

RINEX

The Receiver Independent Exchange Format

Version 3.05

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Acronyms

AODC	Age of Data Clock
AODE	Age of Data Ephemerides
ARP	Antenna Reference Point
AS	Anti-Spoofing (of GPS)
BDS	BeiDou System
BDT	BeiDou Time
BIPM	International Bureau of Weights and Measures (from French)
BNK	Blank
BOC	Binary Offset Carrier
CNAV	Civil Navigation (message)
DCB	Differential Code Bias
DVS	Data Validity Status
FNAV	Free Navigation (message, of Galileo)
GEO	Geostationary Earth Orbit
GLONASS	Globalnaja Nawigazionnaja Sputnikowaja Sistema
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GST	Galileo System Time
ICD	Interface Control Document
INAV	Integrity Navigation (message, of Galileo)
IOD	Issue of Data
IODC	Issue of Data, Clock
IODE	Issue of Data, Ephemerides
NavIC/IRNSS	Navigation Indian Constellation/Indian Regional Navigation System
LLI	Loss-of-Lock Indicator
LNAV	Legacy Navigation (message)
MBOC	Multiplexed BOC
MEO	Medium Earth Orbit
PCV	Phase Center Variation
PR	Pseudorange
PRN	Pseudo-Random Noise
QZSS	Quasi-Zenith Satellite System
RCV	Receiver
RINEX	Receiver INdependent EXchange format
SA	Selective Availability (of GPS)
SAASM	Selective Availability Anti-Spoofing Module
SBAS	Satellite Based Augmentation System
SSI	Signal Strength Indicator
SNR	Signal to Noise Ratio
SU	Soviet Union
SV	Space Vehicle
TOE	Time of Ephemerides
TOW	Time of Week
URA	User Range Accuracy
URAI	User Range Accuracy Index
USNO	United States Naval Observatory
UTC	Universal Time Coordinated

1 RINEX 3.04 TO 3.05 REVISION HISTORY

23-Nov-2018	RINEX 3.04 Released
25-Apr-2019	<ul style="list-style-type: none"> - Improved the description of BeiDou Frequency Band / Frequency in Table 19 - Added GLONASS Band 3 to SYS/#/OBS TYPES in Table A2 - Added parentheses: “(nd*86400)” in Table A10 - Reformatted NAV. RECORD column of Table A14 - Added types B1A and B3A to the BDS section in Table A23
31-Jul-2020	<ul style="list-style-type: none"> - Improved Revision History Table and added all correct release dates for each version. - Changed 3.04 to 3.05 as needed throughout the document - Corrected minor format issues, corrected all figures and tables names, corrected all numbered headings to simplify document update - Updated the acknowledgements
3-Aug-2020	<ul style="list-style-type: none"> - Deleted “Note 2” from the LEAP SECONDS line definition in Table A2 “GNSS Observation data file header section” and Table A5 “GNSS Navigation Message File Header”. GPS Leap Seconds line is always allowed. BDS Leap Seconds line are allowed and should not be limited to a specific set of navigation files.
10-Aug-2020	<ul style="list-style-type: none"> - Moved the RINEX 3.04 Section 4 “The Exchange of RINEX Files”, on detailed file naming, to the Annex A1 with the rest of the long filename information. - Added a small section on the RINEX 3 long filenames to the new Section 5.1.
12-Aug-2020	<ul style="list-style-type: none"> - Removed the RINEX 3.04 Section 5.16 “Navigation message files” since it contained only differences to RINEX 2 Navigation files already defined elsewhere. - Changed the RINEX 3.04 Section 6 title, “Additional Hints and Tips” to “RINEX Line Formatting Specifications”. - Removed the RINEX 3.04 Section 6.10 “Two-digit years” since this does not apply to RINEX 3 files.
16-Aug-2020	<ul style="list-style-type: none"> - Removed the RINEX 3.04 Section 6.11 “Fit Interval (GPS Navigation message file)”, section 6.12 “Satellite health (GPS Navigation message file)” and section 6.13 “Transmission time of message (GPS Navigation message file)” since this is explained in the GPS navigation file definition section. - Removed the RINEX 3.04 Section 7 “RINEX under Antispoofing (AS)” since RINEX 3 has ways to indicate the observable type than using the LLI as was done in RINEX 2.

18-Aug-2020	<ul style="list-style-type: none"> - Created a new section 5.2 “Observation File Header” to describe and explain different header elements in a consolidated location, this section collects the RINEX 3.04 version sections; <p>Section 5.1 “Observation Codes” Section 5.2 “Satellite system dependent list of observables” Section 5.3 “Marker type” Section 5.4 “Half-wavelength observations, half-cycle ambiguities” Section 5.5 “Scale factor” Section 5.6 “Information about receivers on a vehicle” Section 5.8 “Date/Time format in the header record” Section 5.14 “Corrections of DCBs” Section 5.15 “Corrections of antenna PCVs” Section 6.5 “Order of the header records...” Section 6.9 “Receiver clock offset” Section 6.14 “Antenna references, phase centers”</p>
19-Aug-2020	<ul style="list-style-type: none"> - Added Table of Tables as part of the Index and numbered all Tables automatically. - Updated BDS signal mapping in Table 19 to properly include BDS-3 Signals B1A and B3A - Moved RINEX 3.04 section 8.1 “Time system identifier” to section 4.1 “Time” - Moved RINEX 3.04 section 8.2 “Pseudorange definition” to section 0 “Pseudorange” since the explanations and definitions are more useful together.
21-Aug-2020	<ul style="list-style-type: none"> - Created section 5.3 “Observation Data Records” to explain different observation data record elements in a consolidated location, this section collects the RINEX 3.04 sections; <p>Section 5.7 “Signal strength” Section 5.11 “Observation data records” Section 6.5 “... order of data records” Section 6.8 “Event flag records” Section 8.4 “RINEX observation files for GEO satellites” (part)</p>
24-Aug-2020	<ul style="list-style-type: none"> - Created section 5.4 “Navigation Message Files” to explain different navigation message elements in a consolidated location, this section collects the RINEX 3.04 version sections; <p>Section 8.3 “RINEX navigation message files” Section 8.4 “RINEX observation files for GEO satellites” (part)</p> <ul style="list-style-type: none"> - Removed RINEX 3.04 section 9 “Modifications for Version ...” as redundant with this revision history timeline. Additionally, the RINEX format version documents should describe the current format and some background details but not all historical format changes since those decisions are mostly not relevant to implementing and understanding the current agreed format.

26-Aug-2020	<ul style="list-style-type: none"> - Removed RINEX 3.04 section 5.12 “Ionosphere delay as pseudo-observables” since these are not receiver-based observations but rather they are a ‘product’ of line-of-sight ionosphere delays to each of the visible satellites, which does not belong with receiver satellite observations from signal tracking. This was removed after consultation with the IGS Ionosphere Working Group. - Changed all RINEX files examples in the Appendix to indicate 3.05.
1-Sep-2020	<ul style="list-style-type: none"> - Added a 5th line to the GLONASS navigation message (Table A10) to include missing GLONASS navigation message information; Status flags, L1/L2 group delay difference, accuracy index, and health flags. A few of the new navigation message elements are only for GLO-M/K satellites.
10-Sep-2020	<ul style="list-style-type: none"> - Added the list of Acronyms for the document. - Added section 6.7 to clarify the Observation data record format and added examples. - Added section 6.8 to clarify the Navigation data record format and added examples. - Added section 6.9 to clarify the Navigation data stored bitwise and added more examples. - Sorted and updated the references (section 7) as needed (date and document versions, and on-line links).
14-Sep-2020	<ul style="list-style-type: none"> - Re-inserted the RINEX 3.04 section 9.1 “Phase Cycle Shifts” as section 5.2.12 to clarify the “SYS / PHASE SHIFT” observation file header record from Table A3. - Removed from Table A2 Band value “0” of allowable satellite observation band values, this value is not allowed. - Added the “L1Sb” to the QZSS signal Table 18. This corresponds to the QZSS GEO satellite signal. - Updated the “TIME SYSTEM CORR” description in Table A5 for Week number and UTC to clarify the readability of the text.
13-Oct-2020	<ul style="list-style-type: none"> - Added default values for the 5th line of the GLONASS Navigation message (Table A10). - Added clarification that in the new Health Flag that the bit 0 is to be ignored if the bit 1 is set to zero (Table A10). - Added units (seconds) to the group delay difference value in the 5th line of the GLONASS Navigation message (Table A10).
28-Oct-2020	<ul style="list-style-type: none"> - Removed old revision histories and updated latest internal revision references - Simplified the Note for the TIME SYSTEM CORR on Table A5.
12-Nov-2020	<ul style="list-style-type: none"> - In Table A15, BDS Navigation Message Example, for consistency made the Spare fields blanks in BROADCAST ORBIT- 5, like the BROADCAST ORBIT-7 Spare fields. A Blank/Spare field is to be skipped; thus, no value should be used (Section 6.4). - In Table A18, NavIC/IRNSS Navigation Message Description, changed “Blank” to Spare for consistency with the other navigation message descriptions. - Clarified in Section 6.4 that Blank/Spare fields shall be left blank and skipped when reading/writing since they hold no defined content

	<ul style="list-style-type: none"> - Changed Frequency Band & Code name in Table 18 from L5D to L5S(I), L5P to L5S(Q) and L5(D+P) to L5S(I+Q) to be consistent with the QZSS ICD and consistent with the naming in Table A23. - Added Attribute E to Table A2 for consistency with QZSS signal L6E in Table 18. - Inserted section 5.2.16 (the old RINEX 3.04 section 9.9) explaining the GLONASS COD/PHS/BIS mandatory observation file header element, and added the reference in Table A2 back to section 5.2.16 - Added for clarity the explicit field descriptors for LLI & SSI for the Observation records in Table A3, and reference to section 6.7 for further information and examples - Clarified in the Table A5, Navigation file header description, in the TIME SYSTEM CORR optional header label the satellite ID issue to remove possible confusion of only SBAS PRNs allowed. - Removed from Table A5, Navigation file header description, in the TIME SYSTEM CORR optional header label the line; “S and U fields to be used for SBUT only” since it is no longer applicable - Added clarification to Table A5, Navigation file header description, in the LEAP SECONDS optional header label to indicate that all data fields must come from the indicated Time System Identifier. Also added a clarification Note 3 that GLO only navigation files should not have this optional header line. Added clarification Note 2 of where the BDT leap seconds are from and updated the BDS ICD reference.
13-Nov-2020	<ul style="list-style-type: none"> - Updated Table A23 to indicate that GLO G3 L3Q must be aligned to L3I since the alignment direction is not known. - Updated Table A23 to indicate that BDS B1C & B2A must be aligned to L1D & L5D respectively since the ¼ cycle alignment direction is implementation dependent. - Updated Table A23 to indicate that BDS B2b & B2a+B2b must be aligned to L7D & L8D respectively since alignment direction is not known.
20-Nov-2020	<ul style="list-style-type: none"> - Remove ‘B2’ from Table A2 Band 5 signals to maintain consistency with what is defined in Table 19 : RINEX Version 3.05 BDS Observation Codes.
23-Nov-2020	<ul style="list-style-type: none"> - Inserted NavIC/IRNSS where previously only IRNSS had been written since India has renamed their navigation system, and to remain aligned to the designation in use across the RTCM-SC104.
27-Nov-2020	<ul style="list-style-type: none"> - Introduced in section 4.1.7 a statement about referring all observations to one receiver clock bias in multi-GNSS receiver, to remain consistent with section 4.2 - Updated the references of the GPS ICDs to the 14 May 2020 versions in section 7. - Introduced the reference BDS ICDs for open signals B2b and B3I in section 7. - Clarified the reference to the RTCA DO-229 SBAS Minimum Operational Performance Standard in section 7.

30-Nov-2020	<ul style="list-style-type: none"> - Updated all ftp references in section 7 to the IGS to https links since ftp is being phased out at the IGS from December 2020. - In section 6.7.1 clarified the LLI index and allowed the LLI bit 2 to be set for more than just Galileo. - Removed the spaces after the “*” for optional header lines in column HEADER LABEL and standardized the use of commas in column FORMAT in Table A2 and Table A5 - Added line continuation symbols → to Table 22 to clearly indicate the long line of observables per satellite are wrapped due to the table width.
01-Dec-2020	RINEX 3.05 Released

2 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 Bern for the easy exchange of the Global Positioning System (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 geodetic processing 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, antenna model, etc.

Three major format versions of RINEX have been developed and published to date:

- 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]
- RINEX Version 3 developed in the early 2000s to support multi-GNSS and to clearly identified the tracking modes of each of the observations by introducing and defining 3-character observation codes for all GNSS constellations.

As spin-offs of the idea of a receiver-independent data exchange format, other RINEX-like exchange file formats have been defined over time, 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, 2010]
- Exchange format for the **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, 2010]

Several subversions of RINEX Version 2 were defined over time:

- 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] - ***This is the last official RINEX Version 2***
- 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]

In the early 2000s when new GNSS constellations were being planned, and soon thereafter started transmitting their new navigation signals, it was clear that RINEX 2 was not capable of fully supporting the new signals, tracking modes and satellites efficiently. The new Beidou, Galileo, QZSS, etc and the modernized GPS and GLONASS with new frequencies and observation types needed a leap in the RINEX format.

Especially the possibility to track frequencies on different channels, required a more flexible and more detailed definition of the observation codes.

Several versions of RINEX 3 have been defined:

- RINEX 3.00 (2007) fully supports multi-GNSS observation data storage. The initial RINEX Version 3 also incorporates the version 2.20 definitions for space-borne receivers.
- RINEX 3.01 (2009) introduced the requirement to generate consistent phase observations across different tracking modes or channels, i.e. to apply $\frac{1}{4}$ -cycle shifts prior to RINEX file generation, if necessary, to facilitate the processing of such data.
- RINEX 3.02 (2013) added support for the Japanese, Quasi Zenith Satellite System (QZSS), additional information concerning BeiDou (based on the released ICD) and a new message to enumerate GLONASS code phase biases.
- RINEX 3.03 (2015) adds support for the NavIC/IRNSS and clarifies several implementation issues in 3.02. RINEX 3.03 also changes the BeiDou B1 signal convention back to the 3.01 convention where all B1 signals are identified as C2x (not C1 as in RINEX 3.02). Another issue with the implementation of 3.02 was the GPS navigation message fit interval field. Some implementations wrote the flag and others wrote a time interval. This release specifies that the fit interval should be a time period for GPS and a flag for QZSS. The Galileo Navigation section was updated to clarify the Issue of Data (IOD). RINEX 3.03 was also modified to specify that only known observation tracking modes can be encoded in the standard.
- RINEX 3.04 (2018) adds clarifications for signal tables for GLONASS, QZSS and BeiDou, and a small number of edits and corrections needed from the previous version.
- RINEX 3.05 (2020) is a major restructure and revision of the format document to make it clearer and easier to read, it adds BeiDou signals and tracking codes to fully support BDS-2 and BDS-3, and it also adds missing flags and values to the GLONASS navigation messages.

3 GENERAL FORMAT DESCRIPTION

The RINEX 3.XX format consists of three ASCII file types:

1. Observation data file
2. Navigation message file
3. Meteorological data file

Each file type consists of a header section and a data section. The header section contains global information for the entire file and is placed at the beginning of the file. The header section contains **header labels in columns 61-80** for each line. These labels are mandatory and must appear exactly as given in these descriptions and examples. The header does not have a fixed length and many of the labels are optional depending on the application. Comments can be added freely in the header.

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 observation session, 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. Although the format allows for the insertion of certain header records into the data section, it is not recommended to concatenate data from 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 navigation 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.

RINEX 3 mixed navigation message files are allowed to contain navigation messages of more than one satellite system to make their exchange and the processing more efficient.

The header and data record format descriptions as well as examples for each file type are given in the Appendix Tables at the end of the document.

4 BASIC DEFINITIONS

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

4.1 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.

For single-system data files, it is by default expressed in the time system of the respective satellite system.

For mixed files, the actual time system used **must** be indicated in the **TIME OF FIRST OBS** header record. The details of each GNSS Time and their use in RINEX is defined below.

4.1.1 GPS Time

GPS time runs, apart from small differences ($\ll 1$ microsecond), parallel to UTC. But it is a continuous time scale, i.e. it does not insert any leap seconds. GPS time is usually expressed in GPS weeks and GPS seconds past 00:00:00 (midnight) Saturday/Sunday. GPS time started with week zero at 00:00:00 UTC (midnight) on January 6, 1980.

The GPS week is transmitted by the satellites as a 10-bit number. It has a roll-over after week 1023. The first roll-over happened on August 22, 1999, 00:00:00 GPS time.

In order to avoid ambiguities, the GPS week reported in the RINEX navigation message files is a continuous number without roll-over, i.e. ...1023, 1024, 1025, ...

We use **GPS** as time system identifier for the reported GPS time.

4.1.2 GLONASS Time

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. It is not a continuous time, i.e. it introduces the same leap seconds as UTC.

The reported GLONASS time has the same hours as UTC and not UTC+3 h as the original GLONASS System Time!

We use **GLO** as time system identifier for the reported GLONASS time.

4.1.3 Galileo System Time

Galileo runs on Galileo System Time (GST), which is, apart from small differences (tens of nanoseconds), nearly identical to GPS time:

- The Galileo week starts at midnight Saturday/Sunday at the same second as the GPS week
- The GST week as transmitted by the satellites is a 12-bit value with a roll-over after week 4095. The GST week started at zero at the first roll-over of the broadcast GPS week after 1023, i.e. at Sun, 22-Aug-1999 00:00:00 GPS time

In order to remove possible misunderstandings and ambiguities, the Galileo week reported in the RINEX navigation message files is a continuous number without roll-over, i.e., ...4095, 4096, 4097,... and *it is aligned to the GPS week*.

We use **GAL** as time system identifier for this reported Galileo time.

4.1.4 BeiDou Time

The **BDS** Time (BDT) System is a continuous timekeeping system, with its length of second being an SI second. BDT zero time started at 00:00:00 UTC on January 1st, 2006 (GPS week 1356) therefore BDT is 14 seconds behind GPS time. BDT is synchronized with UTC within 100 nanoseconds (modulo 1 second).

- The **BDT** week starts at midnight Saturday/Sunday
- The **BDT** week is transmitted by the satellites as a 13-bit number. It has a roll-over after week 8191. In order to avoid ambiguities, the BDT week reported in the RINEX navigation message files is a continuous number without roll-over, i.e. ...8191, 8192, 8193, ...

We use **BDT** as time system identifier for the reported BDS time.

4.1.5 QZSS Time

QZSS runs on QZSS time, which conforms to UTC Japan Standard Time Group (JSTG) time and the offset with respect to GPS time is controlled. The following properties apply to the QZSS time definition: the length of one second is defined with respect to International Atomic Time (TAI); QZSS time is aligned with GPS time (offset from TAI by integer seconds); the QZSS week number is defined with respect to the GPS week.

We use **QZS** as a time system identifier for the reported QZSS time.

4.1.6 NavIC/IRNSS System Time

NavIC/IRNSS runs on Indian Regional Navigation Satellite System Time (**IRNSST**). The **IRNSST** start epoch is 00:00:00 on Sunday August 22nd, 1999, which corresponds to August 21st, 1999, 23:59:47 UTC (same time as the first GPS week roll over). Seconds of week are counted from 00:00:00 **IRNSST** hours Saturday/Sunday midnight which also corresponds to the start of the GPS week. Week numbers are consecutive from the start time and will roll over after week 1023 (at the same time as GPS and QZSS roll over).

We use **IRN** as the time system identifier for the reported NavIC/IRNSS time.

4.1.7 GNSS Time Relationships

Apart from the small, sub-microsecond differences, in the realizations of the different time systems, the GNSS time scales differ from UTC and each other by integer seconds. The relations between the various systems are summarized in Table 1 and Table 2.

In order to have the current number of leap seconds available, we recommend including Δt_{LS} by adding a **LEAP SECOND** line into the RINEX file header.

In a multi-GNSS receiver (GPS/GLONASS/Galileo/QZSS/BDS) all pseudorange observations must refer to one receiver clock only.

GLO	=	UTC	=	GPS	-	Δt_{LS}
GPS	=	GAL	=	UTC	+	Δt_{LS}
GPS	=	QZS	=	UTC	+	Δt_{LS}
GPS	=	IRN	=	UTC	+	Δt_{LS}
BDT	=			UTC	+	$\Delta t_{LS_{BDS}}$

Table 1 : Constellation Time Relationships

Δt_{LS}	=	Delta time between GPS and UTC due to leap seconds, as transmitted by the GPS satellites in the almanac (1999-01-01 - 2006-01-01: $\Delta t_{LS} = 13$, 2006-01-01 - 2009-01-01: $\Delta t_{LS} = 14$, 2009-01-01 - 2012-07-01: $\Delta t_{LS} = 15$, 2012-07-01 - 2015-07-01: $\Delta t_{LS} = 16$, 2015-07-01 - 2017-01-01: $\Delta t_{LS} = 17$ and 2017-01-01 - ???-??-?: $\Delta t_{LS} = 18$).
$\Delta t_{LS_{BDS}}$	=	Delta time between BDT and UTC due to leap seconds, as transmitted by the BDS satellites in the almanac (2006-01-01 - 2009-01-01: $\Delta t_{LS_{BDS}} = 0$, 2009-01-01 - 2012-07-01: $\Delta t_{LS_{BDS}} = 1$, 2012-07-01 - 2015-07-01: $\Delta t_{LS_{BDS}} = 2$, 2015-07-01 - 2017-00-01: $\Delta t_{LS_{BDS}} = 3$ and 2017-01-01 - ???-??-?: $\Delta t_{LS} = 4$). See BDS-SIS-ICD-2.0 Section 5.2.4.17

Table 2 : GPS and BeiDou UTC Leap Second Relationship

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

The small differences (modulo 1 second) between: BDS system time, Galileo system time, 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.

4.1.8 GNSS Week numbers

The use of the week number from the start of a GNSS service is a common time reference. The relationships between the different GNSS week numbers are as shown in Table 3.

Constellation /Archival Time Representation	GPS Ephemeris Week Period #1	GPS Ephemeris Week Period #2	GPS Ephemeris Week Period #3	GPS Ephemeris Week Period #4	GPS Ephemeris Week Period #5	GPS Ephemeris Week Period #6
GPS Broadcast	0 – 1023	0 – 1023	0 – 1023	0 – 1023	0 – 1023	0 – 1023
QZSS Broadcast		0 – 1023	0 – 1023	0 – 1023	0 – 1023	0 – 1023
NavIC/IRNSS Broadcast		0 – 1023	0 – 1023	0 – 1023	0 – 1023	0 – 1023
GST Broadcast		0 – 1023	1024 – 2047	2048 – 3071	3072 – 4095	0 – 1023
BDS Broadcast and RINEX		0(RINEX Week 1356) – 691	692 – 1715	1716 – 2739	2740 – 3763	3764 – 4787
GPS/QZS/IRN/ GAL RINEX	0 – 1023	1024 – 2047	2048 – 3071	3072 – 4095	4096 – 5119	5120 -6143

Table 3 : Week Numbers between RINEX and GPS, QZSS, IRN, GST, GAL, BDS

4.2 Pseudorange

The pseudorange (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):

$$PR = \text{distance} + c * (\text{receiver clock offset} - \text{satellite clock offset} + \text{other biases})$$

so that the pseudorange reflects the actual behavior of the receiver and satellite clocks. The pseudorange is stored in units of meters. In the above relation, $c = 299\,792\,458$ m/s denotes the speed of light.

In a mixed-mode GPS/GLONASS/Galileo/QZSS/BDS receiver all pseudorange observations must refer to one receiver clock only,

- the raw GLONASS pseudoranges will show the current number of leap seconds between GPS/GAL/BDT time and GLONASS time if the receiver clock is running in the GPS, GAL or BDT time frame
- the raw GPS, Galileo and BDS pseudoranges will show the negative number of leap seconds between GPS/GAL/BDT time and GLONASS time if the receiver clock is running in the GLONASS time frame

In order to avoid misunderstandings and to keep the code observations within the format fields, the pseudoranges must be corrected in this case as shown in Table 4 to remove the contributions of the leap seconds from the pseudo-ranges.

PR_mod(GPS)	=	PR(GPS)	+	$c * \Delta tLS$	if generated with a receiver clock running in the GLONASS time frame
PR_mod(GAL)	=	PR(GAL)	+	$c * \Delta tLS$	if generated with a receiver clock running in the GLONASS time frame
PR_mod(BDT)	=	PR(BDT)	+	$c * \Delta tLS_{BDS}$	if generated with a receiver clock running in the GLONASS time frame
PR_mod(GLO)	=	PR(GLO)	-	$c * \Delta tLS$	if generated with a receiver clock running in the GPS or GAL time frame
PR_mod(GLO)	=	PR(GLO)	-	$c * \Delta tLS_{BDS}$	if generated with a receiver clock running in the BDT time frame
PR_mod(GPS)	=	PR(GPS)	+	$c * (\Delta tLS - \Delta tLS_{BDS})$	if generated with a receiver clock running in the BDT time frame

Table 4 : Constellation Pseudorange Corrections

ΔtLS is the actual number of leap seconds between GPS/GAL and GLO time, as broadcast in the respective navigation messages and distributed in Circular T of BIPM.

ΔtLS_{BDS} is the actual number of leap seconds between BDT and UTC time, as broadcast in the BeiDou navigation message.

4.3 Phase

The phase observable provided in a RINEX file is the carrier-phase range from the antenna to a satellite measured in whole cycles. Half-cycle phase measurements by squaring-type receivers must be converted to whole cycles and flagged by the respective observation code (see section 5.2.13 for further clarification).

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 observables are not corrected for external effects such as: atmospheric refraction, satellite clock offsets, etc.

If necessary, phase observations are corrected for phase shifts as indicated by the header lines **SYS/PHASE SHIFT** (see section 5.2.12). This is needed to guarantee consistency between phases of the same frequency and satellite system based on different signal channels (See Appendix A23).

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 / pseudorange / epoch must be maintained, i.e. the receiver clock correction shall be applied to all 3 observables as specified in Table 5.

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

Table 5: Observation Corrections for Receiver Clock Offset

*) For detailed definition of QZSS, please refer to section 4.5.

4.4 Doppler

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

4.5 Satellite numbers

For clear unambiguous identification, individual satellites are identified in RINEX files by a two-digit number indicating the PRN code or the slot number. This number is preceded by a one-character system identifier **s** as shown in Figure 1.

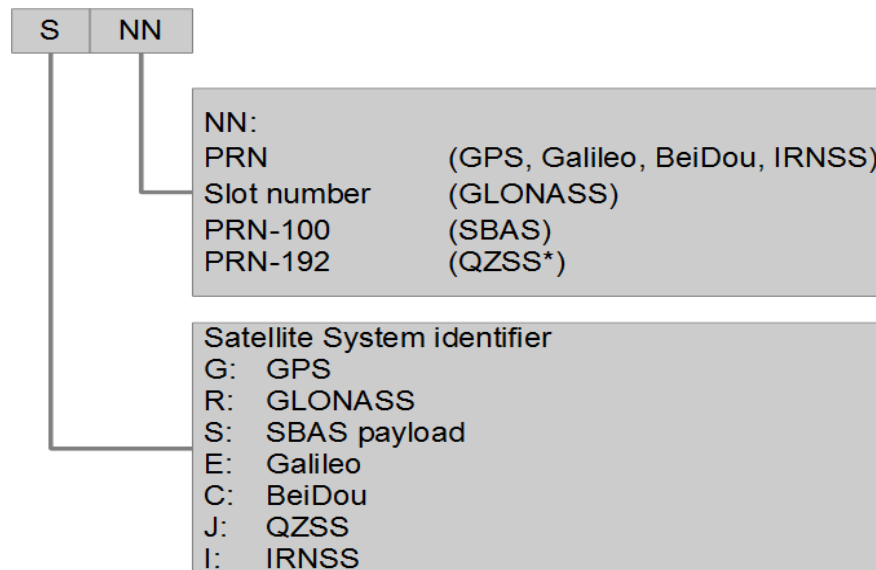


Figure 1: Satellite numbers and Constellation Identifiers

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

QZSS satellites are fully identified the using the standard PRN numbering conventions; J01-J09 as shown in Table 6.

RINEX Satellite ID	Standard PNT Signals and Centimeter Level Augmentation (LEX/L6D) (PRN-192)	Sub-meter Level Augmentation (L1-SAIF/L1S) (PRN-182)	Centimeter Level Augmentation for Experiments (L6E) (PRN-202)	Positioning Technology Verification Service (L5S) (PRN Code)
J01	193	183		
J02	194	184	204	196
J03	195	185	205	200
J04	196	186	206	
J05	197	187	207	
J06	198	188	208	
J07	199	189	209	197
J08	200	190	210	
J09	201	191	211	

Table 6: QZSS PRN to RINEX Satellite Identifier

5 RINEX VERSION 3 FEATURES

This chapter contains description and explanations of the RINEX 3 main features; recommended filenames, the main header elements including the observation codes for each GNSS Constellation, the observation data records, and the navigation files.

5.1 Long Filenames

From RINEX 3.02 onwards the data filenames are recommended to use the proposed long filenames to be more descriptive, flexible and extensible than the previous short file naming convention.

Table 7 lists example filenames for GNSS observation and navigation files, please note that the source of the data, the start time, the duration, the cadence and the data type are now easily visible. This allows files from the same station over the same time period, different sources, different cadences and with different observation types to be stored together easily.

File Name	Comments
ALGO00CAN_R_20121601000_01H_01S_MO.rnx	Mixed RINEX GNSS observation file containing 1 hour of data, with an observation every second
ALGO00CAN_R_20121601000_15M_01S_GO.rnx	GPS RINEX observation file containing 15 minutes of data, with an observation every second
ALGO00CAN_R_20121601000_01D_30S_MO.rnx	Mixed RINEX GNSS observation file containing 1 day of data, with an observation every 30 seconds
ALGO00CAN_R_20121600000_01D_MN.rnx	RINEX mixed navigation file, containing one day's data

Table 7: Examples of long filenames for RINEX 3 data files

See Appendix A1 for the full description of the file naming convention.

5.2 Observation File Header

See the Appendix A2 for a detailed specification of the RINEX 3 observation file header. This section provides general descriptions and clarifications for the observation file header.

5.2.1 Order of the header records

As the header record descriptors in columns 61-80 are mandatory, the software reading a RINEX 3.XX header must decode the header records with formats according to the record descriptor in Appendix A2.

RINEX allows the 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 record in the header

5.2.2 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 defined to be:

yyyymmdd hhmmss zone

zone: 3 – 4 character code for the time zone

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

5.2.3 Marker type

In order to indicate the nature of the marker, a **MARKER TYPE** header record has been defined. Proposed keywords are given in Table 8.

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. However, Event flags ‘2’ and ‘3’ (See Appendix A3) are necessary to flag alternating kinematic and static phases of a receiver visiting multiple earth-fixed monuments. Users may define other project-dependent keywords.

<u>Marker Type</u>	<u>Description</u>
GEODETIC	Earth-fixed high-precision monument
NON_GEODETIC	Earth-fixed low-precision monument
NON_PHYSICAL	Generated from network processing
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 8: Proposed Marker Type Keywords

5.2.4 Antenna references, phase centers

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 with respect 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-dependent and minimum elevation-angle-dependent position of the average phase center above the antenna reference point. Its position is important to know in mixed-antenna networks. It can be given in an absolute sense or relative to a reference antenna using the 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.
- The *Orientation* of the antenna: The “zero direction” should be 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 *Boresight 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 coordinate 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 type of header record.

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

5.2.5 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 contains the position of an *average* phase center relative to the antenna reference point (ARP) for a specific frequency and satellite system.

On vehicles, the phase center position can be reported in the body-fixed coordinate system (**ANTENNA: DELTA X/Y/Z**), see section 5.2.4.

See section 5.2.10 regarding the use of phase center variation corrections.

5.2.6 Antenna orientation

Dedicated header records have been defined to report the orientation of the antenna zero-direction; **ANTENNA: ZERODIR**, as well as the direction of its vertical axis (bore-sight) if mounted tilted on a fixed station; **ANTENNA: B.SIGHT**.

The header records can also be used for antennas on vehicles.

5.2.7 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**
- Boresight 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 5.2.4): **ANTENNA: ZERODIR XYZ**
- Current center of mass of the vehicle (for space borne receivers): **CENTER OF MASS: XYZ**
- Average phase center position: **ANTENNA: PHASECENTER** (see 5.2.5)

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.

5.2.8 Time of First/Last Observations

The header records **TIME OF FIRST OBS** and (if present) **TIME OF LAST OBS** in pure GPS, GLONASS, Galileo, QZSS or BDS observation files can contain the 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 time
- **QZS** to identify QZSS time
- **BDT** to identify BDS time
- **IRN** to identify NavIC/IRNSS time

Pure GPS observation files default to **GPS**, pure GLONASS files default to **GLO**, pure Galileo files default to **GAL**, pure BDS observation files default to **BDT**, etc.

Multi-GNSS observation files **must** contain the system time identifier (one of the above) that all time tags refer to.

5.2.9 Corrections of differential code biases (DCBs)

For special high-precision applications, it might be useful to generate RINEX files with corrections of the differential code biases (DCBs) already applied.

This can be reported by special header records **SYS / DCBS APPLIED** pointing to the file containing the applied corrections.

5.2.10 Corrections of antenna phase center variations (PCVs)

For precise applications it is recommended that elevation-dependent, or elevation and azimuth-dependent Phase Center Variation (PCV) model for the antenna (referring to the agreed-upon ARP) be used during the processing.

For special applications, it might be useful to generate RINEX files with these PCV corrections already applied. This can be reported by special header records **SYS / PCVS APPLIED** pointing to the file containing the PCV correction models.

5.2.11 Scale factor

The *optional* **SYS / SCALE FACTOR** record allows the storage of phase data with 0.0001 of a cycle resolution, if the data was multiplied by a scale factor of 10 before being stored into the RINEX file. This feature is used to increase resolution by 10, 100, etc only.

5.2.12 Phase Cycle Shifts

Carrier phases tracked on different signal channels or modulation bands of the same frequency may differ in phase by 1/4 (e.g., GPS: P/Y-code-derived L2 phase vs. L2C-based phase) or by other fractional parts of a cycle. Appendix Table A23 specifies the reference signal and the phase shifts that are specified by the ICDs of each constellation.

All phase observations **must** be aligned from RINEX 3.01 onwards and the new **SYS / PHASE SHIFT** header is mandatory. See Appendix A2 for the message definition, and the example in Table 10. If the phase alignment is not known, then the observation data **should not** be published in a RINEX 3 observation file. In order to facilitate data processing, phase observations stored in RINEX files **must** be consistent across all satellites of a satellite system and across each frequency band. Within a RINEX 3 file:

- All phase observations must be aligned to the designated constellation and frequency reference signal as specified in Appendix A23, either directly by the receiver or by a

correction program or the RINEX conversion program, prior to RINEX file generation. Additionally, all data must be aligned with the appropriate reference signal indicated in Appendix A23 even when the receiver or reporting device is not tracking and/or providing data from that reference signal e.g. Galileo L5X phase data must be aligned to L5I.

- Phase corrections must be reported in a new mandatory **SYS / PHASE SHIFT** header record to allow the reconstruction of the original values, if needed. The uncorrected reference signal group of observations are left blank in the **SYS / PHASE SHIFT** records. Appendix A23 specifies the reference signal that should be used by each constellation and frequency band. Additionally, it indicates the relationship between the phase observations for each frequency's signals.

Concerning the mandatory **SYS / PHASE SHIFT** header records:

- If the **SYS / PHASE SHIFT** record values are set to zero in the RINEX file, then either the raw data provided by the receiver or the data format (RTCM-Multiple Signal Messages format for example) have already been aligned and the RINEX conversion program did not apply any phase corrections since they had already been applied. In this case, Appendix A23 can be used to determine the fractional cycles that had been added to each signal's phase observation to align the phase observations to the reference signal.
- If the file does not contain any observation pairs affected by phase shifts (i.e. only reference signals reported), then the observation code field is defined and the rest of the **SYS / PHASE SHIFT** header record field of the respective satellite system(s) are left blank.
- If the reported phase correction of an observation type does not affect all satellites of the same system, then the header record allows for the affected satellites to be indicated.
- If the applied phase corrections or the phase alignment is unknown, then the observation code field and the rest of the **SYS / PHASE SHIFT** header record field of the respective satellite system(s) are left blank. This use case is intended for exceptional situations where the data is intended for special projects and analysis.

Sign of the correction $\Delta\phi$:

ϕ_{RINEX}	=	ϕ original	+	$\Delta\phi$
ϕ original	:	Uncorrected or corrected, i.e. as issued by the GNSS receiver or in a standardized data stream such as RTCM-MSM		
$\Delta\phi$:	Phase correction to align the phase to other phases of the same frequency but different channel / modulation band		

Table 9: RINEX Phase Alignment Correction Convention

Example (for definition see Appendix A2):

----	----	1 0----	----	2 0----	----	3 0----	----	4 0----	----	5 0----	----	6 0----	----	7 0----	----	8
G	L2S	-0.25000												SYS	/	PHASE SHIFT
G	L2X	-0.25000												SYS	/	PHASE SHIFT
R	L2P	0.25000												SYS	/	PHASE SHIFT
E	L8Q	-0.25000												SYS	/	PHASE SHIFT

Table 10 : Example **SYS / PHASE SHIFT** Record

5.2.13 Half-wavelength observations, half-cycle ambiguities

Half-wavelength observations of encrypted GPS P(Y)-code signals collected by **codeless** squaring techniques get their own observation codes, see section 5.2.17. 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!

Full-cycle observations collected by receivers with possible half cycle ambiguity (e.g., during acquisition or after loss of lock) are to be flagged with Loss of Lock Indicator bit 1 set (see Appendix A3). **Note:** The loss of lock bit is the least significant bit.

5.2.14 Receiver clock offset

A receiver-derived clock offset can optionally be reported in the RINEX observation files. In order to remove uncertainties about whether the data (epoch, pseudorange, phase) have been corrected or not by the reported clock offset, use the header record: **RCV CLOCK OFFS APPL.**

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

5.2.15 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 3 requests system-dependent observation code lists (header record type **SYS / # / OBS TYPES**), see a full description of all observation types in section 5.2.17.

5.2.16 GLONASS Mandatory Code-Phase Alignment Header Record

Analysis has revealed that some GNSS receivers produce biased GLONASS observations. The code-phase bias results in the code and phase observations are not being measured at the same time. To remedy this problem, a mandatory GLONASS Code-Phase header bias record is required (see Table A2).

Although this header message is mandatory, it can contain zeros if the GLONASS data issued by the receiver is aligned. See the GLONASS CODE/PHASE BIAS (**GLONASS COD/PHS/BIS**) example in Table 11. The GLONASS code-phase alignment message contains: L1C, L1P, L2C and L2P corrections. Phase data from GNSS receivers that issue biased data must be corrected by the amount specified in the **GLONASS COD/PHS/BIS** record before it is written in RINEX format.

To align the non-aligned L1C phase to the pseudo range observation, the following correction is required:

$$\text{AlignedL1Cphase} = \text{ObservedL1Cphase} + (\text{GLONASSC1C_CodePhaseBias_M} / \text{Lambda})$$

where:

- AlignedL1C phase in cycles (written to RINEX file)
- ObservedL1C phase in cycles
- GLONASSC1C_CodePhaseBias_M is in metres
- Lambda is the wavelength for the particular GLONASS frequency

GLONASS L1P, L2C and L2P are handled in the same manner.

Example (See Appendix Table A2 for details):

----	----	1 0----	----	2 0----	----	3 0----	----	4 0----	----	5 0----	----	6 0----	----	7 0----	----	8
C1C	-10.000	C1P	-10.123	C2C	-10.432	C2P	-10.634					GLONASS	COD/PHS/BIS			

Table 11 : Example of GLONASS Code Phase Bias Correction Record

If the GLONASS code phase alignment is unknown, then all fields within GLONASS COD/PHS/BIS header record are left blank (see Table 12). This use case is intended for exceptional situations where the data is intended for special projects and analysis.

----	1 0----	2 0----	3 0----	4 0----	5 0----	6 0----	7 0----	8
						GLONASS	COD/PHS/BIS	

Table 12 : Example of Unknown GLONASS Code Phase Bias Record

5.2.17 Observation codes

Dedicated observation codes are used in RINEX to distinguish individual signals and tracking modes. In order to keep the observation codes short, but still allow for a detailed characterization of the actual signal generation, the observation codes are composed of three characters/digits “**tna**” as detailed in Table 13.

t : observation type	C = pseudo-range	L = carrier phase	D = doppler	S = signal strength	X = channel number
n : band / frequency	1, 2,...,9				
a : attribute	tracking mode or channel, e.g., I , Q , C , P , etc.				

Table 13 : Observation Code Components

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)
- **C2X**: L2C pseudorange derived from the mixed (M+L) codes (GPS)

Blank (unknown) observation attributes (tracking modes or channels) are not supported from RINEX 3.02 onwards. Except for the ‘**x**’ pseudo-observations (see section 5.3.4) which indicate the receiver channel number(s) tracking the specific satellite, and have blank a ‘attribute’ value.

For satellite observations only the complete specification of all signals is allowed i.e. all three fields must be specified. RINEX observation codes for all supported frequencies, signals and tracking modes for all GNSS constellations are detailed in Table 14 to Table 20.

GNSS 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
		L1C (D)	C1S	L1S	D1S	S1S
		L1C (P)	C1L	L1L	D1L	S1L
		L1C (D+P)	C1X	L1X	D1X	S1X
		P (AS off)	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)	C2X	L2X	D2X	S2X
		P (AS off)	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

Table 14 : RINEX Version 3.05 GPS Observation Codes

Antispoofing (AS) of GPS: Various techniques may be used by GPS receivers to track the encrypted GPS P(Y)-Code during Antispoofing (AS). In view of different properties of the resulting observations, which need to be considered in the observation modelling, RINEX offers multiple attributes to unambiguously distinguish the respective observations. 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 frequency using some codeless options use attribute **D**. Z-tracking under AS or similar techniques to recover pseudorange and phase on the “P-code” band use attribute **W**. Y-code tracking receivers (e.g. units employing a

Selective Availability Anti-Spoofing Module (SAASM)) use attribute **Y**.

GNSS System	Freq. Band / Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
GLONASS	G1/ 1602+k*9/16 k= -7....+12	C/A	C1C	L1C	D1C	S1C
		P	C1P	L1P	D1P	S1P
	G1a/ 1600.995	L1OCd	C4A	L4A	D4A	S4A
		L1OCp	C4B	L4B	D4B	S4B
		L1OCd+ L1OCp	C4X	L4X	D4X	S4X
	G2/ 1246+k*7/16	C/A	C2C	L2C	D2C	S2C
		P	C2P	L2P	D2P	S2P
	G2a/ 1248.06	L2CSI	C6A	L6A	D6A	S6A
		L2OCp	C6B	L6B	D6B	S6B
		L2CSI+ L2OCp	C6X	L6X	D6X	S6X
	G3 / 1202.025	I	C3I	L3I	D3I	S3I
		Q	C3Q	L3Q	D3Q	S3Q
		I+Q	C3X	L3X	D3X	S3X

Table 15 : RINEX Version 3.05 GLONASS Observation Codes

GNSS System	Freq. Band / Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
Galileo	E1 / 1575.42	A PRS	C1A	L1A	D1A	S1A
		B OS data	C1B	L1B	D1B	S1B
		C OS pilot	C1C	L1C	D1C	S1C
		B+C	C1X	L1X	D1X	S1X
		A+B+C	C1Z	L1Z	D1Z	S1Z
	E5a / 1176.45	I F/NAV OS	C5I	L5I	D5I	S5I
		Q no data	C5Q	L5Q	D5Q	S5Q
		I+Q	C5X	L5X	D5X	S5X
	E5b / 1207.140	I I/NAV OS/CS/SoL	C7I	L7I	D7I	S7I
		Q no data	C7Q	L7Q	D7Q	S7Q
		I+Q	C7X	L7X	D7X	S7X
	E5(E5a+E5b) / 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 C/NAV 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

Table 16 : RINEX Version 3.05 Galileo Observation Codes

GNSS System	Freq. Band/ Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
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 17 : RINEX Version 3.05 SBAS Observation Codes

GNSS System	Freq. Band / Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
QZSS	L1 / 1575.42	C/A	C1C	L1C	D1C	S1C
		L1C (D)	C1S	L1S	D1S	S1S
		L1C (P)	C1L	L1L	D1L	S1L
		L1C (D+P)	C1X	L1X	D1X	S1X
		L1S/L1-SAIF	C1Z	L1Z	D1Z	S1Z
		L1Sb	C1B	L1B	D1B	S1B
	L2 / 1227.60	L2C (M)	C2S	L2S	D2S	S2S
		L2C (L)	C2L	L2L	D2L	S2L
		L2C (M+L)	C2X	L2X	D2X	S2X
	L5 / 1176.45 *(Block I+II Signals) **(Block II L5S Signals)	I *	C5I	L5I	D5I	S5I
		Q *	C5Q	L5Q	D5Q	S5Q
		I+Q *	C5X	L5X	D5X	S5X
		L5S(I) **	C5D	L5D	D5D	S5D
		L5S(Q) **	C5P	L5P	D5P	S5P
		L5S(I+Q) **	C5Z	L5Z	D5Z	S5Z
	L6 / 1278.75 *(Block I LEX Signals) **(Block II Signals)	L6D *,**	C6S	L6S	D6S	S6S
		L6P *	C6L	L6L	D6L	S6L
		L6(D+P) *	C6X	L6X	D6X	S6X
		L6E **	C6E	L6E	D6E	S6E
		L6(D+E) **	C6Z	L6Z	D6Z	S6Z

Table 18 : RINEX Version 3.05 QZSS Observation Codes

Note: The RINEX 1Z signal code is used for both the initial Block I L1-SAIF signal and the updated L1S signal. L6D is the “code 1” of the L61(Block I) and L62 (Block II) signals, L6P is the “code 2” (or pilot) signal of the L61(Block I) signal and L6E is the “code 2” of the L62 (Block II) signal as specified in IS-QZSS-L6. See section 4.5 and Table 6 for QZSS PRN to RINEX identifier coding.

GNSS System	Freq. Band / Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
BDS	B1 / 1561.098 (BDS-2/3 Signals)	I (B1I signal)	C2I	L2I	D2I	S2I
		Q	C2Q	L2Q	D2Q	S2Q
		I+Q	C2X	L2X	D2X	S2X
	B1C / 1575.42 (BDS-3 Signals)	Data	C1D	L1D	D1D	S1D
		Pilot	C1P	L1P	D1P	S1P
		Data+Pilot	C1X	L1X	D1X	S1X
	B1A / 1575.42 (BDS-3 Signals)	Data	C1S	L1S	D1S	S1S
		Pilot	C1L	L1L	D1L	S1L
		Data+Pilot	C1Z	L1Z	D1Z	S1Z
	B2a / 1176.45 (BDS-3 Signals)	Data	C5D	L5D	D5D	S5D
		Pilot	C5P	L5P	D5P	S5P
		Data+Pilot	C5X	L5X	D5X	S5X
	B2 / 1207.140 (BDS-2 Signals)	I (B2I signal)	C7I	L7I	D7I	S7I
		Q	C7Q	L7Q	D7Q	S7Q
		I+Q	C7X	L7X	D7X	S7X
	B2b / 1207.140 (BDS-3 Signals)	Data	C7D	L7D	D7D	S7D
		Pilot	C7P	L7P	D7P	S7P
		Data+Pilot	C7Z	L7Z	D7Z	S7Z
	B2(B2a+B2b)/1191.795 (BDS-3 Signals)	Data	C8D	L8D	D8D	S8D
		Pilot	C8P	L8P	D8P	S8P
		Data+Pilot	C8X	L8X	D8X	S8X
	B3/1268.52 (BDS-2/3 Signals)	I	C6I	L6I	D6I	S6I
		Q	C6Q	L6Q	D6Q	S6Q
		I+Q	C6X	L6X	D6X	S6X
	B3A / 1268.52 (BDS-3 Signals)	Data	C6D	L6D	D6D	S6D
		Pilot	C6P	L6P	D6P	S6P
		Data+Pilot	C6Z	L6Z	D6Z	S6Z

Table 19 : RINEX Version 3.05 BDS Observation Codes

Note: When reading a RINEX 3.02 file, both 1I/Q/X and 2I/Q/X observation codes should be accepted and treated the same as 2I/Q/X in the current RINEX standard.

GNSS System	Freq. Band / Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
NavIC/ IRNSS	L5 / 1176.45	A SPS	C5A	L5A	D5A	S5A
		B RS (D)	C5B	L5B	D5B	S5B
		C RS (P)	C5C	L5C	D5C	S5C
		B+C	C5X	L5X	D5X	S5X
	S / 2492.028	A SPS	C9A	L9A	D9A	S9A
		B RS (D)	C9B	L9B	D9B	S9B
		C RS (P)	C9C	L9C	D9C	S9C
		B+C	C9X	L9X	D9X	S9X

Table 20 : RINEX Version 3.05 NavIC/IRNSS Observation Codes

5.3 Observation Data Records

See Appendix A3 for a detailed specification of the RINEX 3 data record description. Below are some descriptions and clarifications for some of the data records elements.

Each observation record begins with the satellite identifier **snn** (see section 4.5), 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.

There is no data record length limitation as it depends on the declared constellation observation list and the available observables per satellite per epoch.

Table 21 shows a sample list of observation types for six satellite systems **G, E, S, R, C, J**.

G	22	C1C	L1C	D1C	S1C	C1W	S1W	C2W	L2W	D2W	S2W	C2L	L2L	D2L	SYS / # / OBS TYPES
		S2L	C5Q	L5Q	D5Q	S5Q	C1L	L1L	D1L	S1L					SYS / # / OBS TYPES
E	20	C1C	L1C	D1C	S1C	C6C	L6C	D6C	S6C	C5Q	L5Q	D5Q	S5Q	C7Q	SYS / # / OBS TYPES
		L7Q	D7Q	S7Q	C8Q	L8Q	D8Q	S8Q							SYS / # / OBS TYPES
S	8	C1C	L1C	D1C	S1C	C5I	L5I	D5I	S5I						SYS / # / OBS TYPES
R	20	C1C	L1C	D1C	S1C	C1P	L1P	D1P	S1P	C2P	L2P	D2P	S2P	C2C	SYS / # / OBS TYPES
		L2C	D2C	S2C	C3Q	L3Q	D3Q	S3Q							SYS / # / OBS TYPES
C	20	C1P	L1P	D1P	S1P	C5P	L5P	D5P	S5P	C2I	L2I	D2I	S2I	C7I	SYS / # / OBS TYPES
		L7I	D7I	S7I	C6I	L6I	D6I	S6I							SYS / # / OBS TYPES
J	20	C1C	L1C	D1C	S1C	C2L	L2L	D2L	S2L	C5Q	L5Q	D5Q	S5Q	C1L	SYS / # / OBS TYPES
		L1L	D1L	S1L	C1Z	L1Z	D1Z	S1Z							SYS / # / OBS TYPES

Table 21 : Example Observation Type Records

RINEX observation measures are written as detailed in section 6.7. An epoch and partial observation records example is provided in Table 22. The long observation lines per satellite are wrapped to fit the table width, each new line starts with a PRN and continues (indicated by →) until the next PRN.

>	2020	01	28	00	00	0.0000000	0	48							
C19	24654392.553	7	129559707.78007			-2902.686	7		44.750	24654395.451					
→7	96749126.04807		-2167.576	7		44.500		24654390.675	7	128381880.85807					
→2876.245		7								46.250					
→24654391.375	7	104320752.71507				-2337.249	7		45.250						
E04	23840346.329	7	125281891.86507			1327.432	7		47.250	23840348.158					
→8	101689874.47708		1077.475	8		50.500		23840349.531	8	93554698.18708					
→991.252	8		50.500		23840347.337	8	95995235.59308			1017.092	8				
→50.750		23840348.470	8	94774971.96308		1004.174	8			53.750					
G02	22187868.655	7	116598092.03507			1322.609	7		46.750	22187867.444					
→5		34.750		22187866.324	5	90855658.54005		1030.607	5	34.750					
J02	39360055.791	6	206838418.87206			-2309.902	6		41.500	39360060.423					
→6	161172711.84406		-1799.765	6		38.750		39360062.564	7	154457226.33407					
→1724.901	7		44.250		39360056.067	7	206838395.87407			-2309.921	7				
→42.000		39360052.638	6	206838394.23206		-2309.937	6			41.500					
R02	20785793.428	8	110917264.66308			-3161.955	8		50.000	20785793.589					
→8	110917013.67108		-3161.968	8		50.500		20785800.249	7	86268837.39807					
→2459.221	7		46.250		20785800.084	7	86268905.40407			-2459.355	7				
→45.750															
S29	40051393.288	5	210471465.60005			2.190	5		35.750						
S38	37925915.028	7	199302015.88507			-3.269	7		45.750	37925889.993					
→8	148829334.35608		-2.392	8		49.250									

Table 22 : Example RINEX Observation Epoch

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. The clock correction is optional and is given in units of seconds.

5.3.1 Order of Data records

Multiple epoch observation data records with identical time tags are not allowed (exception: Event records).

Epochs in a RINEX file have to be listed ordered in time.

5.3.2 Event flag records

Special occurrences during the tracking can be indicated in the **EPOCH** event flag in a RINEX file. The event flag is the integer after the number of seconds in the epoch, different such events can be indicated using integers;

- 2 - start moving antenna
- 3 - new site occupation (end of kinematic data) (at least **MARKER NAME** record follows)
- 4 - header information follows
- 5 - external event (epoch is significant, same time frame as observation time tags)

The “number of satellites” field if the event field is ≥ 2 then corresponds to the number of records of the same epoch following the **EPOCH** record. Therefore, the “number of satellites” in the **EPOCH** may be used to skip the appropriate number of data records if certain event flags are not to be evaluated in detail.

5.3.3 RINEX observation data records for GEO & SBAS satellites

Satellite-Based Augmentation System (SBAS) payloads on GEO satellites transmitting navigation signals. The satellite identifier ‘**S**’ is to be used, as shown in Figure 1, in the **RINEX VERSION / TYPE** header line and to identify the satellite. The PRN ‘**nn**’ is defined as being the GEO PRN number minus 100;

e.g.: PRN = 120 \Rightarrow **Snn** = **S20**

For GNSS constellations with mixed multi-frequency MEO satellites and single-frequency GEO payload observations, the fields for the second frequency observations of GEO satellites remain blank, are set to zero values, or (if last in the record) can be truncated.

5.3.4 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 and band/frequency. We may include this information as a pseudo-observable in each epoch data record line per satellite:

t : observation type:	x = Receiver channel number
n : band / frequency :	1, 2, ..., 9
a : attribute:	blank

The lowest channel number allowed is 1 (re-number channels beforehand, if necessary). In the 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. Using a Fortran float number 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

5.4 Navigation Message Files

The navigation file headers are generic for all satellite systems: GPS, GLONASS, Galileo, SBAS, QZSS and NavIC/IRNSS, except for the constellations specific “**IONOSPHERIC CORR**” records (See Appendix A5).

The data portion of the navigation message files contain the broadcast navigation data records with floating point numbers. The navigation message format is similar for all satellite systems. The number of records per message and the contents, however, are satellite system-dependent as detailed in the Appendices A6 - A19.

It is encouraged to generate mixed navigation message files, i.e. files containing navigation messages of more than one satellite system. Header records with system-dependent contents have to be repeated for each satellite system, if applicable. Using the satellite system identifier of the satellite code, the reading program can determine the number of data records to be read for each message block.

The time tags of the navigation messages (e.g., time of ephemeris, time of clock) are given in the respective satellite time systems following the convention described in section 4.1.

It is recommended to avoid storing redundant navigation messages (e.g., the same message broadcast at different times) in the RINEX file.

5.4.1 RINEX navigation data for GPS (LNAV)

The specifications for the GPS (LNAV) satellite navigation message are in Appendix A6. The first data record contains the epoch, and satellite clock information. The following six records contains the orbit parameters for the satellite, the time and period of applicability of the navigation message, the URA index of the satellite corresponding to the maximum URA expected over the fit interval, the GPS week number, the transmission time of message, the fit interval, the satellite health flag, and some other flags.

With the navigation message parameters, the corrections of the satellite time to UTC is as follows:

$$\text{GPS: } T_{\text{utc}} = T_{\text{sv}} - a_{f0} - a_{f1} * (T_{\text{sv}} - T_{\text{oc}}) - \dots - A_0 - \dots - \Delta t_{\text{LS}}$$

5.4.2 RINEX navigation data for GLONASS (FDMA)

The specifications for the GLONASS (FDMA) satellite navigation message are in Appendix A10. The first data record contains the epoch, and satellite clock information. The following three records contain the satellite position, velocity and acceleration, the clock and frequency biases, as well as auxiliary information such as health, satellite frequency (channel) and age of the information.

The last record includes Status and Health flags, the signal group delay difference and the accuracy index, but some of the values in the last record only apply to GLO-M/K satellites.

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

$$\text{GLONASS: } T_{\text{utc}} = T_{\text{sv}} + \tau_{\text{N}} - \gamma_{\text{N}} * (T_{\text{sv}} - T_{\text{b}}) + \tau_{\text{C}}$$

In order to use the same sign conventions, the broadcast GLONASS values are stored in the navigation data message as: $-\tau_{\text{N}}$, $+\gamma_{\text{N}}$, $-\tau_{\text{C}}$.

The time tags in the GLONASS navigation files are given in UTC (i.e. **not** Moscow time or GPS time).

5.4.3 RINEX navigation data for Galileo

The specifications for the Galileo satellite navigation message are in Appendix A8. The Galileo Open Service allows access to two navigation message types: F/NAV (Freely Accessible Navigation) and I/NAV (Integrity Navigation). The content of the two messages differs in various items, however, in general it is very similar to the content of the GPS (LNAV) navigation message, e.g. the orbit parameterization is the same.

There are items in the navigation message that depend on the origin of the message (F/NAV or I/NAV): The SV clock parameters actually define the satellite clock for the dual-frequency ionosphere-free linear combination. F/NAV reports the clock parameters valid for the E5a-E1 combination, the I/NAV reports the parameters for the E5b-E1 combination. The second parameter in the **Broadcast Orbit 5** record (bits 8 and 9) indicates the frequency pair the stored clock corrections are valid for.

RINEX file encoders should encode one RINEX Galileo navigation message for each I/NAV and F/NAV signal decoded. Therefore, if both I/Nav and F/Nav messages are decoded, then the relevant bit fields must be set in the RINEX message and both should be written in separate messages. The Galileo ICD Section 5.1.9.2 indicates that some of the contents of the broadcast navigation message may change, yet the issue of data (IOD) may not change. To ensure that all relevant information is available message encoders should monitor the contents of the file and write new navigation messages when the contents have changed.

RINEX file parsers should expect to encounter F/NAV and I/NAV messages with the same IOD in the same file. Additionally, parsers should also expect to encounter more than one F/NAV or I/NAV ephemeris message with the same IOD, as the navigation message Data Validity Status (DVS) and other parameters may change independently of the IOD, yet some other data may be the same, however, the transmission time will be updated (See Note in Galileo ICD Section 5.1.9.2 Issue of Data).

As mentioned in section 4.1.8 the GAL week in the RINEX navigation message files is a continuous number; it has been aligned to the GPS week by the program creating the RINEX file.

5.4.4 RINEX navigation data for SBAS satellites

The specifications for SBAS satellite navigation message are in Appendix A16. Navigation data records for SBAS satellites are mainly based on the contents of the MT 9 "GEO Navigation Message" with optional health information from the MT 17 "GEO Almanacs" message.

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 (health, URA and IODN).

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

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

$$\text{GEO: } \text{Tutc} = \text{Tsv} - \text{aGf0} - \text{aGf1} * (\text{Tsv} - \text{Toe}) - \text{W0} - \Delta\text{tLS}$$

W0 being the correction to transform the GEO system time to UTC. See Toe, aGf0, aGf1 in the Appendix A16 format definition table.

The *Transmission Time of Message* (**SV / 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*. If necessary, the *Transmission Time of Message* may have to be adjusted by - or + 604800 seconds (which would make it lower than zero or larger than 604800, respectively and then further corrected to correspond to the *Epoch of Ephemeris*) so that it is referenced to the GPS week of the *Epoch of Ephemeris*.

Health is 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

The time system identifier of SBAS GEO satellites generating GPS signals defaults to GPS time. In the SBAS message definitions, bit 3 of the health word 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, as well.

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.

5.4.5 RINEX navigation data for BDS

The BDS Open Service broadcast navigation message is defined in Appendix A14. As with all other message the first data record contains epoch and satellite clock information, followed by the orbit parameters, several time parameters, and health and accuracy flags.

The BDT week number is a continuous number. The broadcast 13-bit BDS System Time week has a roll-over after 8191. It starts at zero on: 1-Jan-2006, hence BDT week = BDT week_BRD + (n*8192) (Where n: number of BDT roll-overs). See Appendix Table A14 for details.

5.4.6 RINEX navigation data for NavIC/IRNSS

The NavIC/IRNSS Open Service broadcast navigation message is similar in content to the GPS LNAV navigation message.

See Appendix A18 and A19 for a description and example of each field.

6 RINEX FORMATTING CLARIFICATIONS

6.1 Versions

Programs developed to read RINEX files have to verify the version number, and take proper action if it cannot deal with it.

Files of newer versions may look different even if they do not use any of the newer features.

6.2 Leading blanks in CHARACTER fields

We propose that routines to read files automatically should 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 largest possible observation record¹ 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/Spare Fields

In view of future format evolutions, we recommend to carefully skip any fields currently defined to be Blank or Spare (format fields nX), because they may be assigned to new contents in future versions.

Blank or Spare fields are recommended to be left blank so as to avoid confusion.

6.5 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 (Blank if Not Known - BNK) 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.

6.6 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.

¹ Record is defined by the satellite system with the largest number of possible observables. The length limitation to 80 characters of the observation data records has been removed.

6.7 Floating point numbers in Observation data records

RINEX observation measures are written as floating point values with three decimals and a total field width of 14 characters (e.g. Fortran F14.3 format). Following each observation, a two-digit field for optional loss-of-lock indicator (LLI) (only for phase observation) and signal strength indicators (SSI) is provided.

Example:

PRN	code (m)	phase (cycles)
---	-----	-----
G02	22187868.655	7 116598092.03507
R09	22677458.268	6 121096420.07006

SSI ↗
LLI ↗ ↗ SSI

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 bit 0 of LLI indicator.

6.7.1 Loss of lock indicator (LLI)

For phase observations only. The LLI values are three-bit codes (binary 000-111) stored as decimals 0-7. Each bit has a special meaning;

0 or blank: OK or not known.

Bit 0 set: Lost lock between previous and current observation: Cycle slip possible. For phase observations only. Note: Bit 0 is the least significant bit.

Bit 1 set: Half-cycle ambiguity/slip possible. Software not capable of handling half cycles should skip this observation. Valid for the current epoch only.

Bit 2 set: BOC-tracking of an MBOC-modulated signal (may suffer from increased noise).

6.7.2 Signal Strength Indicator (SSI)

Signal strength indicators are part of the code and phase observations to offer a compact quality indicator. 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 **sn_raw** is given in **dbHz**:

$$\text{sn_rnx} = \text{MIN}(\text{MAX}(\text{INT}(\text{sn_raw}/6), 1), 9)$$

Carrier to Noise ratio (dbHz)	Carrier to Noise ratio (Observations)
N/A	0 or blank (not known, don't care)
< 12	1 (minimum possible signal strength)
12-17	2
18-23	3
24-29	4
30-35	5 (threshold for good tracking)
36-41	6
42-47	7
48-53	8
≥ 54	9 (maximum possible signal strength)

Table 23 : Standardized SNR Indicators

Additionally, observation codes per signal are specified to store detailed signal strength observations 'Sna' (see Table 14 - Table 20). The **SIGNAL STRENGTH UNIT** header record can be used to indicate the units of these observations.

6.8 Floating point numbers in Navigation data records

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

Examples, from different station navigation files:

```
1.175282523036D-05 4.381518345326D-03 8.882023394108D-06 6.493065311432D+03
1.266124167725E-09 2.000000000000E+00 2.069000000000E+03 1.000000000000E+00
-4.411928222656e+03-3.539047241211e+00 9.313225746155e-10 0.000000000000e+00
```

The same exponent indicator will be used throughout a station navigation file.

6.9 Navigation data stored bitwise

Some Navigation parameters contain the data stored bitwise. The interpretation is as follows:

- Convert the floating-point number read from the RINEX file into the nearest integer
- Extract the values of the requested bits from the integer

Examples:

```
0.170000000000D+02 → 17 → 10001 ; Bits 4,0 are set, all others are zero
1.790000000000E+02 → 179 → 10110011 ; Bits 7,5,4,1,0 are set, all others are zero
6.300000000000e+02 → 63 → 111111 ; all six bits are set
5.130000000000D+02 → 513 → 1000000001 ; Bits 9,0 are set , all others are zero
4.800000000000e+01 → 48 → 110000 ; Bits 5,4 are set , all others are zero
```

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8 APPENDIX: RINEX FORMAT DEFINITIONS AND EXAMPLES

A1 RINEX Long Filenames

Modern operating systems support 255-character file names and thus RINEX has evolved to a file naming convention that is more descriptive, flexible and extensible.

Figure 2 lists the filename elements from the RINEX 3.02 onwards;

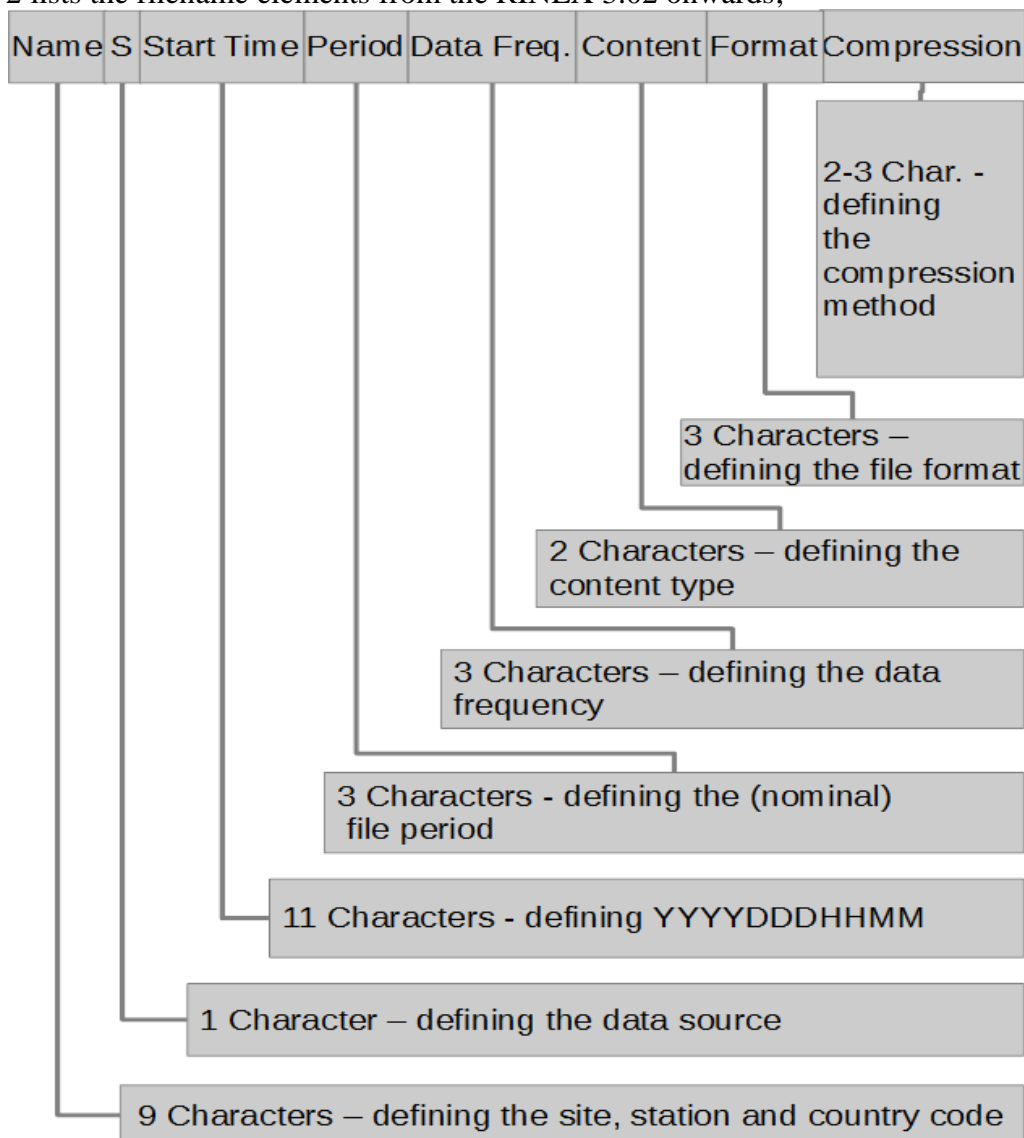


Figure 2: RINEX Long filename parameters.

All elements of the main body of the file name must contain capital ASCII letters or numbers and all elements are fixed length and are separated by an underscore “_”. The file type and compression fields (extension) use a period “.” as a separator and must be ASCII characters and lower case. Fields must be padded with zeros to fill the field width. The file compression field is optional.

In order to further reduce the size of observation files, Yuki Hatanaka developed a 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 standard compression programs.

More information on the Hatanaka compression scheme can be found in:

<http://terras.gsi.go.jp/ja/crx2rnx.html>

- IGS Mails 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.

Table A1 RINEX File name description				
Field	Field Description	Example	Required	Comment/Example
<SITE/ STATION- MONUMENT/ RECEIVER/ COUNTRY>	XXXXMRCCC Where: XXXX - existing IGS station name M – monument or marker number (0-9) R – receiver number (0-9) CCC – ISO Country code (Total 9 characters)	ALGO00CAN	Yes	File name supports a maximum of 10 monuments at the same station and a maximum of 10 receivers per monument. Country codes follow : ISO 3166- 1 alpha-3
<DATA SOURCE>	Data Source R – From Receiver data using vendor or other software S – From data Stream (RTCM or other) U – Unknown (1 character)	R	Yes	This field is used to indicate how the data was collected either from the receiver at the station or from a data stream
<START TIME>	YYYYDDHMM YYYY – Gregorian year 4 digits, DDD – day of Year, HHMM – hours and minutes of day (11 characters)	2012150 1200	Yes	For GPS files use : GPS Year, day of year, hour of day, minute of day (see text below for details) Start time should be the nominal start time of the first observation. GLONASS, Galileo, BeiDou etc use respective time system.
<FILE PERIOD>	DDU DD – file period U – units of file period. File period is used to specify intended collection period of the file. (3 characters)	15M	Yes	File Period 15M–15 Minutes 01H–1 Hour 01D–1 Day 01Y–1 Year 00U-Unspecified
<DATA FREQ>	DDU DD – data frequency	05Z	Mandatory for RINEX Obs. Data.	XXC – 100 Hertz XXZ – Hertz, XXS – Seconds,

Table A1 RINEX File name description				
Field	Field Description	Example	Required	Comment/Example
	U – units of data rate (3 characters)		NOT required for Navigation Files.	XXM – Minutes, XXH – Hours, XXD – Days XXU – Unspecified
<DATA TYPE>	DD DD – Data type (2 characters)	MO	Yes	Two characters represent the data type: GO - GPS Obs. RO - GLONASS Obs. EO - Galileo Obs. JO - QZSS Obs. CO - BDS Obs. IO – NavIC/IRNSS Obs. SO - SBAS Obs. MO - Mixed Obs. GN - Nav. GPS RN - GLONASS Nav. EN - Galileo Nav. JN - QZSS Nav. CN - BDS Nav. IN – NavIC/IRNSS Nav. SN - SBAS Nav. MN – Mixed Nav. (All GNSS Constellations) MM-Meteorological Observation
<FORMAT>	FFF FFF – File format (3 characters)	rnx	Yes	Three character indicating the data format: rnx - RINEX, Hatanaka Compressed RINEX
<COMPRESSION>	(2-3 Characters)	gz	No	gz
Sub Total	34 or 35			Fields
Separators	(7 characters –Obs. File) (6 characters –Eph. File)			_ underscore between all fields and “.” Between data type and file format and the compression method
Total	41-42(Obs. File) 37-38 (Eph. File)			Mandatory IGS RINEX obs. Characters

Filename Details and Examples:

<STATION/PROJECT NAME>: IGS users should follow XXXXMRCCL (9 char) site and station naming convention described above.

GNSS industry users could use the 9 characters to indicate the project name and/or number.

<DATA SOURCE>: With real-time data streaming RINEX files for the same station can be created at many locations. If the RINEX file is derived from data collected at the receiver

(official file) then the source is specified as R. On the other hand if the RINEX file is derived from a real-time data stream then the data source is marked as S to indicate Streamed data source. If the data source is unknown the source is marked as U.

<START TIME>: The start time is the file start time which should coincide with the first observation in the file. GPS file start time is specified in GPS Time. Mixed observation file start times are defined in the same time system as the file observation time system specified in the header. Files containing only: GLONASS, Galileo, QZSS, BDS or SBAS observations are all based on their respective time system.

<FILE PERIOD>: Is used to specify the data collection period of the file.

GNSS observation file name - file period examples:

ALGO00CAN_R_20121601000_15M_01S_GO.rnx.gz //15 min, GPS Obs. 1 sec.

ALGO00CAN_R_20121601000_01H_05Z_MO.rnx.gz //1 hour, Obs Mixed and 5Hz

ALGO00CAN_R_20121601000_01D_30S_GO.rnx.gz //1 day, Obs GPS and 30 sec

ALGO00CAN_R_20121601000_01D_30S_MO.rnx.gz //1 day, Obs. Mixed, 30 sec

GNSS navigation file name - file period examples:

ALGO00CAN_R_20121600000_15M_GN.rnx.gz // 15 minute GPS only

ALGO00CAN_R_20121600000_01H_GN.rnx.gz // 1 hour GPS only

ALGO00CAN_R_20121600000_01D_MN.rnx.gz // 1 day mixed

<DATA FREQ>: Used to distinguish between observation files that cover the same period but contain data at a different sampling rate. GNSS data file - observation frequency examples:

ALGO00CAN_R_20121601000_01D_01C_GO.rnx.gz //100 Hz data rate

ALGO00CAN_R_20121601000_01D_05Z_RO.rnx.gz //5 Hz data rate

ALGO00CAN_R_20121601000_01D_01S_EO.rnx.gz //1 second data rate

ALGO00CAN_R_20121601000_01D_05M_JO.rnx.gz //5 minute data rate

ALGO00CAN_R_20121601000_01D_01H_CO.rnx.gz //1 hour data rate

ALGO00CAN_R_20121601000_01D_01D_SO.rnx.gz //1 day data rate

ALGO00CAN_R_20121601000_01D_00U_MO.rnx.gz //Unspecified

Note: Data frequency field not required for RINEX Navigation files.

< DATA TYPE/ FORMAT/>: The data type describes the content of the file. The first character indicates constellation and the second indicates whether the files contains

observations or navigation data. The next three characters indicate the data file format. GNSS observation filename - format/data type examples:

ALGO00CAN_R_20121601000_15M_01S_GO.rnx.gz //RINEX obs. GPS
 ALGO00CAN_R_20121601000_15M_01S_RO.rnx.gz //RINEX obs. GLONASS
 ALGO00CAN_R_20121601000_15M_01S_EO.rnx.gz //RINEX obs. Galileo
 ALGO00CAN_R_20121601000_15M_01S_JO.rnx.gz //RINEX obs. QZSS
 ALGO00CAN_R_20121601000_15M_01S_CO.rnx.gz //RINEX obs. BDS
 ALGO00CAN_R_20121601000_15M_01S_SO.rnx.gz //RINEX obs. SBAS
 ALGO00CAN_R_20121601000_15M_01S_MO.rnx.gz //RINEX obs. mixed

GNSS navigation filename examples:

ALGO00CAN_R_20121600000_01H_GN.rnx.gz //RINEX nav. GPS
 ALGO00CAN_R_20121600000_01H_RN.rnx.gz //RINEX nav. GLONASS
 ALGO00CAN_R_20121600000_01H_EN.rnx.gz //RINEX nav. Galileo
 ALGO00CAN_R_20121600000_01H_JN.rnx.gz //RINEX nav. QZSS
 ALGO00CAN_R_20121600000_01H_CN.rnx.gz //RINEX nav. BDS
 ALGO00CAN_R_20121600000_01H_SN.rnx.gz //RINEX nav. SBAS
 ALGO00CAN_R_20121600000_01H_MN.rnx.gz //RINEX nav. mixed

Meteorological filename example:

ALGO00CAN_R_20121600000_01D_30M_MM.rnx.gz //RINEX Met.

<COMPRESSION>:

Valid compression methods include: gzip - “.gz”, bzip2 - “.bz2” and “.zip”.

Note: The main body of the file name should contain only ASCII capital letters and numbers. The file extension “.rnx.gz” should be lowercase.

A2 GNSS Observation Data File - Header Description

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
RINEX VERSION / TYPE	– Format version: 3.05 – File type: O for Observation Data – Satellite System: G : GPS R : GLONASS E : Galileo J : QZSS C : BDS I : NavIC/IRNSS S : SBAS payload M : Mixed	F9.2, 11X A1,19X A1,19X
PGM / RUN BY / DATE	– Name of program creating current file – Name of agency creating current file – Date and time of file creation Format: yyyyymmdd hhmmss zone zone: 3-4 char. code for time zone. 'UTC' recommended! 'LCL' if local time with unknown local time system code	A20 A20 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 (also see 5.2.3): GEODETIC : Earth-fixed, high- precision monument NON_GEODETIC : Earth-fixed, low- precision monument NON_PHYSICAL : Generated from network processing SPACEBORNE : Orbiting space vehicle GROUND_CRAFT : Mobile terrestrial vehicle WATER_CRAFT : Mobile water craft AIRBORNE : Aircraft, balloon, etc. 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	A20,40X

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	Record required except for GEODETIC and NON_GEODETIC marker types. Users may define other project-dependent keywords.	
OBSERVER / AGENCY	– Name of observer / agency	A20,A40
REC # / TYPE / VERS	– Receiver number, type, and version (Version: e.g. Internal Software Version)	3A20
ANT # / TYPE	– Antenna number and type	2A20
APPROX POSITION XYZ	– Geocentric approximate marker position (Units: Meters, System: ITRS recommended) Optional for moving platforms	3F14.4
ANTENNA: DELTA H/E/N	– Antenna height: Height of the antenna reference point (ARP) above the marker	F14.4
	– Horizontal eccentricity of ARP relative to the marker (east/north) All units in meters (see section 5.2.4)	2F14.4
*ANTENNA: DELTA X/Y/Z	– Position of antenna reference point for antenna on vehicle (m): XYZ vector in body-fixed coordinate system (see section 5.2.7)	3F14.4
*ANTENNA: PHASECENTER	Average phase center position with respect to antenna reference point (m) (see section 5.2.5) – Satellite system (G/R/E/J/C/I/S) – Observation code – North/East/Up (fixed station) or – X/Y/Z in body-fixed system (vehicle)	A1 1X,A3 F9.4 2F14.4
*ANTENNA: B.SIGHT XYZ	– Direction of the “vertical” antenna axis towards the GNSS satellites. Antenna on vehicle: Unit vector in body-fixed coordinate system. Tilted antenna on fixed station: Unit vector in N/E/Up left-handed system.	3F14.4
*ANTENNA: ZERODIR AZI	– Azimuth of the zero-direction of a fixed antenna (degrees, from north)	F14.4
*ANTENNA: ZERODIR XYZ	– Zero-direction of antenna Antenna on vehicle: Unit vector in body-fixed coordinate system Tilted antenna on fixed station: Unit vector in N/E/Up left-handed system	3F14.4
*CENTER OF MASS: XYZ	– Current center of mass (X,Y,Z, meters) of vehicle in body-fixed coordinate system. Same system as used for attitude. (see section 5.2.7)	3F14.4
SYS / # / OBS TYPES	– Satellite system code (G/R/E/J/C/I/S) – Number of different observation types for the specified satellite system Observation descriptors: Type, Band, Attribute	A1 2X,I3 13(1X,A3)

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	<p>– Use continuation line(s) for more than 13 observation descriptors.</p> <p>In mixed files: Repeat for each satellite system. These records should precede any SYS / SCALE FACTOR records (see below).</p> <p>The following observation descriptors are defined in RINEX Version 3.XX:</p> <p><u>Type:</u></p> <p>C = Code / Pseudorange L = Phase D = Doppler S = Raw signal strength (carrier to noise ratio) X = Receiver channel numbers</p> <p><u>Band:</u></p> <p>1 = L1 (GPS, QZSS, SBAS, BDS) G1 (GLO) E1 (GAL) B1C/B1A (BDS)</p> <p>2 = L2 (GPS, QZSS) G2 (GLO) B1 (BDS)</p> <p>3 = G3 (GLO)</p> <p>4 = G1a (GLO)</p> <p>5 = L5 (GPS, QZSS, SBAS, NavIC/IRNSS) E5a (GAL) B2a (BDS)</p> <p>6 = E6 (GAL) L6 (QZSS) B3/B3A (BDS) G2a (GLO)</p> <p>7 = E5b (GAL) B2/B2b (BDS)</p> <p>8 = E5a+b (GAL) B2a+b (BDS)</p> <p>9 = S (NavIC/IRNSS)</p> <p><u>Attribute:</u></p> <p>A = A channel (GAL, NavIC/IRNSS, GLO)</p> <p>B = B channel (GAL, NavIC/IRNSS, GLO)</p> <p>C = C channel (GAL, NavIC/IRNSS) C code-based (SBAS,GPS,GLO,QZSS)</p> <p>D = Semi-codeless (GPS, QZSS) Data Channel (BDS)</p>	<p>6X, 13(1X,A3)</p>

TABLE A2
GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION

	<p> E = E Channel (QZSS) I = I channel (GPS,GAL, QZSS, BDS) L = L channel (L2C GPS, QZSS) P channel (GPS, QZSS) M = M code-based (GPS) N = Codeless (GPS) P = P code-based (GPS,GLO) Pilot Channel (BDS) Q = Q channel (GPS,GAL,QZSS,BDS) S = D channel (GPS, QZSS) M channel (L2C GPS, QZSS) W = Based on Z-tracking (GPS)(see text) X = B+C channels (GAL, NavIC/IRNSS) I+Q channels (GPS,GAL, QZSS,BDS) M+L channels (GPS, QZSS) D+P channels (GPS, QZSS, BDS) Y = Y code-based (GPS) Z = A+B+C channels (GAL) D+P channels (BDS) I+Q channels. (QZSS) D+E channels. (QZSS) </p> <p>All characters in uppercase only!</p> <p><u>Units:</u></p> <p> Phase; full cycles Pseudorange; meters Doppler; Hz SNR etc.; receiver-dependent Channel #; See 5.3.4 </p> <p>Sign definition: See text.</p> <p>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. (see section 5.3)</p> <p>Note: In RINEX 3.XX, all fields (Type, Band and Attribute) must be defined, only known tracking mode attributes are allowed (except for observation Type ‘X’ which has attribute of blank, see section 5.3.4).</p>	
*SIGNAL STRENGTH UNIT	– Unit of the carrier to noise ratio observables Snn (if present) DBHZ : S/N given in dbHz	A20,40X
*INTERVAL	– Observation interval in seconds	F10.3
TIME OF FIRST OBS	– Time of first observation record (4-digit-year,	5I6,F13.7

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	month, day, hour, min, sec) – Time system (see section 5.2.8): GPS (=GPS time system) GLO (=UTC time system) GAL (=Galileo time system) QZS (= QZSS time system) BDT (= BDS time system) IRN (=NavIC/IRNSS time system) Compulsory in mixed GNSS files Default values for single system GNSS files (not compulsory): GPS for pure GPS files GLO for pure GLONASS files GAL for pure Galileo files QZS for pure QZSS files BDT for pure BDS files IRN for pure NavIC/IRNSS files	5X,A3
*TIME OF LAST OBS	– Time of last observation record (4-digit-year, month, day, hour, min, sec) – Time system: Same value as in TIME OF FIRST OBS record (see section 5.2.8).	5I6,F13.7 5X,A3
*RCV CLOCK OFFS APPL	– Epoch, code, and phase are corrected by applying the real-time-derived receiver clock offset: 1=yes, 0=no; default: 0=no Record required if clock offsets are reported in the EPOCH/SAT records	I6
*SYS / DCBS APPLIED	– Satellite system (G/R/E/J/C/I/S) – Program name used to apply differential code bias corrections – Source of corrections (URL) Repeat for each satellite system. No corrections applied: Blank fields or record not present.	A1 1X,A17 1X,A40
*SYS / PCVS APPLIED	– Satellite system (G/R/E/J/C/I/S) – Program name used to apply phase center variation corrections – Source of corrections (URL) Repeat for each satellite system. No corrections applied: Blank fields or record not present.	A1 1X,A17 1X,A40
*SYS / SCALE FACTOR	– Satellite system (G/R/E/J/C/I/S) – Factor to divide stored observations with before use (1,10,100,1000)	A1 1X,I4

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	<ul style="list-style-type: none"> – Number of observation types involved. 0 or blank: All observation types – List of observation types – Use continuation line(s) for more than 12 observation types. <p>Repeat record if different factors are applied to different observation types. A value of 1 is assumed if record is missing. (see section 5.2.11)</p>	2X,I2 12(1X,A3) 10X 12(1X,A3)
SYS / PHASE SHIFT	<p>Phase shift correction used to generate phases consistent with respect to cycle shifts</p> <ul style="list-style-type: none"> – Satellite system (G/R/E/J/C/I/S) – Carrier phase observation code: Type Band Attribute – Correction applied (cycles) – Number of satellites involved 0 or blank: All satellites of system – List of satellites – Use continuation line(s) for more than 10 satellites. <p>Repeat the record for all affected codes. See section 5.2.12 for more details.</p>	A1,1X A3,1X F8.5 2X,I2.2 10(1X,A3) 18X 10(1X,A3)
GLONASS SLOT / FRQ #	<p>GLONASS slot and frequency numbers</p> <ul style="list-style-type: none"> – Number of satellites in list <p>List of:</p> <ul style="list-style-type: none"> – Satellite numbers (system code, slot) – Frequency numbers (-7...+6) – Use continuation lines for more than 8 Satellites 	I3,1X 8(A1,I2.2, 1X,I2,1X) 4X,8(A1, I2.2,1X,I2, 1X)
GLONASS COD/PHS/BIS	<ul style="list-style-type: none"> – GLONASS Phase bias correction used to align code and phase observations. <ul style="list-style-type: none"> • GLONASS signal identifier: C1C and Code Phase bias correction (meters) • GLONASS signal identifier: C1P and Code Phase bias correction (meters) • GLONASS signal identifier: C2C and Code Phase bias correction (meters) • GLONASS signal identifier: C2P and Code Phase bias correction (meters) 	4(X1,A3,X 1,F8.3)

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	Note: See section 5.2.16 for further details. If the GLONASS code phase bias values are unknown then all fields in the record are left blank and only the record header is defined.	
*LEAP SECONDS	<ul style="list-style-type: none"> – Current Number of leap seconds – Future or past leap seconds $\Delta t_{LSF}(BNK)$, i.e. future leap second if the week and day number are in the future. – Respective week number WN_{LSF} (continuous number) (BNK). For GPS, GAL, QZS and IRN, weeks since 6-Jan-1980. When BDS only file leap seconds specified, weeks since 1-Jan-2006. – Respective day number DN (0-6) BeiDou and (1-7) for GPS and others constellations, (BNK). The day number is the GPS or BeiDou day before the leap second (See Note 1 below). In the case of the Tuesday, June 30/2015 (GPS Week 1851, DN 3) the UTC leap second actually occurred 16 seconds into the next GPS day. – Time system identifier: only GPS and BDT are valid identifiers. Blank defaults to GPS, see Notes section below. Notes: <ol style="list-style-type: none"> 1. GPS, GAL, QZS and IRN time systems are aligned and equivalent with respect to leap seconds (Leap seconds since 6-Jan-1980). See the GPS almanac, and DN reference IS-GPS-200L 20.3.3.5.2.4. 	I6 I6 I6 I6 A3
*# OF SATELLITES	<ul style="list-style-type: none"> – Number of satellites, for which observations are stored in the file 	I6
*PRN / # OF OBS	<ul style="list-style-type: none"> – Satellite IDs, number of observations for each observation type indicated in the SYS / # / OBS TYPES record. – If more than 9 observation types: Use continuation line(s) In order to avoid format overflows, 99999 indicates ≥ 99999 observations in the RINEX file. <p>These records are repeated for each satellite in the data file.</p>	3X A1,I2.2 9I6 6X,9I6
END OF HEADER	Last record in the header section.	60X

Records marked with * are optional

A3 GNSS Observation Data File - Data Record Description

TABLE A3 GNSS OBSERVATION DATA FILE – DATA RECORD DESCRIPTION	
DESCRIPTION	FORMAT
<p><i>EPOCH</i> record</p> <ul style="list-style-type: none"> – Record identifier : > Epoch – year (4 digits): – month, day, hour, min (two digits) – sec – Epoch flag, 0: OK 1: power failure between previous and current epoch >1: Special event – Number of satellites observed in current epoch – (reserved) – Receiver clock offset (seconds, optional) 	<p>A1</p> <p>1X,I4 4(1X,I2.2) F11.7 2X,I1</p> <p>I3 6X F15.12</p>
<p>Epoch flag = 0 or 1: OBSERVATION records follow</p> <ul style="list-style-type: none"> – Satellite number – <i>m</i> fields of observation data (in the same sequence as given in the respective SYS / # / OBS TYPES record), each containing the specified observations for example: pseudorange, phase, Doppler and SNR. – Loss of Lock Indicator - LLI (see Notes, below) – Signal Strength Indicator - SSI (see Notes, below) <p>This record is repeated for each satellite having been observed in the current epoch. The record length is given by the number of observation types for this satellite. For observations formatting see section 6.7.</p> <p>Notes (see also section 6.7):</p> <ol style="list-style-type: none"> 1. Loss of Lock Indicator (LLI) should only be associated with the phase observation. 2. Signal Strength Indicator (SSI) should be deprecated and replaced by a defined SNR field for each signal. However, if this is not possible/practical then SSI should be specified for each phase signal type for example. GPS: L1C, L1W, L2W, L2X and L5X. 3. If only the pseudorange measurements are observed then the SSI should be associated with the code measurements. 	<p>A1,I2.2 <i>m</i>(F14.3,</p> <p>I1, I1)</p>
<p>Epoch flag 2-5: EVENT: <i>Special records</i> may follow</p> <ul style="list-style-type: none"> – Epoch flag; (additionally see section 5.3.2) <ul style="list-style-type: none"> • 2: start moving antenna • 3: new site occupation (end of kinematic data) (at least MARKER NAME record follows) • 4: header information follows • 5: external event (epoch is significant, same time frame as 	<p>2X,I1</p>

TABLE A3 GNSS OBSERVATION DATA FILE – DATA RECORD DESCRIPTION	
observation time tags) – "Number of satellites" contains number of special records 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	I3
Epoch flag = 6: EVENT : <i>Cycle slip records</i> follow – Epoch flag <ul style="list-style-type: none"> • 6: cycle slip records follow to optionally report detected and repaired cycle slips (same format as OBSERVATIONS records; <ul style="list-style-type: none"> • slip instead of observation; • LLI and signal strength blank or zero) 	2X,I1

A4 GNSS Observation Data File – Example #1

TABLE A4 GNSS OBSERVATION DATA FILE - EXAMPLE #1									
3.05	OBSERVATION DATA	M						RINEX VERSION / TYPE	
G = GPS R = GLONASS E = GALILEO S = GEO M = MIXED								COMMENT	
XXRINEXO V9.9	AIUB	20060324 144333 UTC						PGM / RUN BY / DATE	
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	
G APPL_DCB	xyz.uvw.abc//pub/dcb_gps.dat							SYS / DCBS APPLIED	
DBHZ								SIGNAL STRENGTH UNIT	
2006 03 24 13 10 36.0000000	GPS							TIME OF FIRST OBS	
18 R01 1 R02 2 R03 3 R04 4 R05 5 R06 -6 R07 -5 R08 -4								GLONASS SLOT / FRQ #	
R09 -3 R10 -2 R11 -1 R12 0 R13 1 R14 2 R15 3 R16 4								GLONASS SLOT / FRQ #	
R17 5 R18 -5								GLONASS SLOT / FRQ #	
G L1C								SYS / PHASE SHIFT	
G L1W 0.00000								SYS / PHASE SHIFT	
G L2W								SYS / PHASE SHIFT	
R L1C								SYS / PHASE SHIFT	
E L1B								SYS / PHASE SHIFT	
E L5I								SYS / PHASE SHIFT	
S L1C								SYS / PHASE SHIFT	
C1C -10.000 C1P -10.123 C2C -10.432 C2P -10.634								GLONASS COD/PHS/BIS	
								END OF HEADER	
> 2006 03 24 13 10 36.0000000 0 5	-0.123456789012								
G06 23629347.915	.300 8	-0.353 4	23629347.158				24.158		
G09 20891534.648	-0.120 9	-0.358 6	20891545.292				38.123		
G12 20607600.189	-0.430 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 2									
*** FROM NOW ON KINEMATIC DATA! ***								COMMENT	
TWO COMMENT LINES FOLLOW DIRECTLY THE EVENT RECORD								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
9081.1.34
      .9050      .0000      .0000
      --> THIS IS THE START OF A NEW SITE <--
MARKER NAME
MARKER NUMBER
ANTENNA: DELTA H/E/N
COMMENT
> 2006 03 24 13 12 6.00000000 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
      AND AN EVENT FLAG 4 TO ESCAPE FOR THE TWO COMMENT LINES
COMMENT
COMMENT
> 2006 03 24 13 14 12.00000000 0 4      -0.123456012345
G06 21124965.133      0.30213      -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
      *** LOST LOCK ON G 06
COMMENT
.
.
.
>
> 4 1
END OF FILE
COMMENT
-----|-----1|0---|-----2|0---|-----3|0---|-----4|0---|-----5|0---|-----6|0---|-----7|0---|-----8|

```

A4 GNSS Observation Data File – Example #2

TABLE A4																	
GNSS OBSERVATION DATA FILE - EXAMPLE #2																	
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8																	
3.05		OBSERVATION DATA							M	RINEX VERSION / TYPE							
sbfin-9.3.3									20140511	000610	LCL	PGM / RUN BY / DATE					
faal									MARKER NAME								
92201M012									MARKER NUMBER								
Unknown		Unknown							OBSERVER / AGENCY								
3001320		SEPT POLARX4							2.5.1p1		REC # / TYPE / VERS						
725235		LEIAR25.R4							NONE		ANT # / TYPE						
-5246415.0000		-3077260.0000		-1913842.0000		APPROX POSITION XYZ											
0.1262		0.0000		0.0000		ANTENNA: DELTA H/E/N											
G	18	C1C	L1C	D1C	S1C	C1W	S1W	C2W	L2W	D2W	S2W	C2L	L2L	D2L	SYS / # / OBS TYPES		
		S2L	C5Q	L5Q	D5Q	S5Q									SYS / # / OBS TYPES		
E	16	C1C	L1C	D1C	S1C	C5Q	L5Q	D5Q	S5Q	C7Q	L7Q	D7Q	S7Q	C8Q	SYS / # / OBS TYPES		
		L8Q	D8Q	S8Q											SYS / # / OBS TYPES		
S	4	C1C	L1C	D1C	S1C										SYS / # / OBS TYPES		
R	12	C1C	L1C	D1C	S1C	C2P	L2P	D2P	S2P	C2C	L2C	D2C	S2C	SYS / # / OBS TYPES			
C	8	C2I	L2I	D2I	S2I	C7I	L7I	D7I	S7I							SYS / # / OBS TYPES	
J	12	C1C	L1C	D1C	S1C	C2L	L2L	D2L	S2L	C5Q	L5Q	D5Q	S5Q	SYS / # / OBS TYPES			
G	L1C														SYS / PHASE SHIFT		
G	L2W														SYS / PHASE SHIFT		
G	L2L	0.00000														SYS / PHASE SHIFT	
G	L5Q	0.00000														SYS / PHASE SHIFT	
E	L1C	0.00000														SYS / PHASE SHIFT	
E	L5Q	0.00000														SYS / PHASE SHIFT	
E	L7Q	0.00000														SYS / PHASE SHIFT	
E	L8Q	0.00000														SYS / PHASE SHIFT	
S	L1C														SYS / PHASE SHIFT		
R	L1C														SYS / PHASE SHIFT		
R	L2P	0.00000														SYS / PHASE SHIFT	
R	L2C														SYS / PHASE SHIFT		
C	L2I														SYS / PHASE SHIFT		
C	L7I														SYS / PHASE SHIFT		
J	L1C														SYS / PHASE SHIFT		
J	L2L	0.00000														SYS / PHASE SHIFT	
J	L5Q	0.00000														SYS / PHASE SHIFT	
30.000															INTERVAL		
2014	5	10	0	0	0.0000000					GPS	TIME OF FIRST OBS						
2014	5	10	23	59	30.0000000					GPS	TIME OF LAST OBS						
72														# OF SATELLITES			
C1C	0.000	C2C	0.000	C2P	0.000										GLONASS COD/PHS/BIS		
DBHZ															SIGNAL STRENGTH UNIT		
24	R01	1	R02	-4	R03	5	R04	6	R05	1	R06	-4	R07	5	R08	6	GLONASS SLOT / FRQ #
	R09	-2	R10	-7	R11	0	R12	-1	R13	-2	R14	-7	R15	0	R16	-1	GLONASS SLOT / FRQ #
	R17	4	R18	-3	R19	3	R20	2	R21	4	R22	-3	R23	3	R24	2	GLONASS SLOT / FRQ #
															END OF HEADER		
> 2014 05 10 00 00 0.0000000 0 28																	
END OF FILE															COMMENT		
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8																	

A4 GNSS Observation Data File – Example #3

TABLE A4														
GNSS OBSERVATION DATA FILE - EXAMPLE #3														
-----1 0-----2 0-----3 0-----4 0-----5 0-----6 0-----7 0-----8														
3.05 OBSERVATION DATA M: MIXED RINEX VERSION / TYPE														
R25 V3.08 20140513 072944 UTC PGM / RUN BY / DATE														
NR is mapped to RINEX snr flag value [1-9]														COMMENT
X: < 12dBHz -> 1; 12-17dBHz -> 2; 18-23dBHz -> 3														COMMENT
24-29dBHz -> 4; 30-35dBHz -> 5; 36-41dBHz -> 6														COMMENT
42-47dBHz -> 7; 48-53dBHz -> 8; >= 54dBHz -> 9														COMMENT
okio														MARKER NAME
OKI														MARKER NUMBER
J Japan - Leica Geosystems														OBSERVER / AGENCY
870023 LEICA GR25 3.08/6.401														REC # / TYPE / VERS
LEIAS10 NONE														ANT # / TYPE
-3956196.8609 3349495.1794 3703988.8347														APPROX POSITION XYZ
0.0000 0.0000 0.0000														ANTENNA: DELTA H/E/N
16 C1C L1C D1C S1C C2S L2S D2S S2S C2W L2W D2W S2W C5Q														SYS / # / OBS TYPES
L5Q D5Q S5Q														SYS / # / OBS TYPES
12 C1C L1C D1C S1C C2P L2P D2P S2P C2C L2C D2C S2C														SYS / # / OBS TYPES
16 C1C L1C D1C S1C C5Q L5Q D5Q S5Q C7Q L7Q D7Q S7Q C8Q														SYS / # / OBS TYPES
L8Q D8Q S8Q														SYS / # / OBS TYPES
8 C2I L2I D2I S2I C7I L7I D7I S7I														SYS / # / OBS TYPES
12 C1C L1C D1C S1C C2S L2S D2S S2S C5Q L5Q D5Q S5Q														SYS / # / OBS TYPES
4 C1C L1C D1C S1C														SYS / # / OBS TYPES
BHZ														SIGNAL STRENGTH UNIT
1.000														INTERVAL
2014 05 13 07 30 0.0000000 GPS														TIME OF FIRST OBS
2014 05 13 07 34 59.0000000 GPS														TIME OF LAST OBS
0														RCV CLOCK OFFS APPL
L1C														SYS / PHASE SHIFT
L2S -0.25000														SYS / PHASE SHIFT
L2W														SYS / PHASE SHIFT
L5Q -0.25000														SYS / PHASE SHIFT
L1C														SYS / PHASE SHIFT
L2P 0.25000														SYS / PHASE SHIFT
L2C														SYS / PHASE SHIFT
L1C +0.50000														SYS / PHASE SHIFT
L5Q -0.25000														SYS / PHASE SHIFT
L7Q -0.25000														SYS / PHASE SHIFT
L8Q -0.25000														SYS / PHASE SHIFT
L2I														SYS / PHASE SHIFT
L7I														SYS / PHASE SHIFT
L1C														SYS / PHASE SHIFT
L2S														SYS / PHASE SHIFT
L5Q -0.25000														SYS / PHASE SHIFT
L1C														SYS / PHASE SHIFT
24 R01 1 R02 -4 R03 5 R04 6 R05 1 R06 -4 R07 5 R08 6														GLONASS SLOT / FRQ #
R09 -2 R10 -7 R11 0 R12 -1 R13 -2 R14 -7 R15 0 R16 -1														GLONASS SLOT / FRQ #
R17 4 R18 -3 R19 3 R20 2 R21 4 R22 -3 R23 3 R24 2														GLONASS SLOT / FRQ #
C1C 0.000 C1P 0.000 C2C 0.000 C2P 0.000														GLONASS COD/PHS/BIS
16 1694 7														LEAP SECONDS
														END OF HEADER
2014 05 13 07 30 0.0000000 0 25														
END OF FILE														COMMENT
-----1 0-----2 0-----3 0-----4 0-----5 0-----6 0-----7 0-----8														

A5 GNSS Navigation Message File – Header Section Description

[illegible]

TABLE A5 GNSS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	<p>B=BDT 01h-02h; ... X= BDT 23h-24h.</p> <p>This field is mandatory for BDS and optional for the other constellations, (BNK).</p> <p>– SV ID, identify which satellite provided the ionospheric parameters. This field is mandatory for BDS and optional for the other constellations (BNK).</p> <p>Note 1: Multiple IONOSPHERIC CORR message can be written in the header.</p> <p>Note 2: It is recommended that BDS ionospheric broadcast model parameters from BDS GEO satellites, be given the most priority. Then the parameters from BDS IGSO satellites should be given secondary priority and then tertiary priority is given to BDS MEO satellite ionospheric correction parameters.</p>	1X,I2
*TIME SYSTEM CORR	<p>Difference between GNSS system time and UTC or other time systems</p> <p>– Type: GPUT = GPS - UTC (a0, a1) GLUT = GLO - UTC (a0= -TauC, a1=zero) GAUT = GAL - UTC (a0, a1) BDUT = BDS - UTC (a0=A_{0UTC}, a1=A_{1UTC}) QZUT = QZS - UTC (a0, a1) IRUT = IRN - UTC (a0=A_{0UTC}, a1=A_{1UTC}) SBUT = SBAS - UTC (a0, a1)</p> <p>GLGP = GLO - GPS (a0=-TauGPS, a1=zero) GAGP = GAL - GPS (See **Note Below) (a0 = A0G, a1 = A1G for GAL INAV/FNAV; a0 = -A0GGTO, a1 = -A1 GGTO for GPS CNAV) QZGP = QZS - GPS (a0, a1) IRGP =IRN - GPS (a0=A₀, a1=A₁)</p> <p>– a0, a1 coefficients of linear polynomial $\Delta t = a0 + a1 \cdot (t - t_{ref})$ for fractional part (excluding leap seconds) of time system difference (a0; sec, a1; sec/sec)</p>	<p>A4,1X</p> <p>D17.10 D16.9</p>

TABLE A5 GNSS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	<ul style="list-style-type: none"> – T Reference time for polynomial (Seconds into GPS/GAL/BDS/QZS/IRN/SBAS week) – W Reference week number; <ul style="list-style-type: none"> ○ GPS/GAL/QZS/IRN/SBAS week aligned to GPS, continuous number from 6-Jan-1980 ○ GLONASS T and W zero. ○ BDS week, continuous from: 1-Jan-2006 – Satellite ID; System identifier and PRN/slot number 'snn' of the GNSS satellite (see section 4.5) broadcasting the time system difference or SBAS satellite broadcasting the MT12. Use EGNOS, WAAS, or MSAS for SBAS time differences from MT17. – U UTC Identifier; 0 if unknown 1=UTC(NIST), 2=UTC(USNO), 3=UTC(SU), 4=UTC(BIPM), 5=UTC(Europe Lab), 6=UTC(CRL), 7=UTC(NTSC) (BDS), >7 = not assigned yet. <p>**Note: From RINEX 3.04 the GPGA label is replaced by GAGP, while the value and sign for the Galileo minus GPS time offset remains unchanged.</p>	1XI6 1XI4 1X,A5,1X I2,1X
*LEAP SECONDS	<ul style="list-style-type: none"> – Current Number of leap seconds – Future or past leap seconds Δt_{LSF} (BNK), i.e. future leap second if the week and day number are in the future. – Respective week number WN_LSF (continuous number) (BNK). For GPS, GAL, QZS and IRN, weeks since 6-Jan-1980. When BDS only file leap seconds specified, weeks since 1-Jan-2006. – Respective day number DN (0-6) BeiDou and (1-7) for GPS and others constellations, (BNK). The day number is the GPS or BeiDou day before the leap second (See Note 1 below). In the case of the Tuesday, June 30/2015 (GPS Week 1851, DN 3) the UTC leap second actually occurred 16 seconds into the next GPS day. – Time system identifier: only GPS and BDT 	I6 I6 I6 I6 A3

TABLE A5 GNSS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	<p>are valid identifiers. All data fields <u>must</u> match the indicated time system identifier. Blank defaults to GPS, see Notes section below.</p> <p>Notes:</p> <ol style="list-style-type: none"> 1. GPS, GAL, QZS and IRN time systems are aligned and are equivalent with respect to leap seconds (Leap seconds since 6-Jan-1980). See the GPS almanac and DN reference IS-GPS-200L 20.3.3.5.2.4. 2. For BDT Time System Identifier, the Number of leap seconds since 1-Jan-2006 as transmitted by the BDS almanac Δt_{LS} (see BDS-SIS-ICD-OS_B1C section 7.12.1). 3. GLO-only navigation files should not have this optional header written. 	
END OF HEADER		

Records marked with * are optional, BNK- Blank if Not Know/Defined

A6 GNSS Navigation Message File – GPS Data Record Description

TABLE A6 GNSS NAVIGATION MESSAGE FILE – GPS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
<i>SV / EPOCH / SV CLK</i>	<ul style="list-style-type: none"> - Satellite system (G), sat number (PRN) - Epoch: Toc - Time of Clock (GPS) year (4 digits) - month, day, hour, minute, second - SV clock bias (seconds) - SV clock drift (sec/sec) - SV clock drift rate (sec/sec²) 	A1,I2.2, 1X,I4, 5(1X,I2.2), 3D19.12 *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - IODE Issue of Data, Ephemeris - Crs (meters) - Delta n (radians/sec) - M0 (radians) 	4X,4D19.12 ***)
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Cuc (radians) - e Eccentricity - Cus (radians) - sqrt(A) (sqrt(m)) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Toe Time of Ephemeris (sec of GPS week) - Cic (radians) - OMEGA0 (radians) - Cis (radians) 	4X,4D19.12
BROADCAST ORBIT - 4	<ul style="list-style-type: none"> - i0 (radians) - Crc (meters) - omega (radians) - OMEGA DOT (radians/sec) 	4X,4D19.12
BROADCAST ORBIT - 5	<ul style="list-style-type: none"> - IDOT (radians/sec) - Codes on L2 channel - GPS Week # (to go with TOE) Continuous number, not mod(1024)! - L2 P data flag 	4X,4D19.12
BROADCAST ORBIT - 6	<ul style="list-style-type: none"> - SV accuracy (meters) See GPS ICD Section 20.3.3.3.1.3 use specified equations to define nominal values, N = 0-6: use $2^{(1+N/2)}$ (round to one decimal place i.e. 2.8, 5.7 and 11.3) , N= 7-15:use $2^{(N-2)}$, 8192 specifies use at own risk - SV health (bits 17-22 w 3 sf 1) - TGD (seconds) - IODC Issue of Data, Clock 	4X,4D19.12
BROADCAST ORBIT - 7	<ul style="list-style-type: none"> - Transmission time of message **) (sec of GPS week, derived e.g. from Z-count in Hand Over Word (HOW)) - Fit Interval in hours; bit 17 w 10 sf 2 + IODC & Table 20-XII of GPS ICD. (BNK if Unknown). - Spare(x2) (see Section 6.4) 	4X,4D19.12

*) see section 6.8.

) Adjust the *Transmission time of message* by ± 604800 to refer to the reported week in **BROADCAST ORBIT 5, if necessary. Set value to **.999999999999E+09** if not known.

***) Angles and their derivatives transmitted in units of semi-circles and semi-circles/sec have to be converted to radians by the RINEX generator.

A7 GPS Navigation Message File – Example

TABLE A7											
GPS NAVIGATION MESSAGE FILE - EXAMPLE											

A8 GNSS Navigation Mssg File – GALILEO Data Record Description

TABLE A8 GNSS NAVIGATION MESSAGE FILE - GALILEO DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
SV / EPOCH / SV CLK	<ul style="list-style-type: none"> - Satellite system (E), satellite number - Epoch: Toc - Time of Clock GALyear (4 digits) - month, day, hour, minute, second - SV clock bias (seconds) af0 - SV clock drift (sec/sec) af1 - SV clock drift rate (sec/sec²) af2 (see <i>Br.Orbit-5</i>, data source, bits 8+9) 	A1,I2.2, 1X,I4, 5(1X,I2.2), 3D19.12 *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - IODnav Issue of Data of the nav batch - Crs (meters) - Delta n (radians/sec) - M0 (radians) 	4X,4D19.12 ***)
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Cuc (radians) - e Eccentricity - Cus (radians) - sqrt(a) (sqrt(m)) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Toe Time of Ephemeris (sec of GAL week) - Cic (radians) - OMEGA0 (radians) - Cis (radians) 	4X,4D19.12
BROADCAST ORBIT - 4	<ul style="list-style-type: none"> - i0 (radians) - Crc (meters) - omega (radians) - OMEGA DOT (radians/sec) 	4X,4D19.12
BROADCAST ORBIT - 5	<ul style="list-style-type: none"> - IDOT (radians/sec) - Data sources (FLOAT → INTEGER) Bit 0 set: I/NAV E1-B Bit 1 set: F/NAV E5a-I Bit 2 set: I/NAV E5b-I Bits 0 and 2 : Both can be set if the navigation messages were merged, however, bits 0-2 cannot all be set, as the I/NAV and F/NAV messages contain different information. Bit 3 reserved for Galileo internal use Bit 4 reserved for Galileo internal use Bit 8 set: af0-af2, Toc, SISA are for E5a,E1 Bit 9 set: af0-af2, Toc, SISA are for E5b,E1 Bits 8-9 : exclusive (only one bit can be set) - GAL Week # (to go with TOE) - Spare (see Section 6.4) 	4X,4D19.12 *****) *****)
BROADCAST ORBIT - 6	<ul style="list-style-type: none"> - SISA Signal in space accuracy (meters) No Accuracy Prediction Available(NAPA) / 	4X,4D19.12

TABLE A8 GNSS NAVIGATION MESSAGE FILE - GALILEO DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
	unknown: -1.0 - SV health (FLOAT → INTEGER) See Galileo ICD Section 5.1.9.3 Bit 0: E1B DVS Bits 1-2: E1B HS Bit 3: E5a DVS Bits 4-5: E5a HS Bit 6: E5b DVS Bits 7-8: E5b HS - BGD E5a/E1 (seconds) - BGD E5b/E1 (seconds)	*****)
BROADCAST ORBIT - 7	- Transmission time of message **) (sec of GAL week, derived from WN and TOW of page type 1) - Spare(x3) (see Section 6.4)	4X,4D19.12

*) see section 6.8.

) Adjust the *Transmission time of message* by + or -604800 to refer to the reported week in **BROADCAST ORBIT 5, if necessary. Set value to **.999999999999E+09** if not known.

***) Angles and their derivatives transmitted in units of semi-circles and semi-circles/sec have to be converted to radians by the RINEX generator.

****) For Navigation data fields stored bitwise see section 6.9.

*****) The GAL week number is a continuous number, aligned to (and hence identical to) the continuous GPS week number used in the RINEX navigation message files. The broadcast 12-bit Galileo System Time (GST) week has a roll-over after 4095. It started at zero at the first GPS roll-over (continuous GPS week 1024). Hence GAL week = GST week + 1024 + n*4096 (n: number of GST roll-overs).

*****) For Navigation data fields stored bitwise see section 6.9. If bit 0 or bit 2 of Data sources (**BROADCAST ORBIT - 5**) is set then the SV health parameter; 'E1B DVS' & 'E1B HS', 'E5b DVS' & 'E5b HS' and both 'BGDs' are valid. If bit 1 of Data sources is set then 'E5a DVS' & 'E5a HS' and BGD E5a/E1 are valid. Non-valid parameters are set to 0 and to be ignored.

A9 GALILEO Navigation Message File – Examples

TABLE A9															
GALILEO NAVIGATION MESSAGE FILE - EXAMPLES															
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8															
3.05				N: GNSS NAV DATA				E: GALILEO NAV DATA RINEX VERSION / TYPE							
NetR9 5.01				Receiver Operator				20150619 000000 UTC PGM / RUN BY / DATE							
GAL .1248D+03				.5039D+00 .2377D-01 .0000D+00				IONOSPHERIC CORR							
GAUT .3725290298D-08				.532907052D-14 345600 1849 E10 5				TIME SYSTEM CORR							
16 17 1851 3								LEAP SECONDS							
END OF HEADER															
E12 2015 06 19 02 10 00 -.138392508961D-02 -.131464616970D-09 .000000000000D+00															
.930000000000D+02 -.165531250000D+03 .285797618904D-08 .138275888459D+01															
-.782497227192D-05 .346679124050D-03 .114385038614D-04 .544062509727D+04															
.439800000000D+06 .298023223877D-07 -.296185101312D+01 -.111758708954D-07															
.965683294025D+00 .993750000000D+02 -.629360976005D+00 -.541593988135D-08															
-.571452374714D-11 .516000000000D+03 .184900000000D+04															
.312000000000D+01 .000000000000D+00 -.651925802231D-08 -.605359673500D-08															
.440734000000D+06															
E12 2015 06 19 02 10 00 -.138392508961D-02 -.131464616970D-09 .000000000000D+00															
.930000000000D+02 -.165531250000D+03 .285797618904D-08 .138275888459D+01															
-.782497227192D-05 .346679124050D-03 .114385038614D-04 .544062509727D+04															
.439800000000D+06 .298023223877D-07 -.296185101312D+01 -.111758708954D-07															
.965683294025D+00 .993750000000D+02 -.629360976005D+00 -.541593988135D-08															
-.571452374714D-11 .513000000000D+03 .184900000000D+04															
.312000000000D+01 .000000000000D+00 -.651925802231D-08 -.605359673500D-08															
.440725000000D+06															
3.05				NAVIGATION DATA				M (Mixed)				RINEX VERSION / TYPE			
BCEmerge				congo				20150620 012902 GMT				PGM / RUN BY / DATE			
Merged GPS/GLO/GAL/BDS/QZS/SBAS navigation file												COMMENT			
based on CONGO and MGEX tracking data												COMMENT			
DLR: O. Montenbruck; TUM: P. Steigenberger												COMMENT			
BDUT 5.5879354477e-09				-2.042810365e-14				14 492				B10 7 TIME SYSTEM CORR			
GAUT 3.7252902985e-09				5.329070518e-15				345600 1849				E10 5 TIME SYSTEM CORR			
GLGP -3.7252902985e-09				0.000000000e+00				345600 1849				R10 0 TIME SYSTEM CORR			
GLUT 1.0710209608e-08				0.000000000e+00				345600 1849				R10 0 TIME SYSTEM CORR			
GAGP -2.0081643015e-09				-9.769962617e-15				432000 1849				E12 0 TIME SYSTEM CORR			
GPUT 4.5110937208e-09				7.105427358e-15				372608 1849				G10 2 TIME SYSTEM CORR			
QZUT 1.9557774067e-08				1.598721155e-14				61440 1850				J01 0 TIME SYSTEM CORR			
18												LEAP SECONDS			
END OF HEADER															
E12 2015 06 19 02 10 00-1.383925089613e-03-1.314646169703e-10 0.000000000000e+00															
9.300000000000e+01-1.655312500000e+02 2.857976189037e-09 1.382758884589e+00															
-7.824972271919e-06 3.466791240498e-04 1.143850386143e-05 5.440625097275e+03															
4.398000000000e+05 2.980232238770e-08-2.961851013120e+00-1.117587089539e-08															
9.656832940254e-01 9.937500000000e+01-6.293609760051e-01-5.415939881349e-09															
-5.714523747137e-12 5.130000000000e+02 1.849000000000e+03															
3.120000000000e+00 0.000000000000e+00-6.519258022308e-09-6.053596735001e-09															
4.404850000000e+05															
E12 2015 06 19 02 10 00-1.383925322443e-03-1.314504061156e-10 0.000000000000e+00															
9.300000000000e+01-1.655312500000e+02 2.857976189037e-09 1.382758884589e+00															
-7.824972271919e-06 3.466791240498e-04 1.143850386143e-05 5.440625097275e+03															
4.398000000000e+05 2.980232238770e-08-2.961851013120e+00-1.117587089539e-08															
9.656832940254e-01 9.937500000000e+01-6.293609760051e-01-5.415939881349e-09															
-5.714523747137e-12 2.580000000000e+02 1.849000000000e+03															
3.120000000000e+00 0.000000000000e+00-6.519258022308e-09 0.000000000000e+00															
4.405300000000e+05															
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8															

A10 GNSS Navigation Mssg File – GLONASS Data Record Description

TABLE A10 GNSS NAVIGATION MESSAGE FILE – GLONASS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
<i>SV / EPOCH / SV CLK</i>	<ul style="list-style-type: none"> - Satellite system (R), satellite number (slot number in sat. constellation) - Epoch: Toc - Time of Clock (UTC) year (4 digits) - month, day, hour, minute, second - SV clock bias (sec) (-TauN) - SV relative frequency bias (+GammaN) - Message frame time (tk+(nd*86400)) in seconds of the UTC week 	A1,I2.2, 1X,I4, 5(1X,I2.2), 3D19.12 *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - Satellite position X (km) - velocity X dot (km/sec) - X acceleration (km/sec2) - health (0=healthy, 1=unhealthy) (MSB of 3-bit Bn) 	4X,4D19.12
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Satellite position Y (km) - velocity Y dot (km/sec) - Y acceleration (km/sec2) - frequency number (-7...+13) (-7...+6 ICD 5.1) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Satellite position Z (km) - velocity Z dot (km/sec) - Z acceleration (km/sec2) - Age of oper. information (days) (E) 	4X,4D19.12
BROADCAST ORBIT - 4	<ul style="list-style-type: none"> - Status Flags (FLOAT → INTEGER) 9-bit binary number (BNK if Unknown); M ; bit 7-8, GLO type indicator (00=GLO, 01=GLO-M/K) P4 ; bit 6, <i>GLO-M/K only</i>, 1=data updated, 0=data not updated P3 ; bit 5, num of satellites in current frame almanac (0 = 4 sats, 1 = 5 sats) P2 ; bit 4, indicate even (0) or odd (1) of time interval P1 ; bit 2-3, update and validity interval (00 = 0 min, 01 = 30 min, 10=45 min, 11=60 min) P ; bit 0-1, <i>GLO-M/K only</i>, time offset parameters τ_c, τ_{GPS} source (00 =ground, 01 = τ_c ground, τ_{GPS} on-board, 10 = τ_c on-board, τ_{GPS} ground, 	4X,4D19.12 **)

TABLE A10 GNSS NAVIGATION MESSAGE FILE – GLONASS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
	<p>11 = on-board)</p> <ul style="list-style-type: none"> - L1/L2 group delay difference $\Delta\tau$.(in seconds) ***) - URAI ; <i>GLO-M/K only</i> – raw accuracy index F_T. ****) - Health Flags (FLOAT → INTEGER) 3-bit binary number (BNK if Unknown) *****); <p>$I_{(3)}$; bit 2, <i>GLO-M/K only</i>, health bit of string 3</p> <p>A_C ; bit 1, 1 = almanac health reported in ephemerides record, 0 = not reported</p> <p>C ; bit 0, almanac health bit (1 = healthy, 0 = not healthy)</p> <p><i>GLO-M/K exclusive flags and values only to be valid when flag M set to “01”</i></p>	

*) see section 6.8.

**) For Navigation data fields stored bitwise see section 6.9.

***) .999999999999E+09 if Unknown

****) 1.500000000000E+01 if Unknown

*****) bit 0 (C) is to be ignored if bit 1 (A_C) is zero

A11 GNSS Navigation Mssg File – Example: Mixed GPS / GLONASS

TABLE A11												
GNSS NAVIGATION MESSAGE FILE - EXAMPLE MIXED GPS/GLONASS												
----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- -----												
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8												
3.05			N: GNSS NAV DATA				M: MIXED			RINEX VERSION / TYPE		
XXRINEXN V3			AIUB				20061002 000123 UTC			PGM / RUN BY / DATE		
EXAMPLE OF VERSION 3.05 FORMAT										COMMENT		
GPSA		0.1025E-07		0.7451E-08		-0.5960E-07		-0.5960E-07		IONOSPHERIC CORR		
GPSB		0.8806E+05		0.0000E+00		-0.1966E+06		-0.6554E+05		IONOSPHERIC CORR		
GPWT		0.2793967723E-08		0.0000000000E+00		147456		1395		G10 2 TIME SYSTEM CORR		
GLUT		0.7823109626E-06		0.0000000000E+00		0		1395		R10 0 TIME SYSTEM CORR		
14										LEAP SECONDS		
END OF HEADER												
G01 2006 10 01 00 00 00 0.798045657575E-04 0.227373675443E-11 0.000000000000E+00												
0.560000000000E+02-0.787500000000E+01 0.375658504827E-08 0.265129935612E+01												
-0.411644577980E-06 0.640150101390E-02 0.381097197533E-05 0.515371852875E+04												
0.000000000000E+00 0.782310962677E-07 0.188667086536E+00-0.391155481338E-07												
0.989010441512E+00 0.320093750000E+03-0.178449589759E+01-0.775925177541E-08												
0.828605943335E-10 0.000000000000E+00 0.139500000000E+04 0.000000000000E+00												
0.200000000000E+01 0.000000000000E+00-0.325962901115E-08 0.560000000000E+02												
-0.600000000000E+02 0.400000000000E+01												
G02 2006 10 01 00 00 00 0.402340665460E-04 0.386535248253E-11 0.000000000000E+00												
0.135000000000E+03 0.467500000000E+02 0.478269921862E-08-0.238713891022E+01												
0.250712037086E-05 0.876975362189E-02 0.819191336632E-05 0.515372778320E+04												
0.000000000000E+00-0.260770320892E-07-0.195156738598E+01 0.128522515297E-06												
0.948630520258E+00 0.214312500000E+03 0.215165003775E+01-0.794140221985E-08												
-0.437875382124E-09 0.000000000000E+00 0.139500000000E+04 0.000000000000E+00												
0.200000000000E+01 0.000000000000E+00-0.172294676304E-07 0.391000000000E+03												
-0.600000000000E+02 0.400000000000E+01												
R01 2006 10 01 00 15 00-0.137668102980E-04-0.454747350886E-11 0.900000000000E+02												
0.157594921875E+05-0.145566368103E+01 0.000000000000E+00 0.000000000000E+00												
-0.813711474609E+04 0.205006790161E+01 0.931322574615E-09 0.700000000000E+01												
0.183413398438E+05 0.215388488770E+01-0.186264514923E-08 0.100000000000E+01												
1.790000000000E+02 8.381903171539E-09 2.000000000000E+00 3.000000000000E+00												
R02 2006 10 01 00 15 0-0.506537035108E-04 0.181898940355E-11 0.300000000000E+02												
0.155536342773E+05-0.419384956360E+00 0.000000000000E+00 0.000000000000E+00												
-0.199011298828E+05 0.324192047119E+00-0.931322574615E-09 0.100000000000E+01												
0.355333544922E+04 0.352666091919E+01-0.186264514923E-08 0.100000000000E+01												
5.200000000000E+01 9.456379289034E-09 0.000000000000E+00 0.000000000000E+00												
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8												

A12 GNSS Navigation Mssg File – QZSS Data Record Description

TABLE A12 QZSS NAVIGATION MESSAGE FILE – QZSS DATA RECORD DESCRIPTION		
NAV. RECORD (Columns 61-80)	DESCRIPTION	FORMAT
SV / EPOCH / SV CLK	<ul style="list-style-type: none"> - Satellite system (J), Satellite PRN-192 - Epoch: Toc - Time of Clock year (4 digits) - month, day, hour, minutes, seconds - SV clock bias (seconds) - SV clock drift (sec/sec) - SV clock drift rate (sec/sec²) 	A1,I2, 1X,I4, 5(1X,I2), 3D19.12 *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - IODE Issue of Data, Ephemeris - Crs (meters) - Delta n (radians/sec) - M0 (radians) 	4X,4D19.12
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Cuc (radians) - e Eccentricity - Cus (radians) - sqrt(A) (sqrt(m)) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Toe Time of Ephemeris (sec of GPS week) - Cic (radians) - OMEGA (radians) - CIS (radians) 	4X,4D19.12
BROADCAST ORBIT - 4	<ul style="list-style-type: none"> - i0 (radians) - Crc (meters) - omega (radians) - OMEGA DOT (radians/sec) 	4X,4D19.12
BROADCAST ORBIT - 5	<ul style="list-style-type: none"> - IDOT (radians/sec) - Codes on L2 channel (fixed to 2, see IS-QZSS-PNT 4.1.2.7) - GPS Week # (to go with TOE) Continuous number, not mod(1024)! - L2P data flag set to 1 since QZSS does not track L2P 	4X,4D19.12
BROADCAST ORBIT - 6	<ul style="list-style-type: none"> - SV accuracy (meters) (IS -QZSS-PNT, Section 5.4.3.1) which refers to: IS-GPS-200 Section 20.3.3.3.1.3 use specified equations to define nominal values, N = 0-6: use $2^{(1+N/2)}$ (round to one decimal place i.e. 2.8, 5.7 and 11.3) , N= 7-15:use $2^{(N-2)}$, 8192 specifies use at own risk - SV health (bits 17-22 w 3 sf 1) (see IS-QZSS-PNT 5.4.1) - TGD (seconds) The QZSS ICD specifies a do not use bit pattern 	4X,4D19.12

TABLE A12 QZSS NAVIGATION MESSAGE FILE – QZSS DATA RECORD DESCRIPTION		
NAV. RECORD (Columns 61-80)	DESCRIPTION	FORMAT
	"10000000" this condition is represented by a blank field. - IODC Issue of Data, Clock	
BROADCAST ORBIT – 7	- Transmission time of message **) (sec of GPS week, derived e.g. from Z-count in Hand Over Word (HOW)) - Fit interval flag (0 / 1) (see IS-QZSS-PNT, 4.1.2.4(3) 0 – two hours), 1 – more than 2 hours. Blank if not known. - Spare(x2) (see Section 6.4)	4X,4D19.12

Records marked with * are optional

*) see section 6.8.

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

A13 QZSS Navigation Message File – Example

TABLE A13										
QZSS NAVIGATION MESSAGE FILE - EXAMPLE										

3.05	N: GNSS NAV DATA		J: QZSS		RINEX VERSION / TYPE					
GR25 V3.08			20140513 072944 UTC		PGM / RUN BY / DATE					
16	1694	7	LEAP SECONDS							
END OF HEADER										
J01	2014 05 13 08 15 12	3.323303535581D-04-1.818989403546D-11	0.000000000000D+00	6.900000000000D+01-4.927812500000D+02	2.222949737636D-09	7.641996743610D-01	-1.654587686062D-05	7.542252133135D-02	1.197867095470D-05	6.492895933151D+03
		2.025120000000D+05-8.381903171539D-07-9.211997910060D-01-2.041459083557D-06		7.082252892260D-01-1.558437500000D+02-1.575843337115D+00-2.349740733276D-09						
		-6.793140104410D-10	2.000000000000D+00	1.792000000000D+03	1.000000000000D+00					
		2.000000000000D+00	1.000000000000D+00-4.656612873077D-09	6.900000000000D+01						
		1.989000000000D+05	0.000000000000D+00							

	1	2	3	4	5	6	7	8		

A14 GNSS Navigation Message File – BDS Data Record Description

Table A14 GNSS NAVIGATION MESSAGE FILE – BDS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
SV /EPOCH / SV CLK	<ul style="list-style-type: none"> - Satellite system (C), sat number (PRN) - Epoch: Toc - Time of Clock (BDT) year (4 digits) - month, day, hour, minute, second - SV clock bias (seconds) - SV clock drift (sec/sec) - SV clock drift rate (sec/sec²) 	A1,I2.2, 1X,I4 5,1X,I2.2, 3D19.12 *)
BROADCAST ORBIT – 1	<ul style="list-style-type: none"> - AODE Age of Data, Ephemeris (as specified in BeiDou ICD Table Section 5.2.4.11 Table 5-8) and field range is: 0-31. - Crs (meters) - Delta n (radians/sec) - M0 (radians) 	4X,4D19.12 **)
BROADCAST ORBIT – 2	<ul style="list-style-type: none"> - Cuc (radians) - e Eccentricity - Cus (radians) - sqrt(A) (sqrt(m)) 	4X,4D19.12
BROADCAST ORBIT – 3	<ul style="list-style-type: none"> - Toe Time of Ephemeris (sec of BDT week) - Cic (radians) - OMEGA0 (radians) - Cis (radians) 	4X,4D19.12
BROADCAST ORBIT – 4	<ul style="list-style-type: none"> - i0 (radians) - Crc (meters) - omega (radians) - OMEGA DOT (radians/sec) 	4X,4D19.12
BROADCAST ORBIT – 5	<ul style="list-style-type: none"> - IDOT (radians/sec) - Spare (see Section 6.4) - BDT Week # - Spare (see Section 6.4) 	4X,4D19.12 ***)
BROADCAST ORBIT – 6	<ul style="list-style-type: none"> - SV accuracy (meters See: BDS ICD Section 5.2.4.: to define nominal values, N = 0-6: use $2^{(1+N/2)}$ (round to one decimal place i.e. 2.8, 5.7 and 11.3) , N= 7-15:use $2^{(N-2)}$, 8192 specifies use at own risk) - SatH1 	4X,4D19.12

	<ul style="list-style-type: none"> - TGD1 B1/B3 (seconds) - TGD2 B2/B3 (seconds) 	
BROADCAST ORBIT – 7	<ul style="list-style-type: none"> - Transmission time of message ****) (sec of BDT week,) - AODC Age of Data Clock (as specified in BeiDou ICD Table Section 5.2.4.9 Table 5-6) and field range is: 0-31. - Spare(x2) (see Section 6.4) 	4X,4D19.12

*) see section 6.8.

**) Angles and their derivatives transmitted in units of semi-circles and semi-circles/sec have to be converted to radians by the RINEX generator.

***) The BDT week number is a continuous number. The broadcast 13-bit BDS System Time week has a roll-over after 8191. It started at zero at 1-Jan-2006, Hence BDT week = BDT week_BRD + (n*8192) where (n: number of BDT roll-overs).

****) Adjust the Transmission time of message by + or -604800 to refer to the reported week in BROADCAST ORBIT -5, if necessary. Set value to **.999999999999E+09** if not known.

A15 BeiDou Navigation Message File – Example

TABLE A15																											
BeiDou NAVIGATION MESSAGE FILE - EXAMPLE																											

----	----	1 0----	----	2 0----	----	3 0----	----	4 0----	----	5 0----	----	6 0----	----	7 0----	----	8											
3.05		NAVIGATION DATA				M (Mixed)		RINEX VERSION / TYPE																			
BCEmerge		montenbruck				20140517 072316 GMT		PGM / RUN BY / DATE																			
DLR: O. Montenbruck; TUM: P. Steigenberger										COMMENT																	
BDUT -9.3132257462e-10		9.769962617e-15		14		435		TIME SYSTEM CORR																			
										END OF HEADER																	
C01	2014	05	10	00	00	00	2.969256602228e-04	2.196998138970e-11	0.000000000000e+00																		
							1.000000000000e+00	4.365468750000e+02	1.318269196918e-09	-3.118148933476e+00																	
							1.447647809982e-05	2.822051756084e-04	8.092261850834e-06	6.493480609894e+03																	
							5.184000000000e+05	-2.654269337654e-08	3.076630958509e+00	-3.864988684654e-08																	
							1.103024081152e-01	-2.506406250000e+02	2.587808789012e+00	-3.039412318009e-10																	
							2.389385241772e-10		4.350000000000e+02																		
							2.000000000000e+00	0.000000000000e+00	1.420000000000e-08	-1.040000000000e-08																	
							5.184000000000e+05	0.000000000000e+00																			
-----										----		----	1 0----	----	2 0----	----	3 0----	----	4 0----	----	5 0----	----	6 0----	----	7 0----	----	8

A16 GNSS Navigation Mssg File – SBAS Data Record Description

TABLE A16 GNSS NAVIGATION MESSAGE FILE – SBAS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
SV / EPOCH / SV CLK	<ul style="list-style-type: none"> - Satellite system (S), satellite number (slot number in sat. constellation) - Epoch: Toc - Time of Clock (GPS) year (4 digits) - month, day, hour, minute, second - SV clock bias (sec) (aGf0) - SV relative frequency bias (aGf1) - Transmission time of message (start of the message) in GPS seconds of the week 	A1,I2.2, 1X,I4, 5(1X,I2.2), 3D19.12, *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - Satellite position X (km) - velocity X dot (km/sec) - X acceleration (km/sec²) - Health: SBAS: See section 5.4.4 for: health, health availability and User Range Accuracy. 	4X,4D19.12
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Satellite position Y (km) - velocity Y dot (km/sec) - Y acceleration (km/sec²) - Accuracy code (URA, meters) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Satellite position Z (km) - velocity Z dot (km/sec) - Z acceleration (km/sec²) - IODN (Issue of Data Navigation, see reference RTCA DO-229, 8 first bits after Message Type if MT9) 	4X,4D19.12

*) see section 6.8.

A17 SBAS Navigation Message File -Example

```

+-----+
|                                     |
|               TABLE A17          |
|               SBAS NAVIGATION MESSAGE FILE - EXAMPLE               |
|                                     |
+-----+
----|----1|0---|----2|0---|----3|0---|----4|0---|----5|0---|----6|0---|----7|0---|----8|
      3.05          N: GNSS NAV DATA      S: SBAS          RINEX VERSION / TYPE
SBAS2RINEX 3.0      CNES                    20031018 140100      PGM / RUN BY / DATE
EXAMPLE OF VERSION 3.05 FORMAT          COMMENT
SBUT  -.1331791282D-06 -.107469589D-12 552960 1025 EGNOS  5 TIME SYSTEM CORR
      13          LEAP SECONDS
This file contains navigation message data from a SBAS      COMMENT
(geostationary) satellite, here AOR-W (PRN 122 = # S22)      COMMENT
          END OF HEADER
S22 2003 10 18  0  1  4-1.005828380585D-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
S22 2003 10 18  0  5 20-9.872019290924D-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
S22 2003 10 18  0  9 36-9.732320904732D-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
S22 2003 10 18  0 13 52-9.592622518539D-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|

```

A18 GNSS Navigation Mssg File – NavIC/IRNSS Data Record Description

TABLE A18 GNSS NAVIGATION MESSAGE FILE – NavIC/IRNSS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
SV / EPOCH / SV CLK	<ul style="list-style-type: none"> - Satellite system (I), sat number (PRN) - Epoch: Toc - Time of Clock (NavIC/IRNSS) year (4 digits) - month, day, hour, minute, second - SV clock bias (seconds) - SV clock drift (sec/sec) - SV clock drift rate (sec/sec²) 	A1,I2.2, 1X,I4, 5(1X,I2.2), 3D19.12 *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - IODEC Issue of Data, Ephemeris and Clock - Crs (meters) - Delta n (radians/sec) - M0 (radians) 	4X,4D19.12 ***)
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Cuc (radians) - e Eccentricity - Cus (radians) - sqrt(A) (sqrt(m)) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Toe Time of Ephemeris (sec of NavIC/IRNSS week) - Cic (radians) - OMEGA0 (radians) - Cis (radians) 	4X,4D19.12
BROADCAST ORBIT - 4	<ul style="list-style-type: none"> - i0 (radians) - Crc (meters) - omega (radians) - OMEGA DOT (radians/sec) 	4X,4D19.12
BROADCAST ORBIT - 5	<ul style="list-style-type: none"> - IDOT (radians/sec) - Blank - IRN Week # (to go with TOE) Continuous number, not mod (1024), counted from 1980 (same as GPS). - Spare (see Section 6.4) 	4X,4D19.12
BROADCAST ORBIT - 6	<ul style="list-style-type: none"> - User Range Accuracy(m), See NavIC/IRNSS ICD Section 6.2.1.4 , use specified equations to define nominal values, N = 0-6: use $2^{(1+N/2)}$ (round to one decimal place i.e. 2.8, 5.7 and 11.3) , N= 7-15:use $2^{(N-2)}$, 8192 specifies use at own risk - Health (Sub frame 1, bits 155(most significant) and 156(least significant)), where 0 = L5 and S healthy, 1 = L5 healthy and S unhealthy, 2= L5 unhealthy 	4X,4D19.12

TABLE A18 GNSS NAVIGATION MESSAGE FILE – NavIC/IRNSS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
	and S healthy, 3= both L5 and S unhealthy - TGD (seconds) - Spare (see Section 6.4)	
BROADCAST ORBIT - 7	- Transmission time of message **) (sec of NavIC/IRNSS week) - Spare(x3) (see Section 6.4)	4X,4D19.12

*) see section 6.8.

) Adjust the *Transmission time of message* by + or -604800 to refer to the reported week in **BROADCAST ORBIT 5, if necessary. Set value to **.999999999999E+09** if not known.

A19 NavIC/IRNSS Navigation Message File – Example

TABLE A19									
NavIC/IRNSS NAVIGATION MESSAGE FILE - EXAMPLE									
3.05	NAVIGATION DATA	I (NavIC/IRNSS)	RINEX VERSION / TYPE						
DecodIRNSS	montenbruck	20141004 164512 GMT	PGM / RUN BY / DATE						
Source: IRNSS-1A Navbits			COMMENT						
			END OF HEADER						
I01	2014 04 01 00 00 00-9.473115205765e-04	1.250555214938e-12	0.000000000000e+00						
	0.000000000000e+00-5.820625000000e+02	4.720196615135e-09	-1.396094758025e+00						
	-1.898035407066e-05	2.257102518342e-03	-1.068413257599e-05	6.493487739563e+03					
	1.728000000000e+05	6.705522537231e-08	-8.912102146884e-01	-5.215406417847e-08					
	4.758105460020e-01	4.009375000000e+02	-2.999907424014e+00	-4.414469594664e-09					
	-4.839487298357e-10	1.786000000000e+03							
	1.130000000000e+01	0.000000000000e+00	-4.190951585770e-09						
	1.728000000000e+05								
I01	2014 04 01 02 00 00-9.473022073507e-04	1.250555214938e-12	0.000000000000e+00						
	1.000000000000e+00-5.101875000000e+02	4.945920303147e-09	-8.741766987741e-01						
	-1.684948801994e-05	2.254169434309e-03	-1.182407140732e-05	6.493469217300e+03					
	1.800000000000e+05	2.346932888031e-07	-8.912408598963e-01	-1.117587089539e-08					
	4.758065024964e-01	4.403750000000e+02	-2.996779607145e+00	-4.508759236491e-09					
	-5.464513333200e-10	1.786000000000e+03							
	1.130000000000e+01	0.000000000000e+00	-4.190951585770e-09						
	1.800000000000e+05								
I01	2014 04 01 04 00 00-9.472924284637e-04	1.250555214938e-12	0.000000000000e+00						
	2.000000000000e+00-5.100000000000e+02	5.217360181136e-09	-3.491339518362e-01						
	-1.697987318039e-05	2.254509832710e-03	-1.212581992149e-05	6.493469842911e+03					
	1.872000000000e+05	1.378357410431e-07	-8.912725364615e-01	2.942979335785e-07					
	4.758010370344e-01	4.460625000000e+02	-2.996772972812e+00	-4.790199531038e-09					
	-6.039537285256e-10	1.786000000000e+03							
	1.130000000000e+01	0.000000000000e+00	-4.190951585770e-09						
	1.872000000000e+05								

A20 Meteorological Data File - Header Section Description

[illegible]

TABLE A20 METEOROLOGICAL DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	- Observation type Record is repeated for each observation type found in # / TYPES OF OBSERV record	A2,1X
SENSOR POS XYZ/H	- Approximate position of the met sensor - Geocentric coordinates X, Y, Z (ITRF or WGS84) - Ellipsoidal height H - Observation type Set X, Y, Z to zero or blank if unknown. Make sure H refers to ITRF or WGS-84. Record required for barometer, recommended for other sensors.	3F14.4, 1F14.4, 1X,A2,1X
END OF HEADER	Last record in the header section.	60X

Records marked with * are optional

A21 Meteorological Data File - Data Record Description

TABLE A21 METEOROLOGICAL DATA FILE - DATA RECORD DESCRIPTION		
OBS. RECORD	DESCRIPTION	FORMAT
EPOCH / MET	- Epoch in GPS time (not local time!) year (4 digits, padded with 0 if necessary) - month, day, hour, min, sec - Met data in the same sequence as given in the header - More than 8 met data types: Use continuation lines	1X,I4.4, 5(1X,I2), mF7.1 4X,10F7.1

A22 Meteorological Data File – Example

TABLE A22 METEOROLOGICAL DATA FILE - EXAMPLE									
3.05	METEOROLOGICAL DATA								RINEX VERSION / TYPE
XXRINEXM V9.9	AIUB			19960401	144333	UTC			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
0.0000		0.0000		0.0000	1234.5678	PR			SENSOR POS XYZ/H
									END OF HEADER
1996	4	1	0	0	15	987.1	10.6	89.5	
1996	4	1	0	0	30	987.2	10.9	90.0	
1996	4	1	0	0	45	987.1	11.6	89.0	

A23 Reference Code and Phase Alignment by Constellation and Frequency Band

TABLE A23 Reference Code and Phase Alignment by Frequency Band					
System	Frequency Band	Frequency [MHz]	Signal	RINEX Observation Code	Phase Correction applied to each observed phase to obtain aligned phase. ($\phi_{\text{RINEX}} = \phi_{\text{original}}$ (as issued by the SV) + $\Delta\phi$)
GPS	L1	1575.42	C/A	L1C	None (Reference Signal)
			L1C-D	L1S	+1/4 cycle
			L1C-P	L1L	+1/4 cycle
			L1C-(D+P)	L1X	+1/4 cycle
			P	L1P	+1/4 cycle
			Z-tracking	L1W	+1/4 cycle
			Codeless	L1N	+1/4 cycle
	L2 See Note 1	1227.60	C/A	L2C	For Block II/IIA/IIR – None; For Block IIR-M/IIF/III -1/4 cycle See Note 2
			Semi-codeless	L2D	None
			L2C(M)	L2S	-1/4 cycle
			L2C(L)	L2L	-1/4 cycle
			L2C(M+L)	L2X	-1/4 cycle
			P	L2P	None (Reference Signal)
			Z-tracking	L2W	None
			Codeless	L2N	None
	L5	1176.45	I	L5I	None (Reference Signal)
			Q	L5Q	-1/4 cycle
			I+Q	L5X	Must be aligned to L5I
GLONASS	G1	1602+k*9/16	C/A	L1C	None (Reference Signal)
			P	L1P	+1/4 cycle
	G1a	1600.995	L1OCd	L4A	None (Reference Signal)
			L1OCp	L4B	None
			L1OCd+L1OCd	L4X	None
	G2	1246+k*7/16	C/A	L2C	None (Reference Signal)
			P	L2P	+1/4 cycle
	G2a	1248.06	L2CSI	L6A	None (Reference Signal)
			L2OCp	L6B	None
			L2CSI+L2OCp	L6X	None

TABLE A23
Reference Code and Phase Alignment by Frequency Band

System	Frequency Band	Frequency [MHz]	Signal	RINEX Observation Code	Phase Correction applied to each observed phase to obtain aligned phase. ($\phi_{\text{RINEX}} = \phi_{\text{original}}$ (as issued by the SV) + $\Delta\phi$)
GLONASS	G3	1202.025	I	L3I	None (Reference Signal)
			Q	L3Q	Must be aligned to L3I
			I+Q	L3X	Must be aligned to L3I
Galileo	E1	1575.42	B I/NAV OS/CS/SoL	L1B	None (Reference Signal)
			C no data	L1C	+1/2 cycle
			B+C	L1X	Must be aligned to L1B
	E5A	1176.45	I	L5I	None (Reference Signal)
			Q	L5Q	-1/4 cycle
			I+Q	L5X	Must be aligned to L5I
	E5B	1207.140	I	L7I	None (Reference Signal)
			Q	L7Q	-1/4 cycle
			I+Q	L7X	Must be aligned to L7I
	E5(A+B)	1191.795	I	L8I	None (Reference Signal)
			Q	L8Q	-1/4 cycle
			I+Q	L8X	Must be aligned to L8I
	E6	1278.75	B	L6B	None (Reference Signal)
			C	L6C	-1/2 cycle
			B+C	L6X	Must be aligned to L6B
QZSS	L1	1575.42	C/A	L1C	None (Reference Signal)
			L1C (D)	L1S	+1/4 cycle (See Note 5 Below)
			L1C (P)	L1L	+1/4 cycle
			L1C-(D+P)	L1X	+1/4 cycle
			L1S	L1Z	N/A
	L2	1227.60	L2C (M)	L2S	None (Reference Signal)
			L2C (L)	L2L	None
			L2C (M+L)	L2X	None
	L5	1176.45	I	L5I	None (Reference Signal)
			Q	L5Q	-1/4 cycle
			I+Q	L5X	Must be aligned to L5I
	L5S	1176.45	I	L5D	None Reference Signal
			Q	L5P	-1/4 cycle
			I+Q	L5Z	None must be aligned to L5D
	L6 (See Note 6 Below)	1278.75	L6D	L6S	None (Reference Signal)
			L6P	L6L	None

TABLE A23
Reference Code and Phase Alignment by Frequency Band

System	Frequency Band	Frequency [MHz]	Signal	RINEX Observation Code	Phase Correction applied to each observed phase to obtain aligned phase. ($\phi_{\text{RINEX}} = \phi_{\text{original}}$ (as issued by the SV) + $\Delta\phi$)
QZSS			L6(D+P)	L6X	None
			L6E	L6E	None
			L6(D+E)	L6Z	None
BDS	B1	1561.098	I	L2I	None (Reference Signal) (See Note 4 Below)
			Q	L2Q	Must be aligned to L2I
			I+Q	L2X	Must be aligned to L2I
	B1C	1575.42	Data (D)	L1D	None (Reference Signal)
			Pilot(P)	L1P	Must be aligned to L1D
			D+P	L1X	Must be aligned to L1D
	B1A	1575.42	Data (D)	L1S	None (Reference Signal)
			Pilot(P)	L1L	Must be aligned to L1S
			D+P	L1Z	Must be aligned to L1S
	B2a	1176.45	Data (D)	L5D	None (Reference Signal)
			Pilot(P)	L5P	Must be aligned to L5D
			D+P	L5X	Must be aligned to L5D
	B2 (BDS-2)	1207.140	I	L7I	None (Reference Signal)
			Q	L7Q	-1/4 cycle
			I+Q	L7X	Must be aligned to L7I
	B2b (BDS-3)	1207.140	Data (D)	L7D	None (Reference Signal)
			Pilot(P)	L7P	Must be aligned to L7D
			D+P	L7Z	Must be aligned to L7D
	B2a+B2b (BDS-3)	1191.795	Data (D)	L8D	None Reference Signal
			Pilot(P)	L8P	Must be aligned to L8D
			D+P	L8X	Must be aligned to L8D
	B3	1268.52	I	L6I	None (Reference Signal)
			Q	L6Q	Must be aligned to L6I
			I+Q	L6X	Must be aligned to L6I
	B3A (BDS-3)	1268.52	Data (D)	L6D	None (Reference Signal)
			Pilot (P)	L6P	Must be aligned to L6D
			D+P	L6Z	Must be aligned to L6D

TABLE A23 Reference Code and Phase Alignment by Frequency Band					
System	Frequency Band	Frequency [MHz]	Signal	RINEX Observation Code	Phase Correction applied to each observed phase to obtain aligned phase. ($\phi_{\text{RINEX}} = \phi_{\text{original}}$ (as issued by the SV) + $\Delta\phi$)
NavIC/ IRNSS	L5	1176.45	A SPS	L5A	None (Reference Signal)
			B RS(D)	L5B	Restricted (See Note 3)
			C RS(P)	L5C	None
			B+C	L5X	Must be aligned to L5A
	S	2492.028	A SPS	L9A	None (Reference Signal)
			B RS(D)	L9B	Restricted (See Note 3)
			C RS(P)	L9C	None
			B+C	L9X	Must be aligned to L9A

Notes:

1. The GPS L2 phase shift values ignore FlexPower when the phases of the L2W and L2C can be changed on the satellite.
2. The phase of the L2 C/A signal is dependent on the GPS satellite generation.
3. There is no public information available concerning the restricted service signals.
4. Note: Both C1x and C2x (RINEX 3.01 definition) have been used to identify the B1 frequency signals in RINEX 3.02 files. If C2x coding is read in a RINEX 3.02 file treat it as equivalent to C1x.
5. There has been a phase alignment change between the QZSS Block I and Block II satellites. The table above shows the Block II alignment. Block I corrections: L1S none, L1L + $\frac{1}{4}$.
6. L6D, L6P, L6E are identical to L61/L62(code1), L61(code2), L62(code2) in IS-QZSS-L6 respectively.