br>2F14.4 | |
| * | **ANTENNA: DELTA X/Y/Z** | Position of antenna reference point for<br>antenna on vehicle (m):<br>XYZ vector in body-fixed coord. system | 3F14.4 | * |
| * | **ANTENNA: PHASECENTER** | Average phase center position w/r to<br>antenna reference point (m)<br>- Satellite system (**G**/**R**/**E**/**S**)<br>- Observation code<br>- North/East/Up (fixed station) or<br>X/Y/Z in body-fixed system (vehicle) | <br><br>A1,<br>1X,A3,<br>F9.4,<br>2F14.4 | * |
| * | **ANTENNA: B.SIGHT XYZ** | Direction of the “vertical” antenna axis<br>towards the GNSS satellites.<br>Antenna on vehicle:<br>Unit vector in body-fixed coord. system<br>Tilted antenna on fixed station:<br>Unit vector in N/E/Up left-handed system | 3F14.4 | * |
| * | **ANTENNA: ZERODIR AZI** | Azimuth of the zero-direction of a<br>fixed antenna (degrees, from north) | F14.4 | * |
| * | **ANTENNA: ZERODIR XYZ** | Zero-direction of antenna<br>Antenna on vehicle:<br>Unit vector in body-fixed coord. system<br>Tilted antenna on fixed station:<br>Unit vector in N/E/Up left-handed system | 3F14.4 | * |
| * | **CENTER OF MASS: XYZ** | Current center of mass (X,Y,Z, meters) of<br>vehicle in body-fixed coordinate system.<br>Same system as used for attitude. | 3F14.4 | * |
| | **SYS / # / OBS TYPES** | - Satellite system code (**G**/**R**/**E**/**S**)<br>- Number of different observation types<br>for the specified satellite system<br>- Observation descriptors:<br>- Type<br>- Band<br>- Attribute<br><br>Use continuation line(s) for more than<br>13 observation descriptors.<br><br>In mixed files: Repeat for each<br>satellite system.<br><br>These records should precede any<br>**SYS / DCBS APPLIED** or<br>**SYS / SCALE FACTOR** records (see below).<br><br>The following observation descriptors<br>are defined in RINEX Version 3.00:<br><br>Type: **C** = Code / Pseudorange<br>**L** = Phase<br>**D** = Doppler<br>**S** = Raw signal strength<br>**I** = Ionosphere phase delay<br>**X** = Receiver channel numbers<br>Band: **1** = L1 (GPS,SBAS)<br>G1 (GLO)<br>E2-L1-E1 (GAL)<br>**2** = L2 (GPS)<br>G2 (GLO)<br>**5** = L5 (GPS,SBAS)<br>E5a (GAL) | A1,<br>2X,I3,<br><br>13(1X,A3)<br><br><br><br><br>6X,<br>13(1X,A3) | |

```
 |                    |       6 = E6                     (GAL) |            |
 |                    |       7 = E5b                    (GAL) |            |
 |                    |       8 = E5a+b                  (GAL) |            |
 |                    |       0   for type X             (all) |            |
 |                    | Attribute:                             |            |
 |                    |       P = P code-based       (GPS,GLO) |            |
 |                    |       C = C code-based  (SBAS,GPS,GLO) |            |
 |                    |       Y = Y code-based           (GPS) |            |
 |                    |       M = M code-based           (GPS) |            |
 |                    |       A = A channel              (GAL) |            |
 |                    |       B = B channel              (GAL) |            |
 |                    |       C = C channel              (GAL) |            |
 |                    |       I = I channel          (GPS,GAL) |            |
 |                    |       Q = Q channel          (GPS,GAL) |            |
 |                    |       S = M channel        (L2C GPS)   |            |
 |                    |       L = L channel        (L2C GPS)   |            |
 |                    |       X = B+C channels           (GAL) |            |
 |                    |           I+Q channels       (GPS,GAL) |            |
 |                    |           M+L channels       (GPS)     |            |
 |                    |       W = based on Z-tracking  (GPS)   |            |
 |                    |           (see text)                   |            |
 |                    |       Z = A+B+C channels         (GAL) |            |
 |                    |   blank : for types I and X      (all) |            |
 |                    |           or unknown tracking mode     |            |
 |                    |                                        |            |
 |                    | All characters in uppercase only!      |            |
 |                    |                                        |            |
 |                    | Units : Phase       : full cycles      |            |
 |                    |         Pseudorange : meters           |            |
 |                    |         Doppler     : Hz               |            |
 |                    |         SNR etc     : receiver-dependent |          |
.|                    |         Ionosphere  : full cycles      |            |
 |                    |         Channel #   : See text         |            |
 |                    |                                        |            |
 |                    | Sign definition: See text.             |            |
 |                    |                                        |            |
 |                    | The sequence of the observations in the |           |
 |                    | observation records has to correspond to |          |
 |                    | the sequence of the types in this record |          |
 |                    | of the respective satellite system.    |            |
 |                    |                                        |            |
 |                    | The attribute can be left blank if not |            |
 |                    | known. See text!                       |            |
 +--------------------+----------------------------------------+------------+
*|SIGNAL STRENGTH UNIT| - Unit of the signal strength          |  A20,40X   |*
 |                    |   observables Snn (if present)         |            |
 |                    |                                        |            |
 |                    |     DBHZ : S/N given in dbHz           |            |
 |                    |      ...                               |            |
 +--------------------+----------------------------------------+------------+
*|INTERVAL            | Observation interval in seconds        |  F10.3     |*
 +--------------------+----------------------------------------+------------+
 |TIME OF FIRST OBS   | - Time of first observation record     | 5I6,F13.7, |
 |                    |   (4-digit-year, month,day,hour,min,sec) |          |
 |                    | - Time system: GPS (=GPS time system)  |  5X,A3     |
 |                    |                GLO (=UTC time system)  |            |
 |                    |                GAL (=Galileo System Time)|          |
 |                    |   Compulsory in mixed GNSS 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     | 5I6,F13.7, |*
 |                    |   (4-digit-year, month,day,hour,min,sec) |          |
 |                    | - Time system: Same value as in        |  5X,A3     |
 |                    |                TIME OF FIRST OBS record |           |
 +--------------------+----------------------------------------+------------+
*|RCV CLOCK OFFS APPL | Epoch, code, and phase are corrected by |    I6     |*
 |                    | applying the realtime-derived receiver |            |
 |                    | clock offset: 1=yes, 0=no; default: 0=no |          |
 |                    | Record required if clock offsets are   |            |
```

```
 |                    | reported in the EPOCH/SAT records        |            |
 +--------------------+------------------------------------------+------------+
*|SYS / DCBS APPLIED  | - Satellite system (G/R/E/S)             |    A1,     |*
 |                    | - Observ. code of affected observable    |    A3,     |
 |                    | - Satellite system (G/R/E/S) and         | 1X,A1,     |
 |                    | - Observ. code of reference observable   |    A3,     |
 |                    | - Correction to pseudorange (m)          |   F8.3,    |
 |                    | - Corrections applied: 1 = yes, 0 = no   |  1X,I1,    |
 |                    | - Source of corrections                  | 1X,A20,    |
 |                    | - Program name used to apply corrections |    A20     |
 |                    |                                          |            |
 |                    | Repeat for each observable if necessary. |            |
 +--------------------+------------------------------------------+------------+
*|LEAP SECONDS        | Number of leap seconds since 6-Jan-1980  |    I6      |*
 |                    | as transmitted by the GPS almanac.       |            |
 |                    | Recommended for mixed GLONASS files      |            |
 +--------------------+------------------------------------------+------------+
*|# OF SATELLITES     | Number of satellites, for which          |    I6      |*
 |                    | observations are stored in the file      |            |
 +--------------------+------------------------------------------+------------+
*|SYS / SCALE FACTOR  | - Satellite system (G/R/E/S)             |    A1,     |*
 |                    | - Factor to divide stored observations   |  1X,I4,    |
 |                    |   with before use (1,10,100,1000)        |            |
 |                    | - Number of observation types involved.  |  2X,I2,    |
 |                    |   0 or blank: All observation types      |            |
 |                    | - List of observation types              | 12(1X,A3)  |
 |                    |                                          |            |
 |                    | Use continuation line(s) for more than   |  10X,      |
 |                    | 12 observation types.                    | 12(1X,A3)  |
 |                    |                                          |            |
 |                    | Repeat record if different factors are   |            |
 |                    | applied to different observation types.  |            |
 |                    |                                          |            |
 |                    | A value of 1 is assumed if record is     |            |
 |                    | missing.                                 |            |
 +--------------------+------------------------------------------+------------+
*|PRN / # OF OBS      | Satellite numbers, number of observations|    3X,     |*
 |                    | for each observation type indicated      | A1,I2.2,   |
 |                    | in the SYS / # / OBS TYPES record.       |    9I6     |
 |                    |                                          |            |
 |                    |   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

## A 2 GNSS Observation Data File - Data Record Description

```
 +----------------------------------------------------------------------------+
 |                                 TABLE A2                                   |
 |             GNSS OBSERVATION DATA FILE - DATA RECORD DESCRIPTION           |
 +---------------------------------------------------------------+------------+
 | DESCRIPTION                                                   |   FORMAT   |
 +---------------------------------------------------------------+------------+
 |                                                               |            |
 | EPOCH record                                                  |            |
 |                                                               |            |
 | - Record identifier : >                                       |    A1,     |
 | - Epoch :                                                     |            |
 |   - year (4 digits)                                           |  1X,I4,    |
 |   - month,day,hour,min (two digits)                           | 4(1X,I2.2),|
 |   - sec                                                       |  F11.7,    |
 | - Epoch flag                                                  |  2X,I1,    |
 |          0: OK                                                |            |
```

```
|          1: power failure between previous and current epoch  |            |
|         >1: Special event                                      |            |
| - Number of satellites observed in current epoch               |     I3,    |
|   (reserved)                                                   |     6X,    |
| - Receiver clock offset (seconds, optional)                    | 6X,F15.12, |
|   (reserved)                                                   |     3X     |
+----------------------------------------------------------------+------------+
|                                                                |            |
| Epoch flag = 0 or 1: OBSERVATION records follow                |            |
|                                                                |            |
| - Satellite number                                             |  A1,I2.2,  |
|                                                                |            |
| - Observation      | repeat within record for each observation|  m(F14.3,  |
| - LLI              | type (same sequence as given in the       |     I1,    |
| - Signal strength  | respective SYS / # / OBS TYPES record)    |     I1)    |
|                                                                |            |
| This record is repeated for each satellite having been         |            |
| observed in the current epoch. The record length is given by   |            |
| number of observation types for this satellite.                |            |
|                                                                |            |
| Observations: Definition see text.                             |            |
| 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).                                  |            |
|  0 or blank: OK or not known                                   |            |
|  Bit 0 set : Lost lock between previous and current            |            |
|              observation: Cycle slip possible.                 |            |
|              For phase observations only.                      |            |
|                                                                |            |
| Signal strength projected into interval 1-9:                   |            |
|  1: minimum possible signal strength                           |            |
|  5: average S/N ratio                                          |            |
|  9: maximum possible signal strength                           |            |
|  0 or blank: not known, don't care                             |            |
|  Standardization for S/N values given in dbHz: See text.       |            |
|                                                                |            |
+----------------------------------------------------------------+------------+
|                                                                |            |
| Epoch flag  2-5: EVENT: Special records may follow             |            |
|                                                                |            |
|   - Epoch flag                                                 |  [2X,I1]   |
|     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)               |            |
|                                                                |            |
|   - "Number of satellites" contains number of special records  |    [I3]    |
|      to follow. 0 if  no special records follow.               |            |
|     Maximum number of records: 999                             |            |
|                                                                |            |
|   For events without significant epoch the epoch fields in     |            |
|   the EPOCH RECORD can be left blank                           |            |
+----------------------------------------------------------------+------------+
|                                                                |            |
| Epoch flag = 6: EVENT: Cycle slip records follow               |            |
|                                                                |            |
|   - Epoch flag                                                 |  [2X,I1]   |
|     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)                |            |
+----------------------------------------------------------------+------------+
```

# A 3 GNSS Observation Data File - Example

```
+------------------------------------------------------------------------------+
|                                   TABLE A3                                   |
|                     GNSS OBSERVATION DATA FILE - EXAMPLE                     |
+------------------------------------------------------------------------------+

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

     3.00           OBSERVATION DATA    M                   RINEX VERSION / TYPE
G = GPS  R = GLONASS  E = GALILEO  S = GEO  M = MIXED       COMMENT
XXRINEXO V9.9       AIUB                20010324 144333 UTC PGM / RUN BY / DATE
EXAMPLE OF A MIXED RINEX FILE VERSIOIN 3.00                 COMMENT
The file contains L1 pseudorange and phase data of the      COMMENT
geostationary AOR-E satellite (PRN 120 = S20)               COMMENT
A 9080                                                      MARKER NAME
9080.1.34                                                   MARKER NUMBER
BILL SMITH          ABC INSTITUTE                           OBSERVER / AGENCY
X1234A123           GEODETIC            1.3.1               REC # / TYPE / VERS
G1234               ROVER                                   ANT # / TYPE
  4375274.       587466.      4589095.                      APPROX POSITION XYZ
         .9030         .0000         .0000                  ANTENNA: DELTA H/E/N
     0                                                      RCV CLOCK OFFS APPL
G    5 C1C L1W L2W C1W S2W                                  SYS / # / OBS TYPES
R    2 C1C L1C                                              SYS / # / OBS TYPES
E    2 L1B L5I                                              SYS / # / OBS TYPES
S    2 C1C L1C                                              SYS / # / OBS TYPES
    18.000                                                  INTERVAL
GC1C GC1P  -0.123 1 CODE P1-C1 082-2006 CC2NONCC            DCBS APP / SRC / PGM
DBHZ                                                        SIGNAL STRENGTH UNIT
  2006    03    24    13    10   36.0000000     GPS         TIME OF FIRST OBS
                                                            END OF HEADER
> 2006 03 24 13 10 36.0000000  0  5      -0.123456789012
G06  23629347.915            .300 8         -.353 4  23629347.158          24.158
G09  20891534.648           -.120 9         -.358 6  20891545.292          38.123
G12  20607600.189           -.430 9          .394 5  20607600.848          35.234
E11          .324 8          .178 7
S20  38137559.506      335849.135 9
> 2006 03 24 13 10 54.0000000  0  7      -0.123456789210
G06  23619095.450      -53875.632 8    -41981.375 4  23619095.008          25.234
G09  20886075.667      -28688.027 9    -22354.535 7  20886076.101          42.231
G12  20611072.689       18247.789 9     14219.770 6  20611072.410          36.765
R21  21345678.576       12345.567 5
R22  22123456.789       23456.789 5
E11     65432.123 5     48861.586 7
S20  38137559.506      335849.135 9
> 2006 03 24 13 11 12.0000000  2  1
>                              4  1
            *** FROM NOW ON KINEMATIC DATA! ***             COMMENT
> 2006  3 24 13 11 12.0000000  0  4      -0.123456789876
G06  21110991.756       16119.980 7     12560.510 4  21110991.441          25.543
G09  23588424.398     -215050.557 6   -167571.734 6  23588424.570          41.824
G12  20869878.790     -113803.187 8    -88677.926 6  20869878.938          36.961
G16  20621643.727       73797.462 7     57505.177 2  20621644.276          15.368
>                              3  4
A 9081                                                      MARKER NAME
9081.1.34                                                   MARKER NUMBER
         .9050         .0000         .0000                  ANTENNA: DELTA H/E/N
          --> THIS IS THE START OF A NEW SITE <--           COMMENT
> 2006 03 24 13 12  6.0000000  0  4      -0.123456987654
G06  21112589.384       24515.877 6     19102.763 4  21112589.187          25.478
G09  23578228.338     -268624.234 7   -209317.284 6  23578228.398          41.725
G12  20625218.088       92581.207 7     72141.846 5  20625218.795          35.143
G16  20864539.693     -141858.836 8   -110539.435 2  20864539.943          16.345
> 2006 03 24 13 13  1.2345678  5  0
>                              4  2
      AN EVENT FLAG 5 WITH A SIGNIFICANT EPOCH              COMMENT
  AND AN EVENT FLAG 4 TO ESCAPE FOR THE TWO COMMENT LINES   COMMENT
> 2006 03 24 13 14 12.0000000  0  4      -0.123456012345
G06  21124965.133         0.30253        -0.62614  21124965.275          27.528
```

```
G09  23507272.372     -212616.150 7   -165674.789 7  23507272.421          42.124
G12  20828010.354     -333820.093 6   -260119.395 6  20828010.129          37.002
G16  20650944.902      227775.130 7    177487.651 3  20650944.363          18.040
>                              4  1
           *** ANTISPOOFING ON G 06 AND LOST LOCK           COMMENT
 .
 .
 .
>                              4  1
END OF FILE                                                 COMMENT
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|0-
```

## A 4 GPS Navigation Message File - Header Section Description

```
 +----------------------------------------------------------------------------+
 |                                 TABLE A4                                   |
 |        GPS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION            |
 +--------------------+-------------------------------------------+------------+
 |    HEADER LABEL    |               DESCRIPTION                 |   FORMAT   |
 |  (Columns 61-80)   |                                           |            |
 +--------------------+-------------------------------------------+------------+
 |RINEX VERSION / TYPE| - Format version : 2.10                   | F9.2,11X,  |
 |                    | - File type: N for Navigation data)       |   A1,19X   |
 +--------------------+-------------------------------------------+------------+
 |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     |*
 +--------------------+-------------------------------------------+------------+
*|ION ALPHA           | Ionosphere parameters A0-A3 of almanac    |  2X,4D12.4 |*
 |                    | (page 18 of subframe 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| 3X,2D19.12,|*
 |                    | (page 18 of subframe 4)                   |    2I9     |
 |                    | A0,A1: terms of polynomial                |            |
 |                    | T    : reference time for UTC data        |     *)     |
 |                    | W    : UTC reference week number.         |            |
 |                    |        Continuous number, not mod(1024)!  |            |
 +--------------------+-------------------------------------------+------------+
*|LEAP SECONDS        | Delta time GPS-UTC due to leap seconds    |     I6     |*
 +--------------------+-------------------------------------------+------------+
 |END OF HEADER       | Last record in the header section.        |    60X     |
 +--------------------+-------------------------------------------+------------+
```

Records marked with * are optional

## A 5 GPS Navigation Message File - Data Record Description

```
 +----------------------------------------------------------------------------+
 |                                 TABLE A5                                   |
 |         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 (sec of GPS week)| 3X,4D19.12 |
|                    | - 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       **) | 3X,4D19.12 |
|                    |         (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                                 |            |
+--------------------+-----------------------------------------+------------+
```

*) 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.

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

## A 6 GPS Navigation Message File – Example

```
+------------------------------------------------------------------------------+
|                                   TABLE A6                                   |
|                    GPS NAVIGATION MESSAGE FILE - EXAMPLE                     |
+------------------------------------------------------------------------------+

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

     2.10           N: GPS NAV DATA                         RINEX VERSION / TYPE
XXRINEXN V3         AIUB                1999-09-02 19:22:36 PGM / RUN BY / DATE
EXAMPLE OF VERSION 2.10 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|
```

## A 7 GLONASS Navigation Message File - Header Section Description

```
 +----------------------------------------------------------------------------+
 |                                 TABLE A7                                   |
 |        GLONASS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION        |
 +--------------------+-------------------------------------------+------------+
 |    HEADER LABEL    |               DESCRIPTION                 |   FORMAT   |
 |  (Columns 61-80)   |                                           |            |
 +--------------------+-------------------------------------------+------------+
 |RINEX VERSION / TYPE| - Format version : 2.10                   | F9.2,11X,  |
 |                    | - File type: G = GLONASS nav mess 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    |*
 +--------------------+-------------------------------------------+------------+
*|CORR TO SYSTEM TIME | - Time of reference for system time corr |            |*
 |                    |   (year, month, day)                      |    3I6,    |
 |                    | - Correction to system time scale (sec)   | 3X,D19.12  |
 |                    |   to correct GLONASS system time to       |            |
 |                    |   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

## A 8 GLONASS Navigation Message File - Data Record Description

```
 +----------------------------------------------------------------------------+
 |                                 TABLE A8                                   |
 |         GLONASS NAVIGATION MESSAGE FILE - DATA RECORD DESCRIPTION          |
 +--------------------+-------------------------------------------+------------+
 |    OBS. RECORD     | DESCRIPTION                               |   FORMAT   |
 +--------------------+-------------------------------------------+------------+
 |PRN / EPOCH / SV CLK| - Satellite number:                       |     I2,    |
 |                    |       Slot number in sat. constellation   |            |
 |                    | - Epoch of ephemerides             (UTC) |            |
 |                    |     - year (2 digits, padded with 0,      |  1X,I2.2,  |
 |                    |                if necessary)              |            |
 |                    |     - month,day,hour,minute,              | 4(1X,I2),  |
 |                    |     - second                              |   F5.1,    |
 |                    | - SV clock bias (sec)             (-TauN)|  D19.12,   |
 |                    | - SV relative frequency bias    (+GammaN)|  D19.12,   |
 |                    | - message frame time                 (tk)|  D19.12    |
 |                    |   (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|            |
 +--------------------+-------------------------------------------+------------+
```

```
 | 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) |            |
 +--------------------+------------------------------------------+------------+
```

*) 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.

## A 9 GLONASS Navigation Message File – Example

```
+------------------------------------------------------------------------------+
|                                   TABLE A9                                   |
|                  GLONASS NAVIGATION MESSAGE FILE - EXAMPLE                   |
+------------------------------------------------------------------------------+

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

     2.10           GLONASS NAV DATA                        RINEX VERSION / TYPE
ASRINEXG V1.1.0 VM  AIUB                1998-02-15 10:48:20 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|
```

## A10 SBAS Navigation Message File - Header Section Description

```
 +----------------------------------------------------------------------------+
 |                                 TABLE A10                                  |
 |         SBAS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION          |
 +--------------------+------------------------------------------+------------+
 |    HEADER LABEL    |               DESCRIPTION                |   FORMAT   |
 |  (Columns 61-80)   |                                          |            |
 +--------------------+------------------------------------------+------------+
 |RINEX VERSION / TYPE| - Format version: 2.11                   | F9.2,11X,  |
 |                    | - File type: H = GEO nav mess 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 * |
| * | **D-UTC A0,A1,T,W,S,U** | Corrections to transform the system time to UTC<br>A0,A1 Coefficients of 1-deg polynomial<br>A0 sec, A1 sec/sec<br>CORR(s) = A0 + A1*DELTAT<br>T Reference time for polynomial<br>(Seconds into GPS week)<br>W Reference week number<br>(GPS week, continuous number)<br>S EGNOS, WAAS, or MSAS ...<br>(left-justified)<br>Derived from MT17 service provider.<br>If not known: Use Snn with<br>nn = PRN-100 of satellite<br>broadcasting the MT12<br>U UTC Identifier (0 if unknown)<br>1=UTC(NIST), 2=UTC(USNO), 3=UTC(SU),<br>4=UTC(BIPM), 5=UTC(Europe Lab),<br>6=UTC(CRL), >6 = reserved for future<br><br>Omit record if corrections not provided.<br><br>Replaces **CORR TO SYSTEM TIME** ! | <br><br>2D19.12,<br><br><br>I7,<br><br>I5,<br><br>X,A5,X<br><br><br><br><br><br>I2,2X * |
| * | **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

## A11 SBAS Navigation Message File - Data Record Description

**TABLE A11**
**SBAS NAVIGATION MESSAGE FILE - DATA RECORD DESCRIPTION**

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

*) 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.

## A12 SBAS Navigation Message File - Example

```
+------------------------------------------------------------------------------+
|                                TABLE A12                                     |
|                  SBAS NAVIGATION MESSAGE FILE - EXAMPLE                      |
+------------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

     2.11           H: SBAS NAV MSG DATA                    RINEX VERSION / TYPE
SBAS2RINEX 2.0      CNES                2003-10-18 14:01:00 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|
```

## A13 Meteorological Data File - Header Section Description

```
 +----------------------------------------------------------------------------+
 |                                TABLE A13                                   |
 |            METEOROLOGICAL DATA FILE - HEADER SECTION DESCRIPTION           |
 +--------------------+-------------------------------------------+------------+
 |    HEADER LABEL    |                DESCRIPTION                |   FORMAT   |
 |  (Columns 61-80)   |                                           |            |
 +--------------------+-------------------------------------------+------------+
 |RINEX VERSION / TYPE| - Format version : 2.11                   | F9.2,11X,  |
 |                    | - 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                              |    A60     |
 |                    | (preferably identical to MARKER NAME in   |            |
 |                    |  the associated Observation File)         |            |
 +--------------------+-------------------------------------------+------------+
*|MARKER NUMBER       | Station Number                            |    A20     |*
 |                    | (preferably identical to MARKER NUMBER in|            |
 |                    |  the associated Observation File)         |            |
 +--------------------+-------------------------------------------+------------+
 |# / TYPES OF OBSERV | - Number of different observation types   |    I6,     |
 |                    |   stored in the file                      |            |
 |                    | - Observation types                       |  9(4X,A2)  |
 |                    |                                           |            |
```

| | | |
|---|---|---|
| | The following meteorological observation types are defined in RINEX Version 2:<br>**PR** : Pressure (mbar)<br>**TD** : Dry temperature (deg Celsius)<br>**HR** : Relative humidity (percent)<br>**ZW** : Wet zenith path delay (mm)<br>(for WVR data)<br>**ZD** : Dry component of zenith path delay<br>**ZT** : Total zenith path delay (mm)<br>**WD** : Wind azimuth (deg)<br>from where the wind blows<br>**WS** : Wind speed (m/s)<br>**RI** : "Rain increment" (1/10 mm): Rain accumulation since last measurement<br>**HI** : Hail indicator<br>non-zero: Hail detected since last measurement<br><br>The sequence of the types in this record must correspond to the sequence of the measurements in the data records<br><br>If more than 9 observation types are being used, use continuation lines with format (6X,9(4X,A2)) | |
| **SENSOR MOD/TYPE/ACC** | Description of the met sensor<br>- Model (manufacturer)<br>- Type<br>- Accuracy (same units as obs values)<br>- Observation type<br>Record is repeated for each observation type found in **# / TYPES OF OBSERV** record | <br>A20,<br>A20,6X,<br>F7.1,4X,<br>A2,1X |
| **SENSOR POS XYZ/H** | Approximate position of the met sensor<br>- Geocentric coordinates X,Y,Z (ITRF<br>- Ellipsoidal height H or WGS-84)<br>- Observation type<br>Set X,Y,Z to zero if not known.<br>Make sure H refers to ITRF or WGS-84!<br>Record required for barometer, recommended for other sensors. | <br>3F14.4,<br>1F14.4,<br>1X,A2,1X |
| **END OF HEADER** | Last record in the header section. | 60X |

Records marked with * are optional

## A14 Meteorological Data File - Data Record Description

**TABLE A14**
**METEOROLOGICAL DATA FILE - DATA RECORD DESCRIPTION**

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

# A15 Meteorological Data File - Example

```
+----------------------------------------------------------------------------+
|                                TABLE A15                                   |
|                   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                1996-04-02 00:10:12 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|
```