RINEX

The Receiver Independent Exchange Format

Version 4.01

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10 July 2023

Acknowledgement: This version is thanks to the IGS, the RTCM/SC104 and all previous RINEX versions developed from 1989.

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Acronyms

AODC	Age of Data Clock
AODE	Age of Data Ephemerides
APREF	Asia Pacific Reference Frame
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 if Not Known/Not Defined
BOC	Binary Offset Carrier
CNAV	Civil Navigation (message)
DCB	Differential Code Bias
DVS	Data Validity Status
EUREF	European Reference Frame
FNAV	Free Navigation (message, of Galileo)
GEO	Geostationary Earth Orbit
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistema
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GST	Galileo System Time
ICD	Interface Control Document
IGSO	Inclined Geo-Synchronous Orbit
INAV	Integrity Navigation (message, of Galileo)
IOD	Issue of Data
IODC	Issue of Data, Clock
IODE	Issue of Data, Ephemerides
IRNSS	Indian Regional Navigation Sat. System (former name for NavIC)
ISC	Inter-Signal Correction
LLI	Loss-of-Lock Indicator
LNAV	Legacy Navigation (message)
MBOC	Multiplexed BOC
MEO	Medium Earth Orbit
NavIC	Navigation Indian Constellation (final name for the Indian Regional Navigation Sat. System)
NICT	National Institute of Information and Communications Technology (Japan)
PCV	Phase Center Variation
PR	Pseudorange
PRN	Pseudo-Random Noise
QZSS	Quasi-Zenith Satellite System
RCV	Receiver
RINEX	Receiver INdependent EXchange format
RMP	Regional Military Protection
S/C	Spacecraft
SA	Selective Availability (of GPS)
SAASM	Selective Availability Anti-Spoofing Module

SBAS	Satellite Based Augmentation System
SIRGAS	Sistema de Referencia Geocéntrico para las Américas
SISAI	Signal-in-Space Accuracy Index
SISMAI	Signal-in-Space Monitoring Accuracy Index
SISRE	Signal-in-Space Range Error
SNR	Signal-to-Noise Ratio
SSI	Signal Strength Indicator
SU	Soviet Union
SV	Space Vehicle
TGD	Timing Group Delay
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 4.00 TO 4.01 CHANGES

The table below contains the changes between the current and the previous RINEX format versions.

01 Dec 2021	**RINEX 4.00 Released**
Feb 2022	- Updated the internal “4.00” to “4.01” format version number as needed and reworded a few sentences to indicate “from RINEX 4.00”. - Corrected in Table A1 the “<Data Type>” Example column as “MN” was in the text twice, the first instance was corrected to “MO” as it should be. - Corrected Table A9 to Table A34 missing space “1X” between the satellite PRN and the Navigation Message Type. - Corrected Table A22 to Table A24 the Navigation Message Type from “A2” to “A4”.
Aug 2022	- Added to Table 10 new observation codes for GPS in L1 and L2 to cover the future (Block IIIF) RMP antenna navigation signal transmissions using the M code. - Added the “R” Attribute to Table A2 to cover the future RMP antenna navigation signal transmissions. - Added to Table A39 the new signals L1R and L2R with the cursory “Restricted” note since no public information is available.
Oct 2022	- In line with the recommendation in section 6.8 updated all FORMAT columns in Table A9 to Table A34 from “D19.12” to “E19.12” - Added the missing UTC(NIST) to the valid UTC ID entries in section 5.4.9 to be consistent with the values in Table A30. - In Table A31 corrected the name of the second “NAV RECORD” to “EOP MESSAGE LINE – 0”
Nov 2022	- Corrected the Table A12 GPS CNV2 example to leave blanks for unknown values - Added a clarification to section 5.4.6 to indicate that new BDS CNV1/2/3 navigation messages shall not be triggered for t_op/SISAI changes but only for new t_oc . This means that the values of t_op/SISAI for the same satellite and epoch may differ between two RINEX files depending on the exact time of decoding.
Jun 2023	- Added L1 Observation codes for the NavIC constellation in Table 16. - Added the NavIC “Band” and “Attribute” indicators for the new L1 signal to Table A2. - Added to Table A39 the new NavIC signals L1D, L1P and L1X with the L1D for phase alignment as for other similar signals. - Simplified the name “NavIC/IRNSS” for “NavIC” throughout the document as the name of the Navigation Indian Constellation (the final name for the Indian Regional Navigation Satellite System). - Updated the GPS ICDs to the latest version numbers 200N, 705J and 800J , also added the NavIC SPS L1 ICD to the list of references in section 7 - Added the valid UTC IDs for the SBAS in Table 23.
10 Jul 2023	**RINEX 4.01 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 GNSS data use a well-defined set of observables:

- The **carrier-phase measurement** at one or both carriers, 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 **doppler measurement**, the difference between the observed and emitted frequency of the carrier.
- The **signal-to-noise ratio** (SNR) **measurement**, the carrier to noise density ratio (C/N0) or the ratio of the received signal power to the noise power.
- The **observation time**, the reading of the receiver clock at the instant of validity of the measurements.

Usually, geodetic processing software assumes that the observation time in RINEX is valid for **all** 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 as a minimum 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.
- RINEX Version 4 introduced in 2021 as a necessary step to support the modern multi-GNSS navigation messages by introducing and defining navigation 'data records' to hold both individual satellite navigation messages, constellation-wide parameters and global parameters as transmitted by the different GNSS constellations.

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 was 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 ¼-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 (formerly 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. ***This was the last of the RINEX version 3 format series***.
- RINEX 4.00 is launched in 2021 as the results of the RINEX Working Group Navigation Taskforce discussions during the first half of 2021. The work built upon the effort over years from the DLR/GSOC group led by Dr O. Montenbruck to modernize the GNSS Navigation message format.

- RINEX 4.01 is produced in 2023 to correct some minor erratas in the previous format document, add some necessary clarifications and add new observations codes for upcoming GPS satellites, and for L1 NavIC signals.

3 GENERAL FORMAT DESCRIPTION

The RINEX 4 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 4 mixed navigation message files are expected to contain navigation messages of all tracked navigation satellite systems, so as to make the exchange and processing of navigation data more efficient.

The header and data record format descriptions as well as examples for each file type are given in the Appendix Tables of Section 8 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. The time of the measurement is considered identical for all of them (phase, pseudorange, etc) and considered identical for all satellites observed at that epoch.

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

For mixed files, the actual system time used **must** be indicated in the **`TIME OF FIRST OBS`** header record (Table A2). The details of each GNSS Time and their use in RINEX is defined below.

Each GNSS maintains a system time that is distinct from any particular UTC reference but is steered or linked to some such reference as designated by the respective ICDs. The details of each GNSS system time and their use in RINEX is defined below.

4.1.1 GPS Time

GPS time is steered to UTC(USNO), i.e. the local realization of UTC maintained by the United States Naval Observatory (USNO). 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, …

RINEX uses **`GPS`** as system time identifier for the reported GPS time.

4.1.2 GLONASS Time

GLONASS time is basically running on UTC(SU) (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.

RINEX uses **`GLO`** as system time identifier for the reported GLONASS time.

4.1.3 Galileo System Time

Galileo runs on Galileo System Time (GST), which is steered to a UTC realization from an ensemble of clocks maintained at several metrological institutes in Europe by the Galileo Time Service Provider. Apart from small differences (tens of nanoseconds), GST is nearly identical to GPS Time in that:

- 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.*

RINEX uses **GAL** as system time identifier for the reported Galileo time.

4.1.4 BeiDou Time

The **BDS** Time (BDT) System is a continuous timekeeping system which is steered to UTC(NTSC). 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, …

RINEX uses **BDT** as system time identifier for the reported BDS time.

4.1.5 QZSS Time

QZSS runs on QZSS time, which is steered to UTC(NICT), i.e. the local realization of UTC maintained by the Japan National Institute of Information and Communications Technology (NICT). 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.

RINEX uses **QZS** as a system time identifier for the reported QZSS time.

4.1.6 NavIC System Time

NavIC runs on Indian Regional Navigation Satellite System Time (**IRNSST**) which is steered to UTC(NPLI). 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).

RINEX uses **IRN** as the system time identifier for the reported NavIC time.

4.1.7 GNSS Time Relationships

Apart from the small, sub-microsecond differences, in the realizations of the different system times, 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 ΔtLS by adding a **LEAP SECOND** header line into the RINEX Observation file header (see Table A2).

The **LEAP SECOND** header line is now compulsory in the RINEX Navigation file header (see Table A7).

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

Table 1 : Constellation Time Relationships

GLO	=	UTC	=	GPS	-	ΔtLS
GPS	=	GAL	=	UTC	+	ΔtLS
GPS	=	QZS	=	UTC	+	ΔtLS
GPS	=	IRN	=	UTC	+	ΔtLS
BDT	=			UTC	+	ΔtLS_{BDS}

Table 2 : GPS and BeiDou UTC Leap Second Relationship

ΔtLS	=	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: ΔtLS = 13 seconds
		2006-01-01 - 2009-01-01: ΔtLS = 14 seconds
		2009-01-01 - 2012-07-01: ΔtLS = 15 seconds
		2012-07-01 - 2015-07-01: ΔtLS = 16 seconds
		2015-07-01 - 2017-01-01: ΔtLS = 17 seconds
		2017-01-01 - ????-??-??: ΔtLS = 18 seconds
ΔtLS_{BDS}	=	Delta time between BDT and UTC due to leap seconds, as transmitted by the BDS satellites in the almanac. ΔtLS_{BDS} = ΔtLS -14 seconds
		2006-01-01 - 2009-01-01: ΔtLS_{BDS} = 0 seconds
		2009-01-01 - 2012-07-01: ΔtLS_{BDS} = 1 seconds
		2012-07-01 - 2015-07-01: ΔtLS_{BDS} = 2 seconds
		2015-07-01 - 2017-00-01: ΔtLS_{BDS} = 3 seconds
		2017-01-01 - ????-??-??: ΔtLS_{BDS} = 4 seconds

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.

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

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 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

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 = distance + c * (receiver clock offset –satellite clock offset) + 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. RINEX pseudoranges must be corrected depending on the receiver tracking time, as shown in Table 4, to remove the contributions of the leap seconds from the pseudo-ranges.

Table 4 : Constellation Pseudorange Corrections

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

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 with the pseudorange (i.e. if the pseudorange increases with time, the phase increases as well). The phase observations between epochs must be connected by including the integer number of cycles.

If necessary, phase observations have to be corrected for phase shifts so as to be aligned to the referenced signal as indicated in Table A39. This is needed to guarantee consistency between phases of the same frequency and satellite system based on different signal channels.

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 observables as specified in Table 5.

Table 5: Observation Corrections for Receiver Clock Offset

Time (corr)	=	Time(r)	-	dT(r)
PR (corr)	=	PR (r)	-	dT(r)*c
phase (corr)	=	phase (r)	-	dT(r)*freq
Doppler (corr)	=	Doppler (r)	-	$d\dot{T}$(r)*freq

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.

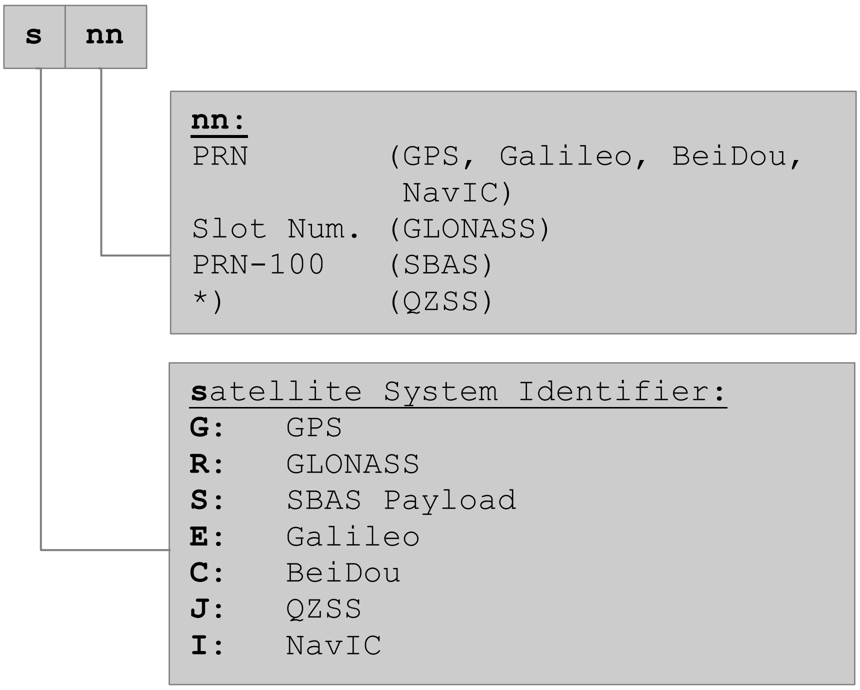

Figure 1: Satellite numbers and Constellation Identifiers

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

*) QZSS satellites make use of signal-specific PRN codes. In RINEX files, QZSS satellites are therefore distinguished by the space vehicle identifier (SV ID) as used in the QZSS LNAV almanac. The mapping of QZSS RINEX designators (**J01-J10**) and QZSS PRNs for individual signals is shown in Table 6.

Table 6: QZSS PRN to RINEX Satellite Identifier

RINEX Satellite ID	Standard PNT Signals / Centimeter Level Augmentation	Standard PNT Signals	Sub-meter Level Augmentation	Centimeter Level Augmentation for Experiments	Positioning Technology Verification Service
	Nominal	L1 C/B	L1-SAIF / L1S	L6E	L5S
J01	193		183	203	
J02	194		184	204	184
J03	195		185	205	185
J04	196	203	186	206	186
J05	197	204		207	
J06	198			208	
J07	199		189	209	189
J08	200	205		210	205
J09	201	206		211	206
J10	202	202		212	

5 RINEX VERSION 3 AND 4 FEATURES

This chapter contains description and explanations of the RINEX 3 and 4 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 RINEX short file naming convention. RINEX file naming 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, EUREF, APREF, SIRGAS, etc.

The filename recommendations herein, and fully described in Table A1, are included for convenience as they have been agreed across many institutions. Each organization can use or adapt these names as they see fit, or use any other file naming scheme, this has no material effect on the RINEX file format.

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 in the filename to ease in sorting, storing and identifying data files.

This proposed naming scheme 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. See Table A1 for the full description of the file naming convention.

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

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

5.2 Observation File Header

See Table A2 for a detailed specification of the RINEX 4 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 4 header must decode the header records with formats according to the record descriptor in Table 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 **PGM / RUN BY / DATE** line must be the second record(line) in all RINEX files. In RINEX Observation files additional records of this type from previous file modifications or updates can be stored if needed as the lines immediately following the second line.
- 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.
- 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 line **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 an unknown local time was used.

In RINEX Observation files additional **PGM / RUN BY / DATE** header lines can appear immediately after the second line if needed to preserve the history of previous actions on the file.

5.2.3 Marker type

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 Table 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.

Table 8: Predefined Marker Type Keywords

Marker Type	Description
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.

Marker Type	Description
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

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 section 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, BeiDou, or NavIC observation files **can** contain the system time 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
- **GAL** to identify Galileo time
- **QZS** to identify QZSS time
- **BDT** to identify BDS time
- **IRN** to identify NavIC 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 applications, it might be useful to generate RINEX files with corrections of the satellite 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 (Table A2).

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** header 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 in a GNSS constellation 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. To facilitate consistent processing of all signals across different receiver platforms and applications, such phase differences must be compensated at or before the generation of RINEX observation files.

By convention, phase observations in RINEX files must always be aligned to a predefined reference signal. Table A39 specifies the reference signal for each frequency and constellation, and which signals shall align to the reference. This alignment of phases allows interoperability between different signals in the same frequency. There is no ambition to align phases across constellations.

The **SYS / PHASE SHIFT** header lines are now optional in the RINEX observation files and strongly deprecated. They are retained in the RINEX observation file header definition (Table A2) for compatibility with previous RINEX versions but they should be ignored by RINEX decoders and encoders.

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 Table A3). ***Note***: The loss of lock bit is the least significant bit.

5.2.14 Receiver clock offset

A receiver-derived clock offset can be optionally 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**.

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, from RINEX 4.00 it is required to have 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 Code-Phase Alignment Header Record

Some GNSS receivers may produce biased GLONASS observations. The bias is a result of the code and phase observations not being taken at the same instant.

Phase data from GNSS receivers that issue biased data must be corrected to remove the bias.

The GLONASS CODE/PHASE BIAS (**GLONASS COD/PHS/BIS**) header record is now optional and deprecated since RINEX data file users need the data corrected but do not generally care what the correction applied was, and since the corrections may not be known at the time of RINEX file writing.

This deprecated GLONASS code-phase alignment header line contains the C1C, C1P, C2C and C2P corrections. See Table A2 for details.

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 9.

Table 9 : Observation Code Components

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.				

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 10 to Table 16.

Table 10 : RINEX Version 4.01 GPS Observation Codes

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
		M (RMP antenna)	C1R	L1R	D1R	S1R
	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
		M (RMP antenna)	C2R	L2R	D2R	S2R
	L5/1176.45	I	C5I	L5I	D5I	S5I
		Q	C5Q	L5Q	D5Q	S5Q
		I+Q	C5X	L5X	D5X	S5X

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**.

Table 11 : RINEX Version 4.01 GLONASS Observation Codes

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 12 : RINEX Version 4.01 Galileo 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 13 : RINEX Version 4.01 SBAS 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 14 : RINEX Version 4.01 QZSS 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
		C/B	C1E	L1E	D1E	S1E
		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

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.

Table 15 : RINEX Version 4.01 BDS Observation Codes

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

Note: When reading a RINEX 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.

Table 16 : RINEX Version 4.01 NavIC Observation Codes

GNSS System	Freq. Band / Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
NavIC	L1 / 1575.42	Data	C1D	L1D	D1D	S1D
		Pilot	C1P	L1P	D1P	S1P
		Data+Pilot	C1X	L1X	D1X	S1X
	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

5.3 Observation Data Records

See section 8 for a detailed specification of the RINEX 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 17 shows a sample list of observation types for six satellite systems **G,E,S,R,C,J**.

Table 17 : Example Observation Type Records

```
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
```

RINEX observations are written as detailed in section 6.7. An epoch and partial observation records example is provided in Table 18.

Table 18 : Example RINEX Observation Epoch

```
> 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
```

The long observation lines per satellite are wrapped to fit the table width, each new line starts with a PRN and is wrapped (indicated by →) until the next PRN (no width limitation to the satellite observation lines).

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 observation 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 (Table A3).

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 ⇒ **Snn** = **S20**

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 RINEX Navigation Messages

From RINEX 4.00 it is encouraged to record at each station 'Mixed' navigation files containing all the GNSS system navigation messages. Navigation files for individual constellations are allowed but discouraged to reduce the number of files from a station.

Merged RINEX navigation files (whether from an individual station or from a station network) are described in section 6.11 and are always expected to contain the navigation messages of all the tracked satellites in mixed or individual constellation mode.

The data portion of the navigation message files contains the broadcast navigation data records scaled to engineering units and with floating point numbers. The navigation message format is similar for all satellite systems. All legacy navigation messages supported by earlier RINEX versions remain unchanged and all new navigation messages reuse the fixed grid of four columns with a width of 19 characters.

The number of records per message and the contents are constellation and signal dependent as detailed in section 8.3. Using the new Data Record Header Line which contains; a navigation record type, the satellite or constellation identifier and the navigation message type (see section 5.4.1), the reading program can determine the number of fields to be read for each data record as defined in each of the corresponding Appendix Tables.

From RINEX 4.00 constellation and global dependent navigation file contents have been removed from the header and included as specific system time correction, earth orientation and ionosphere navigation messages.

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

A navigation file shall avoid storing redundant navigation messages in the RINEX file (e.g., the same message broadcast at different times, or containing exactly the same data). In case of multiple navigation data sets with identical contents, priority should be given to storing the one with the earliest transmission time.

5.4.1 Navigation Data Record Header Line

From RINEX 4.00 an initial line is included to indicate the start of a new navigation data record. This navigation data record header line contains a starting indicator "**>**", a navigation data record type, the source of the data, and the message type indicator from which the data record is obtained, this is the new Data Record Header Line.

The first element, the record type, is as presented in Table 19.

Table 19: Navigation Data Record Types

Nav Data Record Type	Description
EPH	Ephemerides data including orbit, clock, biases, accuracy and status parameters.
STO	System Time and UTC proxy offset parameters
EOP	Earth Orientation Parameters
ION	Global/Regional ionospheric model parameters

The second element is the source of the navigation data record. It is indicated with the constellation letter (**G,R,E,C,J,I**), plus when necessary the two-digit satellite number of the transmitting satellite. Redundant constellation data records coming from different satellites with the exact same values shall not be repeated.

The navigation message type indicator is the final element of the Data Record Header Line and it depends on the data record type of Table 19.

Table 20: EPH Navigation Message Types

EPH Nav Message Types	Description	Constellation and signal
LNAV	GPS/QZSS/NavIC Legacy Navigation Messages	GPS L1 C/A, QZSS L1 C/A or L1 C/B, NavIC L5/S SPS
FDMA	GLONASS Legacy FDMA Message	GLO L1 C/A
FNAV	Galileo Free Navigation Message	GAL E5a
INAV	Galileo Integrity Navigation Message	GAL E1, E5b
D1	BeiDou-2/3 MEO/IGSO Navigation Message	BDS B1I, B2I, B3I
D2	BeiDou-2/3 GEO Navigation Message	BDS B1I, B2I, B3I
SBAS	SBAS Navigation Message	SBAS L1
CNAV	GPS/QZSS CNAV Navigation Message	GPS/QZSS L2C, L5
CNV1	BeiDou-3 CNAV-1 Navigation Message	BDS-3 B1C
CNV2	GPS/QZSS CNAV-2 Navigation Mssg BeiDou-3 CNAV-2 Navigation Message	GPS/QZSS L1C BDS-3 B2a
CNV3	BeiDou-3 CNAV-3 Navigation Message	BDS-3 B2b

Constellation or System navigation data records (**STO**, **EOP**, **ION** from Table 19) contain data commonly transmitted by different groups of navigation messages and thus the granularity of the message type indicators can be reduced to prevent many copies of the same data being repeated in a navigation file;

Table 21: STO, EOP, ION Navigation Message Types

STO,EOP,ION Nav Message Types	Description	Constellation and signal
LNAV	GPS/QZSS/NavIC Legacy Navigation Messages	GPS L1 C/A, QZSS L1 C/A or L1 C/B, NavIC L5/S SPS
FDMA	GLONASS Legacy FDMA Navigation Message	GLO L1 C/A
IFNV	Galileo INAV or FNAV Navigation Message	GAL E1, E5a, E5b
D1D2	BeiDou-2/3 MEO/IGSO and GEO Navigation Message	BDS B1I, B2I, B3I
SBAS	SBAS Navigation Message	SBAS L1

STO,EOP,ION Nav Message Types	**Description**	**Constellation and signal**
CNVX	GPS/QZSS CNAV Navigation Message BeiDou-3 CNAV-1, CNAV-2 or CNAV-3 Navigation Message	GPS/QZSS L2C, L5 BDS-3 B1C, B2I, B3I

The navigation data message header lines are then, for example;

```
> EPH G01 LNAV
> STO R   FDMA
> ION E08 IFNV
> EOP J01 CNVX
```

5.4.2 EPH Navigation messages for GPS (LNAV, CNAV, CNV2)

The specifications for the GPS satellite navigation messages are in Table A9, Table A10, and Table A11. After the new Data Record Header Line the **LNAV** message is defined exactly as in previous RINEX versions. The first data record always contains the epoch, and satellite clock information. The following lines contain the orbit parameters for the satellite, the time of applicability of the navigation message, health flag, accuracy information, group delays, etc.

5.4.3 EPH Navigation messages for Galileo (INAV, FNAV)

The specifications for the Galileo satellite navigation message are in Table A13. The Galileo Open Service allows access to two navigation message types: **FNAV** (Free Navigation) and **INAV** (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 (**FNAV** or **INAV**): The SV clock parameters actually define the satellite clock for the dual-frequency ionosphere-free linear combination. FNAV reports the clock parameters valid for the E5a-E1 combination, the INAV 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 shall encode one RINEX Galileo navigation message for each **FNAV** and **INAV** signal decoded. Therefore, if both 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 **FNAV** and **INAV** messages with the same IOD in the same file. Additionally, parsers should also expect to encounter more than one **FNAV** or **INAV** 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 EPH Navigation message for GLONASS (FDMA)

The specifications for the GLONASS satellite navigation message are in Table A15. 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 the UTC proxy is as follows:

GLONASS: Tutc = Tsv + TauN –GammaN*(Tsv-Tb) + TauC

In order to use the same sign conventions, the broadcast GLONASS values are stored in the navigation file (in GLONASS **`EPH`** and **`STO`** messages) as: -TauN, +GammaN, -TauC.

The time tags in the GLONASS navigation files are given in UTC (i.e. **not** Moscow time nor GPS time).

5.4.5 EPH Navigation messages for QZSS (LNAV, CNAV, CNV2)

The QZSS navigation messages are defined in Table A17, Table A18 and Table A19. The messages are defined in-line with the GPS equivalent messages but for completeness and in view of some selected differences fully independent definition tables are included.

5.4.6 EPH Navigation messages for BDS (D1/D2, CNV1, CNV2, CNV3)

The BDS Open Service broadcast navigation messages are defined in Table A21, Table A22, Table A23, and Table A24. 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).

New navigation messages shall be triggered only at t_oc changes. This means that the t_op/SISAI values of the CNV1/2/3 navigation messages could be different between RINEX files for the same satellite and epoch depending on the exact time of decoding. The values of the t_op/SISAI change much faster than the other ephemerides but they will not trigger new navigation messages.

5.4.7 EPH Navigation message for SBAS satellites (SBAS)

The specifications for SBAS satellite navigation message are in Table A26. 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 MT17 "GEO Almanacs" message.

The first data record line 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:
GEO: Tutc = Tsv –aGf0 –aGf1 *(Tsv-Toe) –W0 –ΔtLS

W0 being the correction to transform the GEO system time to the UTC proxy. See Toe, aGf0, aGf1 in Table A26 format definition table.

The *Transmission Time of Message* 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

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.

5.4.8 EPH Navigation messages for NavIC (LNAV)

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

See Table A28 and Table A29 for a description and examples of each field.

5.4.9 STO Messages for System Time and UTC Offset

The STO messages replace the previous "**`SYSTEM TIME CORR`**" header line(s).

The STO message is defined in Table A30. GNSS satellites transmit different system time offsets. With these offsets timing information can be converted between GNSS time scales or from a GNSS time scale to a UTC proxy. Only the fractional-second parts of the respective offset are provided in the STO records. Information on full leap seconds between GPS time to UTC (since 6 Jan 1980) is contained in the "**`LEAP SECONDS`**" header line which is now compulsory for navigation files (see Table A7).

Table 22: Navigation Message System Time Offset labels

System		UTC	GPS	GLO	Galileo	BeiDou	QZSS	NavIC
	2 letter codes	**UT**	**GP**	**GL**	**GA**	**BD**	**QZ**	**IR**
GPS	**GP**	**GPUT**						
GLONASS	**GL**	**GLUT**	**GLGP**					
Galileo	**GA**	**GAUT**	**GAGP**	**GAGL**				
BeiDou	**BD**	**BDUT**	**BDGP**	**BDGL**	**BDGA**			

QZSS	**QZ**	**QZUT**	**QZGP**	**QZGL**	**QZGA**	**QZBD**		
NavIC	**IR**	**IRUT**	**IRGP**	**IRGL**	**IRGA**	**IRBD**	**IRQZ**	
SBAS	**SB**	**SBUT**	**SBGP**	**SBGL**	**SBGA**	**SBBD**	**SBQZ**	**SBIR**

In case of the UTC time offsets, the specific UTC proxy referenced is specified by a dedicated indicator; the UTC ID.

Valid UTC ID entries include: **UTC(USNO)**, **UTC(SU)**, **UTCGAL**, **UTC(NTSC)**, **UTC(NICT)**, **UTC(NPLI)**, **UTCIRN**, **UTC(OP)**, **UTC(NIST)**. A UTC ID is necessary, as detailed in Table 23, for every "**UT**" time offset message.

Table 23: Navigation Message System Time UTC indicator

System	UTC Offset label	UTC ID
GPS	**GPUT**	**UTC(USNO)**
GLONASS	**GLUT**	**UTC(SU)**
Galileo	**GAUT**	**UTCGAL**
BeiDou	**BDUT**	**UTC(NTSC)**
QZSS	**QZUT**	**UTC(NICT)**
NavIC	**IRUT**	**UTCIRN /** **UTC(NPLI)**
SBAS	**SBUT**	**UTC(USNO)** **UTC(CRL)** **UTC(NIST)** **UTC(BIPM)** **UTC(OP)** **UTC(NTSC)**

For Galileo, the "UTC" to which the **GAUT** offset refers to comes from an ensemble of clocks maintained at several metrological institutes in Europe by the Galileo Time Service Provider, and the designation **UTCGAL** has been adopted as the proxy for the UTC broadcast by Galileo.

For NavIC, which transmits two distinct offsets of NavIC system time with respect to both UTC and to UTC(NPLI), the correct UTC ID (**UTCIRN** or **UTC(NPLI)**) shall be used for each case.

In terms of SBAS different **SBUT** values will require different UTC IDs for each system. Thus, additionally an SBAS ID indicator must also be specified for every **SBUT** value. Current SBAS ID values are: **WAAS**, **EGNOS**, **MSAS**, **GAGAN**, **SDCM**, **BDSBAS**, **KASS**, **A-SBAS**, **SPAN**. See Table A30 for the structure of the STO message and the use of these indicators.

The time offset parameters for different constellations and navigation messages and how the parameters are to be used are indicated in Table 24.

Table 24: Time Offset Parameters per GNSS and per Navigation Message

System	STO Nav Mssg Type	Definition	Time sys offset labels (Message parameters)
GPS	**LNAV**	$t_{\mathrm{GPS}} - t_{\mathrm{UTC(USNO)}} = \Delta t_{\mathrm{ls}}^{1980} + A_0 + A_1(t - t_{\mathrm{ot}})_{\mathrm{GPS}}$	**GPUT** $(+A_0, +A_1; t_{\mathrm{ot}})$
	CNVX	$t_{\mathrm{GPS}} - t_{\mathrm{UTC(USNO)}} = \Delta t_{\mathrm{ls}}^{1980} + A_0 + A_1(t - t_{\mathrm{ot}})_{\mathrm{GPS}} + A_2(t - t_{\mathrm{ot}})^2_{\mathrm{GPS}}$	**GPUT**

System	STO Nav Mssg Type	Definition	Time sys offset labels (Message parameters)
			$(+A_0, +A_1, +A_2; t_{ot})$
		$t_{GAL} - t_{GPS} = -A_0 - A_1\left(t - t_{ggto}\right)_{GPS} - A_2\left(t - t_{ggto}\right)^2_{GPS}$	**GAGP** $(-A_0, -A_1; t_{ggto})$
GLO	**LNAV**	$t_{UTC(SU)} + 3h - t_{GLO} = \tau_c$	**GLUT** $(-\tau_c; t_{0d})$
		$t_{GPS} - t_{GLO} = -3h + \Delta t_{ls}^{1980} + \tau_{GPS}$	**GLGP** $(-\tau_{GPS}; t_{0d})$
GAL	**IFNV**	$t_{GAL} - t_{UTC} = \Delta t_{ls}^{1980} + A_0 + A_1 \cdot (t - t_{ot})_{GAL}$	**GAUT** $(+A_0, +A_1; t_{ot})$
		$t_{GAL} - t_{GPS} = A_0 + A_1 \cdot \left(t - t_{og}\right)_{GAL}$	**GAGP** $(+A_0, +A_1; t_{og})$
BDS	**D1D2**	$t_{BDS} - t_{UTC(NTSC)} = \Delta t_{ls}^{2006} + A_0 + A_1 \cdot (t - t_{0w})_{BDS}$	**BDUT** $(+A_0, +A_1; t_{0w})$
		$t_{BDS} - t_{GPS} = A_0 + A_1(t - t_{0w})_{BDS}$	**BDGP** $(+A_0, +A_1; t_{0w})$
		$t_{BDS} - t_{GAL} = A_0 + A_1(t - t_{0w})_{BDS}$	**BDGA** $(+A_0, +A_1; t_{0w})$
		$t_{BDS} - t_{GLO} = A_0 + A_1(t - t_{0w})_{BDS}$	**BDGL** $(+A_0, +A_1; t_{0w})$
	CNVX	$t_{BDS} - t_{UTC(NTSC)} = \Delta t_{ls}^{2006} + A_0 + A_1(t - t_{ot})_{BDS} + A_2(t - t_{ot})^2_{BDS}$	**BDUT** $(+A_0, +A_1, +A_2; t_{ot})$
		$t_{BDS} - t_{GPS} = A_0 + A_1\left(t - t_{bgto}\right)_{BDS} + A_2\left(t - t_{bgto}\right)^2_{BDS}$	**BDGP** $(+A_0, +A_1, +A_2; t_{bgto})$
		$t_{BDS} - t_{GAL} = A_0 + A_1\left(t - t_{bgto}\right)_{BDS} + A_2\left(t - t_{bgto}\right)^2_{BDS}$	**BDGA** $(+A_0, +A_1, +A_2; t_{bgto})$
		$t_{BDS} - t_{GLO} = A_0 + A_1\left(t - t_{bgto}\right)_{BDS} + A_2\left(t - t_{bgto}\right)^2_{BDS}$	**BDGL** $(+A_0, +A_1, +A_2; t_{bgto})$
QZSS	**LNAV**	$t_{QZS} - t_{UTC(NICT)} = \Delta t_{ls}^{1980} + A_0 + A_1(t - t_{ot})_{QZS}$	**QZUT** $(+A_0, +A_1; t_{ot})$
	CNVX	$t_{QZS} - t_{UTC(NICT)} = \Delta t_{ls}^{1980} + A_0 + A_1(t - t_{ot})_{QZS} + A_2(t - t_{ot})^2_{QZS}$	**QZUT** $(+A_0, +A_1, +A_2; t_{ot})$
NavIC	**LNAV**	$t_{IRS} - t_{UTC} = \Delta t_{ls}^{1980} + A_0 + A_1(t - t_{ot})_{IRS} + A_2(t - t_{ot})^2_{IRS}$	**IRUT** $(+A_0, +A_1, +A_2; t_{ot})$
		$t_{IRS} - t_{UTC(NPLI)} = \Delta t_{ls}^{1980} + A_0 + A_1(t - t_{ot})_{IRS} + A_2(t - t_{ot})^2_{IRS}$	**IRUT** $(+A_0, +A_1, +A_2; t_{ot})$
		$t_{IRS} - t_{GPS} = A_0 + A_1(t - t_{ot})_{IRS} + A_2(t - t_{ot})^2_{IRS}$	**IRGP** $(+A_0, +A_1, +A_2; t_{ot})$
		$t_{IRS} - t_{GLO} = A_0 + A_1(t - t_{ot})_{IRS} + A_2(t - t_{ot})^2_{IRS}$	**IRGL** $(+A_0, +A_1, +A_2; t_{ot})$
		$t_{IRS} - t_{GAL} = A_0 + A_1(t - t_{ot})_{IRS} + A_2(t - t_{ot})^2_{IRS}$	**IRGA** $(+A_0, +A_1, +A_2; t_{ot})$
SBAS	**SBAS**	$t_{SBAS(i)} - t_{UTC(j)} = \Delta t_{ls}^{1980} + A_0 + A_1 \cdot (t - t_{ot})_{SBAS(i)}$	**SBUT** $(+A_0, +A_1; t_{ot}; i; j)$ i ; SBAS ID j ; UTC ID

Where $\Delta t_{\mathrm{ls}}^{1980}$ / $\Delta t_{\mathrm{ls}}^{2006}$: leap seconds since Jan.1980 / 2006; t_{ot}: reference epoch; t_{0w}: start-of-week epoch; t_{0d}: start-of-day epoch.

The reference epoch of the time offset polynomial is given in the form of a calendar date in analogy with the clock epoch of the **EPH** ephemeris records. In addition, the transmission time is provided in field 4 of line 1 to identify, at which instant the time offset information has become available in the receiver.

The reference epoch and the transmit time refer to the system time of the originating constellation, which is identified in the **STO** record header. In accord with the conventions for ephemeris data, the epoch and transmit time of STO information transmitted by GLONASS satellites should be aligned to UTC by subtracting 3 h from the respective values in Moscow Time.

5.4.10 EOP Messages for Earth Orientation Parameters

The **EOP** messages are new from the RINEX 4.00 navigation files onwards. The messages are defined in Table A31.

Earth orientation parameters (EOPs) are presently supported by four constellations: GPS, QZSS, NavIC, and BeiDou-3. In all cases pole coordinates (x, y) and ΔUT1 and the respective rates are provided for a specified reference epoch. For the GLONASS **CDMA** navigation messages, second-order derivatives will be provided for all three parameters.

The reference epoch of the **EOP** data is given in the form of a calendar date as with the clock epoch of the **EPH** ephemeris records. In addition, the transmission time of the **EOP** data is provided, at which instant the **EOP** information has become available in the receiver.

5.4.11 ION Messages for Ionosphere Model Parameters

The **ION** messages replace the previous "**IONOSPHERE CORR**" navigation message file header line(s). The ionospheric messages for the different models are defined in Table A32, Table A33, and Table A34.

To support navigation with single-frequency observations, most GNSSs transmit a system-specific set of parameters based on which navigation users can model the ionospheric slant electron content and thus correct the ionospheric path delays. The choice of model varies with constellation and navigation message type, and includes:

- The Klobuchar model used in GPS, BeiDou-2/3, QZSS, and NavIC
- The NeQuick-G model of Galileo
- The BDGIM model used in BeiDou-3

The Klobuchar model is jointly used by four constellations, but the model coefficients are independently determined for each of these systems. In case of regional systems such as BeiDou-2, QZSS, and NavIC, the model parameters are typically optimized for use in the respective service area. As a unique feature of QZSS, two independent sets of Klobuchar model coefficients for "wide area" and "Japan area" users are jointly transmitted in each of the LNAV, CNAV, and CNAV-2 messages. For other constellations, only a single parameter set is provided.

The ionosphere model parameters provided by the various GNSSs are not associated with a reference epoch or validity period.

6 RINEX FORMATTING CLARIFICATIONS

6.1 Versions

Programs developed to read RINEX files have to verify the version number and take proper action if they 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

When writing CHARACTER fields content should be left-justified. When reading CHARACTER fields leading and trailing white space should be discarded.

6.3 Variable-length records

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 Spare Fields

In view of future format evolutions, we recommend to carefully skip any fields currently defined to be Spare or left blank in the navigation message definition tables (section 8.3), because they may be assigned to new contents in future versions.

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

6.5 Missing items, duration of the validity of values

Header items that are not known at the file creation time can be set to zero or blank (Blank if Not Known/Not Defined - 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.

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**:

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

Table 25 : Standardized SNR Indicators

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

Additionally, observation codes per signal are specified to store detailed signal strength observations '**Sna**' (see Table 10 - Table 16). 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

The exponent indicator; **E**, **e**, are recommended between the fraction and exponent of all floating-point numbers for the navigation messages. The indicators; **D**, and **d** are allowed but strongly deprecated. Zero-padded two-digit exponents are required.

Examples, from different station navigation files:

```
     1.266124167725E-09 2.000000000000E+00 2.069000000000E+03 1.000000000000E+00
     7.304595403547E-01-1.565625000000E+01-1.559470529133E+00-9.082521180606E-10


    -4.411928222656e+03-3.539047241211e+00 9.313225746155e-10 0.000000000000e+00
     2.101021875000e+04 1.440399169922e+00-1.862645149231e-09 0.000000000000e+00
```

The same exponent indicator will be used throughout a navigation file (station or merged).

6.9 Units in Navigation data records

In the **EPH** Navigation Data Records angles and their derivatives transmitted in units of semi-circles and semi-circles/sec have to be converted to radians and radians/sec by the RINEX generator.

In the **ION** navigation Data Records semi-circles are not converted. ICD specific units are retained, no conversion takes place as indicated in Table A32, Table A33, and Table A34.

6.10 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:

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
5.130000000000E+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

6.11 Navigation message transmission time

The transmission time (t_tm) in the navigation message definition tables in Section 8.3 denotes the approximate time at which the navigation data were received. It shall allow to discriminate between repetitive transmissions of the same information and is expected to refer to an instant between the beginning of the first navigation frame or message and the end of the last navigation frame or message contributing data to a given RINEX ephemeris record.

The t_tm is referred to the constellation specific system time (i.e. GPS time for GPS, BDS time for BDS, etc.) and given in seconds of week. Adjust by +/-604800s to align t_tm to the same week as of the epoch in the **SV / EPOCH / SV CLK** line.

Legacy navigation records without transmit time are permitted for compatibility with past RINEX standards, but strongly deprecated.

Provision of the transmit time is mandatory for all new navigation records introduced in RINEX 4.0.

6.12 Merged Navigation files

A merged navigation file is created by a provider that consolidates the navigation message data from several individual stations over a time period specified in the filename, or from the same individual station to create a station file covering a longer time period.

The aim of the merged navigation file is to contain a complete set of non-redundant navigation records over a specified time frame. This simplifies for the user the task of finding all the original messages over many individual files, plus some quality control can be applied to the messages and the records sorted.

Merged navigation files sorting should aim to include global messages (**STO, ION, EOP**) at the start of the file and then the **EPH** messages either sorted by constellation prn or by the **EPOCH** record dates.

Merged navigation files should indicate it in their header via the **MERGED FILE** header line, and if known include the number of files merged and the number of stations that participated in the merge. See Table A7 for exact details and an example in Table A8.

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8 APPENDIX: RINEX FORMAT DEFINITIONS AND EXAMPLES

8.1 RINEX Long Filenames

The file naming and compression recommendations are strictly speaking not part of the RINEX format definition as described in section 5.1.

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;

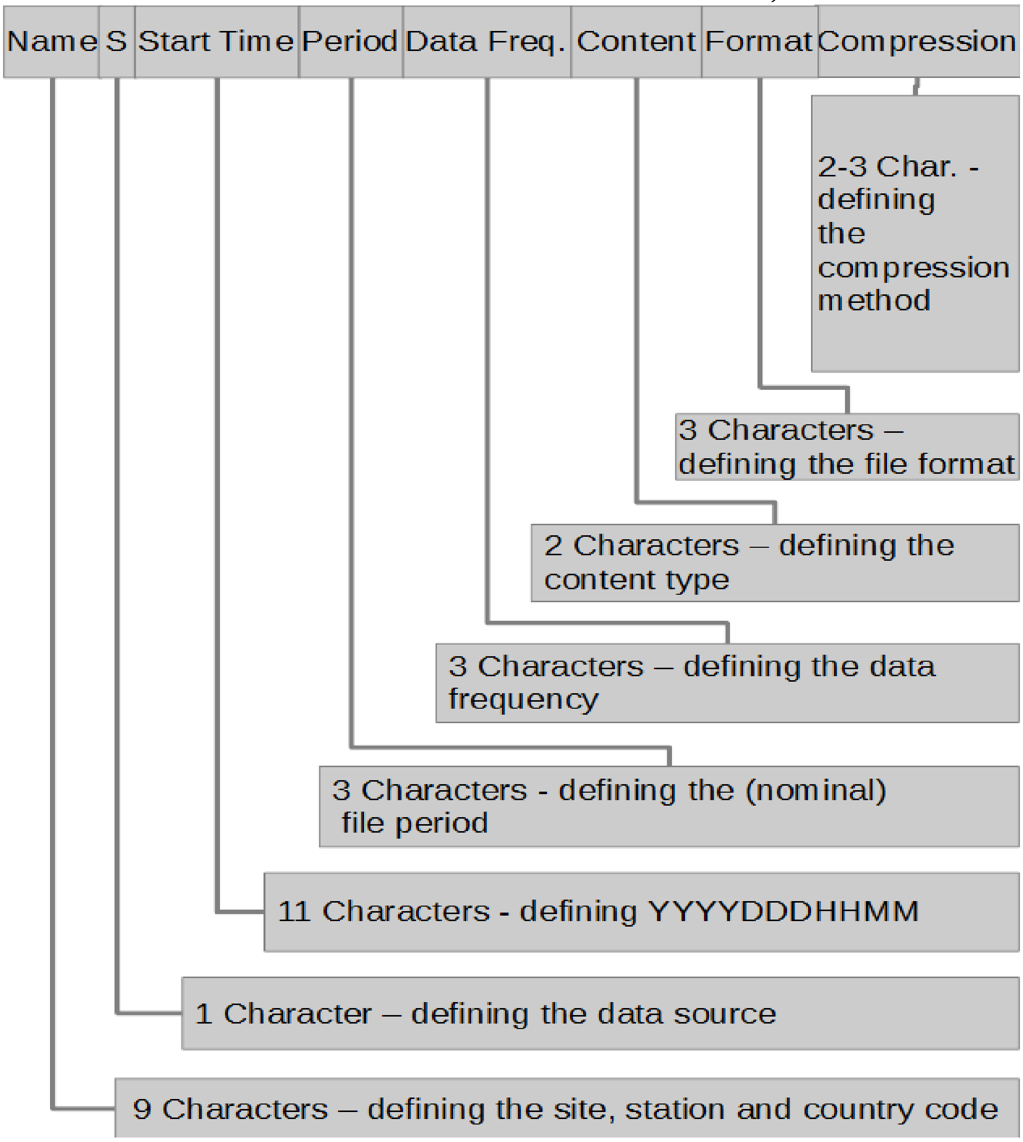

Figure 2: RINEX Long filename parameters.

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, Dr. 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:

- **https://terras.gsi.go.jp/ja/crx2rnx.html**
- IGSMails 1525,1686,1726,1763,1785,4967,4969,4975

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

Table A1 : RINEX Filename Description

TABLE A1 RINEX FILENAME DESCRIPTION				
Field	**Field Description**	**Example**	**Required**	**Comment/Example**
<SITE/ STATION-MONUMENT/ RECEIVER/ COUNTRY or REGION>	XXXXMRCCC Where: XXXX - 4 character site designation M – monument or marker number (0-9) R – receiver number (0-9) CCC – ISO Country or Region 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 or Region code to 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>	YYYYDDDHHMM 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 system time.
<FILE PERIOD>	DDU DD – file period U – units of file period. File period is used to specify intended collection period of the file.	15M	Yes	File Period 15M–15 Minutes 01H–1 Hour 01D–1 Day 01Y–1 Year 00U-Unspecified

TABLE A1 RINEX FILENAME DESCRIPTION				
Field	**Field Description**	**Example**	**Required**	**Comment/Example**
	(3 characters)			
<**DATA FREQ**>	DDU DD – data frequency U – units of data rate (3 characters)	05Z	Mandatory for RINEX Obs. Data. NOT required for Navigation Files.	XXC – 100 Hertz XXZ – Hertz, XXS – Seconds, XXM – Minutes, XXH – Hours, XXD – Days XXU – Unspecified
<**DATA TYPE** >	DD DD – Data type (2 characters)	MO	Yes	Two characters represent the data type: MO - Mixed Obs. (All GNSS Constellations tracked) GO - GPS Obs. RO - GLONASS Obs. EO - Galileo Obs. JO - QZSS Obs. CO - BDS Obs. IO - NavIC Obs. SO - SBAS Obs. MN - Mixed Nav. (All GNSS Constellations tracked) GN - GPS Nav. RN - GLONASS Nav. EN - Galileo Nav. JN - QZSS Nav. CN - Beidou Nav. IN - NavIC Nav. SN - SBAS Nav. MM-Meteorological Observation
<**FORMAT**>	FFF FFF – File format (3 characters)	rnx	Yes	Three characters indicating the data format: rnx – RINEX file crx - Hatanaka Compressed RINEX file
<**COMPRESSION**>	(2-3 Characters)	gz, bz2, zip	No	Suggested to use gzip, but other options are of course bzip2 and zip , for example.
Sub Total	34 or 35			Fields
Separators	(7 characters –Obs. File) (6 characters –Nav. File)			_ underscore between all fields and "." Between data type and file format and the compression method
Total	41-42(Obs. File) 37-38 (Nav. File)			Mandatory IGS RINEX obs. Characters

Filename Details and Examples:

<STATION/PROJECT NAME>: IGS users should follow XXXXMRCCC (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 system time as the file observation system time specified in the header. Files containing only: GLONASS, Galileo, QZSS, BDS or SBAS observations are all based on their respective system time.

<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_20121600000_01D_30S_GO.rnx.gz //1 day, Obs GPS and 30 sec
ALGO00CAN_R_20121600000_01D_30S_MO.rnx.gz //1 day, Obs. Mixed, 30 sec

GNSS mixed navigation file name - file period examples:

ALGO00CAN_R_20121600000_15M_MN.rnx.gz // 15-minute mixed nav file
ALGO00CAN_R_20121600000_01H_MN.rnx.gz // 1 hour mixed nav file
ALGO00CAN_R_20121600000_01D_MN.rnx.gz // 1 day mixed nav file

<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 contain observations or navigation data. The next three-character extension indicates 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_MN.rnx.gz //RINEX nav. Mixed
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

Meteorological filename example:

ALGO00CAN_R_20121600000_01D_30M_MM.rnx.gz //RINEX Met.

<COMPRESSION>:

Suggested RINEX file 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 and compression i.e.; ".rnx.gz" should be lowercase.

8.2 GNSS Observation Data Files

Table A2 : GNSS Observation Data File – Header Section Description

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
RINEX VERSION / TYPE	– Format version: **4.01** – File type: **O** for Observation Data – Satellite System: **G**: GPS **R**: GLONASS **E**: Galileo **J**: QZSS **C**: BDS **I**: NavIC **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 (section 5.2.2) Format: yyyymmdd hhmmss zone zone: 3-4 char. code for time zone. '**UTC** ' recommended! '**LCL** ' if local time with unknown time code ***Note***; This header line must be the second line in the header. Additional lines of this type can appear together after the second line, if needed to preserve the history of previous actions on the file.	A20 A20 A20
***COMMENT**	– Comment header line(s)	A60
MARKER NAME	– Name of antenna marker ***Note***; This is a free text field to identify the station with a name as decided by the station operator. To facilitate the identification of RINEX data in large user communities like IGS, EUREF, APREF, SIRGAS, etc the 9-character station ID is expected; XXXXMRCCC (see Table A1)	A60

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
`*MARKER NUMBER`	– Number of antenna marker ***Note***; This is an optional free text field to identify the station with some numbering system as decided by the station operator. To facilitate the identification of RINEX data in large user communities like IGS, EUREF, APREF, SIRGAS, etc the IERS DOMES number assigned to the station marker is expected; https://itrf.ign.fr/domes_request.php	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 Record required except for **`GEODETIC`** and **`NON_GEODETIC`** marker types. Users may define other project-dependent keywords.	A20,40X
`OBSERVER / AGENCY`	– Name of Observer / Agency	A20,A40
`REC # / TYPE / VERS`	– Receiver number, type, and version (Version: e.g. Internal Software Version)	3A20
`ANT # / TYPE`	– Antenna number and type	2A20
`APPROX POSITION XYZ`	– Geocentric approximate marker position (Units: Meters, Frame: ITRF recommended) Optional for moving platforms	3F14.4

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
`ANTENNA: DELTA H/E/N`	– Antenna height: Height of the antenna reference point (ARP) above the marker – Horizontal eccentricity of ARP relative to the marker (east/north) All units in meters (see section 5.2.4)	F14.4 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
`*DOI`	– Digital Object Identifier (DOI) for data citation i.e. https://doi.org/<DOI-number>	A60
`*LICENSE OF USE`	– Line(s) with the data license of use. Name of the license plus link to the specific version of the license. Using standard data license as from https://creativecommons.org/licenses/ – i.e. : CC BY 04 ; https://creativecommons.org/licenses/by/4.0/	A60

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
`*STATION INFORMATION`	– Line(s) with the link(s) to persistent URL with the station metadata (site log, GeodesyML, etc)	A60
`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 – Use continuation line(s) for more than 13 observation descriptors. In mixed files: Repeat for each satellite system. These records should precede any **`SYS / SCALE FACTOR`** records (see below). The following observation descriptors are defined in RINEX 4: **<u>Type</u>**: **`C`** = Code / Pseudorange **`L`** = Phase **`D`** = Doppler **`S`** = Raw signal strength (carrier to noise ratio) **`X`** = Receiver channel numbers **<u>Band</u>**: **`1`** = L1 (GPS, QZSS, SBAS, BDS, NavIC) G1 (GLO) E1 (GAL) B1C/B1A (BDS) **`2`** = L2 (GPS, QZSS) G2 (GLO) B1 (BDS) **`3`** = G3 (GLO) **`4`** = G1a (GLO) **`5`** = L5 (GPS, QZSS, SBAS, NavIC) E5a (GAL) B2a (BDS) **`6`** = E6 (GAL) L6 (QZSS) B3/B3A (BDS) G2a (GLO) **`7`** = E5b (GAL) B2/B2b (BDS) **`8`** = E5a+b (GAL) B2a+b (BDS)	A1 2X,I3 13(1X,A3) 6X, 13(1X,A3)

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
	9 = S (NavIC) **Attribute**: **A** = A channel (GAL, NavIC, GLO) **B** = B channel (GAL, NavIC, GLO) **C** = C channel (GAL, NavIC) C/A code-based (GPS,GLO,QZSS, SBAS) **D** = Semi-codeless (GPS) Data Channel (BDS, QZSS, NavIC) **E** = C/B (QZSS) 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, NavIC) **Q** = Q channel (GPS,GAL,QZSS,BDS) **R** = R channel (GPS) **S** = D channel (GPS, QZSS, NavIC) M channel (L2C GPS, QZSS) **W** = Based on Z-tracking (GPS)(see text) **X** = B+C channels (GAL, NavIC) I+Q channels (GPS,GAL, QZSS,BDS) M+L channels (GPS, QZSS) D+P channels (GPS, QZSS, BDS, NavIC) **Y** = Y code-based (GPS) **Z** = A+B+C channels (GAL) D+P channels (BDS) I+Q channels. (QZSS) D+E channels. (QZSS) All characters in uppercase only! **Units**; Phase; cycles Pseudorange; meters Doppler; Hz SNR etc.; receiver-dependent Channel #; See 5.3.4 Sign definition: See text.	

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
	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) ***Note*:** In RINEX 4, 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).	
`*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, month, day, hour, min, sec) – System time (see section 5.2.8): **GPS** (=GPS system time) **GLO** (=UTC system time) **GAL** (=Galileo system time) **QZS** (= QZSS system time) **BDT** (= BDS system time) **IRN** (=NavIC system time) 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 files	5I6,F13.7 5X,A3
`*TIME OF LAST OBS`	– Time of last observation record (4-digit-year, month, day, hour, min, sec) – System time: 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 (see section 5.2.14)	I6

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
	Note: Record required if clock offsets are reported in the **`EPOCH`** observation data file record (see Table A3).	
`*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) – 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. 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)	A1 1X,I4 2X,I2 12(1X,A3) 10X 12(1X,A3)
`*SYS / PHASE SHIFT`	***Note:*** This header line is strongly deprecated. It is allowed in this version for compatibility with previous RINEX versions but the lines should be ignored by RINEX decoders and encoders. (see section 5.2.12) Phase shift correction used to generate phases consistent with respect to cycle shifts – Satellite system (`G/R/E/J/C/I/S`) – Carrier phase observation code: **Type**	 A1,1X A3,1X

<table>
<tr><th colspan="3">TABLE A2
GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION</th></tr>
<tr><th>HEADER LABEL
(Columns 61-80)</th><th>DESCRIPTION</th><th>FORMAT</th></tr>
<tr><td></td><td>Band
Attribute
– Correction applied (cycles) or blank if none
– Number of satellites involved 0 or blank: All satellites of system
– List of satellites
– Use continuation line(s) for more than 10 satellites.</td><td>F8.5
2X,I2.2

10(1X,A3)
18X
10(1X,A3)</td></tr>
<tr><td><code>GLONASS SLOT / FRQ #</code></td><td>GLONASS slot and frequency numbers
– Number of satellites in list
List of:
– Satellite numbers (system code, slot)
– Frequency numbers (-7...+6)
– Use continuation lines for more than 8 Satellites</td><td>I3,1X

8(A1,I2.2,
1X,I2,1X)
4X,8(A1,
I2.2,1X,I2,
1X)</td></tr>
<tr><td><code>*GLONASS COD/PHS/BIS</code></td><td>Note: This header line is strongly deprecated. It is allowed in this version for compatibility with previous RINEX versions but the lines should be ignored by RINEX decoders and encoders. (see section 5.2.16)

– GLONASS Phase bias correction used to align code and phase observations.
• 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)

Note: See section 5.2.16 for further details. If the GLONASS code phase bias correction values are unknown or 0.00 then this optional header line should be omitted.</td><td>4(X1,A3,X
1,F8.3)</td></tr>
</table>

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
`*LEAP SECONDS`	– Current Number of leap seconds since 6 Jan 1980. – Future or past leap seconds ΔtLSF, i.e. future leap second if the week and day number are in the future. (BNK) – Respective week number WN_LSF (continuous number) (BNK), weeks since 6-Jan-1980. – Respective day number (1-7) (BNK). – System time identifier: only **GPS** is valid identifier. Blank defaults to **GPS**, see Notes section below. ***Notes***: 1. GPS, GAL, QZS and IRN system times are aligned and equivalent with respect to leap seconds (Leap seconds since 6-Jan-1980). See the ICD reference; IS-GPS-200M, section 20.3.3.5.2.4 2. When generating the leap second record from BDS navigation data the week count and day number must be adapted to GPS/GAL/QZS/IRN leap second conventions.	I6 I6 I6 I6 A3
`*# OF SATELLITES`	– Number of satellites, for which observations are stored in the file	I6
`*PRN / # OF OBS`	– 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. These records are repeated for each satellite in the data file.	3X A1,I2.2 9I6 6X,9I6
`END OF HEADER`	Last record in the header section.	60X

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

Table A3 : GNSS Observation Data File – Data Record Description

TABLE A3 GNSS OBSERVATION DATA FILE – DATA RECORD DESCRIPTION	
DESCRIPTION	**FORMAT**
EPOCH record – Record start 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 (see below) – Number of satellites observed in current epoch – (reserved) – Receiver clock offset correction (seconds, optional)	 A1 1X,I4 4(1X,I2.2) F11.7 2X,I1 I3 6X F15.12
Epoch flag = 0 or 1: ***OBSERVATION*** records follow – Satellite number (see section 4.5) – *m* fields of observation data (in the same sequence as given in the respective **SYS / # / OBS TYPES** header record), each containing the specified observations for example: pseudorange, phase, Doppler and SNR. – Loss of Lock Indicator - LLI (see Note 1) – Signal Strength Indicator - SSI (see Note 2) 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. ***Notes*** (see also section 6.7): 1. Loss of Lock Indicator (LLI) should only be associated with the phase observation. 2. Signal Strength Indicator (SSI) is deprecated and should be 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.	 A1,I2.2 *m*(F14.3, I1, I1)
Epoch flag 2-5: ***EVENT***: *Special records* may follow – Epoch flag; (additionally see section 5.3.2) • 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) – "Number of satellites" contains number of special records to follow. 0 if no special records follow.	 2X,I1 I3

TABLE A3 GNSS OBSERVATION DATA FILE – DATA RECORD DESCRIPTION	
Maximum number of records: 999 For events without significant epoch the epoch fields in the EPOCH RECORD can be left blank	
Epoch flag = 6: ***EVENT***: *Cycle slip records* follow – Epoch flag • 6: cycle slip records follow to optionally report detected and repaired cycle slips (same format as ***OBSERVATIONS*** records; • slip instead of observation; • LLI and signal strength blank or zero)	2X,I1

Table A4 : GNSS Observation Data File – Example #1

```
+----------------------------------------------------------------------------+
|                                 TABLE A4                                   |
|                  GNSS OBSERVATION DATA FILE - EXAMPLE #1                   |
+----------------------------------------------------------------------------+

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
     4.01           OBSERVATION DATA    M                   RINEX VERSION / TYPE
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 #
 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         -.353 4  23629347.158          24.158
G09  20891534.648           -.120 9         -.358 6  20891545.292          38.123
G12  20607600.189           -.430 9          .394 5  20607600.848          35.234
E11          .324 8          .178 7
S20  38137559.506      335849.135 9
> 2006 03 24 13 10 54.0000000  0  7      -0.123456789210
G06  23619095.450      -53875.632 8    -41981.375 4  23619095.008          25.234
G09  20886075.667      -28688.027 9    -22354.535 7  20886076.101          42.231
G12  20611072.689       18247.789 9     14219.770 6  20611072.410          36.765
R21  21345678.576       12345.567 5
R22  22123456.789       23456.789 5
```

```
E11     65432.123 5     48861.586 7
S20  38137559.506      335849.135 9
> 2006 03 24 13 11 12.0000000  2  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                                                      MARKER NAME
9081.1.34                                                   MARKER NUMBER
         .9050         .0000         .0000                  ANTENNA: DELTA H/E/N
          --> THIS IS THE START OF A NEW SITE <--           COMMENT
> 2006 03 24 13 12  6.0000000  0  4      -0.123456987654
G06  21112589.384       24515.877 6     19102.763 4  21112589.187          25.478
G09  23578228.338     -268624.234 7   -209317.284 6  23578228.398          41.725
G12  20625218.088       92581.207 7     72141.846 5  20625218.795          35.143
G16  20864539.693     -141858.836 8   -110539.435 2  20864539.943          16.345
> 2006 03 24 13 13  1.2345678  5  0
>                             4  2
      AN EVENT FLAG 5 WITH A SIGNIFICANT EPOCH              COMMENT
  AND AN EVENT FLAG 4 TO ESCAPE FOR THE TWO COMMENT LINES   COMMENT
> 2006 03 24 13 14 12.0000000  0  4      -0.123456012345
G06  21124965.133           0.30213        -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|
```

The receiver clock offset 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.

Table A5 : GNSS Observation Data File – Example #2

```
+----------------------------------------------------------------------------+
|                                 TABLE A5                                   |
|                   GNSS OBSERVATION DATA FILE - EXAMPLE #2                  |
+----------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
     4.01           OBSERVATION DATA    M                   RINEX VERSION / TYPE
RINEXSOFTWARE V1    User                20210702 000126 UTC PGM / RUN BY / DATE
REDU00BEL                                                   MARKER NAME
13102M001                                                   MARKER NUMBER
AUTOMATIC           ESA/ESOC                                OBSERVER / AGENCY
4503038             GNSS_RECEIVER       5.4.0               REC # / TYPE / VERS
5644                GEOANTENNA      NONE                    ANT # / TYPE
  4091423.7190   368380.6530  4863179.9940                  APPROX POSITION XYZ
        0.1150        0.0000        0.0000                  ANTENNA: DELTA H/E/N
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   24 C1P L1P D1P S1P C5P L5P D5P S5P C2I L2I D2I S2I C7I  SYS / # / OBS TYPES
       L7I D7I S7I C6I L6I D6I S6I C7D L7D D7D S7D          SYS / # / OBS TYPES
I    4 C5A L5A D5A S5A                                      SYS / # / OBS TYPES
   30.000                                                   INTERVAL
  2021     7     1     0     0    0.0000000     GPS         TIME OF FIRST OBS
  2021     7     1    23    59   30.0000000     GPS         TIME OF LAST OBS
   133                                                      # OF SATELLITES
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
> 2021 07 01 00 00  0.0000000  0 42
C05
→40308490.226 5 209896917.35805        10.104 5        34.250    40308489.226 6
→162305626.46606         7.618 6        40.500    40308491.534 6 170558460.27806
→8.101 6        38.000
C07
→40159332.888 5 209120231.34705      -749.184 5        31.000    40159329.424 7
→161705024.13707      -578.916 7        42.000    40159329.948 6 169927318.33206
→-608.432 6        41.250
C10
→38657500.889 6 201299802.28006      -213.194 6        40.500    38657500.797 7
→155657788.03207      -164.830 7        45.500    38657500.159 7 163572598.58707
→-173.232 7        43.000
[…]
E02  26254562.136 6 137968706.53306     -2449.736 6        40.500    26254562.526 7
→111987610.52607     -1988.494 7        44.500    26254562.708 7 103028609.46407
→-1829.371 7        46.250    26254560.506 7 105716299.84207     -1877.171 7
→46.000    26254561.518 8 104372462.72608     -1853.269 8        49.000
E07  23635638.708 8 124206162.80708      -871.617 8        48.750    23635637.971 8
→100816721.15408      -707.498 8        52.500    23635640.586 8  92751411.05508
→-650.899 8        53.000    23635639.032 8  95171010.23608      -667.883 8
→53.750    23635639.494 9  93961204.71809      -659.388 9        56.500
E08  24972516.642 6 131231506.27606     -2679.842 6        40.000    24972519.075 7
→106519133.68107     -2175.224 7        43.250    24972516.933 7  97997606.95207
→-2001.200 7        43.500    24972515.374 7 100554056.30907     -2053.459 7
→44.250    24972516.248 7  99275831.20407     -2027.334 7        46.750
[…]
```

```
G14  21030170.112 8 110514320.19008       642.342 8        48.250    21030169.835 6
→41.250    21030168.238 6  86115066.21306       500.526 6        41.250
→21030168.748 8  86115068.21708       500.505 8        49.000    21030171.716 9
→82526956.44709       479.678 9        54.000    21030170.080 8 110514301.19908
→642.295 8        48.250
G15  21142785.686 8 111106130.51808      2210.595 8        49.250    21142785.360 7
→42.250    21142783.280 7  86576198.32207      1722.539 7        42.250
→21142783.830 7  86576199.32607      1722.505 7        45.500
G18  24315176.881 4                     -1296.168 4
26.750
→24315171.412 3                     -1007.045 3        21.000    24315179.308 5
→95417985.50605      -967.978 5        33.250    24315177.474 4                     -
→1296.538 4        26.500
[…]
I02  37579958.788 6 147471902.39806       207.789 6        41.250
I06  38895003.676 6 152632382.60606        -8.242 6        39.000
R04  24104058.479 5 129076151.77705     -4263.115 5        32.500    24104057.540 5
→129076153.74305     -4262.717 5        32.000    24104064.842 5 100392603.45705
→-3315.798 5        31.750    24104063.510 5 100392591.36005     -3315.375 5
→32.000
R05  20012862.544 8 106980270.92208     -2486.308 8        52.500    20012862.822 8
→106980260.92808     -2486.286 8        53.000    20012866.969 8  83206909.39508
→-1933.770 8        49.750    20012866.589 8  83206896.39008     -1933.786 8
49.250
R06  19816526.726 7 105744797.08507      2182.678 7        44.250    19816526.502 7
→105744790.10007      2182.521 7        43.500
R09  24411449.113 6 130355805.45406      4217.981 6        36.000    24411450.687 6
→130355790.41406      4218.252 6        36.500    24411457.447 5 101387862.28405
→3280.773 5        35.750    24411458.534 6 101387898.24806      3280.926 6
→37.250    24411444.199 5  97878261.11305      3167.148 5        34.500
[…]
S23  38851570.438 7 204166366.73207         4.096 7        42.250    38851545.524 6
→152461811.71106         3.160 6        37.500
S25  38896540.414 5 204402846.86405      -273.406 5        35.250
S26  40715470.533 5 213961234.62705        74.939 5        30.750
S27  39936243.694 5 209866371.26905        -1.504 5        31.250    39936216.245 5
→156718290.21505        -1.331 5        33.000
S36  38379035.028 7 201683190.91007         1.906 7        43.250    38379007.297 6
→150607468.03806         1.723 6        39.000
S48   8153661.082 6  42847492.65406        66.518 6        37.750
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

Long observation lines per satellite are wrapped to fit the table width, each new line starts with a PRN and continues (indicated by →).

Table A6 : GNSS Observation Data File – Example #3

```
+------------------------------------------------------------------------------+
|                                  TABLE A6                                    |
|                    GNSS OBSERVATION DATA FILE - EXAMPLE #3                   |
+------------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
     4.01           OBSERVATION DATA    M: MIXED            RINEX VERSION / TYPE
SW   V3.08                              20140513 072944 UTC PGM / RUN BY / DATE
SNR is mapped to RINEX snr flag value [1-9]                 COMMENT
LX:      < 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
Tokyo                                                       MARKER NAME
TOKI                                                        MARKER NUMBER
USER                Organization                            OBSERVER / AGENCY
1870023             RECEIVER NAME       3.08/6.401          REC # / TYPE / VERS
                    ANTENNA         NONE                    ANT # / TYPE
 -3956196.8609  3349495.1794  3703988.8347                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
G   16 C1C L1C D1C S1C C2S L2S D2S S2S C2W L2W D2W S2W C5Q  SYS / # / OBS TYPES
       L5Q D5Q S5Q                                          SYS / # / OBS TYPES
R   12 C1C L1C D1C S1C C2P L2P D2P S2P C2C L2C D2C S2C      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
C    8 C2I L2I D2I S2I C7I L7I D7I S7I                      SYS / # / OBS TYPES
J   12 C1C L1C D1C S1C C2S L2S D2S S2S C5Q L5Q D5Q S5Q      SYS / # / OBS TYPES
S    4 C1C L1C D1C S1C                                      SYS / # / OBS TYPES
DBHZ                                                        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
 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
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.3 GNSS Navigation Message Files

8.3.1 Navigation File Header

Table A7 : GNSS Navigation Message File – Header Section Description

TABLE A7 GNSS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
`RINEX VERSION / TYPE`	– Format version: **4.01** – File type ('**N**' for Navigation Data) – Satellite System: `G`: GPS `R`: GLONASS `E`: Galileo `J`: QZSS `C`: Beidou `I`: NavIC `S`: SBAS `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 (section 5.2.2) Format: yyyymmdd hhmmss zone zone: 3-4 char. code for time zone. '`UTC` ' recommended! '`LCL` ' if local time with unknown time code	A20 A20 A20
`*REC # / TYPE / VERS`	– Receiver number, type, and version (Version: e.g. Internal Software Version) ***Notes:*** **1.** Station navigation files are to include this receiver line, as in the RINEX Observation files. **2.** Merged navigation files from multiple stations are not to include this header line.	3A20
`*COMMENT`	Free text comment line(s)	A60
`*MERGED FILE`	– Number of files merged (BNK) ***Note***: This merged file comment line should be included in merged navigation files. (see section 6.11)	I9 51X
`*DOI`	– Digital Object Identifier (DOI) for data citation i.e. https://doi.org/<DOI-number>	A60

TABLE A7 GNSS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
`*LICENSE OF USE`	– Line(s) with the data license of use. Name of the license plus link to the specific version of the license. Using standard data license as from https://creativecommons.org/licenses/ – i.e. : CC BY 04 , https://creativecommons.org/licenses/by/4.0/	A60
`*STATION INFORMATION`	– Line(s) with the link(s) to persistent URL with the station metadata (site log, GeodesyML, etc)	A60
`LEAP SECONDS`	– Current Number of leap seconds since 6 Jan 1980. – Future or past leap seconds ΔtLSF, i.e. future leap second if the week and day number are in the future. (BNK) – Respective week number WN_LSF (continuous number) (BNK), weeks since 6-Jan-1980. – Respective day number (1-7) (BNK). – System time identifier: only **`GPS`** is valid identifier. Blank defaults to **`GPS`**, see Notes section below. ***Notes***: 1. GPS, GAL, QZS and IRN system times are aligned and equivalent with respect to leap seconds (Leap seconds since 6-Jan-1980). See the ICD reference; IS-GPS-200M, section 20.3.3.5.2.4. 2. When generating the leap second record from BDS navigation data the week count and day number must be adapted to GPS/GAL/QZS/IRN leap second conventions.	I6 I6 I6 I6 A3
`END OF HEADER`		

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

Table A8 : GNSS Navigation Message File Header – Examples

```
+------------------------------------------------------------------------------+
|                                  TABLE A8                                    |
|                 GNSS NAVIGATION MESSAGE FILE HEADER - EXAMPLES               |
+------------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
     4.01           NAVIGATION DATA     M                   RINEX VERSION / TYPE
BCEmerge            congo               20210706 004604 UTC PGM / RUN BY / DATE
        78                                                  MERGED FILE
Merged GPS/GLO/GAL/BDS/QZS/SBAS/NavIC navigation file       COMMENT
based on CONGO and IGS tracking data                        COMMENT
    18    18  1929     7                                    LEAP SECONDS
                                                            END OF HEADER
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

```
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
     4.01           N: GNSS NAV DATA    M: MIXED            RINEX VERSION / TYPE
genericSW           User                20210205 000517 UTC PGM / RUN BY / DATE
4503037             GNSS REC.           5.4.0               REC # / TYPE / VERS
    18                                                      LEAP SECONDS
                                                            END OF HEADER
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.3.2 GPS LNAV Navigation Message

Table A9 : GPS LNAV Navigation Message Record Description

TABLE A9 GPS LNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**G**), sat number (PRN) - Navigation Message Type - **LNAV**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**G**), sat number (PRN) 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), 3E19.12 *)
BROADCAST ORBIT - 1	- IODE Issue of Data, Ephemeris - C_rs (meters) - Delta n (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT - 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT - 3	- T_oe Time of Ephemeris (sec of GPS wk) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT - 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Codes on L2 channel (bits 1-2 w3 sf 1) - GPS Week # (to go with T_oe) Continuous number, not mod(1024)! - L2 P data flag (bit 1 w 4 sf 1)	4X,4E19.12
BROADCAST ORBIT - 6	- 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,4E19.12

TABLE A9 GPS LNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT - 7	- t_tm : Transmission time of message (sec of GPS week, see section 6.11) 2*) - Fit Interval in hours; bit 17 w 10 sf 2 + IODC & Table 20-XII of GPS ICD. (BNK)	4X,2E19.12

BNK- Blank if Not Known/Not Defined

*) see section 6.8.

2*) Adjust the *Transmission time of message* by ±604800 to refer to the reported week in ***BROADCAST ORBIT 5***, if necessary. Set value to **.9999E+09** if not known. Legacy navigation records without transmit time are permitted for compatibility, but strongly deprecated.

8.3.3 GPS CNAV Navigation Message

Table A10 : GPS CNAV Navigation Message Record Description

TABLE A10 GPS CNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**G**), sat number (PRN) - Navigation Message Type - **CNAV**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**G**), sat number (PRN) Toc - Time of Clock (GPS) : - year (4 digits) - month, day, hour, minute, second - SV clock bias; a_f0 (seconds) - SV clock drift; a_f1 (sec/sec) - SV clock drift rate; a_f2 (sec/sec2)	A1,I2.2, 1X,I4, 5(1X,I2.2), 3E19.12 *), 2*)
BROADCAST ORBIT - 1	- A DOT (meters/sec) - C_rs (meters) - Delta n0 (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT - 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT - 3	- t_op (seconds) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT - 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Delta n0 dot (radians/sec^2) - URAI_NED0 - URAI_NED1	4X,4E19.12
BROADCAST ORBIT - 6	- URAI_ED - SV health (bits 52(MSB)-54(LSB) of msg 10, providing L1,L2,L5 Health) - TGD (seconds) - URAI_NED2	4X,4E19.12
BROADCAST ORBIT - 7	- ISC_L1CA (seconds) - ISC_L2C (seconds) - ISC_L5I5 (seconds) - ISC_L5Q5 (seconds)	4X,4E19.12

TABLE A10 GPS CNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT - 8	- t_tm : Transmission time of message (sec of GPS week, see section 6.11) 3*) - wn_op : GPS continuous week number with the ambiguity resolved	4X,2E19.12

*) see section 6.8.
2*) As per IS-GPS-705 20.3.4.4 first sentence, Toe must be equal to Toc. Therefore, only Toc is provided.
3*) Adjust the Transmission time of message by ±604800 to refer to the week in the “SV / EPOCH / SV CLK” line, if necessary.

8.3.4 GPS CNAV-2 Navigation Message

Table A11 : GPS CNAV-2 Navigation Message Record Description

TABLE A11 GPS CNAV-2 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**G**), sat number (PRN) - Navigation Message Type – **CNV2**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**G**), sat number (PRN) Toc - Time of Clock (GPS): - year (4 digits) - month, day, hour, minute, second - SV clock bias; a_f0 (seconds) - SV clock drift; a_f1 (sec/sec) - SV clock drift rate; a_f2 (sec/sec2)	A1,I2.2, 1X,I4, 5(1X,I2.2), 3E19.12 *), 2*)
BROADCAST ORBIT - 1	- A DOT (meters/sec) - C_rs (meters) - Delta n0 (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT - 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT - 3	- t_op (seconds) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT - 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Delta n0 dot (radians/sec^2) - URAI_NED0 - URAI_NED1	4X,4E19.12
BROADCAST ORBIT - 6	- URAI_ED - SV health (L1C health, bit 33 of sf 2) - TGD (seconds) - URAI_NED2	4X,4E19.12
BROADCAST ORBIT - 7	- ISC_L1CA (seconds) - ISC_L2C (seconds) - ISC_L5I5 (seconds) - ISC_L5Q5 (seconds)	4X,4E19.12

TABLE A11 GPS CNAV-2 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT - 8	- ISC_L1Cd (seconds) - ISC_L1Cp (seconds)	4X,2E19.12
BROADCAST ORBIT - 9	- t_tm : Transmission time of message (sec of GPS week, see section 6.11) 3*) - wn_op : GPS continuous week number with the ambiguity resolved	4X,2E19.12

*) see section 6.8.
2*) As per IS-GPS-800, paragraph 3.5.3.7.1, users shall use t_oe, to replace t_oc in the user algorithms for SV clock correction data. Therefore, only a single reference epoch t_oe = t_oc is provided.
3*) Adjust the Transmission time of message by ±604800 to refer to the week in the "SV / EPOCH / SV CLK" line, if necessary.

Table A12 : GPS Navigation Messages - Example

```
+--------------------------------------------------------------------------------+
|                                   TABLE A12                                      |
|                     GPS NAVIGATION MESSAGES - EXAMPLE                          |
+--------------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> EPH G04 LNAV
G04 2019 03 14 04 00 00 1.330170780420e-04 7.275957614183e-12 0.000000000000e+00
     9.800000000000e+01-1.718750000000e+00 4.639836124941e-09 2.148941747752e+00
    -1.881271600723e-07 3.355251392350e-04 8.245930075645e-06 5.153800453186e+03
     3.600000000000e+05-1.676380634308e-08 5.171400020311e-01 1.490116119385e-08
     9.601921900531e-01 2.187187500000e+02-1.736906885738e+00-8.044977962767e-09
    -2.932264997750e-10 1.000000000000e+00 2.044000000000e+03 0.000000000000e+00
     4.000000000000e+00 6.300000000000e+01-8.847564458847e-09 8.660000000000e+02
     3.553500000000e+05 4.000000000000e+00
> EPH G04 CNAV
G04 2019 03 14 03 30 00 1.330042141490e-04 7.226219622680e-12 0.000000000000e+00
     2.001762390137e-03 6.914062500000e-01 4.625906973308e-09 1.887277537485e+00
     1.024454832077e-08 3.348654136062e-04 8.376315236092e-06 5.153800325291e+03
     2.412000000000e+05-4.656612873077e-09 5.171544951605e-01 2.328306436539e-08
     9.601927657114e-01 2.174140625000e+02-1.737767543851e+00-8.034028170143e-09
    -2.950122884460e-10-1.312310522376e-14-2.000000000000e+00 2.000000000000e+00
     0.000000000000e+00 7.000000000000e+00-8.789356797934e-09 5.000000000000e+00
    -5.820766091347e-10-6.606569513679e-09-1.178705133498e-08-1.178705133498e-08
     3.558540000000e+05 2.044000000000e+03
> EPH G04 CNV2
G04 2019 03 14 03 30 00 1.330042141490e-04 7.226219622680e-12 0.000000000000e+00
     2.001762390137e-03 6.914062500000e-01 4.625906973308e-09 1.887277537485e+00
     1.024454832077e-08 3.348654136062e-04 8.376315236092e-06 5.153800325291e+03
     2.412000000000e+05-4.656612873077e-09 5.171544951605e-01 2.328306436539e-08
     9.601927657114e-01 2.174140625000e+02-1.737767543851e+00-8.034028170143e-09
    -2.950122884460e-10-1.312310522376e-14-2.000000000000e+00 2.000000000000e+00
     0.000000000000e+00 1.000000000000e+00-8.789356797934e-09 5.000000000000e+00

    -3.492459654808e-10-7.858034223318e-10
     3.550860000000e+05 2.044000000000e+03

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

8.3.5 GALILEO INAV/FNAV Navigation Message

Table A13 : GALILEO INAV/FNAV Navigation Message Record Description

TABLE A13 GALILEO INAV/FNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**E**), sat number (PRN) - Navigation Message Type – **INAV** or **FNAV**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**E**), satellite number Toc - Time of Clock GAL: - year (4 digits) - month, day, hour, minute, second - SV clock bias; af0 (seconds) - SV clock drift; af1 (sec/sec) - SV clock drift rate; af2 (sec/sec2) (see *Br.Orbit-5*, data source, bits 8+9)	A1,I2.2, 1X,I4, 5(1X,I2.2), 3E19.12 *)
BROADCAST ORBIT - 1	- IODnav Issue of Data of the nav batch - C_rs (meters) - Delta n (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT - 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT - 3	- Toe Time of Ephemeris (sec of GAL week) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT - 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12

TABLE A13 GALILEO INAV/FNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Data sources (binary number) 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 **`INAV`** navigation messages were merged, however, bits cannot all be set, as the **`INAV`** and **`FNAV`** 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)	4X,3E19.12 4*) 5*)
BROADCAST ORBIT - 6	- SISA Signal in space accuracy (meters) No Accuracy Prediction Available (NAPA) / unknown: -1.0 - SV health (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)	4X,4E19.12 4*)
BROADCAST ORBIT - 7	- t_tm : Transmission time of message (sec of GAL week, see section 6.11) 2*)	4X,1E19.12

*) see section 6.8.

2*) Adjust the *Transmission time of message* by + or -604800 to refer to the reported week in ***`BROADCAST ORBIT 5`***, if necessary. Set value to **`.9999E+09`** if not known. Legacy navigation records without transmit time are permitted for compatibility, but strongly deprecated.

4*) For Navigation data fields stored bitwise see section 6.10.

5*) 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).

6*) For Navigation data fields stored bitwise see section 6.10. 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 '`BGD`s' 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.

Table A14 : GALILEO Navigation Messages - Examples

```
+----------------------------------------------------------------------------+
|                                  TABLE A14                                 |
|                    GALILEO NAVIGATION MESSAGES - EXAMPLES                  |
+----------------------------------------------------------------------------+

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> EPH E12 INAV
E12 2020 09 15 00 40 00 5.605182959698e-03-1.881517164293e-11 0.000000000000e+00
     3.600000000000e+01 1.090625000000e+02 2.811188525857e-09-2.481435854929e+00
     5.209818482399e-06 1.468013506383e-04 1.532956957817e-06 5.440609727859e+03
     1.752000000000e+05-1.676380634308e-08 8.103706855689e-01 7.450580596924e-09
     9.891660140720e-01 3.219375000000e+02 5.171049929386e-01-5.815956543649e-09
     2.982267080537e-10 5.170000000000e+02 2.123000000000e+03
     3.120000000000e+00 0.000000000000e+00-1.303851604462e-08-1.280568540096e-08
     1.764340000000e+05
> EPH E11 FNAV
E11 2020 09 15 23 30 00 5.537368822843e-03 2.744400262600e-10 0.000000000000e+00
     4.500000000000e+01 1.730312500000e+02 2.871548182937e-09-1.103934352668e-01
     8.083879947662e-06 2.968260087073e-04 3.607943654060e-06 5.440606000900e+03
     2.574000000000e+05-5.774199962616e-08 8.098963343817e-01-1.005828380585e-07
     9.891873024559e-01 2.774062500000e+02 1.248848716430e+00-5.818456647788e-09
     5.564517498775e-10 2.580000000000e+02 2.123000000000e+03
     3.120000000000e+00 0.000000000000e+00-1.583248376846e-08 0.000000000000e+00
     2.581000000000e+05
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.3.6 GLONASS FDMA Navigation Message

Table A15 : GLONASS FDMA Navigation Message Record Description

TABLE A15 GLONASS FDMA NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**R**), sat number (slot number) - Navigation Message Type – **FDMA**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**R**), satellite number (slot number in sat. constellation) 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), 3E19.12 *)
BROADCAST ORBIT - 1	- Satellite position X (km) - velocity X dot (km/sec) - X acceleration (km/sec2) - health (0=healthy, 1=unhealthy) (MSB of 3-bit Bn)	4X,4E19.12
BROADCAST ORBIT - 2	- Satellite position Y (km) - velocity Y dot (km/sec) - Y acceleration (km/sec2) - frequency number (-7...+13) (-7...+6 ICD 5.1)	4X,4E19.12
BROADCAST ORBIT - 3	- Satellite position Z (km) - velocity Z dot (km/sec) - Z acceleration (km/sec2) - Age of oper. information (days) (E)	4X,4E19.12
BROADCAST ORBIT - 4	- Status Flags 9-bit binary number (BNK if Unknown); **M** ; bit 7-8, GLO type indicator (00=GLO, 01=GLO-M/K) **P4** ; bit 6, *GLO-M/K only*, 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)	4X,4E19.12 2*)

TABLE A15 GLONASS FDMA NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
	P ; bit 0-1, *GLO-M/K only*, 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, 11 = on-board) - L1/L2 group delay difference $\Delta\tau$.(in seconds) 3*) - URAI ; *GLO-M/K only* – raw accuracy index F_T. 4*) - Health Flags 3-bit binary number (BNK if Unknown): 5*) **$l_{(3)}$** ; bit 2, *GLO-M/K only*, health bit of string 3 **AC** ; bit 1, 1 = almanac health reported in ephemerides record, 0 = not reported **C** ; bit 0, almanac health bit (1 = healthy, 0 = not healthy) *GLO-M/K exclusive flags and values only to be valid when flag M set to "01"*	

BNK- Blank if Not Known/Not Defined
*) see section 6.8.
2*) For Navigation data fields stored bitwise see section 6.10.
3*) **.999999999999E+09** if Unknown
4*) **1.500000000000E+01** if Unknown
5*) bit 0 (**C**) is to be ignored if bit 1 (**A_C**) is zero

Table A16 : GLONASS Navigation Message Files - Example

```
+------------------------------------------------------------------------------+
|                                TABLE A16                                     |
|                 GLONASS NAVIGATION MESSAGE FILE - EXAMPLE                    |
+------------------------------------------------------------------------------+

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> EPH R01 FDMA
R01 2020 09 15 23 45 00 6.761029362679e-05 0.000000000000e+00 2.587200000000e+05
    -1.390448925781e+04 2.552483558655e+00-4.656612873077e-09 0.000000000000e+00
    -3.950272460938e+03-1.328901290894e+00 1.862645149231e-09 1.000000000000e+00
     2.101021875000e+04 1.440399169922e+00-1.862645149231e-09 0.000000000000e+00
     1.470000000000e+02 8.381903171539e-09 2.000000000000e+00 0.000000000000e+00
> EPH R04 FDMA
R04 2020 09 15 22 45 00 5.470402538776e-05 9.094947017729e-13 2.541000000000e+05
     1.043976806641e+04-2.930776596069e+00 3.725290298462e-09 0.000000000000e+00
     8.152179687500e+03 5.874986648560e-01 0.000000000000e+00 6.000000000000e+00
    -2.177643408203e+04-1.184345245361e+00 9.313225746155e-10 0.000000000000e+00
     2.430000000000e+02-2.793967723846e-09 4.000000000000e+00 3.000000000000e+00
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.3.7 QZSS LNAV Navigation Message

Table A17 : QZSS LNAV Navigation Message Record Description

TABLE A17 QZSS LNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**J**), sat number (see Table 6) - Navigation Message Type – **LNAV**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**J**), sat number (see Table 6) 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), 3E19.12 ***)**
BROADCAST ORBIT - 1	- IODE Issue of Data, Ephemeris - C_rs (meters) - Delta n (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT - 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT - 3	- Toe Time of Ephemeris (sec of GPS week) - C_ic (radians) - OMEGA (radians) - CIS (radians)	4X,4E19.12
BROADCAST ORBIT - 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT – 5	- 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,4E19.12

TABLE A17 QZSS LNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT – 6	- SV accuracy (meters) (IS -QZSS-PNT, Section 5.4.3.1) 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 "10000000" this condition is represented by a blank field. - IODC Issue of Data, Clock	4X,4E19.12
BROADCAST ORBIT – 7	- t_tm : Transmission time of message (sec of GPS week, see section 6.11) 2*) - Fit interval flag (0 / 1) (see IS-QZSS-PNT, 4.1.2.4(3) 0 – two hours), 1 – more than 2 hours (BNK).	4X,2E19.12

BNK- Blank if Not Known/Not Defined

*) see section 6.8.

2*) Adjust the *Transmission time of message* by ±604800 to refer to the reported week in ***BROADCAST ORBIT 5***, if necessary. Set value to **.9999E+09** if not known. Legacy navigation records without transmit time are permitted for compatibility, but strongly deprecated.

8.3.8 QZSS CNAV Navigation Message

Table A18 : QZSS CNAV Navigation Message Record Description

TABLE A18 QZSS CNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**J**), sat number (see Table 6) - Navigation Message Type - **CNAV**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**J**), sat number (see Table 6) Toc - Time of Clock (QZSS): - year (4 digits) - month, day, hour, minute, second - SV clock bias; a_f0 (seconds) - SV clock drift; a_f1 (sec/sec) - SV clock drift rate; a_f2 (sec/sec2)	A1,I2.2, 1X,I4, 5(1X,I2.2), 3E19.12 *)
BROADCAST ORBIT - 1	- A DOT (meters/sec) - C_rs (meters) - Delta n0 (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT - 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT - 3	- t_op (seconds) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT - 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Delta n0 dot (radians/sec^2) - URAI_NED0 - URAI_NED1	4X,4E19.12
BROADCAST ORBIT - 6	- URAI_ED - SV health (bits 52(MSB)-54(LSB) of msg 10, providing L1,L2,L5 Health) - TGD (seconds) 3*) - URAI_NED2	4X,4E19.12

TABLE A18 QZSS CNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT - 7	- ISC_L1CA (seconds) - ISC_L2C (seconds) - ISC_L5I5 (seconds) - ISC_L5Q5 (seconds)	4X,4E19.12 3*)
BROADCAST ORBIT - 8	- t_tm : Transmission time of message (sec of GPS week, see section 6.11) 2*) - wn_op : GPS continuous week number with the ambiguity resolved	4X,2E19.12

*) see section 6.8.

2*) Adjust the Transmission time of message by ±604800 to refer to the week in the "SV / EPOCH / SV CLK" line, if necessary.

3*) The QZSS ICD specifies a **do not use** bit pattern "1000000000000" for CNAV TGD and ISC values. This condition is represented by a blank field in the RINEX record.

8.3.9 QZSS CNAV-2 Navigation Message

Table A19 : QZSS CNAV-2 Navigation Message Record Description

TABLE A19 QZSS CNAV-2 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**J**), sat number (see Table 6) - Navigation Message Type – **CNV2**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**J**), sat number (PRN, see Table 6) Toc - Time of Clock (GPS): - year (4 digits) - month, day, hour, minute, second - SV clock bias; a_f0 (seconds) - SV clock drift; a_f1 (sec/sec) - SV clock drift rate; a_f2 (sec/sec2)	A1,I2.2, 1X,I4, 5(1X,I2.2), 3E19.12 *)
BROADCAST ORBIT - 1	- A DOT (meters/sec) - C_rs (meters) - Delta n0 (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT - 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT - 3	- t_op (seconds) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT - 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Delta n0 dot (radians/sec^2) - URAI_NED0 - URAI_NED1	4X,4E19.12
BROADCAST ORBIT - 6	- URAI_ED - SV health (L1C health) - TGD (seconds) 3*) - URAI_NED2	4X,4E19.12
BROADCAST ORBIT - 7	- ISC_L1CA (seconds) - ISC_L2C (seconds) - ISC_L5I5 (seconds) - ISC_L5Q5 (seconds)	4X,4E19.12 3*)

TABLE A19 QZSS CNAV-2 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT - 8	- ISC_L1Cd (seconds) - ISC_L1Cp (seconds) 3*)	4X,2E19.12
BROADCAST ORBIT - 9	- t_tm : Transmission time of message (sec of GPS week, see section 6.11) 2*) - wn_op : GPS continuous week number with the ambiguity resolved	4X,2E19.12

*) see section 6.8.

2*) Adjust the Transmission time of message by ±604800 to refer to the week in the "SV / EPOCH / SV CLK" line, if necessary.

3*) The QZSS ICD specifies a **do not use** bit pattern "1000000000000" for CNAV TGD and ISC values. This condition is represented by a blank field in the RINEX record.

Table A20 : QZSS Navigation Message File - Examples

```
+------------------------------------------------------------------------------+
|                                 TABLE A20                                    |
|                   QZSS NAVIGATION MESSAGE FILE - EXAMPLE                     |
+------------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> EPH J01 LNAV
J01 2021 01 23 02 00 00-3.374307416379e-04-1.364242052659e-12 0.000000000000e+00
     1.330000000000e+02 9.578125000000e+01 1.388272112820e-09-2.070362217868e+00
     2.535060048103e-06 7.562357175630e-02 5.446374416351e-06 6.493648595810e+03
     5.256000000000e+05-1.164153218269e-06 4.173927833877e-01-3.390014171600e-06
     7.304595403547e-01-1.565625000000e+01-1.559470529133e+00-9.082521180606e-10
     1.361128125021e-09 2.000000000000e+00 2.141000000000e+03 1.000000000000e+00
     2.800000000000e+00 0.000000000000e+00-5.587935447693e-09 9.010000000000e+02
     5.220060000000e+05 0.000000000000e+00
> EPH J01 CNAV
J01 2021 01 23 02 00 00-3.374309453648e-04-1.364242052659e-12 0.000000000000e+00
    -2.224636077881e-02 9.925390625000e+01 2.809759894921e-09-2.070460582285e+00
     2.630054950714e-06 7.561515661655e-02 6.853602826595e-06 6.493646338351e+03
     5.256000000000e+05 2.942979335785e-07 4.174090012975e-01 2.151355147362e-07
     7.304471282263e-01-5.480078125000e+01-1.559404111189e+00-2.726307082255e-09
     5.480585431239e-10 5.534811322777e-14-3.000000000000e+00 0.000000000000e+00
    -8.000000000000e+00 0.000000000000e+00-5.675246939063e-09 0.000000000000e+00
     0.000000000000e+00 3.667082637548e-09 2.561137080193e-09 1.949956640601e-09
     5.220060000000e+05 2.141000000000e+03
> EPH J01 CNV2
J01 2021 01 23 02 00 00-3.374309453648e-04-1.364242052659e-12 0.000000000000e+00
    -2.224636077881e-02 9.925390625000e+01 2.809759894921e-09-2.070460582285e+00
     2.630054950714e-06 7.561515661655e-02 6.853602826595e-06 6.493646338351e+03
     5.256000000000e+05 2.942979335785e-07 4.174090012975e-01 2.151355147362e-07
     7.304471282263e-01-5.480078125000e+01-1.559404111189e+00-2.726307082255e-09
     5.480585431239e-10 5.534811322777e-14-3.000000000000e+00 0.000000000000e+00
    -8.000000000000e+00 0.000000000000e+00-5.675246939063e-09 0.000000000000e+00
     0.000000000000e+00 3.667082637548e-09 2.561137080193e-09 1.949956640601e-09
     4.365574568510e-10 2.910383045673e-10
     5.220180000000e+05 2.141000000000e+03


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

8.3.10 BEIDOU D1/D2 Navigation Message

Table A21 : BEIDOU D1/D2 Navigation Message Record Description

Table A21 BEIDOU D1/D2 NAVIGATION MESSAGES RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**C**), sat number (PRN) - Navigation Message Type – **D1** or **D2** ***Note***: **D1** is the BDS-2/3 MEO/IGSO legacy navigation message, **D2** is the BDS-2/3 GEO legacy navigation message.	A1 1X,A3 1X,A3 1X,A2
SV / EPOCH / SV CLK	- Satellite system (**C**), sat number (PRN) 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/sec^2)	A1,I2.2, 1X,I4 5,1X,I2.2, 3E19.12 *)
BROADCAST ORBIT – 1	- AODE Age of Data, Ephemeris (as specified in BeiDou B1I and B3I ICDs Table Section 5.2.4.11 Table 5-8) and field range is: 0-31. - C_rs (meters) - Delta n (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT – 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT – 3	- ToE Time of Ephemeris (sec of BDT week) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT – 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT – 5	- IDOT (radians/sec) - Spare (see Section 6.4) - BDT Week # - Spare (see Section 6.4)	4X,E19.12, A19, E19.12, A19

Table A21 BEIDOU D1/D2 NAVIGATION MESSAGES RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT – 6	- 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 - TGD1 B1/B3 (seconds) - TGD2 B2/B3 (seconds)	4X,4E19.12
BROADCAST ORBIT – 7	- t_tm: Transmission time of message (sec of BDT week, see section 6.11) 2*) - AODC Age of Data Clock (as specified in BeiDou B1I and B3I ICDs Table Section 5.2.4.8, Table 5-6) and field range is: 0-31.	4X,2E19.12

*) see section 6.8.

2*) Adjust the Transmission time of message by + or -604800 to refer to the reported week in BROADCAST ORBIT -5, if necessary. Set value to **`.9999E+09`** if not known. Legacy navigation records without transmit time are permitted for compatibility, but strongly deprecated.

8.3.11 BEIDOU CNAV-1 Navigation Message

Table A22 : BEIDOU CNAV-1 Navigation Message Record Description

TABLE A22 BEIDOU CNAV-1 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**C**), sat number (PRN) - Navigation Message Type – **CNV1** ***Note***: **CNV1** is the navigation message on the Beidou-3 B1C signal.	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**C**), sat number (PRN) Toc - Time of Clock (BDT): - year (4 digits) - month, day, hour, minute, second - SV clock bias; a_f0 (sec) - SV clock drift; a_f1 (sec/sec) - SV clock drift rate; a_f2 (sec/sec^2)	A1,I2.2, 1X,I4 5(1X,I2.2), 3E19.12 *)
BROADCAST ORBIT - 1	- A DOT (meters/sec) - C_rs (meters) - Delta n0 (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT – 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT – 3	- ToE Time of Ephemeris (sec of BDT week) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT – 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Delta n0 dot (radians/sec^2) - SatType: **0**=reserved, **1**=GEO, **2**=IGSO, **3**=MEO - t_op (seconds)	4X,4E19.12
BROADCAST ORBIT – 6	- SISAI_oe - SISAI_ocb - SISAI_oc1 - SISAI_oc2	4X,4E19.12

TABLE A22 BEIDOU CNAV-1 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT – 7	- ISC_B1Cd (seconds) - Spare(x1) (see Section 6.4) - TGD_B1Cp (seconds) - TGD_B2ap (seconds)	4X,E19.12, A19, 2E19.12
BROADCAST ORBIT – 8	- SISMAI - Health: 2-bits health word from sf 3 (0=healthy, 1=unhealthy or in test, others reserved) - B1C Integrity flags: 3-bits word from sf 3 (bit 2(MSB)=DIF, bit 1 = SIF, bit 0(LSB) = AIF) - IODC	4X,4E19.12
BROADCAST ORBIT – 9	- t_tm: Transmission time of message (sec of BDT week, see section 6.11) 2*) - Spare(x2) (see Section 6.4) - IODE ***Note***: for a matched pair of orbit and clock data, the IODE are the same as the 8 LSBs of IODC	4X,E19.12, 2A19, E19.12

*) see section 6.8.

2*) Adjust the Transmission time of message by ±604800 to refer to the week in the “SV / EPOCH / SV CLK” line, if necessary.

8.3.12 BEIDOU CNAV-2 Navigation Message

Table A23 : BEIDOU CNAV-2 Navigation Message Record Description

TABLE A23 BEIDOU CNAV-2 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**C**), sat number (PRN) - Navigation Message Type – **CNV2** ***Note***: **CNV2** is the navigation message on the Beidou-3 B2a signal.	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**C**), sat number (PRN) Toc - Time of Clock (BDT): - year (4 digits) - month, day, hour, minute, second - SV clock bias; a_f0 (sec) - SV clock drift; a_f1 (sec/sec) - SV clock drift rate; a_f2 (sec/sec^2)	A1,I2.2, 1X,I4 5,1X,I2.2, 3E19.12 *)
BROADCAST ORBIT - 1	- A DOT (meters/sec) - C_rs (meters) - Delta n0 (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT – 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT – 3	- ToE Time of Ephemeris (sec of BDT week) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT – 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Delta n0 dot (radians/sec^2) - SatType: **0**=reserved, **1**=GEO, **2**=IGSO, **3**=MEO - t_op (seconds)	4X,4E19.12
BROADCAST ORBIT – 6	- SISAI_oe - SISAI_ocb - SISAI_oc1 - SISAI_oc2	4X,4E19.12

TABLE A23 BEIDOU CNAV-2 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT – 7	- Spare(x1) (see Section 6.4) - ISC_B2ad (seconds) - TGD_B1Cp (seconds) - TGD_B2ap (seconds)	4X,A19, 3E19.12
BROADCAST ORBIT – 8	- SISMAI - Health: 2-bits health word from msg 11, 30-34, 40 (0=healthy, 1=unhealthy or in test, others reserved) - B2a+B1C Integrity flags: 6-bits word with integrity bits in msg 10-11, 30-34 or 40 (bit 5(MSB) = DIF(B2a), bit 4 = SIF(B2a), bit 3 = AIF(B2a), bit 2 = DIF(B1C), bit1 = SIF (B1C), bit 0(LSB)=AIF(B1C)) - IODC	4X,4E19.12
BROADCAST ORBIT – 9	- t_tm: Transmission time of message (sec of BDT week, see section 6.11) 2*) - Spare(x2) (see Section 6.4) - IODE ***Note***: for a matched pair of orbit and clock data, the IODE are the same as the 8 LSBs of IODC	4X,E19.12, 2A19, E19.12

*) see section 6.8.

2*) Adjust the Transmission time of message by ±604800 to refer to the week in the “SV / EPOCH / SV CLK” line, if necessary.

8.3.13 BEIDOU CNAV-3 Navigation Message

Table A24 : BEIDOU CNAV-3 Navigation Message Record Description

TABLE A24 BEIDOU CNAV-3 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**C**), sat number (PRN) - Navigation Message Type – **CNV3** ***Note***: **CNV3** is the navigation message of the Beidou-3 MEO and IGSO satellites on B2b signal.	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**C**), sat number (PRN) Toc - Time of Clock (BDT): - year (4 digits) - month, day, hour, minute, second - SV clock bias; a_f0 (seconds) - SV clock drift; a_f1 (sec/sec) - SV clock drift rate; a_f2 (sec/sec^2)	A1,I2.2, 1X,I4 5,1X,I2.2, 3E19.12 *)
BROADCAST ORBIT - 1	- A DOT (meters/sec) - C_rs (meters) - Delta n0 (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT – 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT – 3	- ToE Time of Ephemeris (sec of BDT week) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT – 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Delta n0 dot (radians/sec^2) - SatType: **0**=reserved, **1**=GEO, **2**=IGSO, **3**=MEO - t_op (seconds)	4X,4E19.12
BROADCAST ORBIT – 6	- SISAI_oe - SISAI_ocb - SISAI_oc1 - SISAI_oc2	4X,4E19.12

TABLE A24 BEIDOU CNAV-3 NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT – 7	- SISMAI - Health: 2-bits health word from msg 30 (0=healthy, 1=unhealthy or in test, others reserved) - B2b Integrity flags: 3-bits word from msg 10 (bit 2(MSB)=DIF, bit 1 = SIF, bit 0(LSB) = AIF) - TGD_B2bI (seconds)	4X,4E19.12
BROADCAST ORBIT – 8	- t_tm : Transmission time of message (sec of BDT week, see section 6.11) 2*)	4X,E19.12

*) see section 6.8.
2*) Adjust the Transmission time of message by ±604800 to refer to the week in the "SV / EPOCH / SV CLK" line, if necessary.

Table A25 : BEIDOU Navigation Messages - Examples

```
+------------------------------------------------------------------------------+
|                                  TABLE A25                                   |
|                    BeiDou NAVIGATION MESSAGES - EXAMPLE                      |
+------------------------------------------------------------------------------+
> EPH C05 D2
C05 2021 07 05 22 00 00-5.836377386004e-05 1.694644424788e-11 0.000000000000e+00
     0.000000000000e+00-5.881250000000e+01 1.949724070976e-09-1.593114605012e+00
    -1.817941665649e-06 7.691901409999e-04 1.800991594791e-05 6.493525815964e+03
     1.656000000000e+05 2.072192728519e-07 2.624951167227e+00-1.122243702412e-07
     1.151558582809e-01-5.497031250000e+02-4.954214719500e-01-8.100337411567e-10
     6.564559154524e-10                    8.090000000000e+02
     2.000000000000e+00 0.000000000000e+00 0.000000000000e+00-9.500000000000e-09
     1.656000000000e+05 0.000000000000e+00
> EPH C20 D1
C20 2021 07 05 02 00 00-8.545715827495e-04 1.170086250113e-11 0.000000000000e+00
     1.000000000000e+00-2.265625000000e+00 4.092313318419e-09-1.556359938124e-01
    -6.286427378654e-08 8.448450826108e-04 6.472226232290e-06 5.282618293762e+03
     9.360000000000e+04 2.328306436539e-09-2.772255179876e+00-1.164153218269e-08
     9.665781566257e-01 2.337656250000e+02-6.218441883865e-01-6.809926517917e-09
     4.171602335410e-10                    8.090000000000e+02
     2.000000000000e+00 0.000000000000e+00 2.300000000000e-08 2.300000000000e-08
     9.360000000000e+04 1.000000000000e+00
> EPH C20 CNV1
C20 2021 07 05 22 00 00-8.537324611098e-04 1.167599350538e-11 0.000000000000e+00
    -3.525733947754e-03 1.960937500000e+00 3.931056601429e-09-2.980266083268e+00
     7.729977369308e-08 8.434175979346e-04 7.596798241138e-06 5.282624978926e+03
     1.656000000000e+05-4.190951585770e-08-2.772741033988e+00-2.514570951462e-08
     9.666057809078e-01 2.101328125000e+02-6.122205141961e-01-6.644205329250e-09
     4.784127849557e-10 2.655139894109e-14 3.000000000000e+00 1.656000000000e+05
     0.000000000000e+00-4.000000000000e+00-1.000000000000e+00-1.000000000000e+00
    -3.492459654808e-10                    2.328306436539e-08-2.968590706587e-09
    -1.000000000000e+00 0.000000000000e+00 0.000000000000e+00 1.800000000000e+01
     1.656000000000e+05                                       1.800000000000e+01
> EPH C20 CNV2
C20 2021 07 05 23 00 00-8.536910172552e-04 1.159872198286e-11 0.000000000000e+00
    -4.044532775879e-03 1.300781250000e+00 3.943199964392e-09-2.492861436039e+00
     0.000000000000e+00 8.432919275947e-04 7.565133273602e-06 5.282623812254e+03
     1.692000000000e+05-4.656612873077e-08-2.772764954893e+00-3.632158041000e-08
     9.666074588748e-01 2.102968750000e+02-6.120578881764e-01-6.652598536003e-09
     4.810914679621e-10 2.790294798407e-14 3.000000000000e+00 1.692000000000e+05
     0.000000000000e+00-5.000000000000e+00-1.000000000000e+00-1.000000000000e+00
                       -2.502929419279e-09 2.328306436539e-08-2.968590706587e-09
     1.500000000000e+01 0.000000000000e+00 0.000000000000e+00 1.900000000000e+01
     1.692000000000e+05                                       1.900000000000e+01
> EPH C20 CNV3
C20 2021 07 05 00 00 00-8.546562166885e-04 1.154543127768e-11 0.000000000000e+00
    -2.965450286865e-03-6.914062500000e-01 4.088206004475e-09-1.129589146916e+00
    -6.891787052155e-08 8.444703416899e-04 6.626360118389e-06 5.282619899994e+03
     8.640000000000e+04 3.725290298462e-08-2.772205880999e+00 0.000000000000e+00
     9.665752168918e-01 2.300390625000e+02-6.230324874839e-01-6.829570193298e-09
     3.953736117551e-10 2.727077181880e-14 3.000000000000e+00 8.640000000000e+04
     0.000000000000e+00-5.000000000000e+00 0.000000000000e+00-1.000000000000e+00
     1.500000000000e+01 0.000000000000e+00 0.000000000000e+00-1.746229827404e-09
     8.640000000000e+04
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.3.14 SBAS Navigation Message Record

Table A26 : SBAS Navigation Message Record Description

TABLE A26 SBAS NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**S**), sat number (PRN-100) - Navigation Message Type - **SBAS**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**S**), sat number (PRN-100) Toc - Time of Clock (GPS): - year (4 digits) - month, day, hour, minute, second - SV clock bias; aGf0 (seconds) - SV relative frequency bias; aGf1 (sec/sec) - Transmission time of message in GPS seconds of the week, see section 6.11	A1,I2.2, 1X,I4, 5(1X,I2.2), 3E19.12, *)
BROADCAST ORBIT - 1	- Satellite position X (km) - velocity X dot (km/sec) - X acceleration (km/sec2) - Health: SBAS: See section 5.4.7 for: health, health availability and User Range Accuracy.	4X,4E19.12
BROADCAST ORBIT - 2	- Satellite position Y (km) - velocity Y dot (km/sec) - Y acceleration (km/sec2) - Accuracy code (URA, meters)	4X,4E19.12
BROADCAST ORBIT - 3	- 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 of MT9)	4X,4E19.12

*) see section 6.8.

Table A27 : SBAS Navigation Message - Example

```
+----------------------------------------------------------------------------+
|                                 TABLE A27                                  |
|                     SBAS NAVIGATION MESSAGE - EXAMPLE                      |
+----------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> EPH S28 SBAS
S28 2020 09 15 23 56 48 5.075708031654e-08-2.091837814078e-11 2.589840000000e+05
     5.159782400000e+03 7.125000000000e-04-2.500000000000e-08 0.000000000000e+00
     4.185231736000e+04-2.462500000000e-04-3.750000000000e-08 4.096000000000e+03
    -8.261200000000e+00-1.328000000000e-03 6.250000000000e-08 1.200000000000e+01
> EPH S30 SBAS
S30 2020 09 15 00 00 00 1.937150955200e-07 0.000000000000e+00 1.728330000000e+05
    -3.228075088000e+04 1.990000000000e-03-1.375000000000e-07 1.000000000000e+00
     2.711642576000e+04-1.374375000000e-03-1.000000000000e-07 3.276700000000e+04
    -1.045603600000e+03-3.671600000000e-02 2.750000000000e-06 5.900000000000e+01
> EPH S23 SBAS
S23 2020 09 15 00 01 52 0.000000000000e+00 0.000000000000e+00 1.729280000000e+05
     3.594460000000e+04 0.000000000000e+00 0.000000000000e+00 1.000000000000e+00
     2.204414000000e+04 0.000000000000e+00 0.000000000000e+00 3.276700000000e+04
     0.000000000000e+00 0.000000000000e+00 0.000000000000e+00 5.800000000000e+01
> EPH S23 SBAS
S23 2020 09 15 00 04 16 0.000000000000e+00 0.000000000000e+00 1.730570000000e+05
     3.594460000000e+04 0.000000000000e+00 0.000000000000e+00 1.000000000000e+00
     2.204414000000e+04 0.000000000000e+00 0.000000000000e+00 3.276700000000e+04
     0.000000000000e+00 0.000000000000e+00 0.000000000000e+00 5.900000000000e+01
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.3.15 NavIC LNAV Navigation Message

Table A28 : NavIC LNAV Navigation Message Record Description

TABLE A28 NavIC LNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EPH** - Satellite system (**I**), sat number (PRN) - Navigation Message Type - **LNAV**	A1 1X,A3 1X,A3 1X,A4
SV / EPOCH / SV CLK	- Satellite system (**I**), sat number (PRN) Toc - Time of Clock (NavIC): - 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), 3E19.12 *)
BROADCAST ORBIT - 1	- IODEC Issue of Data, Ephemeris and Clock - C_rs (meters) - Delta n (radians/sec) - M0 (radians)	4X,4E19.12
BROADCAST ORBIT - 2	- C_uc (radians) - e Eccentricity - C_us (radians) - sqrt(A) (sqrt(m))	4X,4E19.12
BROADCAST ORBIT - 3	- Toe Time of Ephemeris (sec of NavIC week) - C_ic (radians) - OMEGA0 (radians) - C_is (radians)	4X,4E19.12
BROADCAST ORBIT - 4	- i0 (radians) - C_rc (meters) - omega (radians) - OMEGA DOT (radians/sec)	4X,4E19.12
BROADCAST ORBIT - 5	- IDOT (radians/sec) - Spare (see Section 6.4) - IRN Week # (to go with TOE) Continuous number, not mod (1024), counted from 1980 (same as GPS). - Spare (see Section 6.4)	4X,E19.12, A19, E19.12, A19

TABLE A28 NavIC LNAV NAVIGATION MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
BROADCAST ORBIT - 6	- User Range Accuracy(m), See NavIC 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 and S healthy, 3= both L5 and S unhealthy - TGD (seconds) - Spare (see Section 6.4)	4X,E19.12, E19.12, E19.12, A19
BROADCAST ORBIT - 7	- Transmission time of message 2*) (sec of NavIC week, see section 6.11)	4X,E19.12

*) see section 6.8.

2*) Adjust the *Transmission time of message* by + or -604800 to refer to the reported week in ***BROADCAST ORBIT 5***, if necessary. Set value to **.9999E+09** if not known. Legacy navigation records without transmit time are permitted for compatibility, but strongly deprecated.

Table A29 : NavIC Navigation Message – Example

```
+--------------------------------------------------------------------------------+
|                                  TABLE A29                                     |
|                       NavIC NAVIGATION MESSAGE - EXAMPLE                       |
+--------------------------------------------------------------------------------+

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> EPH I02 LNAV
I02 2020 09 15 02 05 36 6.225099787116e-04 1.773514668457e-11 0.000000000000e+00
     1.690000000000e+02-5.793750000000e+02 4.834487090078e-09-4.281979621524e-01
    -1.904368400574e-05 2.015684265643e-03-3.430992364883e-06 6.493289550781e+03
     1.803360000000e+05 2.495944499969e-07-1.337499015334e+00 7.450580596924e-08
     5.022043764738e-01 1.946250000000e+02-2.970970345572e+00-4.461614415577e-09
    -9.578970431139e-10                    2.123000000000e+03
     2.000000000000e+00 0.000000000000e+00-1.862645149231e-09
     1.804920000000e+05
> EPH I02 LNAV
I02 2020 09 15 02 20 48 6.225225515664e-04 1.500666257925e-11 0.000000000000e+00
     1.700000000000e+02-5.798125000000e+02 4.847344768509e-09-3.616804200470e-01
    -1.905485987663e-05 2.015971462242e-03-3.460794687271e-06 6.493290285110e+03
     1.812480000000e+05 2.346932888031e-07-1.337503058840e+00 8.568167686462e-08
     5.022034285029e-01 1.955625000000e+02-2.970975986584e+00-4.478757986819e-09
    -9.593256740507e-10                    2.123000000000e+03
     2.000000000000e+00 0.000000000000e+00-1.862645149231e-09
     1.814040000000e+05
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.4 STO, EOP and ION Navigation File Messages

8.4.1 System Time Offset (STO) Message

Table A30 : System Time Offset (STO) Message Record Description

TABLE A30 SYSTEM TIME OFFSET MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **STO** - Satellite system (**G,R,E,C,J,I**) - Sat number (PRN) (or BNK) *) - Navigation Message Type – **LNAV, FDMA,IFNV,D1D2,SBAS,CNVX** 2*)	A1 1X,A3 1X,A1 A2 1X,A4
EPOCH / SYSTEM CORR TYPE / SBAS ID / UTC ID	t_ot – Reference epoch for time offset information: - year (4 digits) - month, day, hour, minute, second - Time offset "2-char + 2-char" of system time codes; **GP, GL, GA, BD, QZ, IR, SB, UT** 3*) - SBAS ID for **SBUT** system time offset indicator; **WAAS, EGNOS, MSAS, GAGAN, SDCM, BDSBAS, KASS, A-SBAS, SPAN** (BNK if not **SBUT**) (see section 5.4.9) - UTC ID for **UT** times offsets – **UTC(USNO), UTC(SU), UTCGAL, UTC(NTSC), UTC(NICT), UTC(NPLI), UTCIRN, UTC(OP), UTC(NIST)**. (see section 5.4.9, Table 23)	 4X,I4, 5(1X,I2.2), 1X,A18 (left justified) 1X,A18 (left justified) 1X,A18 (left justified)
STO MESSAGE LINE - 1	- t_tm - Transmission time of message 4*) (sec of GNSS system week, see sect. 6.11) - A_0 (sec) - A_1 (sec/sec) - A_2 (sec/sec^2) (zero if not available)	4X,4E19.12

BNK- Blank if Not Known/Not Defined

*) To indicate the constellation providing the data (and optionally the specific satellite).

2*) Indicate the **STO** navigation message type in which the data was received (see section 5.4.1)

3*) Indicate the 4-character Time offset correction type by relating two 2-letter system time codes such as **GPUT** ; GPS-UTC, **GLGP** ; GLO-GPS, etc (see section 5.4.9, see relevant system ICD for details)

4*) The transmission time of message is defined to hold the number of seconds since start of the reference epoch week, it may attain both positive and negative values and its magnitude may exceed the number of seconds per week (604800).

8.4.2 Earth Orientation Parameter (EOP) Message

Table A31 : Earth Orientation Parameter (EOP) Message Record Description

TABLE A31 EOP MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **EOP** - Satellite system (**G,C,J,I**) - Sat number (PRN) (or BNK) *) - Navigation Message Type – **LNAV,CNVX** 2*)	A1 1X,A3 1X,A1 A2 1X,A4
EOP MESSAGE LINE - 0	t_EOP – Reference epoch of EOP data: - year (4 digits) - month, day, hour, minute, second - Xp (arc-sec) - dXp/dt (arc-sec/day) - dXp/dt^2 (arc-sec/day^2) 3*)	4X,I4, 5(1X,I2.2), 3E19.12
EOP MESSAGE LINE - 1	- Spare (see Section 6.4) - Yp (arc-sec) - dYp/dt (arc-sec/day) - dYp/dt^2 (arc-sec/day^2) 3*)	4X,A19, 3E19.12
EOP MESSAGE LINE - 2	- t_tm : Transmission time of message 4*) (sec of GNSS system week, see section 6.11) - ΔUT1 (sec) ***Note***: depending on the constellation and the applicable ICD version, Delta UT1 may provide the UT1-UTC difference (always smaller than 1s by magnitude) or the UT1-GPST difference (always negative and larger than 1s by magnitude). - dΔUT1/dt (sec/day) - $d\Delta UT1/dt^2$ (sec/day^2) 3*)	4X,4E19.12

*) To indicate the constellation providing the data (and optionally the specific satellite)
2*) Indicate the EOP navigation message type in which the data was received (see section 5.4.1)
3*) Unavailable EOP parameters should be set to zero
4*) The transmission time of message is defined to hold the number of seconds since start of the reference epoch week, it may attain both positive and negative values and its magnitude may exceed the number of seconds per week (604800).

8.4.3 Ionosphere (ION) Klobuchar Model Message

Table A32 : Ionosphere (ION) Klobuchar Model Message Record Description

TABLE A32 ION KLOBUCHAR MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **ION** - Satellite system (**G,C,J,I**) - Sat number (PRN) (or BNK) *) - Navigation Message Type – **LNAV, D1D2, CNVX** 2*)	A1 1X,A3 1X,A1 A2 1X,A4
ION MESSAGE LINE - 0	t_tm – Transmit time of ionosphere data: - year (4 digits) - month, day, hour, minute, second - Alpha0 (sec) - Alpha1 (sec/semi-circle) - Alpha2 (sec/semi-circle^2)	 4X,I4, 5(1X,I2.2), 3E19.12
ION MESSAGE LINE - 1	- Alpha3 (sec/semi-circle^3) - Beta0 (sec) - Beta1 (sec/semi-circle) - Beta2 (sec/semi-circle^2)	4X,4E19.12
ION MESSAGE LINE - 2	- Beta3 (sec/semi-circle^3) - Region code: **0** or blank (wide area parameters), **1** (QZSS only - Japan area coefficients)	4X,2E19.12

BNK- Blank if Not Known/Not Defined
*) To indicate the constellation providing the data (and optionally the specific satellite)
2*) Indicate the ION navigation message type in which the data was received (see section 5.4.1)

8.4.4 Ionosphere (ION) NEQUICK-G Model Message

Table A33 : Ionosphere (ION) NEQUICK-G Model Message Record Description

TABLE A33 ION NEQUICK-G MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **ION** - Satellite system (**E**) - Sat number (PRN) (or BNK) *) - Navigation Message Type – **IFNV** 2*)	A1 1X,A3 1X,A1 A2 1X,A4
ION MESSAGE LINE - 0	t_tm – Transmit time of ionosphere data: - year (4 digits) - month, day, hour, minute, second - a_{i0} (sfu) - a_{i1} (sfu/deg) - a_{i2} (sfu/deg^2) 3*)	 4X,I4, 5(1X,I2.2), 3E19.12
ION MESSAGE LINE - 1	- Disturbance flags: 5-bit field from FNAV page 1 or INAV word 5 (bit 4 (MSB) = flag for region 1, bit 3 = flag for region 2, bit 2 = flag for region 3, bit 1 = flag for region 4, bit 0 (LSB) = flag for region 5)	4X,E19.12

BNK- Blank if Not Known/Not Defined
*) To indicate the constellation providing the data (and optionally the specific satellite)
2*) Indicate the ION navigation message type in which the data was received (see section 5.4.1)
3*) The 'sfu' (solar flux unit) is not an SI unit but can be converted as 1 sfu = 10^{-22}W/(m^2*Hz) (Section 5.1.6, Galileo SiS ICD)

8.4.5 Ionosphere (ION) BDGIM Model Message

Table A34 : Ionosphere (ION) BDGIM Model Message Record Description

TABLE A34 ION BDGIM MODEL MESSAGE RECORD DESCRIPTION		
NAV. RECORD	**DESCRIPTION**	**FORMAT**
TYPE / SV / MSSG	- New Record identifier: **>** - Navigation Data Record Type – **ION** - Satellite system (**C**) - Sat number (PRN) (or BNK) *) - Navigation Message Type – **CNVX**	A1 1X,A3 1X,A1 A2 1X,A4
ION MESSAGE LINE - 0	t_tm – Transmit time of ionosphere data: - year (4 digits) - month, day, hour, minute, second - Alpha1 (TECu) - Alpha2 (TECu) - Alpha3 (TECu)	 4X,I4, 5(1X,I2.2), 3E19.12
ION MESSAGE LINE - 1	- Alpha4 (TECu) - Alpha5 (TECu) - Alpha6 (TECu) - Alpha7 (TECu)	4X,4E19.12
ION MESSAGE LINE - 2	- Alpha8 (TECu) - Alpha9 (TECu)	4X,2E19.12

BNK- Blank if Not Known/Not Defined

*) To indicate the constellation providing the data (and optionally the specific satellite)

8.4.6 STO, EOP, ION - Examples

Table A35 : STO, EOP, ION Messages - Examples

```
+--------------------------------------------------------------------------------+
|                                   TABLE35                                      |
|                      STO, EOP, ION MESSAGES - EXAMPLES                         |
+--------------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> STO E   IFNV
    2020 09 15 00 00 00 GAUT                                 UTCGAL
     1.735000000000e+05-1.862645149231e-09 0.000000000000e+00 0.000000000000e+00
> STO G24 CNVX
    2020 09 18 19 56 48 GPUT                                 UTC(USNO)
     2.532240000000e+05 9.895302355289e-10-1.154631945610e-14 0.000000000000e+00
> STO E   LEG
    2020 09 16 00 00 00 GAGP
     2.173000000000e+05 2.299202606082e-09 0.000000000000e+00 0.000000000000e+00
> STO I02 LNAV
    2020 09 15 00 04 48 IRUT                                 UTCIRN
     1.731720000000e+05-8.614733815193e-09-1.776356839400e-15 0.000000000000e+00
> STO I02 LNAV
    2020 09 15 00 04 48 IRUT                                 UTC(NPLI)
     1.732200000000e+05 2.619344741106e-10 3.996802888651e-15 0.000000000000e+00
> STO J02 LNAV
    2020 09 18 02 52 48 QZUT                                 UTC(NICT)
     1.837140000000e+05-9.313225746155e-10 0.000000000000e+00 0.000000000000e+00
> STO C46 CNVX
    2021 07 05 23 20 00 BDGL
     1.714860000000e+05-3.768946044147e-08-3.730349362741e-13-2.168404344971e-19
```

```
> STO C46 CNVX
    2021 07 05 00 20 00 BDGP
     8.865000000000e+04-3.181048668921e-08 2.176037128265e-14 2.134523027081e-19
> STO C46 CNVX
    2021 07 05 04 11 28 BDUT                                  UTC(NTSC)
     1.030500000000e+05-3.696186468005e-09 0.000000000000e+00 0.000000000000e+00

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> EOP G24 CNVX
    2020 09 18 19 56 48 2.070846557617e-01-2.679824829102e-04 0.000000000000e+00
                        3.392457962036e-01-1.400947570801e-03 0.000000000000e+00
     2.532480000000e+05-1.759799122810e-01-7.975101470947e-05 0.000000000000e+00
> EOP C20 CNVX
    2020 09 15 00 00 00 2.084112167358e-01-3.948211669922e-04 0.000000000000e+00
                        3.408145904541e-01-1.317977905273e-03 0.000000000000e+00
     1.749900000000e+05-1.752023100853e-01 2.140104770660e-04 0.000000000000e+00
> EOP J01 CNVX
    2020 09 15 01 00 00 2.082471847534e-01-6.551742553711e-04 0.000000000000e+00
                        3.444433212280e-01-9.121894836426e-04 0.000000000000e+00
     1.729860000000e+05-1.754972934723e-01 5.635917186737e-04 0.000000000000e+00
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
> ION G14 CNVX
    2021 07 05 23 30 42 7.450580596924e-09 2.235174179077e-08-5.960464477539e-08
    -1.192092895508e-07 9.216000000000e+04 1.310720000000e+05-6.553600000000e+04
    -5.242880000000e+05
> ION E13 IFNV
    2021 07 05 00 11 04 5.450000000000e+01 3.593750000000e-01 1.358032226562e-02
     0.000000000000e+00
> ION E12 IFNV
    2021 07 05 23 41 40 5.450000000000e+01 3.593750000000e-01 1.358032226562e-02
     0.000000000000e+00
> ION C03 D1D2
    2021 07 05 00 09 00 7.450580596924e-09 4.470348358154e-08-4.172325134277e-07
     5.960464477539e-07 1.187840000000e+05 1.802240000000e+05-6.553600000000e+05
     5.242880000000e+05
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.5 Meteorological Data File

Table A36 : Meteorological Data File – Header Section Description

TABLE A36 METEOROLOGICAL DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
`RINEX VERSION / TYPE`	- Format version: **`4.01`** - File type: **`M`** for Meteorological Data	F9.2,11X, A1,39X
`PGM / RUN BY / DATE`	– Name of program creating current file – Name of agency creating current file – Date and time of file creation (section 5.2.2) Format: yyyymmdd hhmmss zone zone: 3-4 char. code for time zone. '**`UTC`** ' recommended '**`LCL`** ' if local time with unknown time code	A20, A20, A20
`*COMMENT`	- Comment line(s)	A60
`MARKER NAME`	- Station Name (preferably identical to **`MARKER NAME`** in the associated Observation File)	A60
`*MARKER NUMBER`	- Station Number (preferably identical to **`MARKER NUMBER`** in the associated Observation File)	A20
`*DOI`	- Digital Object Identifier (DOI) for data citation i.e. https://doi.org/<DOI-number>	A60
`*LICENSE OF USE`	– Line(s) with the data license of use. Name of the license plus link to the specific version of the license. Using standard data license as from https://creativecommons.org/licenses/ – i.e. : CC BY 04 ; https://creativecommons.org/licenses/by/4.0/	A60
`*STATION INFORMATION`	- Line(s) with the link(s) to persistent URL with the station metadata (site log, GeodesyML, etc)	A60
`# / TYPES OF OBSERV`	- Number of different observation types stored in the file - Observation types; The following meteorological observation types are defined in RINEX: **`PR`** : Pressure (mbar) **`TD`** : Dry temperature (deg Celsius) **`HR`** : Relative humidity (percent) **`ZW`** : Wet zenith path delay (mm) (for WVR data) **`ZD`** : Dry component of zen.path delay (mm) **`ZT`** : Total zenith path delay (mm) **`WD`** : Wind azimuth (deg)	I6, 9(4X,A2)

TABLE A36 METEOROLOGICAL DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	**DESCRIPTION**	**FORMAT**
	(from where the wind blows) **`WS`** : Wind speed (m/s) **`RI`** : "Rain increment" (1/10 mm) (Rain accumulation since last measure) **`HI`** : Hail indicator non-zero (Hail detected since last measurement) The sequence of the types in this record must correspond to the sequence of the measurements in the data records. - If more than 9 observation types are being used, use continuation lines with format	(6X,9(4X,A2))
`SENSOR MOD/TYPE/ACC`	Description of the met sensor - Model (manufacturer) - Type - Accuracy (same units as obs values) - Observation type Record is repeated for each observation type found in **`# / TYPES OF OBSERV`** record	A20, A20,6X, F7.1,4X, A2,1X
`SENSOR POS XYZ/H`	- Approximate position of the met sensor - Geocentric coordinates **X, Y, Z** (ITRF 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

Table A37 : Meteorological Data File – Data Record Description

TABLE A37 METEOROLOGICAL DATA FILE - DATA RECORD DESCRIPTION		
OBS. RECORD	**DESCRIPTION**	**FORMAT**
EPOCH / MET	Epoch in GPS 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

Table A38 : Meteorological Data File – Example

```
+----------------------------------------------------------------------------+
|                                TABLE A38                                   |
|                     METEOROLOGICAL DATA FILE - EXAMPLE                     |
+----------------------------------------------------------------------------+
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
     4.01           METEOROLOGICAL DATA                     RINEX VERSION / TYPE
GR50 V4.11          BADAN INFORMASI GEOS20210106 235942 UTC PGM / RUN BY / DATE
bako                                                        MARKER NAME
23101M002                                                   MARKER NUMBER
     3    PR    TD    HR                                    # / TYPES OF OBSERV
Press.  PTU300      M2710010                             PR SENSOR MOD/TYPE/ACC
Temp.   PTU300      M2710010                             TD SENSOR MOD/TYPE/ACC
Rel.Hum PTU300      M2710010                             HR SENSOR MOD/TYPE/ACC
 -1836969.2810  6065617.0086  -716257.8580      158.1170 PR SENSOR POS XYZ/H
 -1836969.2810  6065617.0086  -716257.8580      158.1170 TD SENSOR POS XYZ/H
 -1836969.2810  6065617.0086  -716257.8580      158.1170 HR SENSOR POS XYZ/H
                                                            END OF HEADER
 2021  1  7  0  0  0  993.3   23.0   90.0
 2021  1  7  0  0 30  993.3   23.0   90.0
 2021  1  7  0  1  0  993.3   23.1   90.0
 2021  1  7  0  1 30  993.3   23.1   90.0
 2021  1  7  0  2  0  993.3   23.1   90.0
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

8.6 Reference Phase Alignment by Constellation and Frequency Band

Phase alignment in RINEX was introduced from RINEX 3.01 as a way to align phases within a signal in a specific constellation with no ambition to align across constellations.

This alignment of phases allows interoperability between different signals in the same frequency while signals are being deployed over a constellation, and when receivers do not track the same set of signals for all satellites of a constellation.

Table A39 : Reference Phase Alignment by Frequency Band

TABLE A39 Reference Phase Alignment by Frequency Band					
System	**Frequency Band**	**Frequency [MHz]**	**Signal**	**RINEX Observation Code**	**Phase Alignment**
GPS	L1	1575.42	C/A	L1C	**None (Reference Signal)**
			L1C-D	L1S	Must be aligned to L1C
			L1C-P	L1L	Must be aligned to L1C
			L1C-(D+P)	L1X	Must be aligned to L1C
			P	L1P	Must be aligned to L1C
			Z-tracking	L1W	Must be aligned to L1C
			Codeless	L1N	Must be aligned to L1C
			M (RMP)	L1R	Restricted (*see Note 3*)
	L2 (*See Note 1*)	1227.60	C/A	L2C	For Block II/IIA/IIR; None, For Block IIR-M/IIF/III; Must be aligned to L2P (*See Note 2*)
			Semi-codeless	L2D	None
			L2C(M)	L2S	Must be aligned to L2P
			L2C(L)	L2L	Must be aligned to L2P
			L2C(M+L)	L2X	Must be aligned to L2P
			P	L2P	**None (Reference Signal)**
			Z-tracking	L2W	None
			Codeless	L2N	None
			M (RMP)	L1R	Restricted (*see Note 3*)
	L5	1176.45	I	L5I	**None (Reference Signal)**
			Q	L5Q	Must be aligned to L5I
			I+Q	L5X	Must be aligned to L5I
GLONASS	G1	1602 + k*9/16	C/A	L1C	**None (Reference Signal)**
			P	L1P	Must be aligned to L1C
	G1a	1600.995	L1OCd	L4A	**None (Reference Signal)**
			L1OCp	L4B	None
			L1OCd+ L1OCd	L4X	None

TABLE A39 Reference Phase Alignment by Frequency Band					
System	**Frequency Band**	**Frequency [MHz]**	**Signal**	**RINEX Observation Code**	**Phase Alignment**
GLONASS	G2	1246 + k*7/16	C/A	L2C	**None (Reference Signal)**
			P	L2P	Must be aligned to L2C
	G2a	1248.06	L2CSI	L6A	**None (Reference Signal)**
			L2OCp	L6B	None
			L2CSI+ L2OCp	L6X	None
	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	Must be aligned to L1B
			B+C	L1X	Must be aligned to L1B
	E5A	1176.45	I	L5I	**None (Reference Signal)**
			Q	L5Q	Must be aligned to L5I
			I+Q	L5X	Must be aligned to L5I
	E5B	1207.140	I	L7I	**None (Reference Signal)**
			Q	L7Q	Must be aligned to L7I
			I+Q	L7X	Must be aligned to L7I
	E5(A+B)	1191.795	I	L8I	**None (Reference Signal)**
			Q	L8Q	Must be aligned to L8I
			I+Q	L8X	Must be aligned to L8I
	E6	1278.75	B	L6B	**None (Reference Signal)**
			C	L6C	Must be aligned to L6B
			B+C	L6X	Must be aligned to L6B
QZSS	L1 (*See Note 6*)	1575.42	C/A	L1C	**None (Reference Signal)**
			C/B	L1E	**None (Reference Signal)**
			L1C (D)	L1S	Must be aligned to L1C/L1E
			L1C (P)	L1L	Must be aligned to L1C/L1E
			L1C-(D+P)	L1X	Must be aligned to L1C/L1E
			L1S	L1Z	N/A
			L1Sb	L1B	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	Must be aligned to L5I
			I+Q	L5X	Must be aligned to L5I

TABLE A39
Reference Phase Alignment by Frequency Band

System	Frequency Band	Frequency [MHz]	Signal	RINEX Observation Code	Phase Alignment
	L5S	1176.45	I	L5D	**None (Reference Signal)**
			Q	L5P	Must be aligned to L5D
			I+Q	L5Z	Must be aligned to L5D
	L6 (*See Note 5*)	1278.75	L6D	L6S	**None (Reference Signal)**
			L6P	L6L	None
			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*)
			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	Must be aligned to L7I
			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 A39 Reference Phase Alignment by Frequency Band					
System	**Frequency Band**	**Frequency [MHz]**	**Signal**	**RINEX Observation Code**	**Phase Alignment**
NavIC	L1	1575.42	D	L1D	**None (Reference Signal)**
			P	L1P	Must be aligned to L1D
			D+P	L1X	Must be aligned to L1D
	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. The phases L2C shall be aligned to L2P when FlexPower is off, the phase shift shall remain applied even if FlexPower is enabled.
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. L6D, L6P, L6E are identical to L61/L62(code1), L61(code2), L62(code2) in IS-QZSS-L6 respectively
6. Either L1C or L1E is broadcast from each QZSS Block IIA or later.