GNSS High Rate Binary Format (v2.1)

1 Overview

This document describes a binary GNSS data format intended for storing both low and high rate (>1Hz) tracking data. To accommodate all modern GNSS measurements we use the RINEX3.02 standard as a guide. In order to maintain simple structures, few efforts are made to compress the information, as this format is intended for disk storage rather than streaming. In addition each field size is a multiple of 8 bits (one byte).

Each data file consists of an observation section and a Trailer section. The observation section contains a set of Epoch Data Records and optionally High Rate Data Records. Epoch Data Records may be written at up to 1Hz. If a data rate of greater than 1Hz is required, a set of High Rate Data Records follow each Epoch Data Record. The Epoch and High Rate data records are stored sorted first by GNSS type (as specified in the trailer), then by PRN, and finally by time. This is done to make extraction of data from a single satellite and time range efficient.

Low rate data are stored in double precision IEEE floating point format (8 bytes). High rate data is stored in user-specified formats which can include signed or unsigned integers of 1, 2, or 4 bytes, as well as 4 or 8 byte floating point numbers. All numeric data are stored in big-endian byte order (most significant bytes first).

The Trailer Record is written at the end of the file and contains metadata. The metadata is written at the end because the data writer accumulates needed information as each file is written and only has all information necessary for the trailer at the end of the process. The trailer provides byte offsets to each satellite represented in the file to enable efficient seeking.

The typical pattern followed in order to extract a time chunk of high rate data from a single PRN is as follows:

- Seek to end of file and read last 9 bytes (see Section 5.1)
- Determine number of GNSS constellations from 9 byte trailer
- Read the index block for each GNSS constellation (Section 5)
- Seek to the correct offset for the constellation and PRN desired
- Read low rate data, examining times until the correct time is hit
- Read low and high rate data until the correct end time is encountered

2 Definitions

These fields are used in multiple places.

Field ID	Field Definition	Description	Notes
N/A	Observation type consists of 16 bits representing the RINEX3 observation code plus metadata 3 bits observation type 3 bits frequency band 5 bits tracking attribute 5 bits metadata	Observation type: 0 = C 1 = L 2 = D 3 = S 4-7 = reserved Frequency band: 0-7, add +1 to interpret Tracking attribute: 0, A-Z 0 = invalid obs type Metadata: 0,A-Z M = model data 0 = no flag	See RINEX3.02 specification, Section 5.
N/A	char (8 bits)	Satellite system: G = GPS R = GLONASS E = Galileo C = BeiDou S = SBAS Blank = invalid/none	

3 Epoch Data Record

Epoch Data Records may be written at up to 1Hz. High Rate Data Records optionally follow a given Epoch Data Record.

Field ID	Field Definition	Description	Notes
1	uint32_t	GPS seconds (epoch 1980-01-06 00:00:00 UTC)	Good for 136 years. Refers to receive time.
2	8 bits	Tracking status flags bit 0 = open/closed loop (1 = open, 0 = closed) bits 1-7 reserved	
3	uint8_t	Receiver antenna ID: 0-255	Typically have 4 antennas for COSMIC.
4	char (8 bits)	Satellite system	See definition in Section 2.
5	uint16_t	SVN: 0-65535	We keep PRN and SVN in case there is an issue with the table used for conversion to SVN.
6	uint8_t	PRN/slot: 0-255	Typically 1-32, but able to handle SBAS.
7	uint16_t	Number of High Rate Data Records to follow: 0-65535	Supports up to 65KHz data. Zero signifies there is no high rate data.
8	uint8_t	Number of low rate data types this epoch	Supports a variable number of low rate records, up to 255. Zero is legal if there is only high rate data.

9	uint8_t	Number of high rate data types this epoch	Supports a variable number of high rate records, up to 255. Zero is legal if only low rate data are present.
10-N	16 bits	Low Rate Data Record Descriptor (16 bits)	See definition in Section 2. One 16 bit field for each low rate data type. Note that all low rate data are stored in doubles.
N+1 - M	24 bits	High Rate Data Record Descriptor (24 bits)	Observation type plus one char, see Section 3.1 for details. One 24 bit field for each high rate data type (field 9).
M -	double (64 bits)	Measurement NaN = invalid	Low rate measurements. One for each Low Rate Data Descriptor (count in field 8)

3.1 High Rate Data Record Descriptor

This three-byte field describes one high-rate data type.

Field ID	Field Definition	Description	Notes
1	16 bits	Observation type	See definition in Section 2.
2	char (8 bits)	Perl 'pack' format data type: S = unsigned short s = signed short (2 bytes) L = unsigned long l = signed long (4 bytes) d = double f = float	All are big-endian
Total:	24 bits (3 bytes)		

4 High Rate Data Record

Field ID	Field Definition	Description	Notes
1	24 bits	Time offset in tenths of microseconds 0-16777215 0-9999999 = valid values	Absolute time = epoch + this value in seconds + high rate data offset (field 1 in Section 5)
2	Data type specified in field 4 in the High Rate Data Descriptor (8-64 bits)	Measurement NaN = invalid for float or double types max(int) = invalid for integer types	Repeat fields as many times as valid observation types are specified in Trailer Record Data Descriptors for this constellation.

5 Trailer Record

The trailer consists of file offsets per PRN for each satellite system stored in this file, followed by a small fixed-length end section specifying which satellite systems are present in the file. Also present is the 'high rate data offset' which tells where all high rate data start in relation to integer seconds. This is usually set to zero, but certain JPL receivers use a -0.5 second offset.

The total length of the trailer record is 9+260*N bytes, where N is the number of satellite systems present. The final 9 bytes of the record are always written and specify N.

Field ID	Field Definition	Description	Notes
1	sint32_t	High rate data offset. The offset in nanoseconds between the integer epoch time and the fractional high rate data time. -0.5e9 to 0.5e9. This is set to -0.5 seconds for JPL RO receivers, can be set to zero for other receivers.	Observation time = epoch time + high rate data offset + 24-bit high rate time offset
2-33	sint64_t * 32	Byte offset from start of file to PRNs 1-32 -1 = not present	
Total: 32 + (64 * 32) = 2080 bits (260 bytes)			

5.1 End Section

The final section of the trailer record specifies the data file version as well as which satellite systems are present in the file.

Field ID	Field Definition	Description	Notes
1	uint8_t	Version ID. 0-255	version = 2
2-9	char (8 bits)	List of up to 8 satellite systems found in this file.	See definition in Section 2. Set to invalid (blank) for constellations not present in the file.
Total:	72 bits (9 bytes)		