

RINEX

The Receiver Independent Exchange Format

Version 3.04

**International GNSS Service (IGS), RINEX Working
Group and Radio Technical Commission for Maritime
Services Special Committee 104 (RTCM-SC104)**

November 23, 2018

Acknowledgement: RINEX Version 3.02, 3.03 and 3.04 are based on RINEX Version 3.01, which was developed by: Werner Gurtner, Astronomical Institute of the University of Bern, Switzerland and Lou Estey, UNAVCO, Boulder, Colorado, USA.

Table of Contents

0. REVISION HISTORY	1
1. THE PHILOSOPHY AND HISTORY OF RINEX	9
2. GENERAL FORMAT DESCRIPTION	11
3. BASIC DEFINITIONS	12
3.1 Time	12
3.2 Pseudo-Range	12
3.3 Phase	12
Table 1: Observation Corrections for Receiver Clock Offset	13
3.4 Doppler	13
3.5 Satellite numbers.....	13
4. THE EXCHANGE OF RINEX FILES	14
Figure 2: Recommended filename parameters.....	14
Table 2: Description of Filename Parameters.....	15
5. RINEX VERSION 3 FEATURES	16
5.1 Observation codes	16
Table 3: Observation Code Components	16
Table 4 : RINEX Version 3.04 GPS Observation Codes.....	17
Table 5 : RINEX Version 3.04 GLONASS Observation Codes.....	18
Table 6 : RINEX Version 3.04 Galileo Observation Codes	19
Table 7 : RINEX Version 3.04 SBAS Observation Codes	19
Table 8 : RINEX Version 3.04 QZSS Observation Codes	20
Table 9 : RINEX Version 3.04 BDS Observation Codes	21
Table 10 : RINEX Version 3.04 IRNSS Observation Codes.....	22
5.2 Satellite system-dependent list of observables.....	22
5.3 Marker type.....	23
Table 11: Proposed Marker Type Keywords	23
5.4 Half-wavelength observations, half-cycle ambiguities	24
5.5 Scale factor.....	24
5.6 Information about receivers on a vehicle.....	24
5.7 Signal strength	25

Table 12: Standardized S/N Indicators	25
5.8 Date/time format in the PGM / RUN BY / DATE header record	25
5.9 Antenna phase center header record	26
5.10 Antenna orientation.....	26
5.11 Observation data records.....	26
Table 13: Example Observation Type Records	26
Table 14: Example Observation Data Records	26
5.12 Ionosphere delay as pseudo-observables	27
Table 15: Ionosphere Pseudo-Observable Coding.....	27
Table 16: Ionosphere Pseudo-Observable Corrections to Observations	27
5.13 Channel numbers as pseudo-observables.....	27
5.14 Corrections of differential code biases (DCBs)	28
5.15 Corrections of antenna phase center variations (PCVs).....	28
5.16 Navigation message files	28
Table 17: Example of Navigation File Satellite System and Number Definition Record	28
Table 18: Example of Navigation File Header IONOSPHERIC CORR Record.....	28
6. ADDITIONAL HINTS AND TIPS	29
6.1 Versions	29
6.2 Leading blanks in CHARACTER fields.....	29
6.3 Variable-length records.....	29
6.4 Blank fields	29
6.5 Order of the header records, order of data records.....	29
6.6 Missing items, duration of the validity of values.....	30
6.7 Unknown / Undefined observation types and header records.....	30
6.8 Event flag records	30
6.9 Receiver clock offset.....	30
6.10 Two-digit years	30
6.11 Fit interval (GPS navigation message file)	31
6.12 Satellite health (GPS navigation message file)	31
Table 19: Description of GPS Satellite Health Field	31
6.13 Transmission time of message (GPS navigation message file).....	31
6.14 Antenna references, phase centers	31

7. RINEX UNDER ANTISPOOFING (AS).....	32
8. DEALING WITH DIFFERENT SATELLITE SYSTEMS	33
8.1 Time system identifier	33
Table 20: Relationship between GPS, QZSS, IRN, GST, GAL, BDS and RINEX Week Numbers..	34
Table 21: Constellation Time Relationships	35
Table 22: GPS and BeiDou UTC Leap Second Relationship	35
8.2 Pseudorange definition.....	36
Table 23: Constellation Pseudorange Corrections	36
8.3 RINEX navigation message files	37
8.3.1 RINEX navigation message files for GLONASS.....	37
Table 24: GLONASS Navigation File Data, Sign Convention.....	37
8.3.2 RINEX navigation message files for Galileo.....	37
8.3.3 RINEX navigation message files for GEO satellites	38
8.3.4 RINEX navigation message files for BDS.....	39
8.3.5 RINEX navigation message files for IRNSS	39
8.4 RINEX observation files for GEO satellites	40
9. MODIFICATIONS FOR VERSION 3.01, 3.02, 3.03 and 3.04	40
9.1 Phase Cycle Shifts.....	40
Table 25: RINEX Phase Alignment Correction Convention	42
Table 26: Example SYS / PHASE SHIFT Record.....	42
9.2 Galileo: BOC-Tracking of an MBOC-Modulated Signal	42
Table 27: Example of RINEX Coding of Galileo BOC Tracking of an MBOC Signal Record.....	42
9.3 BDS Satellite System Code.....	42
9.4 New Observation Codes for GPS L1C and BDS	43
9.5 Header Records for GLONASS Slot and Frequency Numbers	43
Table 28: Example of a GLONASS Slot- Frequency Records	43
9.6 GNSS Navigation Message File: Leap Seconds Record.....	43
9.7 Clarifications in the Galileo Navigation Message File:	43
9.8 Quasi-Zenith Satellite System (QZSS) RINEX Version 3.02.....	43
9.9 GLONASS Mandatory Code-Phase Alignment Header Record.....	43
Table 29: Example of GLONASS Code Phase Bias Correction Record	44
Table 30: Example of Unknown GLONASS Code Phase Bias Record	44

9.10 BDS system (Replaces Compass)	44
9.11 Indian Regional Navigation Satellite System (IRNSS) Version 3.03	44
9.12 Updates for Quasi-Zenith Satellite System (QZSS), BeiDou and GLONASS (CDMA) RINEX Version 3.04.....	44
Table 31: QZSS PRN to RINEX Satellite Identifier.....	45
10 References.....	47
APPENDIX: RINEX FORMAT DEFINITIONS AND EXAMPLES	1
A 1 RINEX File name description.....	1
A 2 GNSS Observation Data File -Header Section Description.....	5
A 3 GNSS Observation Data File -Data Record Description	13
A 4 GNSS Observation Data File – Example #1	15
A 4 GNSS Observation Data File – Example #2	17
A 4 GNSS Observation Data File – Example #3	18
A 5 GNSS Navigation Message File – Header Section Description	19
A 6 GNSS Navigation Message File – GPS Data Record Description.....	23
A 7 GPS Navigation Message File – Example	24
A 8 GNSS Navigation Message File – GALILEO Data Record Description.....	25
A 9 GALILEO Navigation Message File – Examples.....	27
A 10 GNSS Navigation Message File – GLONASS Data Record Description.....	29
A 11 GNSS Navigation Message File – Example: Mixed GPS / GLONASS	30
A 12 GNSS Navigation Message File – QZSS Data Record Description	31
A 13 QZSS Navigation Message File – Example.....	32
A 14 GNSS Navigation Message File – BDS Data Record Description	33
A 15 BeiDou Navigation Message File – Example	34
A 16 GNSS Navigation Message File – SBAS Data Record Description.....	35
A 17 SBAS Navigation Message File -Example	36
A 18 GNSS Navigation Message File – IRNSS Data Record Description.....	37
A 19 IRNSS Navigation Message File – Example	39
A 20 Meteorological Data File -Header Section Description	40
A 21 Meteorological Data File -Data Record Description.....	42
A 22 Meteorological Data File – Example	42
A 23 Reference Code and Phase Alignment by Constellation and Frequency Band.....	43

0. REVISION HISTORY

	Version 3.00
02 Feb 2006	A few typos and obsolete paragraphs removed.
08 Mar 2006	Epochs of met data of met files version 2.11 are in GPS time only (Table A20).
31 Mar 2006	DCB header record label corrected in Table A6: SYS / DCBS APPLIED .
June 2006	Filenames for mixed GNSS nav mess files.
10 Aug 2006	Table A3: Error in format of EPOCH record: One 6X removed. Trailing 3X removed.
12 Sep 2006	GNSS navigation message files version 3.00 included (including Galileo).
	Table A4: Example of the kinematic event was wrong (kinematic event record).
	SYS / DCBS APPLIED header record simplified.
	Tables A6 and A8: Clarification for adjustment of “Transmission time of message“.
03 Oct 2006	Table A11: Mixed GPS/GLONASS navigation message file
26 Oct 2006	Table A4: Removed obsolete antispooing flag
	Tables A6/8/10: Format error in SV / EPOCH / SV CLK : Space between svn and year was missing
	Half-cycle ambiguity flag (re-)introduced (5.4 and Table A4).
	Clarification of reported GLONASS time (8.1).
	New header record SYS / PCVS APPLIED
	New Table 10: Relations between GPS , GST , and GAL weeks
	Recommendation to avoid storing redundant navigation messages (8.3)
14 Nov 2006	Tables A6/10/12: Format error in BROADCAST ORBIT - n : 3X → 4X. Examples were OK.
21 Nov 2006	Marker type NON_PHYSICAL added
19-Dec-2006	Table A4: Example of SYS / DCBS APPLIED was wrong.
13-Mar-2007	Paragraph 3.3: Leftover from RINEX version 2 regarding wavelength factor for squaring- type receiver removed and clarified.
14-Jun-2007	Paragraph 5.11: Clarification regarding the observation record length
28-Nov-2007	Frequency numbers for GLONASS -7..+12 (BROADCAST ORBIT - 2)
	Version 3.01
22-Jun-2009	Phase cycle shifts
	Galileo: BOC-tracking of an MBOC-modulated signal

	Compass satellite system: Identifier and observation codes
	Code for GPS L1C
	Header records for GLONASS slot and frequency numbers
	Order of data records
	Galileo nav. mess record BROADCAST ORBIT - 5 : Bits 3-4 reserved for Galileo internal use
	Version 3.02 – IGS and RTCM-SC104
19-Nov-2011	Added Quasi Zenith Satellite System (QZSS) Constellation Updated text, tables and graphics Added Appendix Table 19 - phase alignment table
21-Jan-2012	Split the Constellation table into a table for each GNSS Added QZSS to the documentation Edited text to improve clarity Corrected sign in the phase alignment table, Removed QZSS P signals
9-May-2012	Edited text to improve clarity, Updated phase alignment table, Changed Met PGM / RUN BY / DATE to support 4 digit year as in all other records also changed format to support 4 digit year for met. Observation record, Changed SYS / PHASE SHIFTS to SHIFT
29-Nov-2012	Changed Table1 and 2 to Figure 1 and 2. Updated all Table numbers. Changed file naming convention, Section 4. Added Appendix Table A1 and increased all, updated all Appendix numbers Removed the option of supporting unknown tracking mode from Section 5.1. Harmonized L1C(new) signal identifiers for QZSS and GPS See : Table 2 and 6. Updated BeiDou System (BDS) (was Compass) information throughout the document added new BDS ephemeris definition to Appendix. (Based on input from the BDS Office) Corrected GLONASS SLOT/FRQ format in section 9.5, changed message status from optional to mandatory (See: Appendix Table A2). Added new mandatory GLONASS Code Phase Bias header record See section 9.9
11-Mar-2013	Updated Sections: 4.x, made .rnx the file name extension and updated Figure 2; 9.1 to clarify the use of the phase alignment header; A1 Edited to reflect file extension of *.rnx; A14 - BDS ephemeris changed AODC to IODC and AODE to IODE (as indicated by BDS Authority and new ICD); Appendix Table A19 (Changed GLONASS Reference Signals to C1-C2) and explicitly identified reference signal for all constellations and frequencies.
26-Mar-2013	Changed BeiDou to BDS for conform to ICD. In table 7 changed BDS signals from: C2x to C1x to more closely reflect existing bands in tables 2-6 and Appendix Tables A2 and A21.

	<p>Updated Section 8.1: First paragraph updated to indicate current number of leap seconds; added a row to Table 12 to show the relationship between GPS week and BDT week. Added a table to show the approximate relationship of BDT to GPS time.</p> <p>Changed order of file type: from OG to GO etc in Appendix Table A1.</p> <p>Updated Appendix table A21 to show X signals and indicate that the X phase is to be aligned to the frequencies reference signal.</p> <p>Fixed a few small typos in A21 for GPS: L1C-D/P and D+P.</p>
	RINEX 3.02 Released
03-Dec-2013	<ul style="list-style-type: none"> – Corrected Sections 3.1 to read: TIME OF FIRST OBS rather than start time record. – Added text to Section 5.4 and A3 to indicate that the Loss of Lock Bit is the least significant bit. – In section 9.5 GLONASS Slot and Frequency Numbers, changed optional to mandatory (as it was changed from optional to mandatory in version 3.02). – In Table A2 record: SYS / # / OBS TYPES changed Satellite system code (G/R/E/J/C/S/M to G/R/E/J/C/S). – In Section 5.7 added descriptive text to Table 12 (header-changed Signal to Carrier and in the body) . – In Table A3 record OBSERVATION changed 5: from average to good. – In note 4 after A8 ...Galileo System Time added (GST) to make the following description more explicit. – Appendix A14 BeiDou Nav. removed the – sign in front of Cis
24-Jan-2014	<ul style="list-style-type: none"> – Appendix A10 Section SV / EPOCH / SV CLK changed TauN to –TauN to agree with section 8.3.1
4-Apr-2014	<ul style="list-style-type: none"> – Galileo Table A8 , BROADCAST ORBIT-5 - Bits 0-2 : changed from non-exclusive to exclusive (only one bit can be set). In *****) section added (GST) – Corrected Table A23 - BeiDou B1 phase correction column signal indicator to agree with BeiDou Table 9. – Corrected Table A2 - Band 1 = E1 (Was E2-L1-E1) to agree with Galileo Table 6. – In Table A5 - optional message TIME SYSTEM CORR added text to clarify the parameters T and W for BeiDou. – Section 8.3.1 Corrected typo in last line of first paragraph.
6-May-2014	<ul style="list-style-type: none"> – Updated Section 10 Document References – Changed A6 from GPS/QZSS to GPS only as A12 contains a description of the QZSS ephemeris. – Corrected typo in Appendix 23 note 1: L2E changed to L2W
21-May-2014	<ul style="list-style-type: none"> – Appendix A4 added two observation file header examples – Appendix A6 GPS Navigation, Broadcast Orbit-7 Fit Interval,

	<p>clarified in accordance with IS-GPS-200H section 20.3.3.4.3.1</p> <ul style="list-style-type: none"> – Appendix A9 added Galileo navigation file example – Appendix A12 QZSS Navigation, Broadcast Orbit-5 field 4 allow define L2P flag to be set to one section 5.2.2.2.3(6)); Broadcast Orbit-7 Fit Interval clarified in accordance with section 5.2.2.2.4(4), IS-QZSS 1.5. – Appendix A13 added QZSS navigation file example – Appendix A15 added BeiDou navigation file example
26-May-2014	<ul style="list-style-type: none"> – Removed “Added” from section 9.8, 9.9 and 9.10 titles – Added a note to section 9.9 (GLONASS COD/PHS/BIS) to allow unknown GLONASS code/phase, observation alignment in exceptional cases. Added a note to Appendix A2: GLONASS COD/PHS/BIS record definition.
9-June-2014	<ul style="list-style-type: none"> – Edited Section 6.11 and Table A6:BO7 (GPS) to indicate that the GPS fit interval field should contain a period in hours. Edited Table A12:BO7 (QZSS) to make it clear that the fit interval is a flag and not a time period. Added support for unknown fit interval (specified as an empty field).
10-June-2014	<ul style="list-style-type: none"> – Removed the reference to QZSS in Appendix 6 SC/EPOCH/SV CLK record as there is now a QZSS navigation file in Appendix 12. – Corrected A12 QZSS ICD reference from 5.1.2.3.2 to 5.1.2.1.3.2
12-June-2014	<ul style="list-style-type: none"> – Added text to section 9.9 to indicate that when the GLONASS COD/PHS/BIS measurements are unknown then all fields in the record should be left blank (added an example). Updated the descriptive text in Table A2 GLONASS COD/PHS/BIS.
10-July-2014	<ul style="list-style-type: none"> – Corrected Appendix numbers in body of the text – Added Note after BeiDou Table 9 to indicate that some RINEX 3.02 files may still use the 3.01 B1 coding convention
16-Jul-2014	<ul style="list-style-type: none"> - Section 9.1 Replaced: Phase observations must be shifted by the respective fraction of a cycle, either directly by the receiver or by a correction program or the RINEX conversion program, prior to RINEX file generation, to align them to each other with: All phase observations must be aligned to the designated constellation and frequency reference signal as specified in Appendix Table A23, either directly by the receiver or by a correction program or the RINEX conversion program, prior to RINEX file generation. Additionally, all data must be aligned with the appropriate reference signal indicated in Appendix Table A23 even when the receiver or reporting device is not tracking and/or providing data from that reference signal e.g. Galileo L5X phase data must be aligned to L5I.
29-Jul-2014	<ul style="list-style-type: none"> - Minor edits - Updated last paragraph of section 8.4 re TIME SYSTEM CORR - Corrected QZSS Appendix Table A12 PRN/EPOCH/SV CLK

	<ul style="list-style-type: none"> record format specification - Reformatted Appendix Table A12 and A14
31-Oct-2014	<ul style="list-style-type: none"> - BeiDou updates: changed B1 signal identifiers to C2x; observation and navigation Header “LEAP SECONDS messages changed to support both GPS and BDS leap seconds; updated the navigation header message “IONOSPHERIC CORR” to support different ionospheric correction parameters from each satellite. Updated BDS navigation message Table A14. Updated Sections 8.1 and 8.2. - Added Description of the Indian Regional Navigation Satellite System (IRNSS) to the document, Updated RINEX release number to 3.03 Draft 1
19-Jan-2015	<ul style="list-style-type: none"> - Table 2 grammatical error corrections - Updated broken http: link on page 17 - Updated Leap Second definition in section 8.1 and Appendix A2 and A5 - Update Galileo Appendix A8 navigation line 5 to indicate the exclusive and non-exclusive bits - Added text to further clarify BeiDou Appendix A14 AODE and AODC definition - Updated IRNSS Appendix 18 line 5, week number to indicate that the Week Number is aligned with the GPS week number - Added IRNSS phase alignment information to Appendix 23
15-April-2015	<ul style="list-style-type: none"> - Editorial changes/corrections: in section 6.6 specified a new acronym Blank Not Known (BNK), 8.1 added text to indicate the relationship between BDT and GPS Time at start of BDT, corrected typo in Section 8.2 last paragraph changed GLO to UTC, clarified Section 9.2 Galileo Tracking, clarified Section 9.6 re BDS, removed Section 9.8 RINEX Meteorological section - Re-formatted Appendix Table A2 and A5 - Clarified Observation (A2) and Navigation (A5) “LEAP SECONDS” record - Clarified Navigation (A5) file “IONOSPHERIC CORR” record - QZSS A12-BO-6, TGD blank if not know - Corrected typo in A22, - Clarified filename start time - Minor punctuation and grammatical corrections throughout the document. - Removed reference to unknown tracking mode in Appendix Table A2 message SYS / # / OBS TYPE. - Updated all table numbers (some tables were not identified), improved table descriptions. - Minor format changes
15-May-2015	<ul style="list-style-type: none"> - Added paragraph to section 8.3.2 to specify that RINEX parsers

	<p>should expect to encounter F/NAV and I/NAV messages in the same file...</p> <ul style="list-style-type: none"> - Removed “The attribute can be left blank if not known. See text!” text from the end of A2, SYS/#/OBS TYPES as it was decided in 3.02 not to allow unknown signals therefore this no longer applies - Updated A8 (Galileo Nav. Message), Record 5 Field 2- Description to specify only I/NAV or F/NAV can be specified - Corrected A9 (Galileo Nav. Example), Record 5 Field 2 from 519 to 517 to indicate I/NAV in accordance with the field specification - Corrected A9, Record 6 Field 1 from 107(broadcast raw value) to 3.12m
25-May-2015	<ul style="list-style-type: none"> - Corrected Table of contents to show Section 10.0, References - Section 2 second last paragraph added IRNSS to list of supported constellations - Section 5.3 last paragraph concerning event flags added reference to Appendix A3 - Section 7, last paragraph, edited second sentence to make it more clear
1-June-2015	<ul style="list-style-type: none"> - Minor punctuation corrections - Added C2X signal tracking example to Section 5.1 example list - Added paragraph 3 to section 5.1, to indicate only known tracking modes are supported in RINEX 3.02 and 3.03 - Added note to Appendix A2, SYS/#/OBS TYPES to indicate only known tracking modes are allowed in RINEX 3.02 and 3.03 - Table 4 in L1 and L2 frequency bands, changed P to P (AS off) to improve clarity - Added :”(e.g. units employing a Selective Availability Anti-Spoofing Module (SAASM))“ to last paragraph on page 18 to improve clarity.
24-June-2015	<ul style="list-style-type: none"> - Updated the last paragraph of Section 1 (RINEX 3.03) - Clarified Section 4: Changed Obs. Freq. To Data Frequency and update Appendix Table A1 to match - Added text to Section 8.3.2 (Galileo Navigation) to describe Issue of Data and related parameters - Added reference to Galileo ICD in Appendix A8 BROADCAST ORBIT-6 - Added Galileo Examples to Appendix Table A9
29-June-2015	<ul style="list-style-type: none"> - Updated BeiDou RINEX 3.02 C1x-C2x Note below Table 9 for clarity - Section 8.3.2 added Galileo ICD publication year to reference - Corrected Beidou C1 to C2 encoding in Appendix A2 SYS/#/OBS TYPES and in Appendix A4 example 2 and 3 - Appendix A2 and A5 Clarified LEAP SECONDS Day number to be 0-6 for BeiDou and 1-7 for GPS and other constellations. - Updated all Appendix table references to contain Axx, to

	differentiate between body and Appendix tables.
14-July-2015	<ul style="list-style-type: none"> - Updated LEAP SECONDS record description in Appendix A2 and A5 - Converted Galileo SISA values in Appendix A9 from broadcast value into metres in accordance with RINEX specification and Galileo ICD Section 5.1.11 Table 76
	- RINEX 3.03 Released
7-Sept.-2016	<ul style="list-style-type: none"> - GLONASS Table 5 G2 Section: added missing / to 7/16 to indicate frequency offset spacing - Updated Tables 29 and 30 to remove errant # from end of message type tag to conform to Appendix A2 definition and examples - Appendix A3 Observation definition clarified - Appendix A10 GLONASS Navigation message, clarified the health indicator to be: 0 = healthy and 1 = unhealthy
03-Oct.-2016	<ul style="list-style-type: none"> - Appendix A3 Observation definition use of Signal Strength Indicator (SSI) further clarified - Appendix A16 SBAS and QZSS SAIF Navigation message: clarified the health bit mask to be in accordance with Section 8.3.3.
06-Oct.-2016	- Appendix A1 Added Meteorological file name example
28-Oct.-2016	- Corrected http link to PRN Assignment Information on page 19
02-Dec-2016	<ul style="list-style-type: none"> - Minor punctuation, typographical and grammatical corrections - Updated Leap second information in Table 22 - Section 8.3.3 and 8.3.4 <i>Transmission Time of Message</i> paragraphs, Changed PRN/EPOCH/SV CLK to SV/EPOCH/SV CLK, reorganized last sentence to improve clarity - Changed PRN/EPOCH/SV CLK to SV/EPOCH/SV CLK in Table A12
24-Jan-2017	- Released RINEX 3.03 Update 1
25-Apr-2018	<ul style="list-style-type: none"> - Updated GLONASS, QZSS and BeiDou signal tables 5, 8 and 9 and related information in Appendix Table A23. - Added Section 9.12 to describe the new signals and features. - Changed RINEX 3.03 to 3.04 throughout the document. - Added the new Constellation ICD information to the References section.
30-July-2018	<ul style="list-style-type: none"> - Corrected format typo in table 26 - Clarified A10 Health Field by specifying most significant bit of 3-bit Bn - Changed A8 and A10 Label from OBS. RECORD to NAV RECORD - Table 5 Changed the GLONASS CDMA signals for G1a to G4 and G2a to G6 to be consistent with labeling conventions used for other constellations - Added new signals in BeiDou Table 9 - Added new Band to Constellation information to A2 - Corrected typo in Table A4 example #3 changed L2Q to L5Q

30-Aug.-2018	<ul style="list-style-type: none"> - Clarified QZSS Block I and II signals in Table 8 - Clarified BDS Generation 2 and 3 tracking signal in Table 9 - Updated Table A5 TIME SYSTEM CORR and related examples in appendix tables - Added Text to specify that the body of RINEX 3.0x files names should be ASCII capital letters and numbers. File extension must be lower case.
11-Sept-2018	<ul style="list-style-type: none"> - Minor edits and document date update
01-Oct-2018	<ul style="list-style-type: none"> - Add clarification information to QZSS Table 8, L6 Channel information column. - Updated Section 9.12 QZSS Block I and II signal coding description.
15-Oct-2018	<ul style="list-style-type: none"> - Updated format of BeiDou Table 9 - Appendix A2 - corrected 4 = G1a (GLO), reordered signal attribute codes to be in alphabetical order (page A8) - Corrected A5 –W Reference week number by removing BDS from the group in parentheses so that it is clear that BDS week starts on 1-Jan-2006, as week zero. Also corrected BDUT example in A9 - Appendix A8 updated definition of SISA for -1.0 to read No Accuracy Precision Available/Unknown - Updated A23 New GLONASS G1 and G2 Frequency Band identifiers to G1a and G2a
22-Oct-2018	<ul style="list-style-type: none"> - Minor format and editorial updates: - Table #9 added text to specify new BDS-3 signals in Frequency Band/Frequency Column - Section 5.12, Table #15, n: band/frequency changed from 1-8 to 1-9. - Header of Table A6, A12, A14, A16 and A18: replaced OBS. with NAV. - Updated release dates for QZSS documents in References section - Corrected A23 QZSS linkage of notes 5 and 6
23-Nov-2018	<ul style="list-style-type: none"> - Changed IGS ftp://igscb.jpl.nasa.gov to ftp://igs.org and ftp://ftp.unibe.ch/aiub to ftp://ftp.aiub.unibe.ch in References section. Minor naming consistency edits.
23-Nov-2018	<ul style="list-style-type: none"> - RINEX 3.04 Released

1. THE PHILOSOPHY AND HISTORY OF RINEX

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

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

- the carrier-phase measurement at one or both carriers (actually being a measurement on the beat frequency between the received carrier of the satellite signal and a receiver-generated reference frequency)
- the pseudorange (code) measurement, equivalent to the difference of the time of reception (expressed in the time frame of the receiver) and the time of transmission (expressed in the time frame of the satellite) of a distinct satellite signal
- the observation time, being the reading of the receiver clock at the instant of validity of the carrier-phase and/or the code measurements

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

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

Until now, two major format versions have been developed and published:

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

Several subversions of RINEX Version 2 have been defined:

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

spaceborne receivers within the IGS LEO pilot project [Gurtner and Estey 2002]

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

- Exchange format for **satellite and receiver clock offsets** determined by processing data of a GNSS tracking network [Ray and Gurtner 2010]
- Exchange format for the complete **broadcast data of space-based augmentation systems** SBAS. [Suard et al. 2004]
- IONEX: Exchange format for **ionosphere models** determined by processing data of a GNSS tracking network [Schaer et al. 1998]
- ANTEX: Exchange format for **phase center variations** of geodetic GNSS antennae [Rothacher and Schmid 2010]

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

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

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

The major change leading to the release of version 3.01 was the requirement to generate consistent phase observations across different tracking modes or channels, i.e. to apply $\frac{1}{4}$ -cycle shifts prior to RINEX file generation, if necessary, to facilitate the processing of such data.

RINEX 3.02 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 adds support for the Indian Regional Satellite System (IRNSS) and clarifies several implementation issues in RINEX 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 8.3.2 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.

2. GENERAL FORMAT DESCRIPTION

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

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

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

The format has been optimized for minimum space requirements independent from the number of different observation types of a specific receiver or satellite system by indicating in the header the types of observations to be stored for this receiver and the satellite systems having been observed. In computer systems allowing variable record lengths, the observation records may be kept as short as possible. Trailing blanks can be removed from the records. There is no maximum record length limitation for the observation records.

Each Observation file and each Meteorological Data file basically contain the data from one site and one session. Starting with Version 2 RINEX also allows including observation data from more than one site subsequently occupied by a roving receiver in rapid static or kinematic applications. Although Version 2 and higher allow 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.

The format of the data records of the RINEX Version 1 navigation message file was identical to the former NGS exchange format. RINEX Version 3 navigation message files may contain navigation messages of more than one satellite system (GPS, GLONASS, Galileo, Quasi Zenith Satellite System (QZSS), BeiDou System (BDS), Indian Regional Navigation Satellite System (IRNSS) and SBAS).

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

3. BASIC DEFINITIONS

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

3.1 Time

The time of the measurement is the receiver time of the received signals. It is identical for the phase and range measurements and is identical for all satellites observed at that epoch. For single-system data files, it is by default expressed in the time system of the respective satellite system. For mixed files, the actual time system used must be indicated in the TIME OF FIRST OBS header record.

3.2 Pseudo-Range

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

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

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

See also clarifications for pseudoranges in mixed GPS/GLONASS/Galileo/QZSS/BDS files in chapter 8.2.

3.3 Phase

The phase is the carrier-phase measured in whole cycles. The half-cycles measured by squaring-type receivers must be converted to whole cycles and flagged by the respective observation code (see Table 4 and Section 5.4, GPS only).

The phase changes in the same sense as the range (negative doppler). The phase observations between epochs must be connected by including the integer number of cycles.

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

If necessary, phase observations are corrected for phase shifts needed to guarantee consistency between phases of the same frequency and satellite system based on different signal channels (See Section 9.1 and Appendix A23).

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

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

Table 1: Observation Corrections for Receiver Clock Offset

3.4 Doppler

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

3.5 Satellite numbers

Starting with RINEX Version 2 the former two-digit satellite numbers **nn** are preceded by a one-character system identifier **s** as shown in Figure 1.

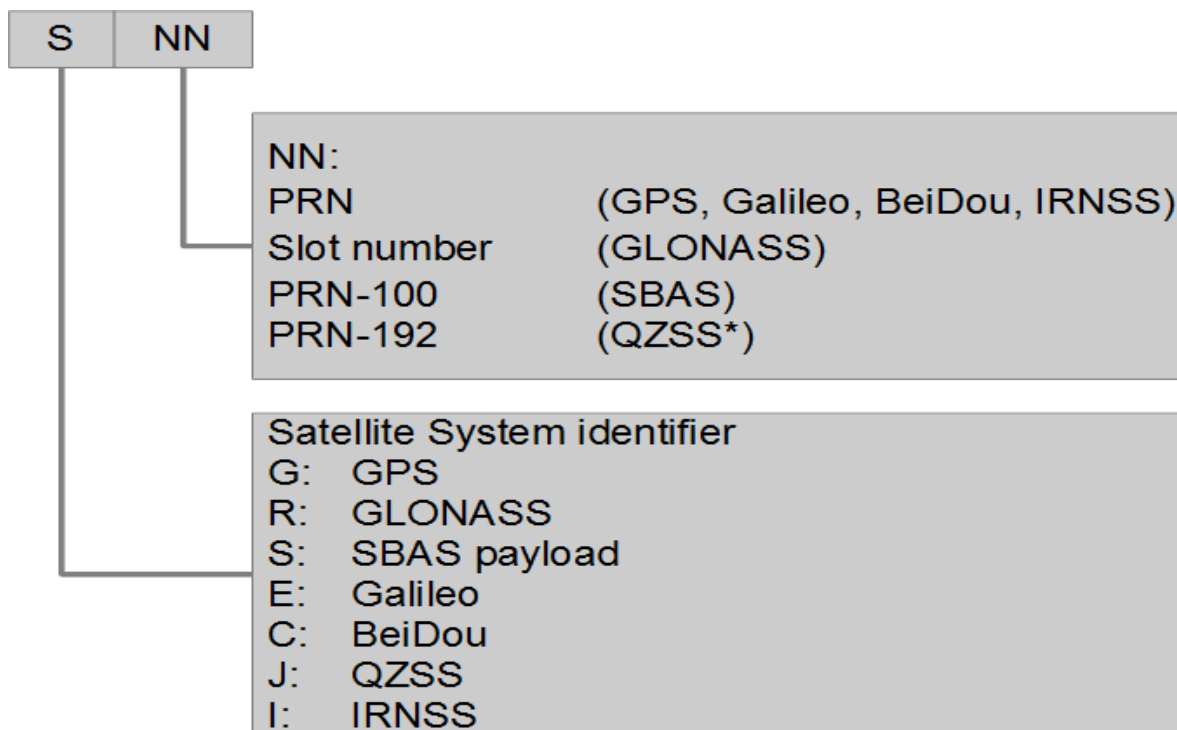


Figure 1: Satellite numbers and Constellation Identifiers

***) For detailed definition of QZSS, please refer the section 9.12)**

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

4. THE EXCHANGE OF RINEX FILES

The original RINEX file naming convention was implemented in the MS-DOS era when file names were restricted to 8.3 characters. Modern operating systems typically support 255 character file names. The goal of the new file naming convention is to be more descriptive, flexible and extensible than the RINEX 2.11 file naming convention. Figure 2 below lists the elements of the RINEX 3.02 (and subsequent versions) file naming convention.

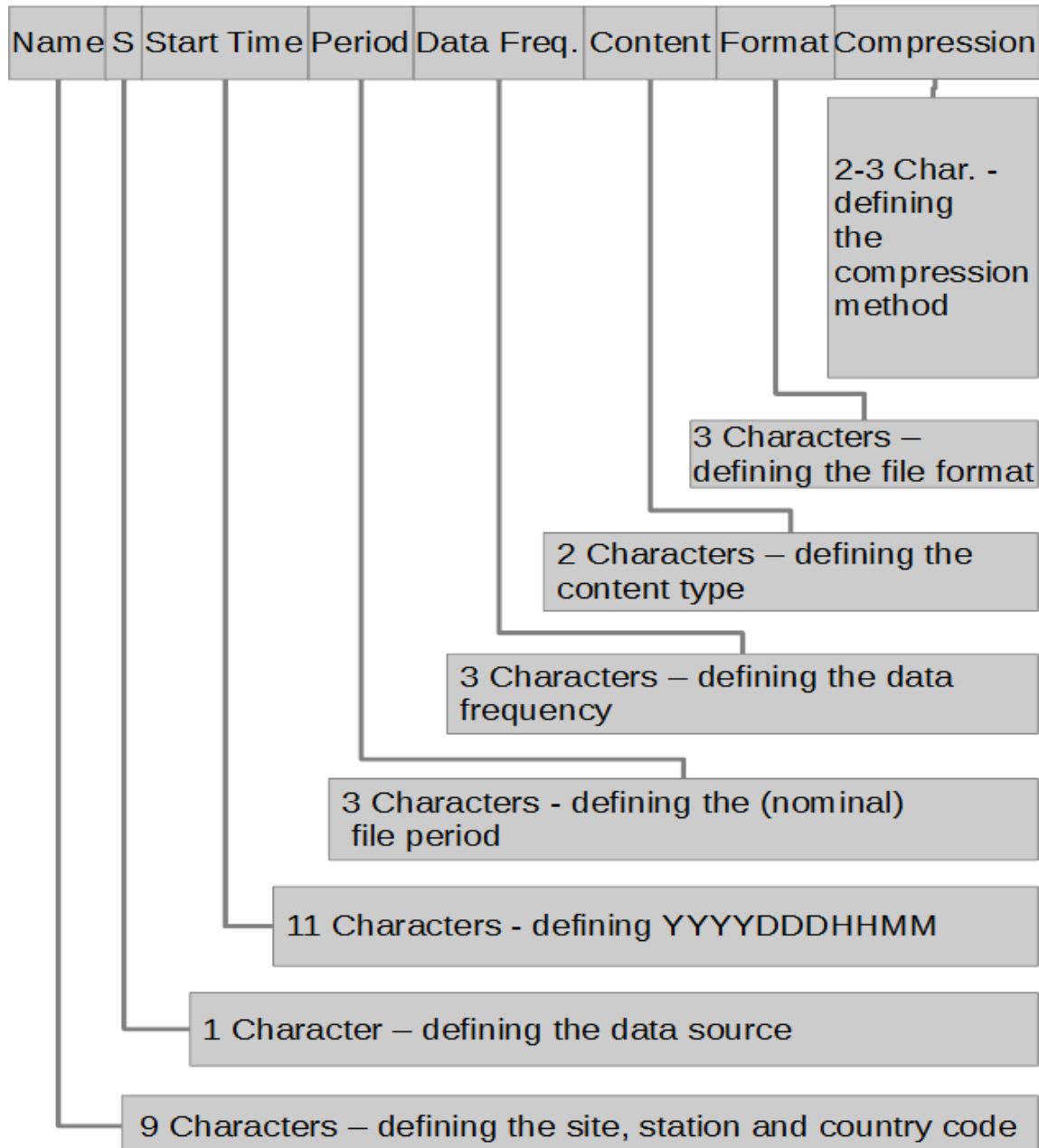


Figure 2: Recommended filename parameters.

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. See Appendix A1 for a detailed description of the RINEX 3.02 (and subsequent versions) file naming convention. Table 2 below lists sample file names for GNSS observation and navigation 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_01H_05Z_MO.rnx	Mixed RINEX GNSS observation file containing 1 hour of data, with 5 observations per second
ALGO00CAN_R_20121601000_01D_30S_GO.rnx	GPS RINEX observation file containing 1 day of data, with an observation every 30 seconds
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_GN.rnx	RINEX GPS navigation file, containing one day’s data
ALGO00CAN_R_20121600000_01D_RN.rnx	RINEX GLONASS navigation file, containing one day’s data
ALGO00CAN_R_20121600000_01D_MN.rnx	RINEX mixed navigation file, containing one day’s data

Table 2: Description of Filename Parameters

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

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

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

- IGS Mails 1525,1686,1726,1763,1785,4967,4969,4975

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

5. RINEX VERSION 3 FEATURES

This chapter contains features that have been introduced for RINEX Version 3.

5.1 Observation codes

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

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

Table 3: Observation Code Components

Examples:

- **L1C**: C/A code-derived L1 carrier phase (GPS, GLONASS) Carrier phase on E2-L1-E1 derived from C channel (Galileo)
- **C2L**: L2C pseudorange derived from the L channel (GPS)
- **C2X**: L2C pseudorange derived from the mixed (M+L) codes (GPS)

Tables 4 to 10 describe each GNSS constellation and the frequencies and signal encoding methods used.

Unknown tracking modes are not supported in RINEX 3.02 and 3.03. Only the complete specification of all signals is allowed i.e. all three fields must be defined as specified in Tables 4-10.

GNSS System	Freq. Band /Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
GPS	L1/1575.42	C/A	C1C	L1C	D1C	S1C
		L1C (D)	C1S	L1S	D1S	S1S
		L1C (P)	C1L	L1L	D1L	S1L
		L1C (D+P)	C1X	L1X	D1X	S1X
		P (AS off)	C1P	L1P	D1P	S1P
		Z-tracking and similar (AS on)	C1W	L1W	D1W	S1W
		Y	C1Y	L1Y	D1Y	S1Y
		M	C1M	L1M	D1M	S1M
		codeless		L1N	D1N	S1N
	L2/1227.60	C/A	C2C	L2C	D2C	S2C
		L1(C/A)+(P2-P1) (semi-codeless)	C2D	L2D	D2D	S2D
		L2C (M)	C2S	L2S	D2S	S2S
		L2C (L)	C2L	L2L	D2L	S2L
		L2C (M+L)	C2X	L2X	D2X	S2X
		P (AS off)	C2P	L2P	D2P	S2P
		Z-tracking and similar (AS on)	C2W	L2W	D2W	S2W
		Y	C2Y	L2Y	D2Y	S2Y
		M	C2M	L2M	D2M	S2M
		codeless		L2N	D2N	S2N
	L5/1176.45	I	C5I	L5I	D5I	S5I
		Q	C5Q	L5Q	D5Q	S5Q
		I+Q	C5X	L5X	D5X	S5X

Table 4 : RINEX Version 3.04 GPS 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 (GLONASS M)	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 5 : RINEX Version 3.04 GLONASS Observation Codes

GNSS System	Freq. Band /Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
Galileo	E1 / 1575.42	A PRS	C1A	L1A	D1A	S1A
		B I/NAV OS/CS/SoL	C1B	L1B	D1B	S1B
		C no data	C1C	L1C	D1C	S1C
		B+C	C1X	L1X	D1X	S1X
		A+B+C	C1Z	L1Z	D1Z	S1Z
	E5a / 1176.45	I 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 6 : RINEX Version 3.04 Galileo Observation Codes

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

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 7 : RINEX Version 3.04 SBAS Observation Codes

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

Table 8 : RINEX Version 3.04 QZSS Observation Codes

Note: RINEX 1Z signal coding 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 9.12 and Table 31 for QZSS PRN to RINEX identifier coding.

GNSS System	Freq. Band / Frequency	Channel or Code	Observation Codes			
			Pseudo Range	Carrier Phase	Doppler	Signal Strength
BDS	B1-2 / 1561.098	I	C2I	L2I	D2I	S2I
		Q	C2Q	L2Q	D2Q	S2Q
		I+Q	C2X	L2X	D2X	S2X
	B1 / 1575.42 (BDS-3 Signals)	Data	C1D	L1D	D1D	S1D
		Pilot	C1P	L1P	D1P	S1P
		Data+Pilot	C1X	L1X	D1X	S1X
		B1A	C1A	L1A	D1A	S1A
		Codeless		L1N	D1N	S1N
	B2a / 1176.45 (BDS-3 Signals)	Data	C5D	L5D	D5D	S5D
		Pilot	C5P	L5P	D5P	S5P
		Data+Pilot	C5X	L5X	D5X	S5X
	B2b / 1207.140 (BDS-2 Signals)	I	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	I	C6I	L6I	D6I	S6I
		Q	C6Q	L6Q	D6Q	S6Q
		I+Q	C6X	L6X	D6X	S6X
		B3A	C6A	L6A	D6A	S6A

Table 9 : RINEX Version 3.04 BDS Observation Codes

Note: When reading a RINEX 3.02 file, both C1x and C2x coding should be accepted and treated as C2x in RINEX 3.03.

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

Table 10 : RINEX Version 3.04 IRNSS Observation Codes

GPS-SBAS and –pseudorandom noise (PRN) code assignments see:
<https://media.defense.gov/2016/Jul/26/2001583103/-1/-1/1/PRN%20CODE%20ASSIGNMENT%20PROCESS.PDF>

Antispoofing (AS) of GPS: True codeless GPS receivers (squaring-type receivers) use the attribute **N**. Semi-codeless receivers tracking the first frequency using C/A code and the second 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**.

Appendix Table A23 enumerates the fractional phase corrections required to align each signal to the frequencies reference signal.

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

5.2 Satellite system-dependent list of observables

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

5.3 Marker type

In order to indicate the nature of the marker, a **MARKER TYPE** header record has been defined. Proposed keywords are given in Table 11.

Marker Type	Description
Geodetic	Earth-fixed high-precision monument
Non Geodetic	Earth-fixed low-precision monument
Non_Physical	Generated from network processing
Space borne	Orbiting space vehicle
Air borne	Aircraft, balloon, etc.
Water Craft	Mobile water craft
Ground Craft	Mobile terrestrial vehicle
Fixed Buoy	“Fixed” on water surface
Floating Buoy	Floating on water surface
Floating Ice	Floating ice sheet, etc
Glacier	“Fixed” on a glacier
Ballistic	Rockets, shells, etc
Animal	Animal carrying a receiver
Human	Human being

Table 11: Proposed Marker Type Keywords

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

Attributes other than **GEODETIC** and **NON_GEODETIC** will tell the user program that the data were collected by a moving receiver. The inclusion of a “start moving antenna” record (event flag 2) into the data body of the RINEX file is therefore not necessary. However, event flags 2 and 3 (See Appendix A3) are still necessary to flag alternating kinematic and static phases of a receiver visiting multiple earth-fixed monuments. Users may define other project-dependent keywords.

5.4 Half-wavelength observations, half-cycle ambiguities

Half-wavelength observations (collected by **codeless** squaring techniques) get their own observation codes. A special wavelength factor header line and bit 1 of the LLI flag in the observation records are no longer necessary. If a receiver changed between squaring and full cycle tracking within the time period of a RINEX file, observation codes for both types of observations have to be inserted into the respective **SYS / # / OBS TYPES** header record.

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

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

5.5 Scale factor

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

5.6 Information about receivers on a vehicle

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

- Antenna position (position of the antenna reference point) in a body-fixed coordinate system: **ANTENNA: DELTA X/Y/Z**
- 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 6.14 below): **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 below)

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

5.7 Signal strength

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 strength¹ **sn_raw** is given in **dbHz**:

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

Carrier to Noise ratio(dbHz)	Carrier to Noise ratio(RINEX)
< 12	1 (minimum possible signal strength)
12-17	2
18-23	3
24-29	4
30-35	5 (threshold for good tracking)
36-41	6
42-47	7
48-53	8
≥ 54	9 (maximum possible signal strength)

Table 12: Standardized S/N Indicators

The raw carrier to noise ratio can be optionally (preferred) stored as **Sna** observations in the data records and should be given in dbHz if possible. The new **SIGNAL STRENGTH UNIT** header record can be used to indicate the units of these observations.

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

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

yyyymmdd hhmmss zone

zone: 3 – 4 character code for the time zone

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

¹S/N is the raw S/N at the output of the correlators, without attempting to recover any correlation losses

5.9 Antenna phase center header record

An *optional* header record for antenna phase center positions **ANTENNA: PHASECENTER** is defined to allow for higher precision positioning without need of additional external antenna information. It can be useful in well-defined networks or applications. It contains the position of an *average* phase center relative to the antenna reference point (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 6.14 below. See section 5.15 regarding the use of phase center variation corrections.

5.10 Antenna orientation

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

5.11 Observation data records

Aside from the new observation code definitions, the most conspicuous modification of the RINEX format concerns the observation records. As the types of the observations and their order within a data record depend on the satellite system, the new format should make it easier for programs as well as human beings to read the data records. Each observation record begins with the satellite number **snn**, the epoch record starts with special character **>**. It is now also much easier to synchronize the reading program with the next epoch record in case of a corrupted data file or when streaming observation data in a RINEX-like format. The record length limitation to 80 characters of RINEX Versions 1 and 2 *has been removed*.

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

G	5 C1P L1P L2X C2X S2X	SYS / # / OBS TYPES
R	2 C1C L1C	SYS / # / OBS TYPES
E	2 L1B L5I	SYS / # / OBS TYPES
S	2 C1C L1C	SYS / # / OBS TYPES

Table 13: Example Observation Type Records

The epoch and observation records are as follows:

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

Table 14: Example Observation Data Records

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

5.12 Ionosphere delay as pseudo-observables

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

t : observation type	I = Ionosphere phase delay
n : band/frequency	1, 2, . . . , 9
a : attribute	blank

Table 15: Ionosphere Pseudo-Observable Coding

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

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

corr_phase(fi)	=	raw_phase(fi)	+	d_ion(fi)
corr_prange(fi)	=	raw_prange(fi)	-	d_ion(fi) • c/fi
d_ion(fk)	=	d_ion(fi)	•	(fi/fk)**2 (accounting for 1 st order effects only)

Table 16: Ionosphere Pseudo-Observable Corrections to Observations

d_ion(fi): Given ionospheric phase correction for frequency fi

5.13 Channel numbers as pseudo-observables

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

- **t** : observation type: **x** = Receiver channel number
- **n** : band / frequency : **1**
- **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. Format F14.3 according to (<5-nc>(2X),<nc>I2.2,'.000'), nc being the number of channels.

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

Examples:

- **0910.000** for channels 9 and 10
- **010203.000** for channels 1, 2, and 3

-----F14.3-----

5.14 Corrections of differential code biases (DCBs)

For special high-precision applications, it might be useful to generate RINEX files with corrections of the differential code biases (DCBs) already applied. There are programs available to correct the observations in RINEX files for differential code biases (e.g., **cc2noncc**, J. Ray 2005). This can be reported by special header records **SYS / DCBS APPLIED** pointing to the file containing the applied corrections.

5.15 Corrections of antenna phase center variations (PCVs)

For more precise applications, an elevation-dependent or elevation and azimuth-dependent Phase Center Variation (PCV) model for the antenna (referring to the agreed-upon ARP) should be used. For special applications, it might be useful to generate RINEX files with these variations already applied. This can be reported by special header records **SYS / PCVS APPLIED** pointing to the file containing the PCV correction models.

5.16 Navigation message files

The header portion has been unified (with respect to the format definitions) for all satellite systems. The first record of each data block now contains the code for the satellite system and the satellite number.

G06 1999 09 02 17 51 44 -.839701388031D-03 -.165982783074D-10 .000000000000D+00

Table 17: Example of Navigation File Satellite System and Number Definition Record

Header records with system-dependent contents also contain the system identifier. They are repeated for each system, if applicable.

GPSA	.1676D-07	.2235D-07	.1192D-06	.1192D-06	IONOSPHERIC CORR
GPSB	.1208D+06	.1310D+06	-.1310D+06	-.1966D+06	IONOSPHERIC CORR
GAL	.1234D+05	.2345D+04	-.3456D+03		IONOSPHERIC CORR

Table 18: Example of Navigation File Header IONOSPHERIC CORR Record

6. ADDITIONAL HINTS AND TIPS

6.1 Versions

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

6.2 Leading blanks in CHARACTER fields

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

6.3 Variable-length records

ASCII files usually have variable record lengths, so we recommend to first read each observation record into a blank string long enough to accommodate the largest possible observation record² and decode the data afterwards. In variable length records, empty data fields at the end of a record may be missing, especially in the case of the optional receiver clock offset.

6.4 Blank fields

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

6.5 Order of the header records, order of data records

As the header record descriptors in columns 61-80 are mandatory, the programs reading a RINEX Version 3 header must decode the header records with formats according to the record descriptor, provided the records have been first read into an internal buffer.

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

- The **RINEX VERSION / TYPE** record must be the first record in a file
- The **SYS / # / OBS TYPES** record(s) should precede any **SYS / DCBS APPLIED** and **SYS / SCALE FACTOR** records
- The **# OF SATELLITES** record (if present) should be immediately followed by the corresponding number of **PRN / # OF OBS** records. These records may be handy for documentary purposes. However, since they may only be created after having read the whole raw data file, we define them to be optional
- The **END OF HEADER** of course is the last record in the header

² Record is defined by the satellite system with the largest number of possible observables plus any “pseudo-observables” such as ionosphere etc. The length limitation to 80 characters of RINEX Versions 1 and 2 has been removed.

Data records: Multiple epoch observation data records with identical time tags are not allowed (exception: Event records). Epochs have to appear ordered in time.

6.6 Missing items, duration of the validity of values

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

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

6.7 Unknown / Undefined observation types and header records

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

6.8 Event flag records

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

6.9 Receiver clock offset

A receiver-derived clock offset can optionally be reported in the RINEX observation files. In order to remove uncertainties about whether the data (epoch, pseudorange, phase) have been corrected or not by the reported clock offset, RINEX Versions 2.10 onward requests a clarifying header record: **RCV CLOCK OFFS APPL**. It would then be possible to reconstruct the original observations, if necessary.

6.10 Two-digit years

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

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

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

Full 4-digit year fields are defined in RINEX version 3 files.

6.11 Fit interval (GPS navigation message file)

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

0 = 4 hours

1 = greater than 4 hours.

Together with the IODC values and Table 20-XII (of the ICD) the actual fit interval can be determined. The second value in the last record of each message shall contain the fit interval in hours determined using IODC, fit flag, and Table 20-XII, according to the Interface Document IS-GPS-200H. Note: The QZSS fit interval is not defined the same way as it is in GPS, see Appendix Table A12.

6.12 Satellite health (GPS navigation message file)

The health of the signal components (bits 18 to 22 of word three in subframe one) are included from version 2.10 on using the health value reported in the second field of the sixth navigation message record.

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

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

Table 19: Description of GPS Satellite Health Field

6.13 Transmission time of message (GPS navigation message file)

The transmission time of a message can be shortly before midnight Saturday/Sunday, with the ToE and ToC of the message already in the next week.

As the reported week in the RINEX nav message (**BROADCAST ORBIT -5** record) goes with ToE (this is different from the GPS week in the original satellite message!), the transmission time of message should be reduced by 604800 (i.e., will become negative) to also refer to the same week.

6.14 Antenna references, 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. For more precise applications, an elevation-dependent or elevation and azimuth-dependent phase center variation (PCV) model for the antenna (referring to the agreed-upon ARP) should be used. For special applications it might be useful to generate RINEX files with these corrections already applied. This can be reported by special header records **SYS / PCVS APPLIED** pointing to the file containing the PCV correction models.
- The *orientation* of the antenna: The “zero direction” is usually oriented towards north on fixed stations. Deviations from the north direction can be reported with the azimuth of the zero-direction in an **ANTENNA: ZERODIR AZI** header record. On vehicles, the zero-direction is reported as a unit vector in the body-fixed coordinate system in an **ANTENNA: ZERODIR XYZ** header record. The zero direction of a tilted antenna on a fixed station can be reported as unit vector in the left-handed north/east/up local coordinate system in an **ANTENNA: ZERODIR XYZ** header record.
- The *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.

7. RINEX UNDER ANTISPOOFING (AS)

Some receivers generate code (pseudorange) delay differences between the first and second frequency using cross-correlation techniques when AS is on and may recover the phase observations on L2 in full cycles. Using the C/A code delay on L1 and the observed difference, it is possible to generate a code delay observation for the second frequency. Other receivers recover P code observations by breaking down the Y code into P and W code.

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

8. DEALING WITH DIFFERENT SATELLITE SYSTEMS

8.1 Time system identifier

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

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

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

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

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

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

GLONASS is basically running on UTC (or, more precisely, GLONASS system time linked to UTC(SU)), i.e. the time tags are given in UTC and not GPS time. It is not a continuous time, i.e. it introduces the same leap seconds as UTC. **The reported GLONASS time has the same hours as UTC and not UTC+3 h as the original GLONASS System Time!**

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

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

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

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

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

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

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

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

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

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

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
IRNSS Broadcast		0 – 1023	0 – 1023	0 – 1023	0 – 1023	0 – 1023
GST Broadcast		0 – 1023	1024 – 2047	2048 – 3071	3072 – 4095	0 – 1023
BDS Broadcast and RINEX		0(RINEX Week 1356) – 691	692 – 1715	1716 – 2739	2740 – 3763	3764 – 4787
GPS/QZS/IRN/ GAL RINEX	0 – 1023	1024 – 2047	2048 – 3071	3072 – 4095	4096 – 5119	5120 -6143

Table 20: Relationship between GPS, QZSS, IRN, GST, GAL, BDS and RINEX Week Numbers

The header records **TIME OF FIRST OBS** and (if present) **TIME OF LAST OBS** in pure GPS, GLONASS, Galileo, QZSS or BDS observation files **can** (in mixed GPS/GLONASS/Galileo/QZSS/BDS/IRNSS observation files **must**) contain the time system identifier defining the system that all time tags in the file are referring to:

- **GPS** to identify GPS time
- **GLO** to identify the GLONASS UTC time system
- **GAL** to identify Galileo time

- **QZS** to identify QZSS time
- **BDT** to identify BDS time
- **IRN** to identify IRNSS time

Pure GPS observation files default to **GPS**, pure GLONASS files default to **GLO**, pure Galileo files default to **GAL** and similarly pure BDS observation files default to **BDT** (same for QZSS and IRNSS).

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

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

Table 21: Constellation Time Relationships

Where:

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

Table 22: GPS and BeiDou UTC Leap Second Relationship

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

If there are known non-integer biases between “GPS receiver clock”, “GLONASS receiver clock”, “BDS receiver clock” or “Galileo receiver clock” in the same receiver, they should be applied in the process of RINEX conversion. In this case, the respective code and phase observations have to be corrected also ($c * \text{bias}$ if expressed in meters).

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.

8.2 Pseudorange definition

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

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

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

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

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

Table 23: Constellation Pseudorange Corrections

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

Δt_{LS} is the actual number of leap seconds between GPS/GAL and **GLO** time, as broadcast in the GPS almanac and distributed in Circular T of BIPM.

$\Delta t_{LS_{BDS}}$ is the actual number of leap seconds between BDT and UTC time, as broadcast in the BDT almanac.

8.3 RINEX navigation message files

The header section of the RINEX Version 3.XX navigation message files have been slightly changed compared to the previous Version 2. The format of the header section is identical for all satellite systems: GPS, GLONASS, Galileo, SBAS, QZSS and IRNSS. One exception is that BDS “IONOSPHERIC CORR” message has a few extra fields (See: Appendix Table A5).

The data portion of the navigation message files contains records with floating point numbers. The format is identical for all satellite systems; the number of records per message and the contents, however, are satellite system-dependent. The format of the version 3 data records has been changed slightly; the satellite codes now also contain the satellite system identifier.

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

The time tags of the navigation messages (e.g., time of ephemeris, time of clock) are given in the respective satellite time systems!

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

8.3.1 RINEX navigation message files for GLONASS

The header section and the first data record (epoch, satellite clock information) are equal to the GPS navigation file. 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 corrections of the satellite time to UTC are as follows:

GPS: $T_{utc} = T_{sv} - af_0 - af_1 * (T_{sv} - T_{oc}) - \dots - A_0 - \dots - \Delta t_{LS}$

GLONASS: $T_{utc} = T_{sv} + \tau_N - \gamma_N * (T_{sv} - T_b) + \tau_C$

In order to use the same sign conventions for the GLONASS corrections as in the GPS navigation files, the broadcast GLONASS values are stored as: $-\tau_N$, $+\gamma_N$, $-\tau_C$.

Table 24: GLONASS Navigation File Data, Sign Convention

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

8.3.2 RINEX navigation message files for Galileo

The Galileo Open Service allows access to two navigation message types: F/NAV (Freely Accessible Navigation) and I/NAV (Integrity Navigation). The content of the two messages differs in various items, however, in general it is very similar to the content of the GPS navigation message,

e.g. the orbit parameterization is the same.

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

Some parameters contain the information 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

Example:

0.170000000000D+02 -> $17 = 2^4 + 2^0$ -> Bits 4 and 0 are set, all others are zero

RINEX file encoders should encode one RINEX Galileo navigation message for each I/NAV and F/NAV signal decoded. Therefore if both: I/Nav and F/Nav messages are decoded, then the relevant bit fields must be set in the RINEX message and both should be written in separate messages. The Galileo ICD (2010) Section 5.1.9.2 indicates that some of the contents of the broadcast navigation message may change, yet the issue of data (IOD) may not change. To ensure that all relevant information is available message encoders should monitor the contents of the file and write new navigation messages when the contents have changed.

RINEX file parsers should expect to encounter F/NAV and I/NAV messages with the same IOD in the same file. Additionally, parsers should also expect to encounter more than one F/NAV or I/NAV ephemeris message with the same IOD, as the navigation message Data Validity Status (DVS) and other parameters may change independently of the IOD, yet some other data may be the same, however, the transmission time will be updated (See Note in Galileo ICD (2010) Section 5.1.9.2 Issue of Data).

As mentioned above, 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.

8.3.3 RINEX navigation message files for GEO satellites

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

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

The first data record contains the epoch and satellite clock information; the following records

contain the satellite position, velocity and acceleration and auxiliary information (health, URA and IODN).

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

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

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

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

The *Transmission Time of Message* (**SV / EPOCH / SV CLK** header record) is expressed in GPS seconds of the week. It marks the beginning of the message transmission. It has to refer to the same GPS week as the *Epoch of Ephemerides*. If necessary, the *Transmission Time of Message* may have to be adjusted by - or + 604800 seconds (which would make it lower than zero or larger than 604800, respectively and then further corrected to correspond to the *Epoch of Ephemeris*) so that it is referenced to the GPS week of the *Epoch of Ephemeris*. This is a redefinition of the Version 2.10 *Message frame time*.

Health shall be defined as follows:

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

8.3.4 RINEX navigation message files for BDS

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

The header section and the first data record (epoch, satellite clock information) are equal to the GPS navigation file. The following six records are similar to GPS.

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

8.3.5 RINEX navigation message files for IRNSS

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

The header section and the first data record (epoch, satellite clock information) are equal to the GPS navigation file. See Appendix Tables A18 and A19 for a description and example of each field.

8.4 RINEX observation files for GEO satellites

A separate satellite system identifier has been defined for the Satellite-Based Augmentation System (SBAS) payloads. **S**, is to be used in the **RINEX VERSION / TYPE** header line and in the satellite identifier **snn**, **nn** being the GEO PRN number minus 100.

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

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

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

Issue Of Data Navigation (IODN)

The IODN is defined as the 8 first bits after the message type 9, called *IODN* in RTCA DO229, Annex A and Annex B and called *spare* in Annex C.

The **D-UTC A0, A1, T, W, S, U** record in Version 2.11 has been renamed the **TIME SYSTEM CORR** record in RINEX 3.x.

9. MODIFICATIONS FOR VERSION 3.01, 3.02, 3.03 and 3.04

9.1 Phase Cycle Shifts

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

All phase observations **must** be aligned in RINEX 3.01 and later files and the new **SYS / PHASE SHIFT** header is mandatory. See Appendix Table A2 for the messages definition. If the phase alignment is not known, then the observation data **should not** be published in a

RINEX 3.0x file. In order to facilitate data processing, phase observations stored in RINEX files **must** be consistent across all satellites of a satellite system and across each frequency band. Within a RINEX 3.0x file:

- All phase observations must be aligned to the designated constellation and frequency reference signal as specified in Appendix Table A23, either directly by the receiver or by a correction program or the RINEX conversion program, prior to RINEX file generation. Additionally, all data must be aligned with the appropriate reference signal indicated in Appendix Table A23 even when the receiver or reporting device is not tracking and/or providing data from that reference signal e.g. Galileo L5X phase data must be aligned to L5I.
- Phase corrections must be reported in a new mandatory **SYS / PHASE SHIFT** header record to allow the reconstruction of the original values, if needed. The uncorrected reference signal group of observations are left blank in the **SYS / PHASE SHIFT** records. Appendix Table A23 specifies the reference signal that should be used by each constellation and frequency band. Additionally, Appendix Table A23 indicates the relationship between the phase observations for each frequency's signals.

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

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

Sign of the correction $\Delta\phi$:

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

Table 25: RINEX Phase Alignment Correction Convention

Example (Definition see Appendix Table A2):

```

-----|-----1|0-----|-----2|0-----|-----3|0-----|-----4|0-----|-----5|0-----|-----6|0-----|-----7|0-----|-----8|
G L2S -0.25000 03 G15 G16 G17                                     SYS / PHASE SHIFT

```

Table 26: Example SYS / PHASE SHIFT Record

9.2 Galileo: BOC-Tracking of an MBOC-Modulated Signal

Galileo E1 will be modulated by the so-called MBOC modulation. Obviously it is possible for a receiver to track the signal also in a BOC mode, though leading to different noise characteristics. In order to keep this non-standard tracking mode of a MBOC signal apart, bit 2 of the loss-of-lock indicator LLI (the antispoofing flag not used for Galileo) in the observation data records is used.

Non-standard BOC tracking of an MBOC-modulated signal: Increase the LLI by 4.

Note: This flag is intended for experimental applications and is optional. In future releases of RINEX, this non-standard tracking mode flag may be removed.

Example: Satellite E11, BOC tracking on L1C, LLI = 4:

```

-----|-----1|0-----|-----2|0-----|-----3|0-----|-----4|0-----|-----5|0-----|-----6|0-----|-----7|0-----|-----8|
G   5 C1C L1W L2W C1W S2W                                     SYS / # / OBS TYPES
R   2 C1C L1C                                                 SYS / # / OBS TYPES
E   2 L1C L5I                                                 SYS / # / OBS TYPES
S   2 C1C L1C                                                 SYS / # / OBS TYPES
    18.000                                                    INTERVAL
                                                    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 .32448 .178 7
S20 38137559.506 335849.135 9

```

Table 27: Example of RINEX Coding of Galileo BOC Tracking of an MBOC Signal Record

9.3 BDS Satellite System Code

The satellite system code for BeiDou navigation satellite System (BDS) has been defined as “C”, see Figure 1.

9.4 New Observation Codes for GPS L1C and BDS

New observation codes for GPS L1C and BDS observables have been defined: See Tables 4 and 9.

9.5 Header Records for GLONASS Slot and Frequency Numbers

In order to make available a cross-reference list between the GLONASS slot numbers used in the RINEX files to designate the GLONASS satellites and the allotted frequency numbers, a mandatory observation file header record is assigned. This allows processing of GLONASS files without having to get this information from GLONASS navigation message files or other sources.

Example (Definition See Appendix Table A2):

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

Table 28: Example of a GLONASS Slot- Frequency Records

9.6 GNSS Navigation Message File: Leap Seconds Record

The optional **LEAP SECONDS** record was modified to also include Δt_{LS} (or $\Delta t_{LS_{BDS}}$ for BDS), WN_{LSF} (adjusted to continuous week number) and DN.

9.7 Clarifications in the Galileo Navigation Message File:

Some clarifications in the Galileo **BROADCAST ORBIT - 5** and **BROADCAST ORBIT - 6** records were added (see Table A8).

9.8 Quasi-Zenith Satellite System (QZSS) RINEX Version 3.02

The version number is adjusted to 3.02. Version 3.02 added QZSS: specifications, parameters and definitions to the document. Each QZSS satellite broadcasts signals using two PRN codes. The GPS compatible signals are broadcast using PRN codes in the range of 193-197. In a RINEX observation file the PRN code is: broadcast prn - 192, yielding: J01, J02 etc In a RINEX SBAS file the PRN code is: broadcast prn - 100, yielding: S83, S84 etc.

See Appendix Table A23 to convert each signal's aligned phase observations back to raw satellite phase.

9.9 GLONASS Mandatory Code-Phase Alignment Header Record

Recent analysis has revealed that some GNSS receivers produce biased GLONASS observations. The code-phase bias results in the code and phase observations not being measured at the same time. To remedy this problem, a mandatory GLONASS Code-Phase header bias record is required. Although this header message is mandatory, it can contain zeros if the GLONASS data issued by the receiver is aligned. See the GLONASS CODE/PHASE BIAS (**GLONASS COD/PHS/BIS**) definition in Appendix Table A2. The GLONASS code-phase alignment message contains: L1C, L1P, L2C and L2P corrections. Phase data from GNSS receivers that issue biased data must be corrected by the amount specified in the **GLONASS COD/PHS/BIS** record before it is written in RINEX format.

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

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

where:

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

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

Example (See Appendix Table A2 for details):

```

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

```

Table 29: Example of GLONASS Code Phase Bias Correction Record

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

```

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

```

Table 30: Example of Unknown GLONASS Code Phase Bias Record

9.10 BDS system (Replaces Compass)

Added BDS: naming convention, time system definition, header section description, and parameters throughout the document. Updated: Sections: 8.1, 8.2, 8.3.5, 9.11 and Appendix Table A2, added ephemeris Table A14 and updated Table A23.

9.11 Indian Regional Navigation Satellite System (IRNSS) Version 3.03

The RINEX version number was changed to 3.03. Version 3.03 adds IRNSS, specifications, parameters and definitions to this document.

9.12 Updates for Quasi-Zenith Satellite System (QZSS), BeiDou and GLONASS (CDMA) RINEX Version 3.04

Added new signal codes to: Table #5, for GLONASS, Table #8 for QZSS and Table #9 for BeiDou

The phase alignment of L1C has changed in QZSS Block II satellites to maintain compatibility

with GPS Block III. See Appendix Table A23 and related notes to convert each signal's aligned phase observations back to raw satellite phase.

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

Table 31: QZSS PRN to RINEX Satellite Identifier

In RINEX 3.04 all QZSS signals are identified the using the standard PRN numbering conventions i.e. Jxx and the Sxx identifier has been dropped. All QZSS signals are identified in RINEX 3.04 as J01-J09 as shown in Table 31.

QZSS Block I satellites have replaced the L1-SAIF signal with the L1S signal. For QZSS Block I observations prior to the introduction of the L1S signal, the observation codes "1Z" refer to tracking of the "L1-SAIF" signal. Similarly, the "6S", "6L", "6X" observation codes refer to tracking of the LEX data channel, LEX pilot channel, and combined LEX pilot+data tracking prior to the introduction of the L61 signal on QZSS Block I.

QZSS Block II satellites broadcast the L1S signal. The L1S signal broadcasts the Sub-Meter-Level Augmentation Service (SLAS) correction data using PRN 183-191. In a RINEX observation file the signal ID of L1S is: broadcast prn-182, yielding J01, J02....J09. QZSS Block II satellites also broadcast the L5S signal. The L5S signals broadcasts the Positioning Technology Verification Service (PTVS) correction data using PRN, 196, 200, 197. PTVS

broadcasts the experimental Dual Frequency Multi-Constellation (DFMC) signal. In a RINEX observation file the signal ID of L5S is PRN 196, 200, 197 and is assigned to J02, J03 and J07 respectively.

The second data channel L6E was introduced on the L6 signal of QZSS Block II. In a RINEX observation file the RINEX signal ID of L6E is: broadcast prn-202, yielding J02, J03...J09.

Updated Tables 5, 8 and 9 and A23 signals codes and information to support new GLONASS CDMA, QZSS and BeiDou 3 signals.

Updated Appendix table A5 TIME SYSTEM CORR message description.

10 References

- Evans, A. (1989): "Summary of the Workshop on GPS Exchange Formats." Proceedings of the Fifth International Geodetic Symposium on Satellite Systems, pp. 917ff, Las Cruces.
- Gurtner, W., G. Mader, D. Arthur (1989): "A Common Exchange Format for GPS Data." CSTG GPS Bulletin Vol.2 No.3, May/June 1989, National Geodetic Survey, Rockville.
- Gurtner, W., G. Mader (1990a): "The RINEX Format: Current Status, Future Developments." Proceedings of the Second International Symposium of Precise Positioning with the Global Positioning system, pp. 977ff, Ottawa.
- Gurtner, W., G. Mader (1990b): "Receiver Independent Exchange Format Version 2." CSTG GPS Bulletin Vol.3 No.3, Sept/Oct 1990, National Geodetic Survey, Rockville.
- Gurtner, W. (1994): "RINEX: The Receiver-Independent Exchange Format." GPS World, Volume 5, Number 7, July 1994.
- Gurtner, W. (2002): "RINEX: The Receiver Independent Exchange Format Version 2.10". <ftp://igs.org/pub/data/format/rinex210.txt>
- Gurtner, W., L. Estey (2002),: "RINEX Version 2.20 Modifications to Accommodate Low Earth Orbiter Data". ftp://ftp.aiub.unibe.ch/rinex/rnx_leo.txt
- Gurtner, W., L. Estey (2005): "RINEX: The Receiver Independent Exchange Format Version 2.11". <ftp://igs.org/pub/data/format/rinex211.txt>
- Gurtner, W., L. Estey (2007): "RINEX: The Receiver Independent Exchange Format Version 3.00". <ftp://igs.org/pub/data/format/rinex300.pdf>
- Hatanaka, Y (2008): " A Compression Format and Tools for GNSS Observation Data". Bulletin of the Geographical Survey Institute, Vol. 55, pp 21-30, Tsukuba, March 2008. <http://www.gsi.go.jp/ENGLISH/Bulletin55.html>
- Ray, J., W. Gurtner (2010): "RINEX Extensions to Handle Clock Information". ftp://igs.org/pub/data/format/rinex_clock302.txt.
- Ray, J. (2005): "Final update for P1-C1 bias values & cc2noncc". IGSMail 5260
- Rothacher, M., R. Schmid (2010): "ANTEX: The Antenna Exchange Format Version 1.4". <ftp://igs.org/pub/station/general/antex14.txt>.
- Schaer, S., W. Gurtner, J. Feltens (1998): "IONEX: The Ionosphere Map Exchange Format Version 1". <ftp://igs.org/pub/data/format/ionex1.pdf>
- Suard, N., W. Gurtner, L. Estey (2004): "Proposal for a new RINEX-type Exchange File for GEO SBAS Broadcast Data". ftp://igs.org/pub/data/format/geo_sbas.txt

Document: RTCA DO 229, Appendix A

Document: Global Positioning Systems Directorate, Systems Engineering and Integration Interface Specification IS-GPS-200H, Navstar GPS Space Segment/Navigation User Interfaces, Sept. 24, 2013

Document: GLObal NAVigation Satellite System (GLONASS), Interface Control Document, (Edition 5.1), 2008.

Document: Global Navigation Satellite System GLONASS, Interface Control Document, General Description of Code Division Multiple Access Signal System, Edition 1.0, 2016.

Document: Global Navigation Satellite System GLONASS, Interface Control Document, Code Division Multiple Access, Open Service Navigation Signal in L1 frequency band, Edition 1.0, 2016.

Document: Global Navigation Satellite System GLONASS, Interface Control Document, Code Division Multiple Access, Open Service Navigation Signal in L2 frequency band, Edition 1.0, 2016.

Document: Global Navigation Satellite System GLONASS, Interface Control Document, Code Division Multiple Access, Open Service Navigation Signal in L3 frequency band, Edition 1.0, 2016.

Document: European GNSS (Galileo) Open Service, Signal In Space, Interface Control Document, Issue 1.3, December, 2016. : (https://www.gsc-europa.eu/system/files/galileo_documents/Galileo-OS-SIS-ICD.pdf)

Document: Quasi-Zenith Satellite System, Interface Specification, Satellite Positioning, Navigation and Timing Service (IS-QZSS-PNT-002), Cabinet Office, January 29, 2018

Document: Quasi-Zenith Satellite System, Interface Specification, Sub-meter Level Augmentation Service (IS-QZSS-L1S-002), Cabinet Office, April 13, 2018

Document: Quasi-Zenith Satellite System, Interface Specification, Centimeter Level Augmentation Service (IS-QZSS-L6-001) Draft, Cabinet Office, August 31, 2018

Document: Quasi-Zenith Satellite System, Interface Specification, Positioning Technology Verification Service (IS-QZSS-TV), Draft Edition, Cabinet Office, July 12, 2016

Document: Quasi-Zenith Satellite System, Interface Specification, Positioning Technology Verification Service (IS-QZSS-TV-001), Cabinet Office, April 13, 2018

Document: BeiDou Navigation Satellite, System, Signal In Space, Interface Control Document, Open Service Signal, (Version2.0), China Satellite Navigation Office December 2013

Document: BeiDou Navigation Satellite, System, Signal In Space, Interface Control Document, Open Service Signal B1C, (Version 1.0), China Satellite Navigation Office, December 2017

Document: BeiDou Navigation Satellite, System, Signal in Space, Interface Control Document, Open Service Signal B2a, (Version 1.0), China Satellite Navigation Office, December 2017

Document: BeiDou Navigation Satellite, System, Signal in Space, Interface Control Document, Open Service Signal B2I, (Version 1.0), China Satellite Navigation Office. February 2017

Document: RTCM Standard 10403.2, Differential GNSS (Global Navigation Satellite Systems) Services – Version 3, November 7, 2013.

Document: Indian Regional Navigation Satellite System Signal in Space ICD for Standard Positioning Service, Version 1.0, June 2014 (Indian Space Research Organization, Bangalore, 2014)

APPENDIX: RINEX FORMAT DEFINITIONS AND EXAMPLES

A 1 RINEX File name description

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

Table A1 RINEX File name description				
Field	Field Description	Example	Required	Comment/Example
<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: GO - GPS Obs., RO - GLONASS Obs., EO - Galileo Obs. JO - QZSS Obs. CO - BDS Obs. IO – IRNSS Obs. SO - SBAS Obs. MO Mixed Obs. GN - Nav. GPS, RN- GLONASS Nav., EN- Galileo Nav., JN- QZSS Nav., CN- BDS Nav. IN – IRNSS Nav. SN- SBAS Nav. MN- Nav. All GNSS Constellations) MM-Meteorological Observation Etc
<FORMAT>	FFF FFF – File format (3 characters)	rnx	Yes	Three character indicating the data format : RINEX - rnx, Hatanaka Compressed RINEX – crx, ETC
<COMPRESSION>	(2-3 Characters)	gz	No	gz
Sub Total	34 or 35			Fields
Separators	(7 characters –Obs. File) (6 characters –Eph. File)			_ underscore between all fields and “.” Between data type and file format and the compression method
Total	41-42(Obs. File) 37-38 (Eph. File)			Mandatory IGS RINEX obs. Characters

Filename Details and Examples:

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

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

<DATA SOURCE>: With real-time data streaming RINEX files for the same station can be created at many locations. If the RINEX file is derived from data collected at the receiver (official file) then the source is specified as R. On the other hand if the RINEX file is derived from a real-time data stream then the data source is marked as S to indicate Streamed data source. If the data source is unknown the source is marked as U.

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

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

GNSS observation file name - file period examples:

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

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

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

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

GNSS navigation file name - file period examples:

ALGO00CAN_R_20121600000_15M_GN.rnx.gz // 15 minute GPS only

ALGO00CAN_R_20121600000_01H_GN.rnx.gz // 1 hour GPS only

ALGO00CAN_R_20121600000_01D_MN.rnx.gz // 1 day mixed

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

ALGO00CAN_R_20121601000_01D_01C_GO.rnx.gz //100 Hz data rate

ALGO00CAN_R_20121601000_01D_05Z_RO.rnx.gz //5 Hz data rate
ALGO00CAN_R_20121601000_01D_01S_EO.rnx.gz //1 second data rate
ALGO00CAN_R_20121601000_01D_05M_JO.rnx.gz //5 minute data rate
ALGO00CAN_R_20121601000_01D_01H_CO.rnx.gz //1 hour data rate
ALGO00CAN_R_20121601000_01D_01D_SO.rnx.gz //1 day data rate
ALGO00CAN_R_20121601000_01D_00U_MO.rnx.gz //Unspecified

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

< **DATA TYPE/ FORMAT**>: The data type describes the content of the file. The first character indicates constellation and the second indicates whether the files contains observations or navigation data. The next three characters indicate the data file format. GNSS observation filename - format/data type examples:

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

GNSS navigation filename examples:

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

Meteorological filename example:

ALGO00CAN_R_20121600000_01D_30M_MM.rnx.gz //RINEX Met.

<COMPRESSION>:

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

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

A 2 GNSS Observation Data File -Header Section Description

TABLE A2		
GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMA T
RINEX VERSION / TYPE	<ul style="list-style-type: none"> – Format version : 3.04 – File type: O for Observation Data – Satellite System: <ul style="list-style-type: none"> G: GPS R: GLONASS E: Galileo J: QZSS C: BDS I: IRNSS S: SBAS payload M: Mixed 	F9.2, 11X, A1,19X, A1,19X
PGM / RUN BY / DATE	<ul style="list-style-type: none"> – Name of program creating current file – Name of agency creating current file – Date and time of file creation Format: yyymmdd hhmmss zone zone: 3-4 char. code for time zone. 'UTC ' recommended! 'LCL ' if local time with unknown local time system code	A20, A20, A20
* COMMENT	– Comment line(s)	A60
MARKER NAME	– Name of antenna marker	A60
* MARKER NUMBER	– Number of antenna marker	A20
MARKER TYPE	<ul style="list-style-type: none"> – Type of the marker: <ul style="list-style-type: none"> 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 	A20,40X

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	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.	
OBSERVER / AGENCY	– Name of observer / agency	A20,A40
REC # / TYPE / VERS	– Receiver number, type, and version (Version: e.g. Internal Software Version)	3A20
ANT # / TYPE	– Antenna number and type	2A20
APPROX POSITION XYZ	– Geocentric approximate marker position (Units: Meters, System: ITRS recommended) Optional for moving platforms	3F14.4
ANTENNA: DELTA H/E/N	– Antenna height: Height of the antenna reference point (ARP) above the marker – Horizontal eccentricity of ARP relative to the marker (east/north) All units in meters	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	3F14.4
*ANTENNA:PHASECENTER	Average phase center position with respect to antenna reference point (m) – 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

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
* 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.	3F14.4
SYS / # / OBS TYPES	– Satellite system code (G/R/E/J/C/I/S) – Number of different observation types for the specified satellite system Observation descriptors: Type, Band, Attribute – 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 Version 3.XX: Type: C = Code / Pseudorange L = Phase D = Doppler S = Raw signal strength(carrier to noise ratio) I = Ionosphere phase delay X = Receiver channel numbers Band: 1 = L1 (GPS, QZSS, SBAS,BDS) G1 (GLO) E1 (GAL) B1 (BDS) 2 = L2 (GPS, QZSS) G2 (GLO) B1-2 (BDS) 4 = G1a (GLO) 5 = L5 (GPS, QZSS, SBAS, IRNSS) E5a (GAL) B2/B2a (BDS) 6 = E6 (GAL) L6 (QZSS) B3 (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

	<p>9 = S (IRNSS)</p> <p>0 for type X (all)</p> <p>Attribute:</p> <p>A = A channel (GAL, IRNSS, GLO)</p> <p>B = B channel (GAL, IRNSS, GLO)</p> <p>C = C channel (GAL, IRNSS)</p> <p>C code-based (SBAS, GPS, GLO, QZSS)</p> <p>D = Semi-codeless (GPS)</p> <p>Data Channel (BDS)</p> <p>I = I channel (GPS, GAL, QZSS, BDS)</p> <p>L = L channel (L2C GPS, QZSS)</p> <p>P channel (GPS, QZSS)</p> <p>M = M code-based (GPS)</p> <p>N = Codeless (GPS)</p> <p>P = P code-based (GPS, GLO)</p> <p>Pilot Channel (BDS)</p> <p>Q = Q channel (GPS, GAL, QZSS, BDS)</p> <p>S = D channel (GPS, QZSS)</p> <p>M channel (L2C GPS, QZSS)</p> <p>W = Based on Z-tracking (GPS)(see text)</p> <p>X = B+C channels (GAL, IRNSS)</p> <p>I+Q channels (GPS, GAL, QZSS, BDS)</p> <p>M+L channels (GPS, QZSS)</p> <p>D+P channels (GPS, QZSS, BDS)</p> <p>Y = Y code-based (GPS)</p> <p>Z = A+B+C channels (GAL)</p> <p>D+P channels (BDS)</p> <p>All characters in uppercase only!</p> <p>Units :</p> <p>Phase : full cycles</p> <p>Pseudorange : meters</p> <p>Doppler : Hz</p> <p>SNR etc. : receiver-dependent</p> <p>Ionosphere : full cycles</p> <p>Channel # : See text</p> <p>Sign definition: See text.</p> <p>The sequence of the observations in the observation records has to correspond to the sequence of the types in this record of the respective satellite system.</p>	
--	--	--

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	Note: In RINEX 3.02, 3.03 and 3.04 all fields (Type, Band and Attribute) must be defined. Only known tracking modes are allowed.	
* 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) – Time system: GPS (=GPS time system) GLO (=UTC time system) GAL (=Galileo time system) QZS (= QZSS time system) BDT (= BDS time system) IRN (= IRNSS time system) Compulsory in mixed GNSS files Defaults: 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 IRNSS files	5I6,F13.7, 5X,A3
* TIME OF LAST OBS	– Time of last observation record (4-digit-year, month, day, hour, min, sec) – Time system: Same value as in TIME OF FIRST OBS record	5I6,F13.7, 5X,A3
* RCV CLOCK OFFS APPL	– Epoch, code, and phase are corrected by applying the real-time-derived receiver clock offset: 1=yes, 0=no; default: 0=no Record required if clock offsets are reported in the EPOCH/SAT records	I6
* SYS / DCBS APPLIED	– Satellite system (G/R/E/J/C/I/S) – Program name used to apply differential code bias corrections – Source of corrections (URL) Repeat for each satellite system. No corrections applied: Blank fields or record not present.	A1, 1X,A17, 1X,A40
* SYS / PCVS APPLIED	– Satellite system (G/R/E/J/C/I/S) – Program name used to apply phase center	A1, 1X,A17,

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	variation corrections – Source of corrections (URL) Repeat for each satellite system. No corrections applied: Blank fields or record not present.	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.	A1, 1X,I4, 2X,I2, 12(1X,A3) 10X, 12(1X,A3)
SYS / PHASE SHIFT	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 Band Attribute – Correction applied (cycles) – Number of satellites involved 0 or blank: All satellites of system – List of satellites – Use continuation line(s) for more than 10 satellites. Repeat the record for all affected codes. See chapter 9.1 for more details!	A1,1X, A3,1X, F8.5 2X,I2.2, 10(1X,A3) 18X, 10(1X,A3)
GLONASS SLOT / FRQ #	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	I3,1X, 8(A1,I2.2, 1X,I2,1X) 4X,8(A1, I2.2,1X,I2, 1X)
GLONASS COD/PHS/BIS	– GLONASS Phase bias correction used to align	4(X1,A3,

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	code and phase observations. <ul style="list-style-type: none"> GLONASS signal identifier : C1C and Code Phase bias correction (metres) GLONASS signal identifier : C1P and Code Phase bias correction (metres) GLONASS signal identifier : C2C and Code Phase bias correction (metres) GLONASS signal identifier : C2P and Code Phase bias correction (metres) Note: If the GLONASS code phase bias values are unknown then all fields in the record are left blank (see example in Section 9.9) and only the record header is defined.	X1,F8.3)
* LEAP SECONDS	<ul style="list-style-type: none"> Current Number of leap seconds Future or past leap seconds $\Delta t_{LSF}(BNK)$, i.e. future leap second if the week and day number are in the future. Respective week number WN_{LSF} (continuous number) (BNK). For GPS, GAL, QZS and IRN, weeks since 6-Jan-1980. When BDS only file leap seconds specified, weeks since 1-Jan-2006. Respective day number DN (0-6) BeiDou and (1-7) for GPS and others constellations, (BNK). The day number is the GPS or BeiDou day before the leap second (See Note 1 below). In the case of the Tuesday, June 30/2015 (GPS Week 1851, DN 3) the UTC leap second actually occurred 16 seconds into the next GPS day. Time system identifier: only GPS and BDS are valid identifiers. Blank defaults to GPS see Notes section below. Notes: 1. GPS, GAL, QZS and IRN time systems are aligned and are equivalent with respect to leap seconds (Leap seconds since 6-Jan-1980). See the GPS almanac, and DN reference IS-GPS-200H 20.3.3.5.2.4. 2. For BDS only observation files, the Number of leap seconds since 1-Jan-2006 as transmitted by the BDS almanac Δt_{LS} (see BDS-SIS-ICD-2.0 5.2.4.17)	I6, I6, I6, I6 A3
* # OF SATELLITES	<ul style="list-style-type: none"> Number of satellites, for which observations are stored in the file 	I6
* PRN / # OF OBS	<ul style="list-style-type: none"> Satellite numbers, number of observations for 	3X,

TABLE A2 GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION		
	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. This record is (these records are) repeated for each satellite present in the data file.	A1,I2.2, 9I6 6X,9I6
END OF HEADER	Last record in the header section.	60X

Records marked with * are optional

A 3 GNSS Observation Data File -Data Record Description

TABLE A3 GNSS OBSERVATION DATA FILE – DATA RECORD DESCRIPTION	
DESCRIPTION	FORMAT
<p>EPOCH record</p> <ul style="list-style-type: none"> – Record identifier : > Epoch – year (4 digits): – month, day, hour, min (two digits) – sec – Epoch flag, 0: OK 1: power failure between previous and current epoch >1: Special event – Number of satellites observed in current epoch – (reserved) – Receiver clock offset (seconds, optional) 	<p>A1,</p> <p>1X,I4, 4(1X,I2.2), F11.7, 2X,I1,</p> <p>I3, 6X, F15.12</p>
<p>Epoch flag = 0 or 1: OBSERVATION records follow</p> <ul style="list-style-type: none"> – Satellite number – m fields of observation data (in the same sequence as given in the respective SYS / # / OBS TYPES record), each containing the specified observations for example: pseudorange, phase, LLI, Doppler and SNR. <p>This record is repeated for each satellite having been observed in the current epoch. The record length is given by the number of observation types for this satellite.</p> <p>Observations: For definition, see text.</p> <p>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.</p> <p>Loss of lock indicator (LLI).</p> <p>0 or blank: OK or not known</p> <p>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.</p> <p>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.</p> <p>Bit 2 set: Galileo BOC-tracking of an MBOC-modulated signal (may suffer from increased noise).</p>	<p>A1,I2.2, m(F14.3, I1, I1)</p>

TABLE A3 GNSS OBSERVATION DATA FILE – DATA RECORD DESCRIPTION	
<p>Signal Strength Indicator (SSI) projected into interval 1-9:</p> <p>1: minimum possible signal strength</p> <p>5: average/good S/N ratio</p> <p>9: maximum possible signal strength</p> <p>0 or blank: not known, don't care</p> <p>Standardization for S/N values given in dBHz: See text.</p> <p>Notes:</p> <ol style="list-style-type: none"> 1. Loss of Lock Indicator (LLI) should only be associated with the phase observation. 2. Signal Strength Indicator (SSI) should be deprecated and replaced by a defined SNR field for each signal. However if this is not possible/practical then SSI should be specified for each phase signal type for example. GPS: L1C, L1W, L2W, L2X and L5X. 3. If only the pseudorange measurements are observed then the SSI should be associated with the code measurements. 	
<p>Epoch flag 2-5: EVENT: <i>Special records</i> may follow</p> <ul style="list-style-type: none"> – Epoch flag <ul style="list-style-type: none"> • 2: start moving antenna • 3: new site occupation (end of kinematic data) (at least MARKER NAME record follows) • 4: header information follows • 5: external event (epoch is significant, same time frame as observation time tags) – "Number of satellites" contains number of special records to follow. 0 if no special records follow. <p>Maximum number of records: 999</p> <p>For events without significant epoch the epoch fields in the EPOCH RECORD can be left blank</p>	<p>[2X,I1]</p> <p>[I3]</p>
<p>Epoch flag = 6: EVENT: <i>Cycle slip records</i> follow</p> <ul style="list-style-type: none"> – Epoch flag <ul style="list-style-type: none"> • 6: cycle slip records follow to optionally report detected and repaired cycle slips (same format as OBSERVATIONS records; <ul style="list-style-type: none"> • slip instead of observation; • LLI and signal strength blank or zero) 	[2X,I1]

A 4 GNSS Observation Data File – Example #1

TABLE A4 GNSS OBSERVATION DATA FILE - EXAMPLE #1									
3.04	OBSERVATION DATA	M							RINEX VERSION / TYPE
G = GPS	R = GLONASS	E = GALILEO	S = GEO	M = MIXED					COMMENT
XXRINEXO V9.9	AIUB			20060324 144333	UTC				PGM / RUN BY / DATE
EXAMPLE OF A MIXED RINEX FILE VERSION 3.04									COMMENT
The file contains L1 pseudorange and phase data of the									COMMENT
geostationary AOR-E satellite (PRN 120 = S20)									COMMENT
A 9080									MARKER NAME
9080.1.34									MARKER NUMBER
BILL SMITH	ABC INSTITUTE								OBSERVER / AGENCY
X1234A123	GEODETIC			1.3.1					REC # / TYPE / VERS
G1234	ROVER								ANT # / TYPE
4375274.	587466.	4589095.							APPROX POSITION XYZ
0	.9030	.0000	.0000						ANTENNA: DELTA H/E/N
G 5 C1C L1W L2W C1W S2W									RCV CLOCK OFFS APPL
R 2 C1C L1C									SYS / # / OBS TYPES
E 2 L1B L5I									SYS / # / OBS TYPES
S 2 C1C L1C									SYS / # / OBS TYPES
18.000									INTERVAL
G APPL_DCB	xyz.uvw.abc/pub/dcb_gps.dat								SYS / DCBS APPLIED
DBHZ									SIGNAL STRENGTH UNIT
2006 03 24 13 10 36.0000000	GPS								TIME OF FIRST OBS
18 R01 1 R02 2 R03 3 R04 4 R05 5 R06 -6 R07 -5 R08 -4									GLONASS SLOT / FRQ #
R09 -3 R10 -2 R11 -1 R12 0 R13 1 R14 2 R15 3 R16 4									GLONASS SLOT / FRQ #
R17 5 R18 -5									GLONASS SLOT / FRQ #
G L1C									SYS / PHASE SHIFT
G L1W 0.00000									SYS / PHASE SHIFT
G L2W									SYS / PHASE SHIFT
R L1C									SYS / PHASE SHIFT
E L1B									SYS / PHASE SHIFT
E L5I									SYS / PHASE SHIFT
S L1C									SYS / PHASE SHIFT
C1C -10.000 C1P -10.123 C2C -10.432 C2P -10.634									GLONASS COD/PHS/BIS
									END OF HEADER
> 2006 03 24 13 10 36.0000000 0 5 -0.123456789012									
G06 23629347.915	.300 8								24.158
G09 20891534.648	-.120 9								38.123
G12 20607600.189	-.430 9								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								25.234
G09 20886075.667	-28688.027 9								42.231
G12 20611072.689	18247.789 9								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|

```

A 4 GNSS Observation Data File – Example #2

TABLE A4																								
GNSS OBSERVATION DATA FILE - EXAMPLE #2																								
3.04				OBSERVATION DATA												M				RINEX VERSION / TYPE				
sbf2rin-9.3.3				20140511 000610 LCL												PGM / RUN BY / DATE								
faal																MARKER NAME								
92201M012																MARKER NUMBER								
Unknown				Unknown												OBSERVER / AGENCY								
3001320				SEPT POLARX4 2.5.1p1												REC # / TYPE / VERS								
725235				LEIAR25.R4 NONE												ANT # / TYPE								
-5246415.0000				-3077260.0000 -1913842.0000												APPROX POSITION XYZ								
0.1262				0.0000 0.0000												ANTENNA: DELTA H/E/N								
G	18	C1C	L1C	D1C	S1C	C1W	S1W	C2W	L2W	D2W	S2W	C2L	L2L	D2L	SYS / # / OBS TYPES									
		S2L	C5Q	L5Q	D5Q	S5Q	SYS / # / OBS TYPES																	
E	16	C1C	L1C	D1C	S1C	C5Q	L5Q	D5Q	S5Q	C7Q	L7Q	D7Q	S7Q	C8Q	SYS / # / OBS TYPES									
		L8Q	D8Q	S8Q	SYS / # / OBS TYPES																			
S	4	C1C	L1C	D1C	S1C	SYS / # / OBS TYPES																		
R	12	C1C	L1C	D1C	S1C	C2P	L2P	D2P	S2P	C2C	L2C	D2C	S2C	SYS / # / OBS TYPES										
C	8	C2I	L2I	D2I	S2I	C7I	L7I	D7I	S7I	SYS / # / OBS TYPES														
J	12	C1C	L1C	D1C	S1C	C2L	L2L	D2L	S2L	C5Q	L5Q	D5Q	S5Q	SYS / # / OBS TYPES										
G	L1C														SYS / PHASE SHIFT									
G	L2W														SYS / PHASE SHIFT									
G	L2L	0.00000														SYS / PHASE SHIFT								
G	L5Q	0.00000														SYS / PHASE SHIFT								
E	L1C	0.00000														SYS / PHASE SHIFT								
E	L5Q	0.00000														SYS / PHASE SHIFT								
E	L7Q	0.00000														SYS / PHASE SHIFT								
E	L8Q	0.00000														SYS / PHASE SHIFT								
S	L1C														SYS / PHASE SHIFT									
R	L1C														SYS / PHASE SHIFT									
R	L2P	0.00000														SYS / PHASE SHIFT								
R	L2C														SYS / PHASE SHIFT									
C	L2I														SYS / PHASE SHIFT									
C	L7I														SYS / PHASE SHIFT									
J	L1C														SYS / PHASE SHIFT									
J	L2L	0.00000														SYS / PHASE SHIFT								
J	L5Q	0.00000														SYS / PHASE SHIFT								
30.000																INTERVAL								
2014 5 10 0 0 0.0000000 GPS																TIME OF FIRST OBS								
2014 5 10 23 59 30.0000000 GPS																TIME OF LAST OBS								
72																# OF SATELLITES								
C1C 0.000 C2C 0.000 C2P 0.000																GLONASS COD/PHS/BIS								
DBHZ																SIGNAL STRENGTH UNIT								
24 R01 1 R02 -4 R03 5 R04 6 R05 1 R06 -4 R07 5 R08 6																GLONASS SLOT / FRQ #								
R09 -2 R10 -7 R11 0 R12 -1 R13 -2 R14 -7 R15 0 R16 -1																GLONASS SLOT / FRQ #								
R17 4 R18 -3 R19 3 R20 2 R21 4 R22 -3 R23 3 R24 2																GLONASS SLOT / FRQ #								
																END OF HEADER								
> 2014 05 10 00 00 0.0000000 0 28																								
END OF FILE																COMMENT								
----				----												----								

A 4 GNSS Observation Data File – Example #3

TABLE A4											
GNSS OBSERVATION DATA FILE - EXAMPLE #3											

A 5 GNSS Navigation Message File – Header Section Description

[illegible]

TABLE A5 GNSS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	<p>A=BDT 00h-01h; B=BDT 01h-02h; ... X= BDT 23h-24h.</p> <p>This field is mandatory for BDS and optional for the other constellations, (BNK).</p> <p>– SV ID, identify which satellite provided the ionospheric parameters. This field is mandatory for BDS and optional for the other constellations (BNK).</p> <p>Note 1: Multiple IONOSPHERIC CORR message can be written in the header.</p> <p>Note 2: It is recommended that BDS ionospheric broadcast model parameters from BDS GEO satellites, be given the most priority. Then the parameters from BDS IGSO satellites should be given secondary priority and then tertiary priority is given to BDS MEO satellite ionospheric correction parameters.</p>	1X,I2
* TIME SYSTEM CORR	<p>Difference between GNSS system time and UTC or other time systems</p> <p>– Type:</p> <p>GPUT = GPS - UTC (a0, a1) GLUT = GLO - UTC (a0= -TauC, a1=zero) GAUT = GAL - UTC (a0, a1) BDUT =BDS - UTC (a0=A_{0UTC}, a1=A_{1UTC}) QZUT = QZS - UTC (a0, a1) IRUT = IRN - UTC (a0=A_{0UTC}, a1=A_{1UTC}) SBUT = SBAS - UTC (a0, a1)</p> <p>GLGP = GLO - GPS (a0=TauGPS, a1=zero) GAGP = GAL – GPS (See **Note Below) (a0 = A_{0G}, a1 = A_{1G} for GAL INAV/FNAV; a0 = -A_{0GGTO}, a1 = -A_{1GGTO} for GPS CNAV) QZGP = QZS - GPS (a0, a1) IRGP =IRN - GPS (a0=A₀, a1=A₁)</p> <p>– a0,a1 coefficients of linear polynomial</p>	<p>A4,1X,</p> <p>D17.10,</p>

TABLE A5 GNSS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	$\Delta t = a_0 + a_1 \cdot (t - t_{\text{ref}})$ for fractional part (excluding leap seconds) of time system difference (a_0 sec, a_1 sec/sec) – T Reference time for polynomial (Seconds into GPS/GAL/BDS/QZS/IRN/SBAS week) – W Reference week number (GPS/GAL/QZS/IRN/SBAS week, continuous number from 6-Jan-1980), T and W zero for GLONASS. BDS week, continuous from: 1-Jan-2006 – S Source System and number Snn of GNSS satellite broadcasting the time system difference or SBAS satellite broadcasting the MT12. Use EGNOS , WAAS , or MSAS for SBAS time differences from MT17. – U UTC Identifier (0 if unknown) 1=UTC(NIST), 2=UTC(USNO), 3=UTC(SU), 4=UTC(BIPM), 5=UTC(Europe Lab), 6=UTC(CRL), 7=UTC(NTSC) (BDS), >7 = not assigned yet S and U for SBAS only. **Note: RINEX 3.04 and 3:03 provides the same sign and value for the Galileo minus GPS time offset but the GPGA label is replaced by GAGP in RINEX 3.04.	D16.9, 1XI6, 1XI4, 1X,A5,1X I2,1X
* LEAP SECONDS	– Current Number of leap seconds – Future or past leap seconds Δt_{LSF} (BNK), i.e. future leap second if the week and day number are in the future. – Respective week number WN_LSF (continuous number) (BNK). For GPS, GAL, QZS and IRN, weeks since 6-Jan-1980. When BDS only file leap seconds specified, weeks since 1-Jan-2006. – Respective day number DN (0-6) BeiDou and (1-7) for GPS and others constellations, (BNK). The day number is the GPS or BeiDou day before the leap second (See Note 1 below). In the case of the Tuesday, June 30/2015 (GPS Week 1851, DN 3) the UTC leap second actually occurred 16 seconds into the next GPS	I6, I6, I6, I6

TABLE A5		
GNSS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	<p>day.</p> <p>– Time system identifier: only GPS and BDS are valid identifiers. Blank defaults to GPS, see Notes section below.</p> <p>Notes:</p> <ol style="list-style-type: none"> 1. GPS, GAL, QZS and IRN time systems are aligned and are equivalent with respect to leap seconds (Leap seconds since 6-Jan-1980). See the GPS almanac and DN reference IS-GPS-200H 20.3.3.5.2.4. 2. For BDS only navigation files, the Number of leap seconds since 1-Jan-2006 as transmitted by the BDS almanac Δt_{LS} (see BDS-SIS-ICD-2.0 5.2.4.17) 	A3
END OF HEADER		

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

A 6 GNSS Navigation Message File – GPS Data Record Description

TABLE A6 GNSS NAVIGATION MESSAGE FILE – GPS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
<i>SV / EPOCH / SV CLK</i>	<ul style="list-style-type: none"> - Satellite system (G), sat number (PRN) - Epoch: Toc - Time of Clock (GPS) year (4 digits) - month, day, hour, minute, second - SV clock bias (seconds) - SV clock drift (sec/sec) - SV clock drift rate (sec/sec2) 	A1,I2.2, 1X,I4, 5(1X,I2.2), 3D19.12 *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - IODE Issue of Data, Ephemeris - Crs (meters) - Delta n (radians/sec) - M0 (radians) 	4X,4D19.12 ***)
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Cuc (radians) - e Eccentricity - Cus (radians) - sqrt(A) (sqrt(m)) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Toe Time of Ephemeris (sec of GPS week) - Cic (radians) - OMEGA0 (radians) - Cis (radians) 	4X,4D19.12
BROADCAST ORBIT - 4	<ul style="list-style-type: none"> - i0 (radians) - Crc (meters) - omega (radians) - OMEGA DOT (radians/sec) 	4X,4D19.12
BROADCAST ORBIT - 5	<ul style="list-style-type: none"> - IDOT (radians/sec) - Codes on L2 channel - GPS Week # (to go with TOE) Continuous number, not mod(1024)! - L2 P data flag 	4X,4D19.12
BROADCAST ORBIT - 6	<ul style="list-style-type: none"> - SV accuracy (meters) See GPS ICD 200H Section 20.3.3.3.1.3 use specified equations to define nominal values, N = 0-6: use $2^{(1+N/2)}$ (round to one decimal place i.e. 2.8, 5.7 and 11.3) , N= 7-15:use $2^{(N-2)}$, 8192 specifies use at own risk - SV health (bits 17-22 w 3 sf 1) - TGD (seconds) - IODC Issue of Data, Clock 	4X,4D19.12
BROADCAST ORBIT - 7	<ul style="list-style-type: none"> - Transmission time of message **) (sec of GPS week, derived e.g.from Z-count in Hand Over Word (HOW)) - Fit Interval in hours see section 6.11. (BNK). 	4X,4D19.12

TABLE A6		
GNSS NAVIGATION MESSAGE FILE – GPS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
	- Spare	
	- Spare	

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

) Adjust the *Transmission time of message* by + or -604800 to refer to the reported week in **BROADCAST ORBIT 5, if necessary. Set value to 0.9999E9 if not known.

A 7 GPS Navigation Message File – Example

TABLE A7									
GPS NAVIGATION MESSAGE FILE - EXAMPLE									

[illegible]

TABLE A8 GNSS NAVIGATION MESSAGE FILE - GALILEO DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
BROADCAST ORBIT - 6	<ul style="list-style-type: none"> - SISA Signal in space accuracy (meters) No Accuracy Prediction Available(NAPA) / unknown: -1.0 - SV health (FLOAT converted to INTEGER) See Galileo ICD Section 5.1.9.3 Bit 0: E1B DVS Bits 1-2: E1B HS Bit 3: E5a DVS Bits 4-5: E5a HS Bit 6: E5b DVS Bits 7-8: E5b HS - BGD E5a/E1 (seconds) - BGD E5b/E1 (seconds) 	4X,4D19.12 *****)
BROADCAST ORBIT - 7	<ul style="list-style-type: none"> - Transmission time of message **) (sec of GAL week, derived from WN and TOW of page type 1) - spare - spare - spare 	4X,4D19.12

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

) Adjust the *Transmission time of message* by + or -604800 to refer to the reported week in **BROADCAST ORBIT 5, if necessary. Set value to 0.9999E9 if not known.

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

****) 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).

*****) If bit 0 or bit 2 of Data sources (**BROADCAST ORBIT - 5**) is set, E1B DVS & HS, E5b DVS & HS and both BGDs are valid. -If bit 1 of Data sources is set, E5a DVS & HS and BGD E5a/E1 are valid. -Non valid parameters are set to 0 and to be ignored

A 9 GALILEO Navigation Message File – Examples

TABLE A9 GALILEO NAVIGATION MESSAGE FILE - EXAMPLES									
3.04	N: GNSS NAV DATA	E: GALILEO NAV DATA	RINEX VERSION / TYPE						
NetR9 5.01	Receiver Operator	20150619 000000 UTC	PGM / RUN BY / DATE						
GAL .1248D+03	.5039D+00	.2377D-01	.0000D+00	IONOSPHERIC CORR					
GAUT .3725290298D-08	.532907052D-14	345600 1849	E10 5	TIME SYSTEM CORR					
16 17 1851 3				LEAP SECONDS					
				END OF HEADER					
E12 2015 06 19 02 10 00	-.138392508961D-02	-.131464616970D-09	.000000000000D+00						
.930000000000D+02	-.165531250000D+03	.285797618904D-08	.138275888459D+01						
-.782497227192D-05	.346679124050D-03	.114385038614D-04	.544062509727D+04						
.439800000000D+06	.298023223877D-07	-.296185101312D+01	-.111758708954D-07						
.965683294025D+00	.993750000000D+02	-.629360976005D+00	-.541593988135D-08						
-.571452374714D-11	.516000000000D+03	.184900000000D+04							
.312000000000D+01	.000000000000D+00	-.651925802231D-08	-.605359673500D-08						
.440734000000D+06									
E12 2015 06 19 02 10 00	-.138392508961D-02	-.131464616970D-09	.000000000000D+00						
.930000000000D+02	-.165531250000D+03	.285797618904D-08	.138275888459D+01						
-.782497227192D-05	.346679124050D-03	.114385038614D-04	.544062509727D+04						
.439800000000D+06	.298023223877D-07	-.296185101312D+01	-.111758708954D-07						
.965683294025D+00	.993750000000D+02	-.629360976005D+00	-.541593988135D-08						
-.571452374714D-11	.513000000000D+03	.184900000000D+04							
.312000000000D+01	.000000000000D+00	-.651925802231D-08	-.605359673500D-08						
.440725000000D+06									
E12 2015 06 19 02 10 00	-.138392532244D-02	-.131450406116D-09	.000000000000D+00						
.930000000000D+02	-.165531250000D+03	.285797618904D-08	.138275888459D+01						
-.782497227192D-05	.346679124050D-03	.114385038614D-04	.544062509727D+04						
.439800000000D+06	.298023223877D-07	-.296185101312D+01	-.111758708954D-07						
.965683294025D+00	.993750000000D+02	-.629360976005D+00	-.541593988135D-08						
-.571452374714D-11	.258000000000D+03	.184900000000D+04							
.312000000000D+01	.000000000000D+00	-.651925802231D-08	.000000000000D+00						
.440730000000D+06									
3.04	NAVIGATION DATA	M (Mixed)	RINEX VERSION / TYPE						
BCEmerge	congo	20150620 012902 GMT	PGM / RUN BY / DATE						
Merged GPS/GLO/GAL/BDS/QZS/SBAS navigation file			COMMENT						
based on CONGO and MGEX tracking data			COMMENT						
DLR: O. Montenbruck; TUM: P. Steigenberger			COMMENT						
BDUT 5.5879354477e-09	-2.042810365e-14	14 492	B10 7	TIME SYSTEM CORR					
GAUT 3.7252902985e-09	5.329070518e-15	345600 1849	E10 5	TIME SYSTEM CORR					
GLGP -3.7252902985e-09	0.000000000e+00	345600 1849	R10 0	TIME SYSTEM CORR					
GLUT 1.0710209608e-08	0.000000000e+00	345600 1849	R10 0	TIME SYSTEM CORR					
GAGP -2.0081643015e-09	-9.769962617e-15	432000 1849	E12 0	TIME SYSTEM CORR					
GPOT 4.5110937208e-09	7.105427358e-15	372608 1849	G10 2	TIME SYSTEM CORR					
QZUT 1.9557774067e-08	1.598721155e-14	61440 1850	J01 0	TIME SYSTEM CORR					
18				LEAP SECONDS					
				END OF HEADER					
E12 2015 06 19 02 10 00	-1.383925089613e-03	-1.314646169703e-10	0.000000000000e+00						
9.300000000000e+01	-1.655312500000e+02	2.857976189037e-09	1.382758884589e+00						
-7.824972271919e-06	3.466791240498e-04	1.143850386143e-05	5.440625097275e+03						
4.398000000000e+05	2.980232238770e-08	-2.961851013120e+00	-1.117587089539e-08						
9.656832940254e-01	9.937500000000e+01	-6.293609760051e-01	-5.415939881349e-09						
-5.714523747137e-12	5.130000000000e+02	1.849000000000e+03							
3.120000000000e+00	0.000000000000e+00	-6.519258022308e-09	-6.053596735001e-09						
4.404850000000e+05									

```
E12 2015 06 19 02 10 00-1.383925322443e-03-1.314504061156e-10 0.000000000000e+00
  9.300000000000e+01-1.655312500000e+02 2.857976189037e-09 1.382758884589e+00
-7.824972271919e-06 3.466791240498e-04 1.143850386143e-05 5.440625097275e+03
4.398000000000e+05 2.980232238770e-08-2.961851013120e+00-1.117587089539e-08
9.656832940254e-01 9.937500000000e+01-6.293609760051e-01-5.415939881349e-09
-5.714523747137e-12 2.580000000000e+02 1.849000000000e+03
3.120000000000e+00 0.000000000000e+00-6.519258022308e-09 0.000000000000e+00
4.405300000000e+05
----|----1|0---|----2|0---|----3|0---|----4|0---|----5|0---|----6|0---|----7|0---|----8|
```

A 10 GNSS Navigation Message File – GLONASS Data Record Description

TABLE A10 GNSS NAVIGATION MESSAGE FILE – GLONASS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
<i>SV / EPOCH / SV CLK</i>	<ul style="list-style-type: none"> - Satellite system (R), satellite number (slot number in sat. constellation) - Epoch: Toc - Time of Clock (UTC) year (4 digits) - month, day, hour, minute, second - SV clock bias (sec) (-TauN) - SV relative frequency bias (+GammaN) - Message frame time (tk+nd*86400) in seconds of the UTC week 	A1,I2.2, 1X,I4, 5(1X,I2.2), 3D19.12 *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - Satellite position X (km) - velocity X dot (km/sec) - X acceleration (km/sec²) - health (0=healthy, 1=unhealthy) (MSB of 3-bit Bn) 	4X,4D19.12
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Satellite position Y (km) - velocity Y dot (km/sec) - Y acceleration (km/sec²) - frequency number(-7...+13) (-7...+6 ICD 5.1) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Satellite position Z (km) - velocity Z dot (km/sec) - Z acceleration (km/sec²) - Age of oper. information (days) (E) 	4X,4D19.12

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

A 11 GNSS Navigation Message File – Example: Mixed GPS / GLONASS

TABLE A11												
GNSS NAVIGATION MESSAGE FILE - EXAMPLE MIXED GPS/GLONASS												
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8												
3.04		N: GNSS NAV DATA			M: MIXED			RINEX VERSION / TYPE				
XXRINEXN V3		AIUB			20061002 000123 UTC			PGM / RUN BY / DATE				
EXAMPLE OF VERSION 3.04 FORMAT								COMMENT				
GPSA	0.1025E-07	0.7451E-08	-0.5960E-07	-0.5960E-07	IONOSPHERIC CORR							
GPSB	0.8806E+05	0.0000E+00	-0.1966E+06	-0.6554E+05	IONOSPHERIC CORR							
GPWT	0.2793967723E-08	0.000000000E+00	147456	1395	G10	2	TIME SYSTEM CORR					
GLUT	0.7823109626E-06	0.000000000E+00	0	1395	R10	0	TIME SYSTEM CORR					
14				LEAP SECONDS								
END OF HEADER												
G01	2006 10 01 00 00 00	0.798045657575E-04	0.227373675443E-11	0.000000000000E+00								
	0.560000000000E+02	-0.787500000000E+01	0.375658504827E-08	0.265129935612E+01								
	-0.411644577980E-06	0.640150101390E-02	0.381097197533E-05	0.515371852875E+04								
	0.000000000000E+00	0.782310962677E-07	0.188667086536E+00	-0.391155481338E-07								
	0.989010441512E+00	0.320093750000E+03	-0.178449589759E+01	-0.775925177541E-08								
	0.828605943335E-10	0.000000000000E+00	0.139500000000E+04	0.000000000000E+00								
	0.200000000000E+01	0.000000000000E+00	-0.325962901115E-08	0.560000000000E+02								
	-0.600000000000E+02	0.400000000000E+01										
G02	2006 10 01 00 00 00	0.402340665460E-04	0.386535248253E-11	0.000000000000E+00								
	0.135000000000E+03	0.467500000000E+02	0.478269921862E-08	-0.238713891022E+01								
	0.250712037086E-05	0.876975362189E-02	0.819191336632E-05	0.515372778320E+04								
	0.000000000000E+00	-0.260770320892E-07	-0.195156738598E+01	0.128522515297E-06								
	0.948630520258E+00	0.214312500000E+03	0.215165003775E+01	-0.794140221985E-08								
	-0.437875382124E-09	0.000000000000E+00	0.139500000000E+04	0.000000000000E+00								
	0.200000000000E+01	0.000000000000E+00	-0.172294676304E-07	0.391000000000E+03								
	-0.600000000000E+02	0.400000000000E+01										
R01	2006 10 01 00 15 00	-0.137668102980E-04									-0.454747350886E-11	0.900000000000E+02
	0.157594921875E+05	-0.145566368103E+01									0.000000000000E+00	0.000000000000E+00
	-0.813711474609E+04	0.205006790161E+01									0.931322574615E-09	0.700000000000E+01
	0.183413398438E+05	0.215388488770E+01									-0.186264514923E-08	0.100000000000E+01
R02	2006 10 01 00 15 00	-0.506537035108E-04	0.181898940355E-11	0.300000000000E+02								
	0.155536342773E+05	-0.419384956360E+00	0.000000000000E+00	0.000000000000E+00								
	-0.199011298828E+05	0.324192047119E+00	-0.931322574615E-09	0.100000000000E+01								
	0.355333544922E+04	0.352666091919E+01	-0.186264514923E-08	0.100000000000E+01								
	----	---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8										

A 12 GNSS Navigation Message File – QZSS Data Record Description

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

TABLE A12 QZSS NAVIGATION MESSAGE FILE – QZSS DATA RECORD DESCRIPTION		
NAV. RECORD (Columns 61-80)	DESCRIPTION	FORMAT
	<ul style="list-style-type: none"> - 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 	
BROADCAST ORBIT – 7	<ul style="list-style-type: none"> - Transmission time of message **) (sec of GPS week, derived e.g. from Z-count in Hand Over Word (HOW) - Fit interval flag (0 / 1) (see IS-QZSS-PNT, 4.1.2.4(3) 0 – two hours), 1 – more than 2 hours. Blank if not known. - Spare - Spare 	4X,4D19.12

Records marked with * are optional

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

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

A 13 QZSS Navigation Message File – Example

TABLE A13									
QZSS NAVIGATION MESSAGE FILE - EXAMPLE									
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8									
3.04		N: GNSS NAV DATA			J: QZSS		RINEX VERSION / TYPE		
GR25 V3.08					20140513 072944 UTC		PGM / RUN BY / DATE		
16		1694		7		LEAP SECONDS			
END OF HEADER									
J01 2014 05 13 08 15 12 3.323303535581D-04-1.818989403546D-11 0.000000000000D+00									
6.900000000000D+01-4.927812500000D+02 2.222949737636D-09 7.641996743610D-01									
-1.654587686062D-05 7.542252133135D-02 1.197867095470D-05 6.492895933151D+03									
2.025120000000D+05-8.381903171539D-07-9.211997910060D-01-2.041459083557D-06									
7.082252892260D-01-1.558437500000D+02-1.575843337115D+00-2.349740733276D-09									
-6.793140104410D-10 2.000000000000D+00 1.792000000000D+03 1.000000000000D+00									
2.000000000000D+00 1.000000000000D+00-4.656612873077D-09 6.900000000000D+01									
1.989000000000D+05 0.000000000000D+00									
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8									

A 14 GNSS Navigation Message File – BDS Data Record Description

Table A14 GNSS NAVIGATION MESSAGE FILE – BDS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
SV /EPOCH / SV CLK	<ul style="list-style-type: none"> - Satellite system (C), sat number (PRN) - Epoch: Toc - Time of Clock (BDT) year (4 digits) - month, day, hour, minute, second - SV clock bias (seconds) - SV clock drift (sec/sec) - SV clock drift rate (sec/sec²) 	A1,I2.2, 1X,I4 5,1X,I2.2, 3D19.12 *)
BROADCAST ORBIT – 1	<ul style="list-style-type: none"> - AODE Age of Data, Ephemeris (as specified in BeiDou ICD Table Section 5.2.4.11 Table 5-8) and field range is: 0-31. - Crs (meters) - Delta n (radians/sec) - M0 (radians) 	4X,4D19.12 **)
BROADCAST ORBIT – 2	<ul style="list-style-type: none"> - Cuc (radians) - e Eccentricity - Cus (radians) - sqrt(A) (sqrt(m)) 	4X,4D19.12
BROADCAST ORBIT – 3	<ul style="list-style-type: none"> - Toe Time of Ephemeris (sec of BDT week) - Cic (radians) - OMEGA0 (radians) - Cis (radians) 	4X,4D19.12
BROADCAST ORBIT – 4	<ul style="list-style-type: none"> - i0 (radians) - Crc (meters) - omega (radians) - OMEGA DOT (radians/sec) 	4X,4D19.12
BROADCAST ORBIT – 5	<ul style="list-style-type: none"> - IDOT (radians/sec) - Spare - BDT Week # - Spare 	4X,4D19.12 ***)
BROADCAST ORBIT – 6	<ul style="list-style-type: none"> - SV accuracy (meters See: BDS ICD Section 5.2.4.: to define nominal values, N = 0-6: use $2^{(1+N/2)}$ (round to one decimal place i.e. 2.8, 5.7 and 11.3) , N= 7-15:use $2^{(N-2)}$, 8192 specifies use at own risk) - SatH1 - TGD1 B1/B3 (seconds) - TGD2 B2/B3 (seconds) 	4X,4D19.12

BROADCAST ORBIT – 7	<ul style="list-style-type: none"> - Transmission time of message ****) (sec of BDT week,) - AODC Age of Data Clock (as specified in BeiDou ICD Table Section 5.2.4.9 Table 5-6) and field range is: 0-31. - Spare - Spare 	4X,4D19.12
<p>*) In order to account for the various compilers, E,e,D, and d are allowed letters between the fraction and exponent of all floating point numbers in the navigation message files. Zero-padded two-digit exponents are required, however.</p> <p>**) Angles and their derivatives transmitted in units of semi-circles and semi-circles/sec have to be converted to radians by the RINEX generator.</p> <p>***) The BDT week number is a continuous number. The broadcast 13-bit BDS System Time week has a roll-over after 8191. It started at zero at 1-Jan-2006, Hence BDT week = BDT week_BRD + (n*8192) where (n: number of BDT roll-overs).</p> <p>****) Adjust the Transmission time of message by + or -604800 to refer to the reported week in BROADCAST ORBIT -5, if necessary. Set value to 0.9999E9 if not known.</p>		

A 15 BeiDou Navigation Message File – Example

+-----+ +-----+											
TABLE A15											
BeiDou NAVIGATION MESSAGE FILE - EXAMPLE											
+-----+											
----	1 0----	2 0----	3 0----	4 0----	5 0----	6 0----	7 0----	8			
3.04	NAVIGATION DATA	M (Mixed)	RINEX VERSION / TYPE								
BCEmerge	montenbruck	20140517 072316 GMT	PGM / RUN BY / DATE								
DLR: O. Montenbruck; TUM: P. Steigenberger									COMMENT		
BDUT -9.3132257462e-10 9.769962617e-15 14 435									TIME SYSTEM CORR		
END OF HEADER											
C01	2014 05 10 00 00 00	2.969256602228e-04	2.196998138970e-11	0.000000000000e+00	1.000000000000e+00	4.365468750000e+02	1.318269196918e-09	3.118148933476e+00	1.447647809982e-05	2.822051756084e-04	8.092261850834e-06
		6.493480609894e+03	5.184000000000e+05	-2.654269337654e-08	3.076630958509e+00	-3.864988684654e-08	1.103024081152e-01	-2.506406250000e+02	2.587808789012e+00	-3.039412318009e-10	2.389385241772e-10
		0.000000000000e+00	4.350000000000e+02	0.000000000000e+00	2.000000000000e+00	0.000000000000e+00	1.420000000000e-08	-1.040000000000e-08	5.184000000000e+05	0.000000000000e+00	0.000000000000e+00
+-----+											
----	1 0----	2 0----	3 0----	4 0----	5 0----	6 0----	7 0----	8			

A 16 GNSS Navigation Message File – SBAS Data Record Description

TABLE A16 GNSS NAVIGATION MESSAGE FILE – SBAS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
SV / EPOCH / SV CLK	<ul style="list-style-type: none"> - Satellite system (S), satellite number (slot number in sat. constellation) - Epoch: Toc - Time of Clock (GPS) year (4 digits) - month, day, hour, minute, second - SV clock bias (sec) (aGf0) - SV relative frequency bias (aGf1) - Transmission time of message (start of the message) in GPS seconds of the week 	A1,I2.2, 1X,I4, 5(1X,I2.2), 3D19.12, *)
BROADCAST ORBIT - 1	<ul style="list-style-type: none"> - Satellite position X (km) - velocity X dot (km/sec) - X acceleration (km/sec2) - Health: SBAS: See Section 8.3.3 bit mask for: health, health availability and User Range Accuracy. 	4X,4D19.12
BROADCAST ORBIT - 2	<ul style="list-style-type: none"> - Satellite position Y (km) - velocity Y dot (km/sec) - Y acceleration (km/sec2) - Accuracy code (URA, meters) 	4X,4D19.12
BROADCAST ORBIT - 3	<ul style="list-style-type: none"> - Satellite position Z (km) - velocity Z dot (km/sec) - Z acceleration (km/sec2) - IODN (Issue of Data Navigation, DO229, 8 first bits after Message Type if MT9) 	4X,4D19.12

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

A 17 SBAS Navigation Message File -Example

TABLE A17									
SBAS NAVIGATION MESSAGE FILE - EXAMPLE									
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8									
3.04	N: GNSS NAV DATA			S: SBAS		RINEX VERSION / TYPE			
SBAS2RINEX 3.0	CNES			20031018 140100		PGM / RUN BY / DATE			
EXAMPLE OF VERSION 3.04 FORMAT						COMMENT			
SBUT -.1331791282D-06 -.107469589D-12 552960 1025 EGNOS 5						TIME SYSTEM CORR			
13						LEAP SECONDS			
This file contains navigation message data from a SBAS						COMMENT			
(geostationary) satellite, here AOR-W (PRN 122 = # S22)						COMMENT			
						END OF HEADER			
S22 2003 10 18 0 1 4-1.005828380585D-07 6.366462912410D-12 5.184420000000D+05									
2.482832392000D+04-3.593750000000D-04-1.375000000000D-07 0.000000000000D+00									
-3.408920872000D+04-1.480625000000D-03-5.000000000000D-08 4.000000000000D+00									
-1.650560000000D+01 8.360000000000D-04 6.250000000000D-08 2.300000000000D+01									
S22 2003 10 18 0 5 20-9.872019290924D-08 5.456968210638D-12 5.186940000000D+05									
2.482822744000D+04-3.962500000000D-04-1.375000000000D-07 0.000000000000D+00									
-3.408958936000D+04-1.492500000000D-03-5.000000000000D-08 4.000000000000D+00									
-1.628960000000D+01 8.520000000000D-04 6.250000000000D-08 2.400000000000D+01									
S22 2003 10 18 0 9 36-9.732320904732D-08 4.547473508865D-12 5.189510000000D+05									
2.482812152000D+04-4.325000000000D-04-1.375000000000D-07 0.000000000000D+00									
-3.408997304000D+04-1.505000000000D-03-5.000000000000D-08 4.000000000000D+00									
-1.606960000000D+01 8.800000000000D-04 6.250000000000D-08 2.500000000000D+01									
S22 2003 10 18 0 13 52-9.592622518539D-08 4.547473508865D-12 5.192110000000D+05									
2.482800632000D+04-4.681250000000D-04-1.375000000000D-07 0.000000000000D+00									
-3.409035992000D+04-1.518125000000D-03-3.750000000000D-08 4.000000000000D+00									
-1.584240000000D+01 8.960000000000D-04 6.250000000000D-08 2.600000000000D+01									
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8									

A 18 GNSS Navigation Message File – IRNSS Data Record Description

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

TABLE A18 GNSS NAVIGATION MESSAGE FILE – IRNSS DATA RECORD DESCRIPTION		
NAV. RECORD	DESCRIPTION	FORMAT
	- TGD (seconds) - Blank	
BROADCAST ORBIT - 7	- Transmission time of message **) (sec of IRNSS week) - Blank - Blank - Blank	4X,4D19.12

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

) Adjust the *Transmission time of message* by + or -604800 to refer to the reported week in **BROADCAST ORBIT 5, if necessary. Set value to 0.9999E9 if not known.

A 19 IRNSS Navigation Message File – Example

TABLE A19									
IRNSS NAVIGATION MESSAGE FILE - EXAMPLE									
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8									
3.04	NAVIGATION DATA				I (IRNSS)	RINEX VERSION / TYPE			
DecodIRNSS	montenbruck				20141004 164512 GMT	PGM / RUN BY / DATE			
Source: IRNSS-1A Navbits						COMMENT			
END OF HEADER									
I01	2014 04 01 00 00 00-	9.473115205765e-04	1.250555214938e-12	0.000000000000e+00	0.000000000000e+00-	5.820625000000e+02	4.720196615135e-09-	1.396094758025e+00	
	-1.898035407066e-05	2.257102518342e-03-	1.068413257599e-05	6.493487739563e+03	1.728000000000e+05	6.705522537231e-08-	8.912102146884e-01-	5.215406417847e-08	
	4.758105460020e-01	4.009375000000e+02-	2.999907424014e+00-	4.414469594664e-09	-4.839487298357e-10	1.786000000000e+03			
	1.130000000000e+01	0.000000000000e+00-	4.190951585770e-09	1.728000000000e+05	I01	2014 04 01 02 00 00-	9.473022073507e-04	1.250555214938e-12	0.000000000000e+00
	1.000000000000e+00-	5.101875000000e+02	4.945920303147e-09-	8.741766987741e-01	-1.684948801994e-05	2.254169434309e-03-	1.182407140732e-05	6.493469217300e+03	
	1.800000000000e+05	2.346932888031e-07-	8.912408598963e-01-	1.117587089539e-08	4.758065024964e-01	4.403750000000e+02-	2.996779607145e+00-	4.508759236491e-09	
	-5.464513333200e-10	1.786000000000e+03				1.130000000000e+01	0.000000000000e+00-	4.190951585770e-09	
	1.800000000000e+05	I01	2014 04 01 04 00 00-	9.472924284637e-04	1.250555214938e-12	0.000000000000e+00	2.000000000000e+00-	5.100000000000e+02	5.217360181136e-09-
	-1.697987318039e-05	2.254509832710e-03-	1.212581992149e-05	6.493469842911e+03	1.872000000000e+05	1.378357410431e-07-	8.912725364615e-01	2.942979335785e-07	
	4.758010370344e-01	4.460625000000e+02-	2.996772972812e+00-	4.790199531038e-09	-6.039537285256e-10	1.786000000000e+03			
	1.130000000000e+01	0.000000000000e+00-	4.190951585770e-09	1.872000000000e+05	----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8				

A 20 Meteorological Data File -Header Section Description

[illegible]

TABLE A20 METEOROLOGICAL DATA FILE - HEADER SECTION DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	<ul style="list-style-type: none"> - Type - Accuracy (same units as obs values) - Observation type Record is repeated for each observation type found in # / TYPES OF OBSERV record	A20,6X, F7.1,4X, A2,1X
SENSOR POS XYZ/H	<ul style="list-style-type: none"> - Approximate position of the met sensor - Geocentric coordinates X,Y,Z (ITRF or WGS84) - Ellipsoidal height H - Observation type Set X, Y, Z to (BNK). 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

A 21 Meteorological Data File -Data Record Description

TABLE A21 METEOROLOGICAL DATA FILE - DATA RECORD DESCRIPTION		
OBS. RECORD	DESCRIPTION	FORMAT
EPOCH / MET	<ul style="list-style-type: none"> - Epoch in GPS time (not local time!) year (4 digits, padded with 0 if necessary) - month, day, hour, min, sec - Met data in the same sequence as given in the header - More than 8 met data types: Use continuation lines 	1X,I4.4, 5(1X,I2), mF7.1 4X,10F7.1

A 22 Meteorological Data File – Example

TABLE A22									
METEOROLOGICAL DATA FILE - EXAMPLE									
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8									
3.04		METEOROLOGICAL DATA					RINEX VERSION / TYPE		
XXRINEXM V9.9		AIUB		19960401 144333 UTC		PGM / RUN BY / DATE			
EXAMPLE OF A MET DATA FILE						COMMENT			
A 9080						MARKER NAME			
3		PR		TD		HR		# / TYPES OF OBSERV	
PAROSCIENTIFIC				740-16B		0.2		PR SENSOR MOD/TYPE/ACC	
HAENNI						0.1		TD SENSOR MOD/TYPE/ACC	
ROTRONIC				I-240W		5.0		HR SENSOR MOD/TYPE/ACC	
0.0000		0.0000		0.0000		1234.5678		PR SENSOR POS XYZ/H	
END OF HEADER									
1996 4 1 0 0 15 987.1 10.6 89.5									
1996 4 1 0 0 30 987.2 10.9 90.0									
1996 4 1 0 0 45 987.1 11.6 89.0									
----- ---1 0--- ---2 0--- ---3 0--- ---4 0--- ---5 0--- ---6 0--- ---7 0--- ---8									

A 23 Reference Code and Phase Alignment by Constellation and Frequency Band

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

TABLE A23 Reference Code and Phase Alignment by Frequency Band					
System	Frequency Band	Frequency [MHz]	Signal	RINEX Observation Code	Phase Correction applied to each observed phase to obtain aligned phase. $(\phi_{\text{RINEX}} = \phi_{\text{original}} + \Delta\phi)$
	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	+1/4 cycle
			I+Q	L3X	Must be aligned to L3I
	Galileo	E1	B I/NAV OS/CS/SoL	L1B	None (Reference Signal)
			C no data	L1C	+1/2 cycle
			B+C	L1X	Must be aligned to L1B
		E5A	I	L5I	None(Reference Signal)
			Q	L5Q	-1/4 cycle
			I+Q	L5X	Must be aligned to L5I
		E5B	I	L7I	None (Reference Signal)
			Q	L7Q	-1/4 cycle
			I+Q	L7X	Must be aligned to L7I
QZSS	L1	1575.42	I	L8I	None (Reference Signal)
			Q	L8Q	-1/4 cycle
			I+Q	L8X	Must be aligned to L8I
		E5(A+B)	I	L8I	None (Reference Signal)
			Q	L8Q	-1/4 cycle
			I+Q	L8X	Must be aligned to L8I
	E6	1278.75	B	L6B	None (Reference Signal)
			C	L6C	-1/2 cycle
			B+C	L6X	Must be aligned to L6B
	L1	1575.42	C/A	L1C	None (Reference Signal)
			L1C (D)	L1S	+1/4 cycle (See Note 5 Below)
			L1C (P)	L1L	+1/4 cycle
			L1C-(D+P)	L1X	+1/4 cycle
			L1S	L1Z	N/A
	L2	1227.60	L2C (M)	L2S	None (Reference Signal)
			L2C (L)	L2L	None
			L2C (M+L)	L2X	None
	L5	1176.45	I	L5I	None (Reference Signal)
			Q	L5Q	-1/4 cycle

TABLE A23 Reference Code and Phase Alignment by Frequency Band					
System	Frequency Band	Frequency [MHz]	Signal	RINEX Observation Code	Phase Correction applied to each observed phase to obtain aligned phase. $(\phi_{\text{RINEX}} = \phi_{\text{original}} + \Delta\phi)$
QZSS	L5S	1176.45	I+Q	L5X	Must be aligned to L5I
			I	L5D	None Reference Signal
			Q	L5P	-1/4 cycle
			I+Q	L5Z	None must be aligned to L5D
	L6 (See Note 6 Below)	1278.75	L6D	L6S	None (Reference Signal)
			L6P	L6L	None
			L6(D+P)	L6X	None
			L6E	L6E	None
			L6(D+E)	L6Z	None
BDS	B1-2	1561.098	I	L2I	None (Reference Signal) (See Note 4 Below)
			Q	L2Q	-1/4 cycle
			I+Q	L2X	Must be aligned to L2I
	B1	1575.42	Data (D)	L1D	None Reference Signal
			Pilot(P)	L1P	+1/4 cycle(preliminary)
			D+P	L1X	Must be aligned to L1D
	B2a	1176.45	Data (D)	L5D	None Reference Signal
			Pilot(P)	L5P	+1/4 cycle(preliminary)
			D+P	L5X	Must be aligned to L5D
	B2b (BDS-2)	1207.140	I	L7I	None (Reference Signal)
			Q	L7Q	-1/4 cycle
			I+Q	L7X	Must be aligned to L7I
	B2b (BDS-3)	1207.140	Data (D)	L7D	None Reference Signal
			Pilot(P)	L7P	+1/4 cycle(preliminary)
			D+P	L7Z	Must be aligned to L7D
	B2a+B2b	1191.795	Data (D)	L8D	None Reference Signal
			Pilot(P)	L8P	+1/4 cycle(preliminary)
			D+P	L8X	Must be aligned to L8D
	B3	1268.52	I	L6I	None (Reference Signal)
			Q	L6Q	-1/4 cycle
			I+Q	L6X	Must be aligned to L6I
			B3A	L6A	Must be aligned to L6I
IRNSS	L5	1176.45	A SPS	L5A	None (Reference Signal)

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

NOTES:

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