AshTech Optimized Messaging

GNSS receiver communication protocol: versions 1/2

Reference Manual

Revision 2.28
July 10, 2013

Ashtech reserves the right to make changes to the ATOM format specification without notice

REVISION HISTORY

Track the revision history of the ATOM format Interface Control Document.

Release	Date	Author	Comments
1.00	Jan 15, 2009		Initial creation
1.01	Feb 28, 2009		Style changes, misprints fixes ATOM RNX section corrected ATOM BAS section completed Appendix C modified Appendix E modified ATOM PVT TTS message description added Antenna name message meaning extended
1.02	March 31, 2009		ATOM PVT COO block modified by adding position type clarifier Invalid GNSS time tag specified ATOM DAT EXT message modified/clarified ATOM ATR SNS message reserved ATOM PVT SVS block modified Azimuth and Elevation definition clarified
1.03	April 30, 2009		Defaults of ATM PVT message changed Adding serial interface to request second PVT message ATOM PVT SVS block description clarified
1.04	May 31, 2009		Definition of PRR data clarified GLONASS almanac description corrected Some re-formatting of the text performed per StephaneM request Few minor changes made in Section 4 to reflect ATM,HED message
1.05	October 15,		Appendix E is modified in section E.5

	2009		ATOM PVT PRR block is clarified ATOM,RNX message finalized (in part of extended observation data) Serial interface related with REF block of ATOM RNX/BAS is added (section 4.5.) Notes regarding ¼ cycle carrier alignment, pseudo-range smoothing and clock steering are added for ATOM,RNX Clarification of Sat usage and diff status flags in ATM,PVT,SVS Intermediate changes in ATOM BAS message description (still not finalized) Some editorial changes done in different parts of the Manual New group (EVT, section 3.10) added; corresponding changes are added to other sections ATOM,PVT,TTS message is moved to EVT group Some fields (AFxxx) description is moved to Appendix G The description of ATM,HED is moved to Appendix G Appendix H removed
1.06	October 23, 2009		Accepting all the previous changes Fixing misprints Syntax changes towards releasing the Manual for user Additional clarification of some fields and serial interface Words ‘GNSS platform’, ‘MB500’ etc are removed ATOM Logo added $PASHSQ,ATM,PAR described in Section 4 ATOM ATR SNS message removed Antenna type (AF006) field description is moved to Appendix G Appendix G is reformatted Some fields in ATM,ATR,OCC/AOP are clarified Section 3.10 is reformatted
1.07	November 2, 2009		Style changes and clarifications Reference documents updated The description of ATM,RNX serial interface simplified The description of ATM,RNX/BAS customization re-fined
1.08	December		Fields AF007 and AF008 are put to Appendix G

	15, 2009		Few style changes done towards releasing the Manual for end user Code quality flag meaning in ATM,RNX,SCN,0 is extended Message B1S is transferred to new STA group under the name BLA Message SNS (Sensors data) is added to ATR group Field AF006 is clarified Some style corrections added User cases of different RNX scenarios are clarified in section 5 Magellan Pro changed to Ashtech
1.09	January 15, 2010		PVT solution type field (AF009) introduced
1.10	February 10, 2010		Style changes from Patrice done towards releasing 1.09 as user Manual Description of ATOM,BAS temporary removed (but section header is still kept) The above changes are accepted for more clear view of the changes which follow More clarifications added about generated position in section 2.4 and 2.5. ATM,ATR,SNS corrected Invalid states for position generated in PVT, MES and RNX are introduced Receiver time status in ATM,RNX position block (Field AF010) introduced Style corrections
1.11	March 10, 2010		Wn field in ALM is clarified Mentioning of $GPRRE message removed Misprint in time tag description fixed Style corrections
1.12	April 15, 2010		Invalid values for some RNX fields clarified ATM STA BLA message clarified AF006 field clarified
1.13	May 31, 2010		ATM,ATR,SNS message modified Field AF011 introduced in ATM,RNX header Section 2.4 modified Block ATM,PVT,LDP is added Block ATM,PVT,CDC is added Reference documents dates updated

1.14	June 30, 2010		PVT solution ID clarified in section 3.4. Correction usage status clarified in section 3.4.10 Time interval usage clarified for DAT and STA messages in sections 3, 4 Notes about clock steering effect on position added to 3.4.4 and 3.8.5 TT1 message mention is added to Appendix G.2 The response to $PASHQ,PAR,ATM is updated Added note in 2.5 about possible GLONASS observation corrections to golden Ashtech receiver Reference documents dates updated
1.15	July 31, 2010		Message STA,BLA modified: earlier reserved fields are now populated Message STA,DDS introduced Message STA,DPS introduced Message STA,RSA introduced Message STA,RSP introduced Message STA,EGB introduced Few clarification sentences added to ATM,PVT and ATM,DAT description
1.16	Aug 31, 2010		Description of field AF006 (Appendix G.1) clarified New ATM,NAV message for Galileo Ephemeris introduced but not finalized New ATM,DAT message for Galileo Navigation data stream introduced but not finalized GALILEO indication bits are added to PVT and RNX messages (GALILEO as primary GNSS system is not yet defined) Few clarifications are given for STA messages
1.17	Sept 30, 2010		Message ATM,STA,DDS is modified Message ATM,STA,DLS is added The logic to output ATM.STA messages is clarified Bits/bytes boundaries and offsets are finalized in ATM,STA messages
1.18	Nov 19, 2010		A number of misprints indicated by System Test fixed. Field AF003 clarified for invalid position (Appendix G) Sat health indication is added to RNX message Some details of receiver clock estimation/steering clarified in section 2.5 Local meteo parameters message added to ATR group

			Carrier shift message added to ATR group APIS message added to PVT group GNSS clock offset message added to STA group Sat health message aged to STA group Some MSM related changes are added to ATM,RNX and some additional clarifications are given Section G.3 is introduced in Appendix G New signals definitions added to signal Mask (Appendix E)
2.01	Jan 24, 2011		The size of Sat and Signal mask is increased which led to reporting ver.2 in headers of ATM,RNX and ATM,PVT messages. See also Appendix E. Few extensions/clarifications are given for some ATM,RNX fields Field AF002 adds 2 more choices Field AF017 introduced Antenna height field added to STA,RSP message ATM,MES description removed (but section header is still kept) Some CQ fixes reflected
2.02	Feb 28, 2011		Few misprints corrected The description of ATOM version switch command added The description of standard and fine resolution is added to ATOM RNX The difference between v.1 and v.2 was better clarified in the text and newly created Appendix H Galileo Ephemeris message updated (but it is still not finalized) PIS block is removed from PVT message
2.03	Mar 31, 2011		Few misprints corrected Number 0 is claimed to be reserved for ATOM DBG group Bit mask definitions clarified in section 3.2. Some clarifications added to Section 4 Mentioning fields AF001 and AF004 removed Section G.4 added Message DLS modified
2.04	Apr 29, 2011		Exact definition for Satellite, Signal and Cell mask is added with reference to RTCM-3 MSM fields DF394, DF395, DF396 Message ATM,ATR,SAH is added

			Message ATM,STA,AST is added Clarifications are given for AF002 and AF009 in ATM,PVT header.
2.05	May 31, 2011		New FST group created with single message PIS New STA message (SSC) created New ATM,PVT sub-block (ROT) created New ATM,DAT,INT message created A number of clarifications are given for ATM,STA messages Some corrections/additions for ATM,RNX to match latest MSM changes
2.06	June 30, 2011		ATR,CSD message is removed as not needed anymore Appendix C is extended with RNX data restoration algorithm Appendix G is extended with description of data link effective ATM,RNX scenario for moving base RTK New fields (or reserved positions) are introduced for ATM,PVT Section 6 (ATOM Utilities) updated Signal, Satellite and Cell masks description updated Detailed clarification of Signals and Satellite IDs is provided for GPS; other GNSS will be updated later
2.07	July 31, 2011		Section G.5 added Detailed clarification of Signals and Satellite IDs is provided for GLONASS, SBAS and GALILEO Message ATM,DAT,GAL finalized Message ATM,DAT,FRM introduced
2.08	August 30, 2011		Field AF006 is reintroduced; it is supposed that later user will use AF019 instead. Message 4095,15 is introduced More clarifications for ATM,PVT header IDs added Max age of DDS message clarified A comment added to carrier polarity indicator in RNX message
2.09	September 30, 2011		DDS message modified, Field AF012 clarified in Appendix G Number of ATM,PVT fields clarified BLN block now can report the assumption about applied clock drift model Field AF020 (request ID) is introduced in ATM,PVT header Block ATM,PVT,ROT finalized

			GPS and GLONASS almanac messages clarified Appendix G modified in different entries, mainly to address field AF020 introduction FST group is renamed to SUP group Two messages of SUP group finalized Message STA,GFN introduced
2.10	October 30, 2011		Message STA,GFN finalized ATM,DAT,FRM message modified Messages ATR,RIO and ATR,CFG added Section 4.3 generalized Sections 5.3 and 5.4 generalized and clarified Section G.6 added
2.11	November 30, 2011		LDP and CDC blocks (ATM,PVT) are modified Section G.6 removed as it is now a part of GNSS f/w platform PSD Section 4 edited Section 5 edited
2.12	December 30, 2011		Section 3.8 edited Galileo EPH message finalized
2.13	January 30, 2012		Galileo EPH message updated to match final RTCM-3 MT 1045 changes The definition of cycle slip counter for ATM,RNX is clarified Note about invalid data generation added to Section 3.1
2.14	February 28, 2012		Galileo almanac message added to NAV group Galileo ephemeris message updated Message STA,GFN modified Message STA,BLA modified Reference documents list updated Note to section C.2 added
2.15	March 31, 2012		Misprint (int16->uint16) corrected for field E in ATM,NAV,ALM(GPS) Galileo almanac message modified Choice QZSS added to GNSS masks
2.16	April 30, 2012		ATOM PVT message edited New block for ATOM PVT is reserved: LMP Section 2.4 is added with short overview of multiple ATOM PVT output

			Section 4.9 added with additional serial interface in case of advanced PVT modes Field AF020 clarified Field AF023 reserved
2.17	June 30, 2012		New block for ATOM PVT is created: LMP Extra notes added to section 2.4 about local positions/projections QZSS Sat and Signals ID description added Message ATM,ATR,CPB created Message ATM,DAT,FRM finalized Some CQ entries addressed QZSS ephemeris message added QZSS almanac message added
2.18	July 24, 2012		Galileo Almanac message updated Message ATR,CPB updated Mentioning of MES and BAS completely removed ATM,PVT,PRR block updated Extended ATM,PVT blocks (local coordinates) updated
2.19	Aug 15, 2012		Additional possibility to extend ATOM are added to Section 2.1 Editorial changes, adding missed fields Group DBG is renamed to ALR and described in given manual (section 3.12) Two messages are added to SUP group
2.20	Sep 25, 2012		Some misprints corrected, some clarifications given
2.21	Sep 28, 2012		Code misprint cleaning
2.22	Sep 30, 2012		Modify valid range and invalid values for number of RNX,PVT,STA fields
2.23	Oct 12, 2012		PVT,LMP block modifications added Message ATM,PVT,BSD introduced ATM,ATR,CPB message corrected
2.24	Nov 24, 2012		NAV,GIT for Galileo and QZSS introduced Fix bug in NAV,GIT, tot field

			ATM,ATR,CPB message corrected Remove all GIOVE-A/B traces Modify PVT,COO Field AF023 clarified Remove section G.4
2.25	Jan 30, 2013		Table 'Supported NAV messages' expanded with GAL and QZS GITs Fix typo ATR,PCB -> ATR,CPB Fix (data types) typos and modify structure for NAV,GIT for GAL Modify ATM,NAV,&GFT, ATM,RNX, ATM,PVT&MIS GNSS time cycles description
2.26	Feb 28, 2013		Fix date of 2.24 release Fix ATM,NAV,&GFT, ATM,RNX, ATM,PVT&MIS GNSS time cycles modulo value GAL ionosphere offset and message length typos First revision for Beidu Ephemeris, almanac, ion&utc message Add Beidu GNSS id for all messages Remove Section 3.3 Satellite, Signal and Cell Masks to Appendix I
2.27	Jun 20, 2013		A number of clarifications with BeiDou is provided in different sections Add more clarifications for AF003 field
2.28	Jul 10, 2013		Appendix J added. Section 6 reduced Corrections made in different parts of text OCC message copied to EVT group Update of ATOM user Manual is branched from given release. The previous release was branched from ver 1.12

REFERENCE DOCUMENTS

Doc ID	Document Name	Date	Version	Author
RD1	NMEA standard for communication between marine electronic devices	01-Nov-2008	4.00	NMEA
RD2	RTCM recommended standards for differential GNSS service – RTCM SC104	20-Aug-2001	2.3	RTCM
RD3	RTCM recommended standards for differential GNSS service – RTCM SC104	March-2012	3.2	RTCM
RD4	GNSS firmware platform ICD	N/A	Latest	Ashtech
RD5	ATOM: Super Compact and Flexible Format to Store and Transmit GNSS Data	15-Sep-2008	N/A	I. Artushkin, A. Boriskin, D. Kozlov, the paper presented on ION GNSS 2008
RD6	The Receiver Independent Exchange Format	22-June-2009	3.01	Werner Gurtner, Lou Estey
RD7	GNSS firmware platform PSD	N/A	Latest	Ashtech

CONTENT

1. WHAT IS ATOM AND WHAT CAN IT DO?

Ashtech has developed its own proprietary binary data format, named "**A**sh**T**ech **O**ptimized **M**essaging" ("ATOM" acronym for short), to adapt to the new GNSS reality and meet all user requirements. The name emphasizes the main distinguishing ATOM feature, which is its ability to present data in compact form. ATOM is open to further extensions with new messages or updates for already existing messages (the ATOM version number is provided for each message). Not all the ATOM fields need to be aligned by integer bytes boundaries. However, for extra convenience, some fields have been grouped together to fit the integer number of bytes.

The key features of ATOM include:

- Delivering the widest variety of GNSS data at any update rate
- Supporting different customization options, from maximally compact to maximally full
- Being in line with existing RTCM-3 and NMEA messages as well as RINEX-3 format
- Backward compatibility with legacy Ashtech proprietary messages
- Easily upgradable to include new versions and/or new messages
- Universal presentation form for different GNSS data
- Capability to use ATOM for raw data recording and as a differential correction protocol

ATOM can be used as the only GNSS data source for different applications. It can also be used in conjunction with existing (including legacy) Ashtech proprietary and standardized data protocols.

The use of a standardized RTCM-3 transport layer allows 3rd party software to detect/synchronize ATOM messages easily.

Depending on their applications, users can take advantage of some particular ATOM messages (e.g. receiver positioning results only), or use the full ATOM function, including generating raw data, providing reference data (base mode) and many others.

GNSS has grown rapidly in recent times. More and more GNSS-related applications have appeared, and new requirements for GNSS data have been formulated. Particularly:

- Ease of use and universal support of different GNSS and their signals
- Generating data with high update rate
- Allowing compact data presentation to save room on the storage device and/or data link bandwidth

ATOM meets all these new requirements.

2. ATOM ORGANIZATION OVERVIEW

Although a proprietary message, ATOM uses the standardized RTCM-3 transport layer. This decision was made to allow any 3rd party vendor to decode ATOM using available RTCM-3 decoders.

2.1 Basic ATOM transport

RTCM-3 message numbers range from 1001 to 4095. Numbers 4001 through 4095 are reserved for proprietary usage. Each vendor can ask RTCM to assign a unique number from this range to be used exclusively for its own data. The number 4095 is reserved for Ashtech and is used by ATOM. As a result, the transport layer used by ATOM is the same as the one of any standardized RTCM-3 message:

Preamble	Reserved	Message Length	Variable Length Data Message 1	Variable Length Data Message 2	CRC
8 bits	6 bits	10 bits	Variable length, integer number of bytes. **Known message 4095 (ATOM) is here**	Variable length, integer number of bytes. **The content can be unknown for older ATOM versions**	24 bits
11010011	Not defined – set to 000000	Message length in bytes	0-1023 bytes as specified in Message Length block		QualComm definition CRC-24Q

Similarly to RTCM-3, ATOM reserves a possibility for potential future extension for each existing ATOM message. These extensions may be introduced by adding data to the end of any ATOM message This flexibility leads to the following claims:

- Actual message length (as decoded from message header) may not match (be greater than) the minimal required message length (as dictated by the content of any particular ATOM message).
- Decoding software shall omit (ignore) any extra block of data at the end of ATOM message. Availability of such extra data shall be considered as a normal occasion and shall not result in raising warning flag.
- Encoding software shall NOT use this possibility for undocumented proprietary data transmission. No any extra information shall be added to the end of MSM message by encoding software unless this would comply with the next releases of ATOM Manual.

If the original known 4095 message does not contain an integer number of bytes, then the needed number of zero bits (0 to 7) is added at the end of the message to make the whole number of bytes an integer.

The high-level presentation form of message 4095 is the following:

Data item	Number of Bits	Range	Comments
Message number	12	1001-4095	111111111111=4095 reserved for Ashtech

Message group sub-number	4	0-15	Message group clarifier (e.g. 0011=3 reserved for PVT)
Message version number	3	0-7	ATOM message version. Set to 1 or 2 for this release
Message body	<=8165		

2.2 Wrapping basic ATOM

2.3 Short ATOM overview

To date, ATOM ver.1/2 supports the following primary groups of GNSS data:

Group type	Group ID	Message clarifier	Standardized counterparts	Group configuration
Receiver alarms	4095,0 or ATOM,ALR	0000	N/A	Group of independent messages or single, composite message.
Supplementary data	4095,1 or ATOM,SUP	0001	N/A	Group of independent messages
Reserved	4095,2			Reserved for future group
Positioning results	4095,3 or ATOM,PVT	0011	NMEA-3 GGA, GST,GSV etc	Group of independent messages or single, composite, configurable message
Receiver attributes	4095,4 or ATOM,ATR	0100	RTCM-3 1007, 1008, 1029, 1033	Group of independent messages
Navigation information	4095,5 or ATOM,NAV	0101	RTCM-3 1019, 1020	Group of independent messages
Data frames	4095,6 or ATOM,DAT	0110	N/A	Group of independent messages
GNSS RINEX observables	4095,7 or ATOM,RNX	0111	RINEX-3, RTCM-3 MSM	Group of independent messages or single, composite, configurable message
Reserved	4095,8/9/10/11/12			Reserved for future groups
Receiver status	4095,13 or ATOM,STA	1101	N/A	Group of independent messages
Receiver events	4095,14 or ATOM,EVT	1110	N/A	Group of independent messages
Any non-RTCM-3 message	4095,15	1111	N/A	Just transport layer to pack any other message. Not described in given Manual

The most of existing ATOM groups is available for 3rd party users. At the same time, there are reserved groups and respective messages numbers which are proprietary and are not available for end users. If third party equipment detects such groups/messages, it must ignore them.

Group RNX refers to ATOM observables. Depending on the desired application and personal preferences, different configurations (scenarios) may be used. A short overview of this group is given below.

Group PVT delivers positioning results such as position, velocity, clock offset, and Satellite tracking/usage status. Additionally it contains the information about position latency and accuracy. These data can be converted to, or generated from standardized NMEA-3 messages. A more detailed view on the ATOM PVT architecture is given in a separate section below.

Group ATR generates receiver/antenna attributes, for example receiver name/serial number/firmware version and/or antenna name/serial number. It is also used to specify the antenna reference point with respect to survey point as well as any user-defined message generation.

Group NAV generates navigation data extracted from GNSS data streams. NAV supports the generation of GPS, GLONASS, SBAS, GALILEO, QZSS, BEIDOU ephemeris and almanac data as well as some other valuable information, like broadcast ionosphere parameters.

Group DAT generates a raw navigation data stream (frames) decoded from any signal a GNSS receiver tracks. Also, this group includes messages containing the binary streams entering the receiver through its physical ports (e.g. external differential data stream).

Group STA provides status information from some receiver firmware modules. Particularly it can output the current receiver configuration parameters, the differential data link status, etc.

Group EVT generates some information about events inside a receiver. It can be the precise time-tagging of the external event marker or PPS time-tagging.

Group ALR is very valuable for identifying receiver problems. These messages are supposed to inform end user about receiver problems or incorrect setups. Each (available for end user) alarm supposes clear set of user actions to restore normal receiver operation. These messages are parts of Ashtech Trouble Log, so called atl.log file which customer can request from any Ashtech receiver in case of problems.

Group SUP contains various data needed mostly to supplement position (PVT) and raw (RNX) data for some specific applications.

There is a special group 4095,15 which intentionally has no 3-letter name assigned. This group is not described in given Manual. This group is a simplest packing frame to encapsulate any other non-RTCM-3 message for special applications.

In future, ATOM is open to adding more groups to the currently supported list.

Each group contains a number of particular sub-messages/sub-blocks, which can optionally be enabled or disabled. Each group has its own default configuration, which can be receiver -type and firmware-version dependent.

Some ATOM messages have fixed length, some others have variable length. Variable length can be caused by the fact that this message contains multiple satellite information (i.e. Nsat dependent). On the other hand, variable length can be caused by some internal switches in the message header defining different presentation forms for the data that follow.

Most of the data ATOM generates are extracted from GNSS signal(s) directly using internal receiver algorithms. These are GNSS observables and navigation data as well as internal receiver positioning results. On the other hand, some ATOM fields refer to receiver hardware configuration or user-entered parameters. For example, a lot of generated attributive information refers to either receiver configuration (e.g. receiver name, serial number, firmware version, etc.) or to some user-entered settings (e.g. antenna name, antenna offset against ground mark, ASCII message, fixed reference position, etc.).

While the general organization of all the ATOM groups is similar, there are however some differences. Messages or groups SUP, ATR, NAV, DAT, STA and EVT are always generated independently of each other. At the same time, messages of groups RNX and PVT can be output differently. Each of these groups contains a unique header often defining which data blocks follow this header. If for example, a receiver is configured to generate more than one block of data for a given group, these data blocks can be grouped within a single message (under the same header and inside the same transport frame) or can be split into sequential and independent transmissions. In the latter case, each independent message provides a so-called multiple-message bit allowing the decoding equipment to compile complete data epochs from sequential transmissions. The next two sections give examples of different transmission strategies for these groups of messages.

2.4 An example of ATOM PVT architecture

A closer look at the organization of the ATOM PVT message for example shows that it starts with a 10-byte header containing the following data (for exact presentation, please refer to the dedicated section):

Field	Comment
Message number	111111111111=4095, reserved for Ashtech
Message sub-number	0011=3, reserved for PVT
Message version	001=1, refers to the first version of the ATOM PVT message
Multiple message bit	1 indicates that more 4095,3 message(s) will follow for the same time tag 0 indicates that it is the last ATOM PVT message tagged to a given time tag
Number of satellites	Number of GNSS satellites (visible, tracked, used in position)
Primary GNSS system	Defines the meaning of time tag and position datum
Time tag	Presentation depends on primary GNSS system
Reserved bits	For future use

Note that multiple-GNSS receivers make an assumption about the primary GNSS system used (default is usually GPS). When a primary GNSS system is specified, then the ATOM message time tag and position datum refer to that primary system.

Currently the following primary PVT data sub-blocks are supported.

Block type	Block ID	Size, in bytes
Position	COO	26
Accuracy	ERR	10
Velocity	VEL	12
Clock	CLC	10
Latency	LCY	3
Attitude	HPR	11
Baseline	BLN	16
Miscellaneous	MIS	23

Attitude supplementary data	ROT	13
Baseline supplementary data	BDS	19
Original datum clarification	CDC	Depends on message content
Local datum position	LDP	Depends on message content
Local map projection	LMP	Depends on message content
Satellites status	SVS	Depends on tracking status

ATOM,PVT allows outputting receiver position tagged to different points, including L1 antenna phase center, antenna reference point or ground mark. Corresponding identifier is provided inside ATOM,PVT body. Antenna height (the height of antenna reference point above ground mark) is usually provided, so user can re-compute position tagging as he/she wants. Having requested antenna name, user is also able to make ease transformations between L1 antenna phase center and antenna reference point positions.

Block COO of ATOM,PVT message outputs position referring to some datum. This datum can be indicated as 'default' which is defined by:

- The datum of broadcast ephemeris (i.e. IGS05 realization of ITRF2005 on current epoch if GPS is primary)
- The datum reference position is tagged to (for RTK and DGNSS only)

It must be noted that often it is not known a priori what the datum of reference position is. In this case, block MIS of ATOM,PVT indicates 'default' datum which is actually correct only if reference position is tagged to the same datum as used ephemeris are. If it is not so, then 'default' actually means unknown for RTK and/or DGNSS positions.

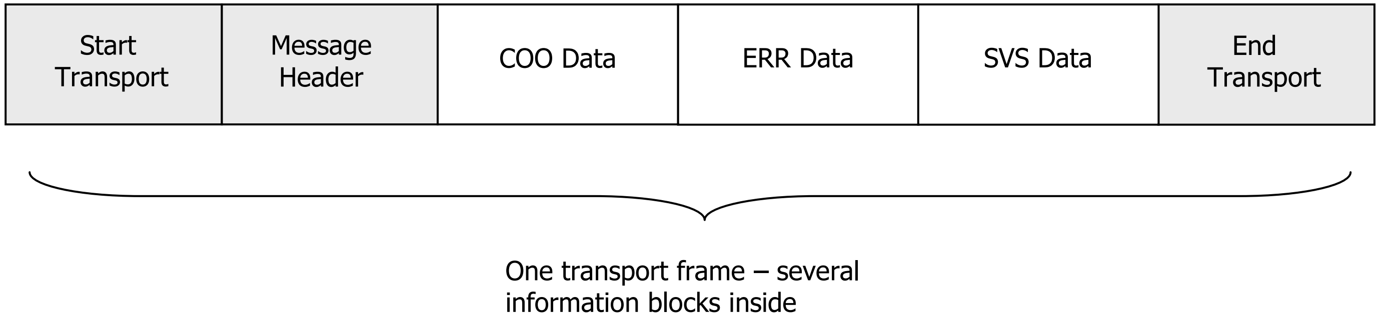
Many users can be interested in getting position in some specific local datum and/or projection. ATOM,PVT applies the ideology that block COO always reports originally computed position (indicated as 'default' or 'custom' in block MIS), while extra block(s) can output block LDP (Local Datum Position) and/or LMP (Local Map Projection). See complete ATOM,PVT description for detailed formats.

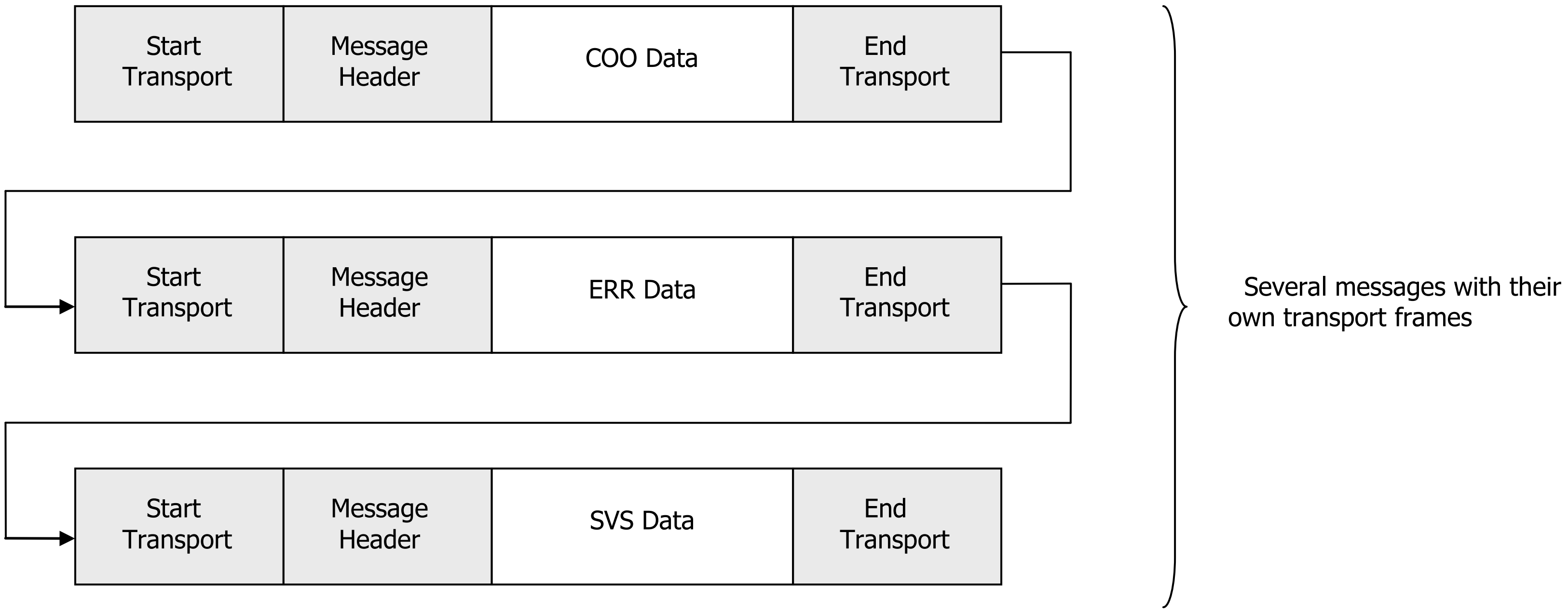
ATOM,PVT is open to adding more sub-blocks in future. It should also be noted that Ashtech PVT data are usually output under the same header (possibly with a unique update rate for each block), i.e. inside a single ATOM,PVT transmission. On the other hand, each particular sub-block (e.g. COO or SVS) can be output under its own header, i.e. using a separate ATOM,PVT transmission. In the latter case, the multiple-message bit in the ATOM,PVT header is set accordingly to allow the receiving entity to compile complete position epoch data from different transmissions. The two diagrams below show different transmission strategies applicable to ATOM PVT messages (3 sub-blocks are given as examples).

In some cases, e.g. when Network provider delivers additional information about the source datum, local datum and map projections, extra ATM,PVT blocks can supplement original position generated in block COO. In general these extra blocks clarify:

- The name of the datum COO position is expressed in (CDC block)
- COO coordinates expressed in a local datum (LDP block)
- COO coordinates expressed in local map projection (LMP block)

Sometimes, a clarification about reference position datum is known a priori (e.g. source datum name from so called RTCM-3 coordinate transformation messages). In this case, block MIS of ATOM,PVT will indicate 'custom' datum and additional ATOM,PVT block CDC (custom datum clarification) which clarifies the name and parameters of this 'custom' datum is generated.

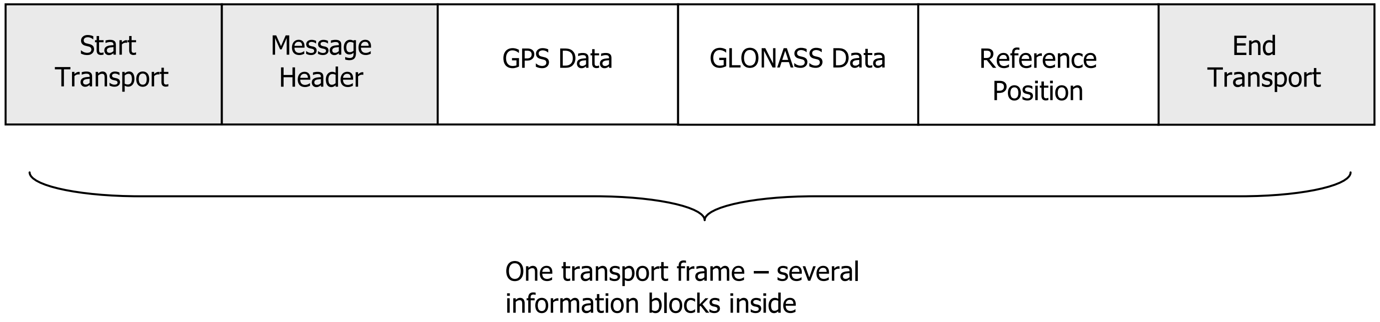


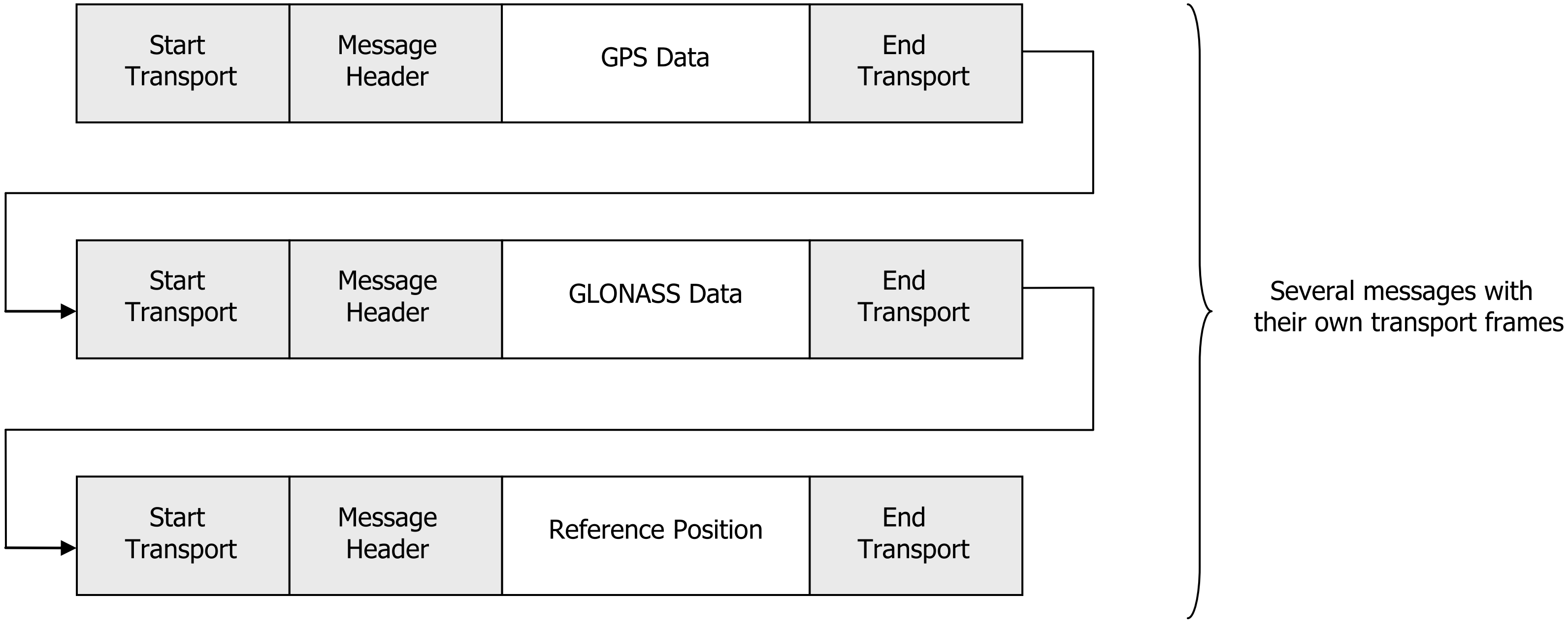


More words must be said about multiple ATOM PVT output. In the most of user cases, complete GNSS solution corresponds to single receiver antenna, single dedicated correcting data stream etc. In this case, all sub-blocks inside ATOM PVT are tagged to this unique GNSS solution. At the same time, Ashtech GNSS platform can deliver to end user advanced GNSS solution which includes more than single antenna and correcting source. For example, Ashtech supports RTK + heading solution, or RTK + Full altitude solution where obviously more than single antenna and corresponding corrections/observations are used. For such advanced GNSS solutions, user can be supplied with more than single PVT message, each responsible for particular GNSS solution. Thanks for generic structure of PVT message, these multiple PVT output can be decoded by the same parser, but receiving entity must interpret these multiple PVT messages correctly. To do this, ATOM PVT generator provides special identifying information inside ATOM PVT header (so called Request ID).

2.5 An overview of ATOM RNX observation message

It contains blocks of GPS, GLONASS, etc., observables as well as optional reference position (static or moving). Presentation of observables is exactly the same for each GNSS. This allows the same source code to be used to construct and parse each GNSS observation block. Each of these blocks can be transmitted inside a single message, or can be spread among several transmissions as shown below. In latter case, decoding equipment must process Multiple Message Bit (available in the header of each observation message) properly. It must be also noted that in some specific cases (e.g. when the number of tracked Signals is too high), the observation data for a single GNSS can be also spread among several sequential transmissions; in this case Multiple Message Bit is also set to allow complete epoch compiling.





RNX message presents receiver data directly in RINEX-3 like manner. The variety of GNSS and their signals is almost unlimited in RNX messages, because it uses universal and flexible data identification. Group RNX can support a number of compact data presentation options making it usable both for raw data recording and as an effective differential protocol.

Since ATOM RNX message allows different customization and optimization scenarios to be implemented, a number of additional explanations/clarifications are provided in **Appendixes C, D** and **E**. These Appendixes allow users to understand in more details what algorithmic background is behind RNX observation message.

ATOM RNX observation message can generate the following primary observables for each tracked signal (RINEX definitions):

- Pseudo-range (C)
- Carrier phase (L)
- Doppler (D)
- Signal strength (S)

Since there is still some ambiguity in interpretation, the statements below clarify the definition of the observables packed into ATOM RNX messages:

- Time tags, pseudo-ranges and carrier phase for each GNSS correspond to RTCM-3 and RINEX conventions

- All pseudo-ranges and carrier phases (at least for a given GNSS) are supposed to be controlled by the same receiver clock
- All carrier phases are matched to their respective pseudo-ranges
- Any C-L, C–C or L-L combination is flat provided continuous carrier tracking is achieved. Only ionosphere and some other effects can cause slow divergence of one observable against another
- Doppler is interpreted as the true carrier phase derivative, i.e. the Doppler sign is equal to the delta-carrier sign
- Signal strength corresponds to the RTCM-3 definition (Carrier-to-Noise Ratio) and is expressed in dBHz

All the generated observables are raw, i.e. not corrected for any specific (e.g. atmospheric) effects. In addition, the statements below enumerate what corrections are applied, or can possibly be applied to original ATOM RNXobservations.

- All the GNSS observables are steered for the same receiver clock value. The clock error in all observables does not exceed about 300 meters. Some observation messages can provide the value of original clock, which can be used to restore original (not steered) observables.
- All carrier phases corresponding to the same GNSS and band are aligned with each other, i.e. the possible ¼ cycle (or other) bias is properly compensated for.
- The initial integer count in all carrier phases is set to match the carrier phase and respective pseudo-range at carrier initialization epoch
- Pseudo-ranges can be smoothed by carrier phases to reduce the noise/multipath error. Some ATOM observations messages can provide the so-called smoothing residual allowing the unsmoothed pseudo-range value to be restored.
- All ATOM observables are never compensated for antenna specific biases. On the other hand, original receiver observations can be matched to the desired virtual antenna name. The corresponding (physical and virtual) antenna names can be provided by ATR messages, thus making it possible if needed to restore the observations corresponding to the physical antenna.
- All ATOM observables are never compensated for receiver specific biases. On the other hand, original GLONASS receiver observations can be corrected to the golden Ashtech receiver type to make GLONASS double difference observations unbiased between given and golden receiver.

The optional reference position which can be generated inside ATOM observation messages is supposed to be referred to proper ITRF epoch year which is usually indicated inside ATOM body. Reference position in ATOM RNX can be tagged to different points including L1 phase center, antenna reference point and ground mark. Usually antenna height (the height of antenna reference point above ground mark) is provided together with reference position, so user can re-compute reference point position to ground mark position and vice versa. Also antenna name can be requested from receiver to allow transformation between L1 antenna phase center and antenna reference point.

Reference position in ATOM RNX can be either static (e.g. entered) position or can be kinematic (moving) position receiver computes each epoch. Latter case allows using RNX as differential data generated by moving receiver. The accuracy indicator of reference position can be also provided.

With multiple GNSS tracking, the definition of receiver clock offset and clock steering must be clarified. Internally receiver can estimate own clock offset against each of available GNSS time scales. Each epoch, some GNSS is selected as primary. Primary GNSS can affect up to:

- time tag presentation for some messages
- default datum for output position
- the reference time system when generating receiver clock offset estimate and making clock steering

Receiver clock offset estimate generated in PVT and RNX messages always refers to primary GNSS system specified in the header of these messages. Clock steering procedure applies this clock estimate equally to all GNSS observables. Receiver clock estimates against all GNSS scales receivers currently supports are output via STA messages group.

3. ATOM MESSAGES DESCRIPTION

This chapter contains the detailed (bit-to-bit) description of messages supported by ATOM format ver.1/2. A short summary of principal differences between v.1 and v.2 is provided in Appendix H. The following ATOM groups are described:

- Positioning results: ATOM PVT
- Attributes data: ATOM ATR
- Navigation data: ATOM NAV
- Raw binary data: ATOM DAT
- GNSS observations: ATOM RNX
- Supplementary data: ATOM SUP
- Status information: ATOM STA
- Events information: ATOM EVT
- Receiver alarms: ATOM ALR

It should be noted that ATOM messages described here are not all necessarily supported by all Ashtech receivers and in all firmware versions. Corresponding warning is provided in Product Manuals (see Appendix J as an example). Some of ATOM messages can be supported outside a GNSS receiver in different service procedures and/or PC tools. Also the reader should be aware that some indicators inside some ATOM messages can be set as follows:

- Adaptively, depending on the current receiver status, or
- To a fixed value, depending on user settings, or
- To some hard-coded value, depending on particular hardware/firmware combinations.

The messages are described independently of each other to allow the reader to concentrate efficiently only on a group of interest. That is why redundant information is introduced in each description, some general comments being repeated for a number of particular messages/fields. Before starting with a particular message, the reader should first be introduced to the generalized organization of the ATOM group that the given message belongs to.

When describing a message, some short information is provided on how it can be requested, what the basic principles are to output this message and what additional cross-information can be interesting regarding the message content and request. The mechanism used to generate ATOM messages is not part of the ATOM standard, but is usually independent of the receiver and firmware version. That is why the reader should not only understand the content of an ATOM message, but also learn how it can be requested and output from a receiver.

For a complete description of the ATOM serial interface please refer to the corresponding section.

3.1 Messages generation mechanism

Any ATOM message can usually be generated onto any available receiver port independently of each other. When describing the serial interface we mention <Port Name> as a substitute for the actual receiver port (A, B etc). The same ATOM message can be requested through more than one port and possibly with different intervals and parameters.

The time priority of one ATOM message over another ATOM message within the same epoch can be receiver/firmware dependent. The time priority of ATOM messages against non-ATOM data within complete epoch data is also receiver/firmware dependent.

When requested, each ATOM message is generated using a specific combination of the following principles:

- On new
- On change
- On time
- On event

'On new' means that the corresponding message is output immediately after being requested. 'On change' means that the corresponding message is output only after its content has changed. 'On time' means that the corresponding message is output on a regular basis, according to the requested time interval x. 'On event' means that a message can be generated, with its content tagged to some event in the receiver.

In some cases however, there is no obvious interpretation as to what is behind such or such output principle. For example 'on event' can be interpreted as 'on change' if the event refers to a change in some receiver state. Nevertheless, in most cases, the meaning is quite clear.

For example, the ATOM PVT message is primarily output using the 'on time' principle. If for example it is requested at an interval of x=0.5 seconds, then it will be output at receiver time tags corresponding to each integer and half-an-integer second. In some specific cases, the ATOM PVT message is output using the 'on event' principle. If for example the receiver is configured to output the so-called Time Tagged (or synchronous) RTK position, then ATOM PVT will be tagged to events when new RTK base data arrive at the rover, are decoded and processed by the RTK engine. But since in most cases, RTK base data arrive at the rover with equal intervals and stable latency, the 'on event' principle is here somehow equivalent to the 'on time' principle.

All ATOM DAT messages are output using the 'on change' principle, i.e. there is no need to specify an interval for outputting them. Each message is generated once the content of the receiver data buffer containing corresponding data has been updated, i.e. changed. In order to have unified serial interface pattern, one still can specify interval to output DAT messages, but this interval will be ignored.

ATOM,STA messages could be output using the 'on change' principle, i.e. a message is generated once the content of the receiver data buffer containing corresponding data has been updated i.e. changed. At the same time, most users can want to see STA messages with some preset interval and Ashtech implemented this strategy. In this case user can miss some internal status updates (if more than one internal update occurred between consecutive STA messages). Or user can get identical information in two consecutive STA messages if there was no any internal update between them.

Most of the ATOM NAV messages are output by combining the ‘on new / on change / on time’ principles. For example, if the ATOM NAV / EPH message is requested at an interval of x=600 seconds, then ephemeris data for a given satellite will be output immediately after request (‘on new’), and then in x=600 seconds (‘on time’) etc. If new ephemeris data (new IODE) for this satellite are decoded, these will be output immediately (‘on change’) and the counting of the interval of x=600 seconds will start from this moment.

About NAV messages, which serve all tracked satellites, it should be understood that such a rule is applied to each satellite independently. In order to save the overall peak throughput, no more than one NAV message is output over a single 1-second epoch. In other words, the minimal interval between any NAV messages is one second, while the nominal interval between NAV messages with fixed content is x seconds (e.g. 600). If the specified interval x is too short to allow all requested NAV messages to be output (one message per second) within this interval, then x will be set internally as low as necessary to satisfy the output strategy.

The x interval between messages cannot be chosen arbitrarily. For ‘fast’ messages, only the following intervals are valid: 0.05/0.1/0.2/0.5 sec. If a receiver supports higher update rates, then intervals 0.02 sec (50 Hz), 0.01 sec (100 Hz) and 0.005 sec (200 Hz) are also admissible. The phase of ‘fast’ messages is chosen in order to ‘acquire’ integer seconds of primary GNSS time. For ‘slow’ messages, any integer second interval is admissible (provided it is less than 999 sec). However, for the RNX group, only the following intervals are supported: 1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute of primary GNSS time (provided it is less than 15 minutes). The ‘phase’ of these messages is chosen in order to ‘acquire’ integer minutes of primary GNSS time. These intervals and shifts are recommended in RTCM-2 standard and ‘are kept in mind’ for all the other standards.

Messages of the PVT group support the same intervals as the RNX group. But in case of integer second intervals, the ‘phase’ of PVT messages is chosen in order to acquire integer minutes of UTC (and not primary GNSS) time. Assuming a 2-sec interval is selected for the RNX and PVT groups, GPS is the primary GNSS used and the GPS-UTC time shift is 15 sec (as from January 1, 2009 until June 30, 2012), then RNX and PVT will always be output for different time tags:

- Each even second of GPS time tag will contain RNX data
- Each odd second of GPS time tag (or each even second of UTC time tag) will contain PVT data.

Some ATOM messages being requested will be generated regardless their content is valid or not. E.g. ATM,PVT,COO data will be generated if receiver cannot compute position or computed position is internally recognized as invalid. In this case, position components will take pre-specified invalid value; at the same time, other fields in ATM,PVT,COO still can report valid values.

On contrary, some other ATOM messages being requested can stop outputting if their content is invalid or no longer actual. Say a particular NAV message (e.g. EPH with expired age of validity) is not output. Or messages of STA group (e.g. differential decoder status) stop outputting in case their content was not updated during some time.

3.2 Data Field Conventions

Each of the binary Data Fields (DF) described below fits one of the types presented in the following table.

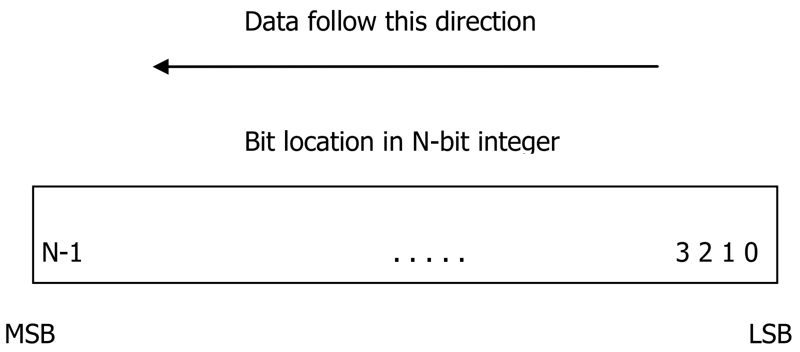
Data type	Description	Range	Example / Notes
bitX	Bit field, each bit is 0 or 1 X is the length of the bit field	0, 1	bit2: 2-bit field bit11: 11-bit field

uintX	X bit unsigned integer	0 to $(2^{X} - 1)$	uint8: 8-bit unsigned integer
intX	X bit 2`s complement integer	$\pm(2^{X-1} - 1)$	int8: 8-bit 2`s complement integer
intSX	X bit sign-magnitude integer	$\pm(2^{X-1} - 1)$	intS14: 14-bit sign-magnitude integer (see notes below)
char(X)	8-bit character set with total length in X chars	Character set with variable length	
utf8(X)	Unicode UTF08 Code Unit	Unicode set with variable length	

Note:

- **The intS** data type refers to a sign-magnitude value. The sign-magnitude representation records the number's sign and magnitude. MSB is 0 for positive numbers and 1 for negative numbers. The rest of the bits are the number's magnitude. For example, for 8-bit words, the representations of numbers "-7" and "+7" in a binary form are 10000111 and 00000111, respectively. Negative zero is not used.

The convention used for the Most and Least Significant Bits (MSB and LSB) for signed and unsigned data is presented in the diagram below.



ATOM uses a number of bit masks (indicated as field bitX) referring to GNSS set being transmitted (GNSS mask), Satellites being present (Satellite mask), Signals available (Signal mask) and many others. In all these masks the first bit is the bit with goes first in binary stream and the last bit is the bit which goes last in binary stream.

To insure quick reference to ATOM data fields, numerical equivalents to some of them are provided. Some ATOM data fields are the exact copy of the corresponding standardized RTCM-3 data fields, some are unique to the ATOM format. That is why ATOM data fields having exact RTCM-3 counterparts are marked as DFxxx. For example, data field 'Message Number' (uint12, 4095 reserved for Ashtech) is referenced as DF002. If reference to a data field is given in form 'see DF…', then it means that described field has something common with standardized DF but does not copy it exactly. Some other ATOM data fields, which are intended for proprietary use only, are referenced as AFxxx, where xxx is a unique number assigned to a given field. All the other fields are not marked.

The description below refers to ATOM ver. 1/2. Further ATOM versions will be marked with higher version numbers. The version number is provided inside each ATOM message (header). The 3rd party decoding equipment should check the version number before parsing the message and make no attempt to interpret it if the detected version number is higher than the currently supported one. Generally, a higher ATOM version number does not guarantee backward compatibility with the previous versions unless the decoder is updated for the new ATOM version.

Some ATOM messages contain reserved fields. 3rd party users should ignore all these fields. With ATOM development, some initially reserved fields (usually defined as zero) can become meaningful. Since 3rd party users ignore them, these changes should not hurt anyone. However, in some cases, newly introduced fields can play a vital role in the interpretation of other ATOM fields. In this case, the version number of the corresponding ATOM message will be increased and the corresponding Manual update (or Amendment) will be issued.

Some ATOM fields contain reserved states (e.g. 'supplementary follow' field in ATOM RNX, which contains one reserved state). ATOM ver. 1/2 does not generate these states, but new ATOM versions could. If a newly introduced state can play a vital role in parsing ATOM data, then the version number of the corresponding ATOM message will be increased and the corresponding Manual update (or Amendment) will be issued.

Some ATOM fields reserve one state to indicate an invalid value (e.g. invalid carrier phase). At the same time, some supplementary fields (e.g. corresponding SNR) can be still valid. Also, on rare occasions, some supplementary fields can take arbitrary values if the 'primary' field is indicated as invalid. In all these cases, the decoding equipment should process correctly (i.e. ignore) invalid fields and be careful with the interpretation of the corresponding supplementary fields.

In almost all the messages, ATOM generates field DF003 (reference station ID). This is the correct name if a receiver is used as reference station. However, if a receiver is not used as a reference station, DF003 field is still used as generalized indicator for a receiver.

3.3 Satellite, Signal and Cell Masks

All information is moved to "**Appendix I :** Satellite, Signal and Cell Masks"

3.4 ATOM PVT Message

ATOM PVT (Position, Velocity, Time) outputs receiver positioning results. It can generate all valuable data contained in the existing standardized NMEA (e.g. GGA, GSV, GST) and proprietary Ashtech (e.g. PBN, POS, SAT) messages. The PVT message is not a group of separated messages but a solid generic message containing a number of sub-block data. Some sub-blocks have fixed length, some others have variable length. Besides, there can be more than one PVT message corresponding to the same epoch time.

The ATOM PVT message with its default set of sub-blocks and intervals can be enabled/disabled using the following command:

$PASHS,ATM,PVT,<Port Name>,ON/OFF

The general organization of the PVT message is presented on Figure 3.4.a.

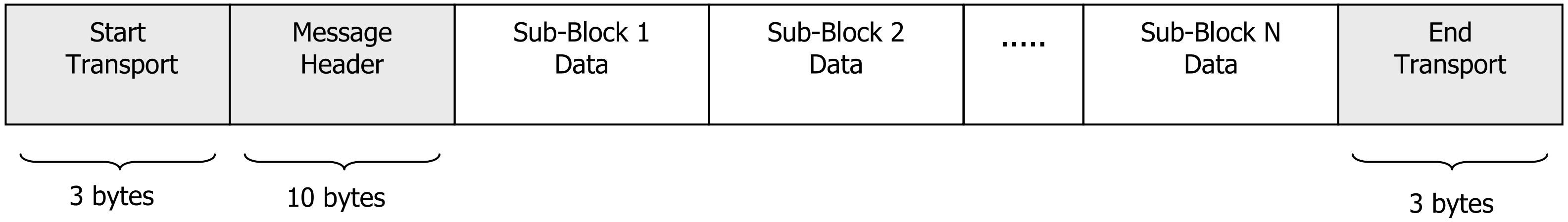


Figure 3.4.a. PVT message organization

The table below sketches the ATOM PVT message and presents the organization of its header.

Table 3.4.a. PVT header organization

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	Bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes	

MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	3 is reserved for ATOM PVT message	
Version	3	uint3	40		0-7	ATOM version number, set to 1 or 2	
Multiple message bit	1	bit1	43		0-1	1 : other PVT message(s) corresponding to given antenna ID, engine ID and request ID will be output for given time tag 0 : no other PVT message(s) corresponding to given antenna ID, engine ID and request ID will be output for given time tag	
Antenna ID	4	uint4	44		0-15	See Appendix G	AF019
Engine ID	6	uint6	48		0-63	See Appendix G	AF002
Request ID	4	uint4	54		0-15	See Appendix G	AF020
Reserved	5	bit5	58		0-31	Set to 00000	
Nsats used	6	uint6	63		0-63	Number of used satellites, 63 means not defined, 62 means 62+	
Nsats seen	6	uint6	69		0-63	Number of visible satellites, 63 means not defined, 62 means 62+	
Nsats tracked	6	uint6	75		0-63	Number of tracked satellites, 63 means not defined, 62 means 62+	
Primary GNSS system	2	uint2	81		0-3	0: GPS is primary 1: GLONASS is primary 2: BEIDOU is primary 3: reserved for other GNSS	
Time Tag	21	Bit21	83			Refers to the primary GNSS system time scale (see tables 3.4.b, 3.4.c and 3.4.d	
MESSAGE DATA							
Sub-blocks of PVT message						See sub-sections below	
END TRANSPORT							

CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

Notes:

- Unlike with other ATOM groups, the station ID is not provided in the ATM,PVT header. But it can be available in extended form (four Characters) in the ATM,PVT MIS block.
- ATOM version switch (1 or 2) affects the content of SVS block only (see below)
- The receiver usually features a number of basic PVT sub-engines; each of them (or some of their combinations) can deliver user position at given epoch, Field AF002 provides the information what PVT sub-engine(s) configuration delivered position results. In general, field AF002 can change with epochs depending on environmental conditions and/or the differential data link status. E.g. when data link stops for a long time, initially reported AF002=9 can transit to AF002=6.
- ATM,PVT is generic message and in some specific cases user can request a number of different PVT-style messages. So with multiple ATM,PVT messages referring to given time tag, end user must understand which messages corresponds to serial commands he/she issued to request them. Field AF020 allows user to match each decoded message with corresponding $PASHS,ATM,*** command request.
- It is supposed that up to more than one antenna connector can serve a particular GNSS board so antenna ID (AF019) is provided. For each h/w configuration each antenna connector can have its own unique index. For MB500 GNSS board, only antenna connector 1 is available. For MB100 GNSS board, two antennae connectors are available: antenna connector 1 refers to so called external antenna and can process L1/L2 signal, while antenna connector 2 refers to so called internal antenna and can process L1 signal only. For other future Ashtech boards there can be other relationships, but user Manual for each board exactly specifies what antenna connector index refers to. The antenna name which is generated in ATM,ATR,ANM message always refer to antenna corresponding to connector reported in this header. The complete status of each potentially available antenna is supposed to be seen via other message (see ATM,STA,AST).
- Usually all the data corresponding to the same antenna ID, engine ID, and request ID are generated within single PVT message (i.e. all blocks under the same header). However for some hardware targets and firmware versions, position data corresponding to the same IDs can be spread over more than one transmission. In this case M-bit is set as described to help PVT listener to compile complete PVT epoch corresponding to particular set of antenna ID, engine ID and request ID.

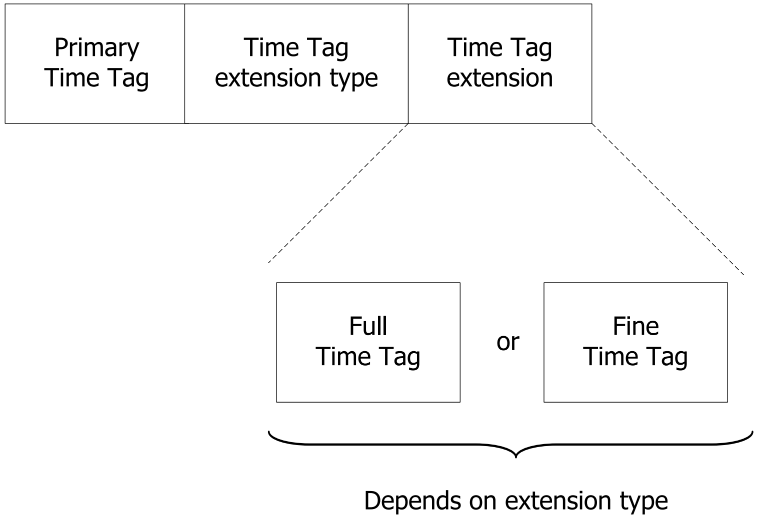


Figure 3.4.b. Time tag organization

Table 3.4.b. Time tag presentation

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
Primary time tag	12	uint12	0	1 second	0-3599	GNSS time modulo 1 hour, 4095 means invalid time	
Time tag extension type	1	bit1	12		0-1	1: fine time tag extension follows 0: full time tag extension follows	
Time tag extension	8		13			Primary time tag extension (see table below)	
Total	21						

Table 3.4.c. FULL Time tag presentation

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number

Hour	5	uint5	0	1 hour	0-23	GNSS hour within GNSS day	
Day	3	uint3	5	1 day	0-7	Set to GPS day (0…6) within GPS week, 0 is Sunday, 1 is Monday etc. Set to GLONASS day (0…6) within GLONASS week, 0 is Sunday, 1 is Monday etc. Se to BDS day (0…6) within BDS week,, 0 is Sunday, 1 is Monday etc. In each case, 7 refers to unknown day	
Total	8						

Table 3.4.d. FINE Time tag presentation

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
Fractional second	8	uint8	0	5 ms	0-995	GNSS time modulo 1 sec	
Total	8						

Notes:

- The time tag always refers to the time scale of the primary GNSS system used, i.e. UTC + Nls (where Nls is the number of leap seconds, i.e. 15 as from Jan 1 2009, and 16 as from July 1 2012 for GPS, and UTC+3 hours for GLONASS.
- The size of the time tag is always fixed.
- Using the switchable time tag presentation, users can cover a full range of GNSS time tags with fine resolution. If the time tag is an integer second, the ATOM generator will insert full extension information to reduce whole time tag ambiguity down to a week number. If the time tag is a fractional second, then the ATOM generator will insert a fine time tag extension thus allowing data to be generated at up to 200 Hz.
- If a leap second occurs, the primary time tag is set to 3600

The supported PVT sub-blocks are presented in Table 3.4.e.

Table 3.4.e. Supported PVT sub-blocks

PVT sub block type	ASCII identifier	Sub-block name	Block size, bytes	Data block ID/subID	Comments	Counterpart
GENERAL PURPOSE BLOCKS						
0		Reserved		0000		
1	COO	Position	26	0001	Position, flags, differential age, base ID etc	$PASHR,POS $GPGGA
2	ERR	Accuracy	10	0010	Accuracy (lat/lon/alt errors covariance)	$GPGST
3	VEL	Velocity	12	0011	Velocity estimates and its attributes	$PASHR,POS $GPVTG
4	CLK	Clock	10	0100	Receiver clock estimates and its attributes	$PASHR,PBN
5	LCY	Latency	3	0101	Position latency	$PASHR,LTN
6	HPR	Attitude	11	0110	Heading, pitch and roll estimates and its attributes	$PASHR,ATT $GPHDT
7	BLN	Baseline	16	0111	3D baseline components and its attributes	$PASHR,VEC
8	MIS	Miscellaneous	23	1000	Position supplementary data	$GPRMC $GPGGA $GPZDA
9	ROT	Extended Attitude Parameters	13	1001	Attitude supplementary data	N/A
10	BSD	Extended Baseline parameters	19	1010	Baseline supplementary data	N/A
11		Reserved		1011		
12		Reserved		1100		
13	PRR	Pseudo-range Residuals	Depends on tracking/usage statust	1101	Pseudo-range Residuals for L1 signal only	$GPGRS
14	SVS	Sat status	Depends on ATM,PVT version and tracking status	1110	Satellite tracking/usage information	$PASHR,SAT $GPGSV
SPECIAL BLOCKS (1111)						
15,0		Reserved		00000000		
15,1	LDP	Local Datum Position	Depends on message	00000001	Position from block COO expressed in local user datum	N/A

			content			
15,2	CDC	Custom Datum Clarification	Depends on message content	00000010	The name and parameters of the custom datum of position in COO block	N/A
15,3	LMP	Local Map Projection	Depends on message content	00000011	Position from block LDP expressed in local cartographic projection	$GPGMP
15,4-15,255		Reserved		00000100-11111111		

All supported PVT blocks (except 15) output general-purpose position information, which is usually available for each GNSS receiver/firmware. In future, reserved blocks can contain some extra general purpose position data. In contrast, block 15 (Special messages) can contain some information specific to particular GNSS receiver/firmware. The organization of general-purpose and special blocks is presented in the tables below.

Table 3.4.f. Presentation of general purpose PVT sub-blocks

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
GENERAL PURPOSE SUB-BLOCK DATA							
Block size, X	8	uint8	0		0-255	The size of given block in bytes including this field	
Block ID	4	uint4	8		0-14	Reserved for general purpose data	
Sub block data			12			Each of blocks 0-14	
Total	8*X						

Table 3.4.g. Presentation of special PVT sub-blocks

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SPECIAL SUB-BLOCK DATA							
Block size, X	8	uint8	0		0-255	The size of given block in bytes including this field	

Block ID	4	uint4	8		15	Reserved for a variety of special data	
Special block sub-ID	8	uint8	12		0-255	Special data block ID	
Special sub block data			20			Each of blocks 15,0-255	
Total	8*X						

The next sections present the structure of each of the currently supported sub-blocks in the ATOM PVT message. Each PVT sub-block is described independently of each other. It is supposed that generally more than one sub-block can follow the ATOM PVT header.

3.4.1 ATOM PVT Message / Sub-Block: Position message

This sub-block contains the most valuable information about computed position. Usually, the position refers to the default datum of the primary GNSS system specified in the ATOM PVT header. But ATOM is open to outputting position on a custom datum. Some additional (not operative yet) position information can be sent through the Miscellaneous (MIS) sub-block, but at a lower rate.

Output Logic: on time
Sub-block Binary size: 26 bytes (208 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&COO
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc., each integer minute but less than 15 min
See also: $PASHR,POS; $GPGGA

Table 3.4.1.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Set to 26	
Block ID	4	uint4	8		0-15	Set to 1	
Position type (GGA presentation)	4	uint4	12		0-15	0: invalid fix 1: standalone 2: diff corrected (including SBAS corrected) 3: GPS PPS mode 4: RTK fixed 5: RTK float 6: dead reckoning 7: entered position 8: simulator mode 9-14: reserved 15: not defined	
GNSS usage mask	8	bit8	16		0-255	Bit1: GPS is used in position Bit2: GLONASS is used in position Bit3: GALILEO is used in position	

						Bit4: SBAS (ranging) is used in position Bit5: QZSS is used in position Bit6: Beidou is used in position Bit7-8: Reserved for other GNSS	
Position mode	3	uint3	24		0-7	0: 3D GNSS position 1: 2D position with entered altitude 2: 2D position with 'frozen' altitude 3-6: reserved 7: not defined	
Position smoothing	3	uint3	27		0-7	0: not smoothed 1: averaged static position 2: smoothed kinematic position 3-6: reserved 7: not defined	
Reserved	4	bit4	30		0-15	Set to 0…0	
PDOP	10	uint10	34	0.1	0-102.2	Corresponds to satellites used (102.3 if not defined or invalid)	
HDOP	10	uint10	44	0.1	0-102.2	Corresponds to satellites used (102.3 if not defined or invalid)	
X coordinate	38	int38	54	0.1 mm	+/-13743895.3471 m	-13743895.3472 m if not defined or invalid	DF025
Y coordinate	38	int38	92	0.1 mm	+/-13743895.3471 m	-13743895.3472 m if not defined or invalid	DF026
Z coordinate	38	int38	130	0.1 mm	+/-13743895.3471 m	-13743895.3472 m if not defined or invalid	DF027
Differential position age	10	uint10	168	1 sec	0-1023	Age of differential corrections applied to PVT (1023 if not defined or invalid, 1022 if valid but >1022)	
Base ID	12	uint12	178		0-4095	Base station ID	DF003
Position type clarifier	4	uint4	190		0-15	See Appendix G	AF003
Differential link age	10	uint10	194	1 sec	0-1023	Age of differential data link (1023 if not defined or invalid, 1022 if valid but >1022)	Differential link age
Reserved	4	uint4	204			See Appendix G	AF023
Total	208						

Notes:

- If invalid fix is reported, some supplementary fields (e.g. Base ID or differential age) can still have some sense.
- If position is invalid, then position type clarifier (AF003) contains the cause of invalid position.
- With at least one GPS or GLONASS or GALILEO or QZSS or SBAS or BeiDou (ranging) satellite used in the position computation, the corresponding bit is set accordingly.
- In differential SBAS, the base station ID is the PRN of the master (or primary) SBAS (120-158).
- Some fields have a reserved state meaning "not defined". This is because not all PVT engines can provide information for these fields.
- The position type clarifier (AF003) is provided to specify in more details what is behind the standardized GGA-type position flag, e.g. to distinguish between DGNSS and DSBAS.
- All DOPs figures are computed assuming independent clock offset for each GNSS, i.e. in case of 3 GNSS systems used (GPS+GLONASS+GALILEO), GDOP matrix is 6x6 matrix.
- Reported Differential position age refers to the difference between current time tag and the time tag to which applied original differential corrections are tagged (i.e. correction project time).. Please note, that last received corrections in some cases can be not applied. So growing of differential position age does not always mean data link stop, but indicates the degree of position degradation.
- On contrary, Differential link age refers to the difference between current time tag and the time tag to which latest decoded corrections are tagged to. So growing differential link age does mean failure on base or in communication.
- Position is reported as Cartesian position. Geodetic position can be computed by user applying proper ellipsoid parameters. The datum bit (default or custom) is provided in MIS block. If datum is 'default', then user must apply corresponding default ellipsoid parameters unique for GNSS specified as primary. If datum is 'custom', then its name and ellipsoid parameters are available via additional CDC (custom datum clarification) block.
- There is no guarantee that reported differential position is tagged to 'default' (specific for a GNSS system selected as primary) datum even it is claimed so. In fact, the datum will be defined by the datum reference position is expressed in. There are evidences that some providers generate reference positions tagged to local datum w/o explicit specification of this, e.g. some Network providers in US generate reference position in NAD83 without any mentioning of this.

3.4.2 ATOM PVT Message / Sub-Block: Accuracy message

This sub-block refers to the data presented in the position (COO) sub-block described above. It contains parameters allowing the complete position covariance matrix (symmetric, positive definite) to be restored. When reporting differential (RTK, DGPS) position accuracy, it is assumed that base coordinates are 100% accurate.

$$S = \begin{bmatrix} s11 & s12 & s13 \\ & s22 & s23 \\ & & s33 \end{bmatrix}$$, where s11, s22 and s33 are always positive. All other terms can be negative.

Here indexes 1, 2, and 3 refer to latitude (northing), longitude (easting), and altitude (up) components of position (baseline) respectively.

Output Logic: on time
Sub-block Binary size: 10 bytes (80 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&ERR
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: $GPGST

Table 3.4.2.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Set to 10	
Block ID	4	uint4	8		0-15	Set to 2	
Sigma	20	uint20	12	0.001 m	0-1048.574 m	1048.575 if not defined or invalid.	
k1	7	uint7	32	1/128	0…1	Have meaning only if Sigma is valid	
k2	7	uint7	39	1/128	0…1	ditto	
k3	7	uint7	46	1/128	0…1	ditto	
r12	8	int8	53	1/128	-1…1	ditto	
r13	8	int8	61	1/128	-1…1	ditto	

r23	8	int8	69	1/128	-1…1	ditto	
Reserved	3	bit3	77		0-7	See Appendix G	AF021
Total	80						

Notes:

- If Sigma is set to an invalid value, then all other fields in this sub-block are also invalid and can take arbitrary values.
- Sigma= $\sqrt{s11 + s22 + s33}$ meter
- $k1 = \frac{\sqrt{s11}}{sigma}$; $k2 = \frac{\sqrt{s22}}{sigma}$; $k3 = \frac{\sqrt{s33}}{sigma}$ all unitless
- $r12 = \frac{s12}{\sqrt{s11 * s22}}$; $r13 = \frac{s13}{\sqrt{s11 * s33}}$; $r23 = \frac{s23}{\sqrt{s22 * s33}}$ all ('square') unitless
- Reported covariance matrix needs not any additional scaling because reports actual 1sigma accuracy figures. E.g. random variable ratio1=err1/sqrt(s11) should theoretically follow Gaussian (0,1) distribution.

3.4.3 ATOM PVT Message / Sub-Block: Velocity message

This sub-block contains receiver velocity components.

Output Logic: on time
Sub-block Binary size: 12 bytes (96 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&VEL
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: $PASHR,POS; $GPVTG

Table 3.4.3.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Set to 12	
Block ID	4	uint4	8		0-15	Set to 3	
X velocity	25	int25	12	0.0001 m/s	+/- 1677.7215 m/s	- 1677.7216 if not defined or invalid	
Y velocity	25	int25	37	0.0001 m/s	+/- 1677.7215 m/s	- 1677.7216 if not defined or invalid	
Z velocity	25	int25	62	0.0001 m/s	+/- 1677.7215 m/s	- 1677.7216 if not defined or invalid	
Velocity type	1	bit1	87		0-1	0: 'instant' velocity 1: 'mean' velocity	
Doppler/velocity smoothing interval	4	uint4	88		0-15	See table 3.4.3.b	
Reserved	4	bit4	92		0-15	See Appendix G	AF022
Total	96						

Table 3.4.3.b Mapping table for velocity smoothing interval

Smoothing interval identifier	Effective interval, sec	Comment
0	0	Refers to instant velocity computed with rough Doppler
1	0-0.005	
2	0.005-0.01	
3	0.01-0.02	
4	0.02-0.05	
5	0.05-0.1	
6	0.1-0.2	
7	0.2-0.5	
8	0.5-1	
9	1-2	
10	2-3	
11	3-4	
12	4-5	
13	Reserved	
14	Reserved	
15	No interval defined	

Notes:

- ‘Instant’ velocity refers to the true estimate of the position derivative for a given time tag, as opposed to ‘mean’ velocity, which refers to the estimate of the position increment on some interval divided by this interval. In this case, the true position derivative is tagged to the center of this interval.

- In case of ‘instant’ velocity, the smoothing interval is that of the corresponding Doppler/velocity filter. In case of ‘mean’ velocity, the smoothing interval is the exact interval of integrated Doppler. In this case, the smoothing interval is equal to the upper bound value corresponding to the selected Smoothing interval identifier. For example, with Smoothing interval identifier=10, the smoothing interval is 3 seconds.

3.4.4 ATOM PVT Message / Sub-Block: Clock message

This sub-block contains receiver clock offset parameters.

Output Logic: on time
Sub-block Binary size: 10 bytes (80 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&CLK
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: $PASHR,PBN

Table 3.4.4.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Set to 10	
Block ID	4	uint4	8		0-15	Set to 4	
Clock steering	1	bit1	12		0-1	1: clock steering is applied 0: clock steering is not applied	
External clock	1	Bit1	13		0-1	1: external clock is used 0: internal clock is used	
Receiver clock offset	30	int30	14	0.001 m	+/-536870.911 m	-536870.912 if not defined or invalid	
Receiver clock drift	22	int22	44	0.001 m/s	+/- 2097.151 m/s	-2097.152 if not defined or invalid	
TDOP	10	uint10	66	0.1	0-102.2	102.3 if not defined or invalid	
Reserved	4	bit4	76		0-15	Set to 0000	
Total	80						

Notes:

- A receiver can apply or not apply the so-called clock steering procedure. However the receiver clock offset and drift reported in this message always refer to the original (internal) receiver clock, which is typically within +/-300 km or so.
- A receiver can be clocked from an internal or external (usually very stable) oscillator. The corresponding bit is therefore provided.

- Reported receiver clock offset and drifts (as well as TDOP value) refers against primary GNSS system specified in PVT message header
- It must be noted that clock steering procedure affects reported position (block COO) for very high dynamic receiver. In this case, user who desires to return to original receiver status (not steered) will have to correct reported position (COO) using the knowledge of reported receiver velocity (block VEL) and internal clock offset (given block).

3.4.5 ATOM PVT Message / Sub-Block: Latency message

This sub-block contains latency of given ATM,PVT message.

Output Logic: on time
Sub-block Binary size: 3 bytes (24 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&LCY
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: $PASHR,LTN

Table 3.4.5.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Set to 3	
Block ID	4	uint4	8		0-15	Set to 5	
Latency	12	uint12	12	1 ms	0-4095	4095 if not defined or invalid, see also the table 3.4.5.b	
Total	24						

Table 3.4.5.b Mapping table for Latency

Latency interval identifier	Effective interval, msec	Comment
0-4087	0-4087	Nominal mode
4088	4088-5000	Latency is within 4.088 to 5 seconds
4089	5001-6000	Latency is within 5 to 6 seconds
4090	6001-7000	Latency is within 6 to 7 seconds

4091	7001-8000	Latency is within 7 to 8 seconds
4092	8001-9000	Latency is within 8 to 9 seconds
4093	9001-10000	Latency is within 9 to 10 seconds
4094	>10000	Latency is >10 seconds but still valid
4095	Invalid latency	Latency is not defined or invalid

Note:

- This latency presentation table is intended to report latency with good resolution for conventional PVT modes when latency is typically below 1 second. On the other hand, in specific positioning modes, such as synchronous (or Time Tagged) RTK, position latency is primarily defined by the data link latency, which can reach 10 seconds in some cases. When latency is too high, then there is no need to report it with ms resolution.
- The reported latency refers to the delay of the ATM,PVT output instance compared to the ATM,PVT time tag. This reported latency is unique for given ATM,PVT message and may differ from the latency reported in the $PASHR,LTN message.

3.4.6 ATOM PVT Message / Sub-Block: Attitude message

This sub-block contains attitude parameters.

Output Logic: on time
Sub-block Binary size: 11 bytes (88 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&HPR
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: $PASHR,ATT; $GPHDT

Table 3.4.6.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Set to 11	
Block ID	4	uint4	8		0-15	Set to 6	
Heading	16	uint16	12	0.01 degree	0-360	Value >360 means not defined or invalid	
Pitch	16	int16	28	0.01 degree	+/-90	Value > 90 & Value < -90 means not defined or invalid	
Roll	16	int16	44	0.01 degree	+/-90	Value >90 & Value < -90 means not defined or invalid	
Calibration mode	1	bit1	60		0-1	0: calibration mode 1: operation mode	
Ambiguity flag	1	bit1	61		0-1	0: fixed ambiguity 1: float ambiguity	
Antenna setup	2	uint2	62		0-3	0: 2 arbitrary moving antennae 1: 2 tightly moving antennae 2: 3 tightly moving antennae 3: 4+ tightly moving antennae	
MRMS	10	uint10	64	0.001 m	0-1.022 m	1.023 means not defined or invalid	
BRMS	10	uint10	74	0.001 m	0-1.022 m	1.023 means not defined or invalid	
Reserved	4	uint4	84		0-15	See Appendix G	AF024
Total	88						

Note:

- For the description of fields MRMS and BRMS, see ATT message definition.
- The BRMS field is reported invalid if the lengths of baselines are not known a priori.
- When antenna setup = 1,2,3, then reported angles refer to platform (where antennae installed on) attitude. When antenna setup=0, then reported heading refers to baseline azimuth, reported pitch refers to baseline elevation, roll is reported as invalid.
- When single baseline (2 antennae) is applied for attitude estimation, either pitch or roll (or both) is not available. When 2 and more baselines (3+antennae) are applied for attitude estimation, all angles can be generally available. But in some singular cases, some of 3 angles can be not available even with 3+ antennae.
- In case of single baseline, HPR block being transmitted with BLN block under the same PVT header indicates that HPR content is based on BLN estimate.

3.4.7 ATOM PVT Message / Sub-Block: Baseline message

This sub-block contains baseline estimates. These estimates are applicable only to MS differential operation. Here MS refers to Measurement Space corrections by contract to Stage Space (SS) corrections for which (SS) baseline is not defined at all.

Output Logic: on time
Sub-block Binary size: 16 bytes (128 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&BLN
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: $PASHR,VEC

Table 3.4.7.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Set to 16	
Block ID	4	uint4	8		0-15	Set to 7	
Baseline coordinate frame	3	uint3	12		0-7	0: XYZ 1: rectilinear ENU centered on rover 2: rectilinear ENU centered on base 3-7: reserved	
Base motion assumption	2	uint2	15		0-3	0: static base 1: moving base 2: reserved 3: unknown	
Base accuracy assumption	2	uint2	17		0-3	0: exact base coordinate 1: approximate base coordinates 2: reserved 3: unknown	
Baseline flag	2	uint2	19		0-3	0: invalid baseline 1: code differential 2: RTK float 3: RTK fixed	

Arrow option	1	Bit1	21		0-1	0: Arrow option is not applied 1: Arrow option is applied	
Baseline 1st component	35	int35	22	0.0001 m	+/- 1717986.9183 m	- 1717986.9184 Means invalid value	
Baseline 2nd component	35	int35	57	0.0001 m	+/- 1717986.9183 m	Ditto	
Baseline 3rd component	35	int35	92	0.0001 m	+/- 1717986.9183 m	Ditto	
Common clock drift mode	1	Bit1	127		0-1	0: base and rover clocks assumed different 1: base and rover clock drifts assumed the same	
Total	128						

Note:

- Baseline components are expressed according to the value of "Baseline coordinate frame".
- Baseline refers to the vector between L1 antenna phase centers.
- If the baseline flag is set to invalid, then the complete block must be considered as invalid and all the fields can take arbitrary values.
- An invalid baseline estimate does not imply an invalid position in sub-block COO (e.g. standalone position for which baseline is not defined).
- Valid COO and BLN blocks being tagged to the same PVT solution ID, source ID and antenna ID are related to each other by the simplest formulae: position=base+baseline, where base is the coordinates of reference receiver (static or moving, physical or virtual).
- Being expressed in XYZ, baseline does not depend on primary GNSS system (i.e. primary datum) reported. To convert XYZ baseline into any rectilinear ENU system proper default ellipsoid model (corresponding to Primary GNSS system) is used.
- Arrow option refers to using or not using a priori knowledge that given baseline has known fixed length. If fixed length is not known yet (e.g. Arrow calibration stage), then given indicator reports 0.
- Common clock drift indicator can be valuable for so called internal heading configuration or when base and rover boards are fed by external occilator.

3.4.8 ATOM PVT Message / Sub-Block: Miscellaneous message

This sub-block contains various supplementary parameters. These are the data that usually change slowly and accompany position sub-block (COO) information. To save throughput, this sub-block can be requested at a lower rate than the position sub-block.

Output Logic: on time
Sub-block Binary size: 23 bytes (184 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&MIS
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: $GPGGA; $GPRMC; $GPZDA

Table 3.4.8.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Set to 23	
Block ID	4	uint4	8		0-15	Set to 8	
Site ID	32	char(4)	12			The same as in $PASHR,PBN message	
Position point	3	uint3	44		0-7	0: Antenna reference point 1: L1 phase center 2-5: Reserved 6: Ground mark 7: unknown	
Reserved	2	uint2	47		0-3	See Appendix G	AF006
Antenna height	16	uint16	49	0.0001 m	0-6.5535	Value 6.5535 means 6.5535+	DF028
Datum	1	Bit1	65		0-1	0: default 1: custom	
Default datum clarification	6	uint6	66		0-63	63 if not defined or invalid	DF021
Geoid height	16	int16	72	0.01m	+/- 327.67	-327.68 if not defined or invalid	
The number of GNSS time cycles	12	uint12	88		0-4095	For GPS wn modulo 4095 cycle	

						For GLO day number of 4 year period (DF129) 4095 means underfined or invalid	
GPS-UTC time shift	6	uint6	100	1 s	0-63	63 if not defined or invalid	See DF054
Magnetic variation	16	int16	106	0.01 degree	+/-180	Value > 180 & Value < -180 means not defined or invalid	
Local zone time offset	11	uint11	122	1 min	0-1439	Value > 1439 if not defined or invalid	
Type of used ephemeris	3	bit3	133		0-15	0: almanac used 1: broadcast ephemeris used 2-6: reserved 7: unknown	
Firmware version	32	char(4)	136			Reserved	
Reserved	16	bit16	168		0-	Set to 0…0	
Total	184						

Notes:

- Normally the position reported by the receiver refers to the so-called default datum, which is generally different depending on the primary GNSS used. The default datum can additionally be clarified, e.g. by specifying the ITRF epoch year when GPS is primary (Default datum clarification field). It must be noted that field DF028 is not still mandatory in RTCM document. It is now reserved to output ITRF epoch year. That is why user is recommended to ignore its content.
- If field ‘datum’ is set to custom, then extra ATM,PVT,CDC (Custom Datum Clarification) block can be generated to clarify what this custom datum is and what its parameters are.
- The receiver can also additionally report position tagged to some local datum. See ATM,PVT,LDP (Local Datum Position) block for details.
- For Geoid height, local zone time offset, magnetic variation, please refer to NMEA-4.0 definitions.
- The number of GNSS time cycles refers to GPS Week number (0-4095; 0 starts midnight January5/January 6 1980, rolls from 4095 to 0) if GPS is primary system.
- The number of GNSS time cycles refers to GLONASS day number (1-1461, day 1 corresponds to January 1 1996, rolls from 1461 to 1, zero means unknown day, values 1462-4095 are not used) if GLONAS is primary system.
- The number of GNSS time cycles refers to BDS Week number (0-4095; 0 starts midnight January 1 2006 (Sunday), rolls from 4095 to 0) if BDS is primary system.
- In all the cases, antenna height refers to the vertical distance between Antenna Reference Point and Ground Mark.

3.4.9 ATOM PVT Message / Sub-Block: Supplementary Attitude Data

This sub-block contains supplementary information to HPR sub-block, such as attitude rate, attitude accuracy and some other valuable indicators. User can request it additionally if HPR information is not sufficient for his/her application.

Output Logic: on time
Sub-block Binary size: 13 bytes (104 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&ROT
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: N/A

Table 3.4.9.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	Uint8	0		0-255	Set to 13	
Block ID	4	Uint4	8		0-15	Set to 9	
Heading speed	16	int16	12	0.01d/s	+/-327.67 d/s	-327.68 means invalid	
Pitch speed	16	int16	28	0.01d/s	+/-327.67 d/s	-327.68 means invalid	
Roll speed	16	int16	44	0.01d/s	+/-327.67 d/s	-327.68 means invalid	
Heading rms error	10	uint10	60	0.01 d	0-10.23 d	10.22 means 10.22+ 10.23 means invalid	
Pitch rms error	10	uint10	70	0.01 d	0-10.23 d	10.22 means 10.22+ 10.23 means invalid	
Roll rms error	10	uint10	80	0.01 d	0-10.23 d	10.22 means 10.22+ 10.23 means invalid	
Extrapolation interval	10	uint10	90	10 ms	0-10230 ms	0 means time tagged estimates 10230 means 10230+	
Reserved	4	bit4	100			See Appendix G	AF017
Total	104						

Note:

- Sign conventions for angular speed needs to be specified.
- Accuracy reported as 0 (zero) does not mean invalid estimate. For example if heading is estimated by very long baseline (e.g. >100 meters), then actual accuracy can be much better than used resolution. So reported zero accuracy actually tells that it is between 0 and 0.01 degree rms.
- Extrapolation interval is considered as true even if associated angles (and their derivatives) are reported as invalid.

3.4.10 ATOM PVT Message / Sub-Block: Baseline Supplementary Data

This sub-block contains supplementary information to BLN sub-block, such as baseline change rate, baseline accuracy and some other valuable indicators. User can request it additionally if BLN information is not sufficient for his/her application.

Output Logic: on time
Sub-block Binary size: 19 bytes (152 bits)
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&BSD
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: N/A

Table 3.4.10.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	Uint8	0		0-255	Set to 19	
Block ID	4	Uint4	8		0-15	Set to 10	
Sigma	20	uint20	12	0.001 m	0-1048.574 m	1048.575 if not defined or invalid.	
K1	7	uint7	32	1/128	0…1	Have meaning only if Sigma is valid	
K2	7	uint7	39	1/128	0…1	Ditto	
K3	7	uint7	46	1/128	0…1	Ditto	
R12	8	int8	53	1/128	-1…1	Ditto	
R13	8	int8	61	1/128	-1…1	Ditto	
R23	8	int8	69	1/128	-1…1	Ditto	
Baseline extrapolation interval	10	Uint10	77	10 ms	0-10230 ms	0 means time tagged estimate 10230 means 10230+	
BaseID	12	Uint12	87		0-4095		
Reserved	5	Bit5	99			Set to 00000	
Reserved	48	Bit48	104			Set to 0…0	

Total	152	

This sub-block refers to the data presented in the baseline (BLN) sub-block described above. It contains parameters allowing the complete baseline covariance matrix (symmetric, positive definite) to be restored. It is assumed that base coordinates are quite accurate and do not insert extra error into baseline estimate. The covariance is defined as

$$S = \begin{bmatrix} s11 & s12 & s13 \\ & s22 & s23 \\ & & s33 \end{bmatrix}$$, where s11, s22 and s33 are always positive. All other terms can be negative.

Here indexes 1, 2, and 3 refer to 1st, 2nd and 3rd baseline components correspondingly as defined by used coordinate frame reported in BLN block. The below is correspondence between covariance matrix elements and BSD fields (the formulae is the same as for ERR block referring to COO accuracy)/

If Sigma is set to an invalid value, then all other fields in this sub-block are also invalid and can take arbitrary values.

Sigma= $\sqrt{s11 + s22 + s33}$ meter

$k1 = \frac{\sqrt{s11}}{sigma}$; $k2 = \frac{\sqrt{s22}}{sigma}$; $k3 = \frac{\sqrt{s33}}{sigma}$ all unitless

$r12 = \frac{s12}{\sqrt{s11 * s22}}$; $r13 = \frac{s13}{\sqrt{s11 * s33}}$; $r23 = \frac{s23}{\sqrt{s22 * s33}}$ all (‘square’) unitless

Reported covariance matrix needs not any additional scaling because reports actual 1sigma baseline accuracy figures. E.g. random variable ratio1=err1/sqrt(s11) should theoretically follow Gaussian (0,1) distribution.

Additionally the block reports baseline extrapolation (if applied) interval with resolution 10 ms and Base station ID. I good number of reserved bits are created to support more baseline supplementary data in future.

3.4.11 ATOM PVT Message / Sub Block: Pseudo-range residuals message

3.4.12 ATOM PVT Message / Sub-Block: Satellite information message

The content of given block is ATOM PVT version dependent. This sub-block contains the status of each visible (by almanac) satellite. No SNR, elevation and other masks are applied to output satellites status. One SVS sub-block describes the status of a single GNSS. If a receiver tracks GPS, GLONASS, SBAS, GALILEO, and QZSS, then 5 SVS sub-blocks will be generated sequentially under the same ATOM PVT header provided PVT message size is still below 1023 bytes. The organization of SVS data is very similar to data organization in the ATOM RNX message (see Section 3.8 and Appendix E).

Output Logic: on time
Sub-block Binary size: depends on the number of signals
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&SVS
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also: $PASHR,SAT; $GPGSV

The complete SVS sub-block for each GNSS includes three groups of data that are generated one after the other:

- SVS header
- Satellite data
- Signal data

Table 3.4.12.a SVS header for ATOM PVT version 2

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SVS HEADER							
Block size	8	uint8	0		0-255	Set to 23 + 3*Nsat + 2*Ncell	
Block ID	4	uint4	8		0-15	Set to 14	
GNSS ID	3	uint3	12		0-7	0: GPS 1: SBAS 2: GLONASS 3: GALILEO 4: QZSS 5: Beidou 6-7: reserved for other GNSS	
Satellite mask	64	Bit64	15			See Appendix E	DF394
Signal mask	32	Bit32	79			See Appendix E	DF395

Cell mask	64	bit64	111			See Appendix E	See DF396
Reserved	9	bit9	175		0-511	Set to 000000000	
Total	184						

Table 3.4.12.b SVS header for ATOM PVT version 1

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SVS HEADER							
Block size	8	uint8	0		0-255	Set to 19 + 3*Nsat + 2*Ncell	
Block ID	4	uint4	8		0-15	Set to 14	
GNSS ID	3	uint3	12		0-7	0: GPS 1: SBAS 2: GLONASS 3: GALILEO 4: QZSS 5: Beidou 6-7: reserved for other GNSS	
Satellite mask	40	bit40	15			See Appendix E	See DF394
Signal mask	24	bit24	55			See Appendix E	See DF395
Cell mask	64	bit64	79			See Appendix E	See DF396
Reserved	9	bit9	143		0-511	Set to 000000000	
Total	152						

Notes:

- Unlike the ATOM RNX message, the size of the Cell mask is always fixed and equal to 64 bits. This is to simplify the parsing of the SVS sub-block. Actually only the first Nsat*Nsig bits in the Cell mask have sense. All the remaining bits are set to zero.
- ATOM,PVT ver.1 defines Sat mask size 40 bits and Signal mask size 24 bits. ATOM,PVT ver.2 defines Sat mask size 64 bits and Signal mask size 32 bits. The meaning of first 40 bits in Sat mask v.2 and Sat mask v.1 is the same. The meaning of first 24 bits in Signal mask v.2 and Signal mask v.1 is the same. Decoding equipment must analyze ATOM,PVT version number and process all the other fields accordingly.

- If experienced size of Cell mask exceeds 64 bits (e.g. 14 Satellites and 5 Signals, i.e. 14*5=70>64), then tracking status for given GNSS can be presented by two or more sequential SVS blocks complementary to each other. Decoding equipment must assume such a possibility.
- A Sat which is visible but not tracked can report single (ghost because it is not tracked yet) signal in signal mask. This is usually signal 1C. At the same time, such a Sat can report no signals, so ATOM PVT SVS parser take into account that while Satellite data are present for it, Signal data are absent.

Table 3.4.12.c Satellite data

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SATELLITE DATA							
Elevation	7 Nsat times	uint7 (Nsat)		1 degree		0-90 means true positive elevation 91 means true elevation -1 degree 92 means true elevation -2 degrees etc. 126 means true elevation less or equal to -36 degrees 127 means invalid elevation	
Azimuth	8 Nsat times	uint8 (Nsat)		2 degree	0-358	>358 means invalid azimuth	
Sat correcting status	4 Nsat times	uint4 (Nsat)			0-15	0: Sat is not tracked 1: no corrections applied 2-14: corrections applied 15: not known status See Appendix G	AF008
Sat usage status	5 Nsat times	uint5 (Nsat)			0-31	0: Sat is not tracked 1-3: Sat is used in position 4-14: Reserved 15: not known status 16-31: Sat is not used in position See Appendix G	AF007
Total	24*Nsat						

Notes:

- Nsat is the number of visible satellites for a given GNSS. It is equal to the number of 1's in the Satellite mask field.
- Each particular field uses internal looping, e.g. the Elevation field includes sequentially following elevations for all visible satellites. Here visible satellite is designed as each which is currently tracked (can have negative elevation in some specific cases) and any other which is not tracked but is above horizon in correspondence with latest almanac.
- The Sat correcting status field informs users if differential corrections are applied to a given satellite (e.g. RTK, DGPS, SBAS etc.).

- If at least one observable of a given satellite is used in position, then this satellite is considered as used. Otherwise, it is considered as not used.
- The Sat correcting status and Sat usage status fields are quite independent of each other. A satellite can be corrected but not used in position, or vice versa.

Table 3.4.12.d Signal data

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SIGNAL DATA							
SNR	6 Ncell times	uint6(Ncell)		1dBHz	0-63 dBHz	Set to 0 if signal is not tracked	
Smooth count	8 Ncell times	uint8(Ncell)		1sec	0-255 sec	Set to 0 if signal is not tracked 255 means 255+	
Quality status	2 Ncell times	bit2(Ncell)			0-3	0: quality is not defined 1: good quality 2: medium quality 3: questionable quality	
Total	16*Ncell						

Notes:

- Ncell is the complete number of available signals. It is equal to the number of 1's in the Cell Mask field.
- Each particular field uses internal looping, e.g. the SNR field includes sequentially following SNRs for all available signals.
- Good quality means that no warning flags are set for a given signal. Medium quality and questionable quality mean that some set of warnings is associated with the signal. See detailed warnings description in ATM RNX message.
- SNR=0 and/or smooth count=0 does not necessarily mean that the signal is not tracked and/or not used in internal receiver position.
- Medium/questionable quality does not necessarily mean that these data are not used in internal receiver position.

3.4.13 ATOM PVT Message / Sub-Block: Position expressed in local datum

This sub-block contains the same position as in COO block but expressed in a local datum. Local datum description (name) is also provided. There is no need to request this block specially; each time when COO block is generated and transformation parameters corresponding to COO positions are available, block LDP is generated. If there is no transformation parameters for given COO position at given epoch, then block LDP is not generated. For example, in some cases some transformation parameters are valid only for differential (e.g. RTK) position; in such cases, when receiver transits to standalone or SBAS differential position (e.g. data link lost), block LDP can be not generated.

Output Logic: on time
Sub-block Binary size: depend on message content
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&COO
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc., each integer minute but less than 15 min
See also:

Table 3.4.13.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Depends on block content	
Block ID	4	uint4	8		0-15	Set to 15	
Sub Block Id	8	uint8	12		0-255	Set to 1	
X coordinate	38	int38	20	0.1 mm	+/- 13743895.3471m	-13743895.3472m if not defined or invalid	
Y coordinate	38	int38	58	0.1 mm	+/- 13743895.3471m	-13743895.3472m if not defined or invalid	
Z coordinate	38	int38	96	0.1 mm	+/- 13743895.3471m	-13743895.3472m if not defined or invalid	
Latitude	38	int38	134	1e-9 deg	+/- 90 deg	Value out of interval [-90, 90] means invalid	
Longitude	39	int39	172	1e-9 deg	+/-180 deg	Value out of interval [-180, 180] means invalid	
Altitude	28	int28	211	0.1 mm	+/-13421.7727m	Value -13421.7728 means invalid	

						Value +13421.7727 means this or higher value	
Reserved	20	bit20	239		0-	Set to 0…0	
Utilized transformation source	3	uint3	259		0-7	0: unknown source 1: RTCM-3 2-7: reserved	
Source clarification	10	bit10	262			DF148 if source==1 Undefined otherwise	See DF148
Descriptor counter, N	8	uint8	272		0-255	Number of characters in local datum descriptor field	See DF145
Local datum descriptor	8*N	char(N)	280			Alphanumeric characters to clarify used local datum name	See DF146
Total							

Notes:

- Negative latitude means South, positive latitude means North. Negative longitude means West, positive longitude means East.
- Negative altitude means below ellipsoid, positive altitude means above ellipsoid
- In some cases reported Cartesian coordinates can be invalid, while Geographic coordinates are valid. Or vice versa. Decoding equipment must track this situation by checking fields for invalid states.
- Utilized transformation source and its clarification currently support RTCM-3 transformation messages. But these fields can be utilized in future to indicate other sources and clarifiers.
- Field DF148 contains the information about particular utilized RTCM transformation messages (1023 through 1027) used in position reported in this block

3.4.14 ATOM PVT Message / Sub-Block: Custom datum clarification

This sub-block contains the clarification (name) and parameters of the datum in which COO position is expressed. There is no need to request this block specially; each time when field 'datum' in MIS block is set to 1 (custom), all clarification parameters are generated in given block.

Output Logic: on time
Sub-block Binary size: depend on message content
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&COO
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc., each integer minute but less than 15 min
See also:

Table 3.4.14.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Depends on message content	
Block ID	4	uint4	8		0-15	Set to 15	
Sub Block Id	8	uint8	12		0-255	Set to 2	
Semi-major axis of datum ellipsoid	24	uint24	20	0.001 m	0 – 16,777.215	Add it to 637000 to get final value	See DF166
Semi-minor axis of datum ellipsoid	25	uint25	44	0.001 m	0 – 33,554.431	Add it to 635000 to get final value	See DF167
Reserved	16	bit16	69			Set to 0…0	
The source of clarification	3	uint3	85		0-7	0: unknown source 1: RTCM-3 2-7: reserved	
Descriptor counter, N	8	uint8	88		0-255	Number of characters in local datum descriptor field	See DF143
Local datum descriptor	8*N	char(N)	96			Alphanumeric characters to clarify used local datum name	See DF144

Total		

Notes:

- These data allow to know what custom datum name and ellipsoid parameters is for position in COO block and getting latitude, longitude and altitude components of Cartesian COO position

3.4.15 ATOM PVT Message / Sub-Block: Position expressed in local cartographic projection

This sub-block LMP (Local Map Projection) is originated by position in COO. There is no need to request the LMP block specially; each time when COO block is generated and projection parameters corresponding to COO positions are available, block LMP is generated. If there is no projection parameters for given COO position at given epoch, then block LMP is not generated or generated with indication all (or some of) fields as invalid. For example, in some cases some projection parameters are valid only for differential (e.g. RTK) position; in such cases, when receiver transits to standalone or SBAS differential position (e.g. data link lost), block LMP can be not generated.

Output Logic: on time
Sub-block Binary size: depend on message content
How to request? $PASHS,ATM,PVT,<Port Name>,ON,x,&COO
Permissible intervals x (sec): 0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc., each integer minute but less than 15 min
See also: $GPGMP

Table 3.4.15.a Sub-Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SUB-BLOCK DATA							
Block size	8	uint8	0		0-255	Depends on block content	
Block ID	4	uint4	8		0-15	Set to 15	
Sub Block Id	8	uint8	12		0-255	Set to 3	
Northing	41	int41	20	0.1 mm	+/- 109951162.7775 m	- 109951162.7776 m if not defined or invalid	
Easting	41	int41	61	0.1 mm	+/- 109951162.7775	- 109951162.7776 m if not defined or invalid	

					m		
Height	29	int29	102	0.1 mm	+/- 26843.5455 m	- 26843.5456 m if not defined or invalid	
Reserved	5	bit5	131			Set to 0…0	
Projection Type	6	uint6	136			DF 170 if source == Undefined otherwise	See DF170
Reserved	18	bit18	142			Set to 0…0	
Geoidal separation	21	int21	160	1mm	+/- 1048.575	- 1048.576 if not defined or invalid	
Height Indicator	2	uint2	181		0-3	0 = Ellipsoidal height 1 = Geoid, Quasi-Geoid or Local height 2-3 - reserved	See DF 151
Reserved	20	bit20	183			Set to 0…0	
Utilized transformation source	3	uint3	203		0-7	0: unknown source 1: RTCM-3 2-7: reserved	
Source clarification	10	bit10	206			DF148 if source==1 Undefined otherwise	See DF148
The Target-Name Counter	8	uint8	216		0-255	Number of characters in local datum descriptor field defines the number of characters (bytes) to follow in Target-Name	See DF145
Name of Target Coordinate-System.	8*N	char(N)	224			Alphanumeric characters to clarify used local datum name . If available, the EPSG identification code for the CRS has to be used. Otherwise, service providers should try to introduce unknown CRS's into the EPSG database or could use other reasonable names	See DF146
Total							

Notes:

- See NMEA $GPGMP message description for additional details.

3.5 ATOM ATR Messages

Messages from the ATR (ATRibutes) group contain different additional and service information such as antenna and receiver description, antenna offset parameters against ground mark. Some messages have fixed length, some others have variable length. All these messages can be requested independently of each other. Only one ATR message can be output over any given 1-sec interval.

The set of default ATOM ATR messages, with default intervals, can be enabled/disabled using the following command:

$PASHS,ATM,ATR,<Port Name>,ON/OFF

The general organization of the ATR message is presented in Figure 4a and in Table 4a.

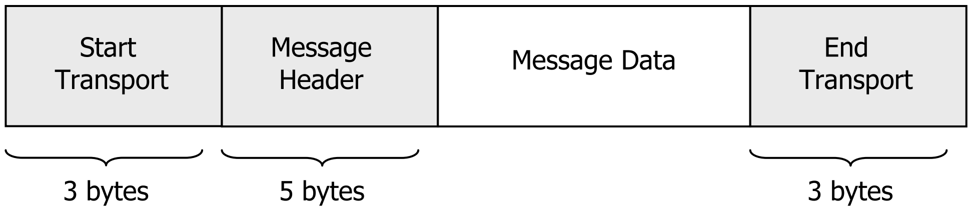


Figure 3.5.a. ATR messages organization

Table 3.5.1.a ATR messages organization

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002

Message sub-number	4	uint4	36		0-15	4 is reserved for ATOM ATR message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
ATR message type	9	uint9	55		0-511	Specifies which ATR message follows	
MESSAGE DATA							
Attribute content						See sub-sections below	
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

The supported ATR messages are presented in Table 4b.

Table 3.5.b. Supported ATR messages

ATR message type	ASCII identifier	Attribute description	Comments	Counterpart
1	ANM	Antenna name	Name, setup ID and serial number	RTCM-3 MT 1008
2	RNM	Receiver name	Name, firmware version and serial number	RTCM-3 MT 1033 (receiver’s part)
3	ANM	Physical antenna name	Name, setup ID and serial number	RTCM-3 MT 1008
5	UEM	User entered message		RTCM-3 MT 1029
6	RIO	Receiver Installed Options	Receiver options	$PASHR,RIO
7	CFG	GNSS configuration receiver supports	Signals receiver can potentially track	$PASHR,CFG
8	CPB	GLONASS Code-Phase Bias value	The reported values allows adjusting Ashtech raw data to ‘golden standard’	RTCM-3 MT 1230
21	AOP	Antenna offset parameters	Slant, radius, vertical offset, horizontal offset, horizontal offset angle	$PASHR,ANT/ANH RTCM-3 MT 1006
23	OCC	Site occupation information	Dynamic index, site name, start/stop	N/A

			etc	
24	SNS	Non-GNSS sensor data	Weather and other parameters	$GPXDR
25	MET	Meteo data	Primary weather parameters	$GPXDR
27	SAH	Extended to Non-GNSS sensor data	Sensor type/name/model/position, can be used instead of block SNS (24)	$PASHR,RXC,PAR

Notes:

- The observables generated in the ATOM MES, RNX and BAS messages always correspond to the antenna name specified in ATR message type 1. At the same time, this name can correspond to either a physical antenna (e.g. MAG990596) or a virtual antenna (e.g. ADVNULLANTENNA) for which raw receiver data can be optionally adjusted before being output. In the latter case, the receiver can additionally generate ATR message type 3, indicating the physical antenna name. If the antenna names specified in ATR message types 1 and 3 are the same, this means that no receiver raw data was adjusted to a virtual antenna. If the antenna names in ATR message types 1 and 3 are different, this means that receiver raw data (corresponding to ATR message type 3) were adjusted to the virtual antenna (specified in ATR message type 1).
- Both ATR messages type 1 and type 3 are requested through the same serial command.
- When processing ATOM MES, RNX and BAS data, these should be corrected using the PCO table, corresponding to the antenna name presented in ATR message type 1. ATR message type 3 is only informative.
- While SNS message is primarily used for recording to the file for further post processing, MET message being compact can be generated inside differential stream to inform real time rover about meteo-conditions on base allowing thereby mitigating residual troposphere error.

3.5.2 ATOM ATR Message / Antenna attributes

This message contains antenna attributes. The generated ATOM observables (MES, RNX and BAS) correspond to this antenna. The content of this message is a copy of standardized RTCM-3 Message Type 1008.

Output Logic: on time
Message Binary size: depends on message content
How to request? $PASHS,ATM,ATR,<Port Name>,ON,x,&ANM
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHS,ANP,OWN; $PASHS,ANP,OUT; RTCM-3 MT 1008

Table 3.5.2.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number

START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	4 is reserved for ATOM ATR message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
ATR message type	9	uint9	55		0-511	Specifies which ATR message follows. 1 refers to the antenna raw data corresponds to 3 refers to physical antenna	
MESSAGE DATA							
Descriptor counter, N	8	uint8			0-31	Number of characters in antenna descriptor field	DF029
Antenna descriptor	8*N	char(N)				Alphanumeric characters describe antenna descriptor	DF030
Antenna setup ID	8	uint8			0-255	0 – Use standard IGS Model 1-255 – Specific Antenna Setup ID	DF031
Serial number counter, M	8	uint8			0-31	Number of characters in antenna serial number field	DF032
Antenna serial number	8*M	char(M)				Alphanumeric characters describe antenna serial number	DF033
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

3.5.3 ATOM ATR Message / Receiver attributes

This message contains receiver attributes. It is a copy of standardized message Type 1033 (receiver part only).

Output Logic: on time
Message Binary size: depends on message content
How to request? $PASHS,ATM,ATR,<Port Name>,ON,x,&RNM
Permissible intervals x (sec): 1/2/3/etc., each integer second but less than 999
See also: $PASHS,RCP,OWN; RTCM-3 MT 1033

Table 3.5.3.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	4 is reserved for ATOM ATR message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
ATR message type	9	uint9	55		0-511	Specifies which ATR message follows. For this message, set to 2	
MESSAGE DATA							
Receiver type descriptor counter, N	8	uint8			0-31	Number of characters in receiver type field	DF227
Receiver type	8*N	char(N)				Standard ASCII characters describe receiver type	DF228

Firmware version descriptor counter, M	8	uint8			0-31	Number of characters in firmware version field	DF229
Firmware version	8*M	char(M)				Standard ASCII characters describe receiver firmware version	DF230
Serial number descriptor counter, K	8	uint8				Number of characters in serial number field	DF231
Serial number	8*K	char(K)				Standard ASCII characters describe receiver serial number	DF232
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

3.5.4 ATOM ATR Message / User message

This message contains readable content users can define at their convenience.

Output Logic: on time
Message Binary size: depends on message content
How to request? $PASHS,ATM,ATR,<Port Name>,x,&UEM
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHS,MSG; RTCM-3 MT 1029; RTCM-2 MT 16

Table 3.5.4.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes.	
MESSAGE HEADER							

Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	4 is reserved for ATOM ATR message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
ATR message type	9	uint9	55		0-511	Specifies which ATR message follows. For this message, set to 5	
MESSAGE DATA							
Modified Julian Day (MJD) Number	16	uint16				Modified Julian Day number (MJD) is the continuous count of day numbers since November 17, 1858 midnight.	DF051
Seconds of Day (UTC)	17	uint17				Seconds of Day (UTC) are the seconds of the day counted from midnight Greenwich time. GPS seconds of week have to be adjusted for the appropriate number of leap seconds. The value of 86,400 is reserved for the case when a leap second has been issued.	DF052
Number of characters to follow	7	uint7				This represents the number of fully formed Unicode characters in the message text. It is not necessarily the number of bytes that are needed to represent the characters as UTF-8.	DF138
Number of UTF-8 code units, N	8	uint8				The length of the message is limited by this field.	DF139
UTF-8 characters code units	8*N	utf8(N)				Code units of a Unicode 8-bit string.	DF140
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

3.5.5 ATOM ATR Message / Antenna offset parameters

This message contains some antenna offset parameters expressed with respect to the survey point.

Output Logic: on time
Message Binary size: 22 bytes (176 bits)
How to request? $PASHS,ATM,ATR,<Port Name>,ON,x,&AOP
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHS,ANP; $PASHS,ANH

Table 3.5.5.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 16 for this message.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	4 is reserved for ATOM ATR message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
ATR message type	9	uint9	55		0-511	Specifies which ATR message follows. For this message, set to 21	
MESSAGE DATA							
Slant	16	uint16	64	0.0001	0-6.5535 [m]	Antenna slant	
Radius	16	uint16	80	0.0001	0-6.5535 [m]	Antenna radius	
Vertical offset	16	uint16	96	0.0001	0-6.5535 [m]	Antenna vertical offset	

Horizontal azimuth	24	uint24	112	0.0001	0-6.2831 rad	Horizontal azimuth measured from the antenna ground mark to the survey point, with respect to the WGS84 north Unit in radians	
Horizontal Offset	16	uint16	136	0.0001	0-6.5535 [m]	Antenna horizontal offset	
END TRANSPORT							
CRC	24	uint24	152			24-bit Cyclic Redundancy Check (CRC)	
Total	176						

3.5.6 ATOM ATR Message / Site occupation information

This message contains information about site occupation. It is copied in EVT group (see section 3.10).

Output Logic: on new / on change
Message Binary size: depends on message content
How to request? N/A
Permissible intervals x (sec): N/A
See also: N/A

Table 3.5.6.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							

Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	4 is reserved for ATOM ATR message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
ATR message type	9	uint9	55		0-511	Specifies which ATR message follows. For this message set to 23	
MESSAGE DATA							
Time tag	21	bit21				GPS time tag. See Time Tag description for PVT message.	
Occupation type	3	bit3			0-7	0: static 1: quasi-static 2: dynamic 3: event 4: Kinematic bar	
Occupation event	1	bit1			0-1	0: begin 1: end	
Reserved	7	bit7			0	Set to 0000000	
Occupation name counter, N	8	uint8			0-255	Number of characters in occupation name field	
Occupation name	8*N	char(N)				Standard ASCII characters describe occupation name	
Occupation description counter, M	8	uint8			0-255	Number of characters in occupation description field	
Occupation description	8*M	char(M)				Standard ASCII characters describe occupation description	
END TRANSPORT							

CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

3.5.7 ATOM ATR Message / External Sensors Data

3.5.8 ATOM ATR Message / Meteo Data

This message contains information about local (in reasonable vicinity of GNSS antenna) meteo parameters allowing mitigating troposphere error. It is supposed that given message can be generated together with other attributive information (receiver/antenna names) from base to rover with not so high speed. It can be also used as a source of RINEX meteo file. It is supposed that given meteo information is either automatically available at the MET message generator (meteo sensors streams it reading to MET generator), or local meteo parameters are entered receiver on some regular basis via available serial interface. The meteo data generated in SNS and MET messages are the same.

Output Logic: on new / on change
Message Binary size: 142 bits (18 bytes)
How to request? $PASHS,ATM,ATR,<Port Name>,ON,&MET
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $GPXDR

Table 3.5.8.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 12 for this message.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	4 is reserved for ATOM ATR message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	

Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
ATR message type	9	uint9	55		0-511	Specifies which ATR message follows. For this message, set to 25	
MESSAGE DATA							
Reserved	3	bit3					
Temperature	11	int11		0.1 degree	+/-102.3	Value -102.4 means invalid	
Pressure	17	uint17		0.01 mb	0-1310.71	Value 1310.71 means invalid	
Relative humidity	10	uint10		0.1 %	0-102.23	Value 102.3 means invalid	
Reserved	15	bit15				Set to 0…0	
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total	142						

3.5.9 ATOM ATR Message / External Sensors Data Additional Header

3.5.10 ATOM ATR Message / Receiver Installed Options

3.5.11 ATOM ATR Message / Receiver Configuration

3.5.12 ATOM ATR Message / GLONASS Code-Phase Bias

This message generates so called GLONASS Code-Phase bias values for up to all FDMA GLONASS observations. It is extended copy of RTCM-3 MT 1230. For applicability CPB value to GLONASS FDMA observations, please see the description of RTCM-3 MT 1230. The content of given message is equally applicable to all raw/differential proprietary/standardized data generated by Ashtech receiver, from legacy MCA/MPC and RTCM-2 towards modern ATM,RNX and RTCM-3 MSM.

Output Logic: on time
Message Binary size: depends on message content
How to request? $PASHS,ATM,ATR,<Port Name>,ON,x,&CPB

Permissible intervals x (sec): 1/2/3/etc., each integer second but less than 999
See also: ATM,RNX, RTCM-3 MSM, RTCM-3 MT 1230

Table 3.5.12.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	Bit6	8			Set to 000000	
Message Length	10	uint10	14			Message length in bytes.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	4 is reserved for ATOM ATR message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
ATR message type	9	uint9	55		0-511	Specifies which ATR message follows. For this message, set to 8	
MESSAGE DATA							
GLONASS Code-Phase Bias indicator	1	bit1	64			0: the GLONASS data are not corrected 1: GLONASS data are corrected to 'Golden receiver' using below reported values	DF421
Reserved	3	bit3	65			Set to 000	
GLONASS signals bitset	4	bit4	68			Bit1: GLONASS L1CA bias follows Bit2: GLONASS L1P bias follows Bit3: GLONASS L2CA bias follows Bit4: GLONASS L2P bias follows	DF422
GLONASS bias for up to 4 signals	K*16	K*int16	72	0.02 m	+/-655.34	GLONASS biases are packed only for signals having 1 in corresponding positions of GLONASS signal bitset. Invalid values?	DF 423-426

END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

3.6 ATOM NAV Messages

Messages of the NAV (NAVigation data) group contain selected information which can be extracted from GPS, GLONASS, SBAS, QZSS, GALILEO and other navigation signals. All these messages can be requested independently of each other. Messages EPH and ALM are requested by the same command regardless of the GNSS they pertain to. Only one NAV message can be output over any given 1-second interval.

The set of default ATOM NAV messages, with default intervals, can be enabled/disabled using the following command:

$PASHS,ATM,NAV,<Port Name>,ON/OFF

The general organization of the NAV message is presented on Figure 3.6.a and in Table 3.6.a.

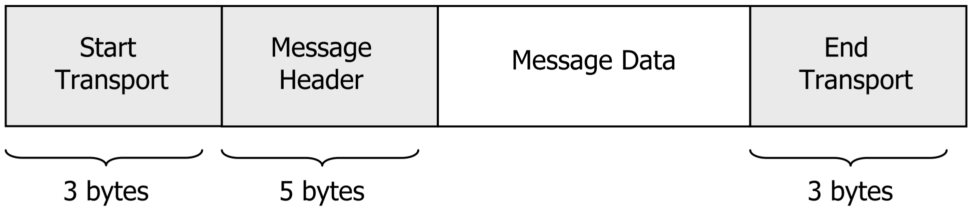


Figure 3.6.a. NAV messages organization

Table 3.6.a. NAV messages organization

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes	
MESSAGE HEADER							

Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows	
MESSAGE DATA							
Navigation content						See sub-sections below	
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

Supported NAV messages are presented in Table 3.6.b.

Table 3.6.b. Supported NAV messages

NAV message type	ASCII identifier	Attribute description	Comments	Counterpart
1	EPH	GPS ephemeris from L1CA signal data	Copy of standardized message RTCM-3 type 1019	RTCM-3 MT 1019
2	EPH	GLO ephemeris from L1CA signal data	Copy of standardized message RTCM-3 type 1020	RTCM-3 MT 1020
3	EPH	SBAS ephemeris from L1CA signal data	Copy of SNW message, but in compact presentation	RTCM-3 MT ??? (not yet standardized)
4	EPH	GAL ephemeris (I/NAV) from E1b/E5b signal data	Modified copy of RTCM-3 type 1046 draft	RTCM-3 MT 1046 (not yet standardized)
5	EPH	QZSS ephemeris from L1CA signal data	Modified copy of EPH(GPS)	RTCM-3 MT 1044 (not yet standardized)
6	EPH	BDS ephemeris from 2I signal data		RTCM-3 MT ??? (not yet standardized)

11	ALM	GPS almanac	Copy of SAL, but in compact presentation	$PASHR,SAL
12	ALM	GLO almanac	Copy of SAG, but in compact presentation	$PASHR,SAG
13	ALM	SBAS almanac	Copy of SAW, but in compact presentation	$PASHR,SAW
14	ALM	Galileo almanac		N/A
15	ALM	QZSS almanac	Modified copy of ALM(GPS)	N/A
16	ALM	BDS almanac		N/A
21	GIT	GPS ionosphere and time shift parameters	Copy of ION message, but in compact presentation	$PASHR,ION
24	GIT	Galileo ionosphere and time shift parameters		N/A
25	GIT	QZSS ionosphere and time shift parameters		N/A
26	GIT	BDS ionosphere and time shift parameters		N/A
22	GFT	GPS full time parameters	Seconds of week, week number, GPS-UTC time shift	RTCM-3 MT 1013

3.6.1 ATOM NAV Message / GPS Ephemeris

This message contains GPS ephemeris data for a given GPS satellite. For detailed information about GPS ephemeris data, please refer to the ICD-GPS-200 document.

Output Logic: on time / on change / on new
Message Binary size: 72 bytes (576 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&EPH
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SNV; RTCM-3 Message 1019

Table 3.6.1.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	

Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 66 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message set to 1	
MESSAGE DATA							
Standardized message number	12	uint12	64			Set to 1019	
SVPRN	6	uint6	76		1-32	Satellite PRN number	DF009
Wn	10	uint10	82		0-1023	GPS week number	DF076
Accuracy	4	uint4	92			User range accuracy	DF077
Code on L2	2	bit2	96			00 = reserved; 01 = P code ON; 10 = C/A code ON; 11 = L2C ON	DF078
Idot	14	int14	98	2^{-43}		Rate of inclination (semicircles/sec)	DF079
Iode	8	uint8	112			Orbit data issue	DF071
Toc	16	uint16	120	16		Clock data reference time (sec)	DF081
af2	8	int8	136	2^{-55}		Clock correction (sec/sec^2)	DF082
af1	16	int16	144	2^{-43}		Clock correction (sec/sec)	DF083
af0	22	int22	160	2^{-31}		Clock correction (sec)	DF084
Iodc	10	uint10	182			Clock data issue	DF085
Crs	16	int16	192	2^{-5}		Harmonic correction term (meters)	DF086

Δn	16	int16	208	2^{-43}		Mean anomaly correction (semicircles/sec)	DF087
m0	32	int32	224	2^{-31}		Mean anomaly at reference time (semicircles)	DF088
Cuc	16	int16	256	2^{-29}		Harmonic correction term (radians)	DF089
E	32	uint32	272	2^{-33}		Eccentricity	DF090
Cus	16	int16	304	2^{-29}		Harmonic correction term (radians)	DF091
$A^{1/2}$	32	uint32	320	2^{-19}		Square root of semi-major axis ($meters^{1/2}$)	DF092
Toe	16	uint16	352	16		Reference ephemeris time	DF093
Cic	16	int16	368	2^{-29}		Harmonic correction term (radians)	DF094
ω0	32	int32	384	2^{-31}		Longitude of ascending node (semicircles)	DF095
Cis	16	int16	416	2^{-29}		Harmonic correction term (radians)	DF096
i0	32	int32	432	2^{-31}		Inclination angle (semicircles)	DF097
Crc	16	int16	464	2^{-5}		Harmonic correction term (meters)	DF098
ω	32	int32	480	2^{-31}		Argument of perigee (semicircles)	DF099
ω dot	24	int24	512	2^{-43}		Rate of right ascension (semicircles/sec)	DF100
Tgd	8	int8	536	2^{-31}		Group delay (sec)	DF101
Health	6	uint6	544			Satellite health	DF102
L2 P data flag	1	bit1	550			0: L2 P-Code NAV data ON 1: L2 P-Code NAV data OFF	DF103
Fit Interval	1	bit1	551			Curve fit interval	DF137
END TRANSPORT							
CRC	24	uint24	552			24-bit Cyclic Redundancy Check (CRC)	
Total	576						

Notes:

- See **Appendix B** for decoding sample

3.6.2 ATOM NAV Message / GLONASS Ephemeris

This message contains GLONASS ephemeris data for a given GLONASS satellite. For detailed information about GLONASS ephemeris data, please refer to the GLONASS ICD ver.5 document.

Output Logic: on time / on change / on new
Message Binary size: 56 bytes (448 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&EPH
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SNG; RTCM-3 Message 1020

Table 3.6.2.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 50 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 2	
MESSAGE DATA							
Standardized message number	12	uint12	64			If 1020, then all the data below exactly correspond to standardized RTCM message 1020 (see official RTCM 3). If 0, then shaded fields are declared as reserved and	

						can take arbitrary values.	
SatNum	6	uint6	76		1 - 24	Satellite number	DF038
Frequency Channel Number	5	uint5	82			The GLONASS Satellite Frequency Channel Number identifies the frequency of the GLONASS satellite. 0 indicates channel number –07 1 indicates channel number –06 ….. 13 indicates channel number +6 31 indicates invalid channel number	DF040
Health	1	bit1	87			GLONASS almanac health	DF104
Almanac health availability	1	bit1	88			0= GLONASS almanac has not been received: GLONASS almanac health is not available; 1= GLONASS almanac has been received: GLONASS almanac health is available;	DF105
P1	2	bit2	89			P1 flag (see GLONASS ICD)	DF106
Hour	5	uint5	91			The integer number of hours elapsed since the beginning of current day	DF107
Minutes	6	uint6	96			The integer number of minutes	DF107
Half	1	bit1	102			The number of thirty-second intervals	DF107
MSB of B_n word	1	bit1	103			GLONASS MSB of B_n word. It contains the ephemeris health flag.	DF108
P2	1	bit1	104			P2 flag (see GLONASS ICD)	DF109
Tb	7	uint7	105	900		Time to which GLONASS navigation data are referenced	DF110
Velx	24	intS24	112	2^{-20}*1000		GLONASS ECEF-X component of satellite velocity vector in PZ-90 datum	DF111
Posx	27	intS27	136	2^{-11}*1000		GLONASS ECEF-X component of satellite coordinates in PZ-90 datum	DF112
Accx	5	intS5	163	2^{-30}*1000		GLONASS ECEF-X component of satellite acceleration in PZ-90 datum	DF113
Vely	24	intS24	168	2^{-20}*1000		GLONASS ECEF-Y component of satellite velocity vector in PZ-90 datum	DF114
Posy	27	intS27	192	2^{-11}*1000		GLONASS ECEF-Y component of satellite	DF115

						coordinates in PZ-90 datum	
Accy	5	intS5	219	2^{-30}*1000		GLONASS ECEF-Y component of satellite acceleration in PZ-90 datum	DF116
Velz	24	intS24	224	2^{-20}*1000		GLONASS ECEF-Z component of satellite velocity vector in PZ-90 datum	DF117
Posz	27	intS27	248	2^{-11}*1000		GLONASS ECEF-Z component of satellite coordinates in PZ-90 datum	DF118
Accz	5	intS5	275	2^{-30}*1000		GLONASS ECEF-Z component of satellite acceleration in PZ-90 datum	DF119
P3	1	bit1	280			P3 flag (see GLONASS ICD)	DF120
γ_n	11	intS11	281	2^{-40}		Relative deviation of predicted satellite carrier frequency from nominal value	DF121
GLONASS-M P	2	bit2	292			GLONASS-M P word	DF122
GLONASS-M l_n (3 string)	1	bit1	294			GLONASS-M l_n word extracted from third string of the subframe	DF123
τ_n	22	intS22	295	2^{-30}		GLONASS correction to the satellite time relative to GLONASS system time	DF124
GLONASS-M $\Delta\tau_n$	5	intS5	317	2^{-30}		Time difference between navigation RF signal transmitted in L2 sub-band and navigation RF signal transmitted in L1 sub-band	DF125
En	5	uint5	322	1 day		The age of GLONASS navigation data	DF126
GLONASS-M P4	1	bit1	327			GLONASS-M P4 word	DF127
GLONASS-M F_T	4	uint4	328			GLONASS-M predicted satellite user range accuracy at time t_b	DF128
GLONASS-M N_T	11	uint11	332	1 day		GLONASS calendar number of day within four-year interval starting from the 1st of January in a leap year.	DF129
GLONASS-M M	2	bit2	343			Type of GLONASS satellite. If this data field contains “01”, the satellite is GLONASS-M	DF130
Availability of additional data	1	bit1	345			See DF131 field description in official RTCM-3 documents.	DF131
N^A	11	uint11	346	1 day		GLONASS calendar number of day within the four-year period to which τ_c is referenced	DF132
τ_c	32	intS32	357	2^{-31}		Difference between GLONASS system time	DF133

						and UTC	
GLONASS-M N_4	5	uint5	389	4-year interval		GLONASS four-year interval number starting from 1996	DF134
GLONASS-M τ_{GPS}	22	intS22	394	2^{-31}		Correction to GPS system time relative to GLONASS system time	DF135
GLONASS-M l_n (5 string)	1	bit1	416			GLONASS-M l_n word extracted from fifth string of the subframe	DF136
Reserved	7	bit7	417			Set to 0000000	
END TRANSPORT							
CRC	24	uint24	424			24-bit Cyclic Redundancy Check (CRC)	
Total	448						

Notes:

- The 12-bit standardized message number is used in this message as a switch taking the value 1020 or 0. It was created to ensure backward compatibility with legacy Ashtech messages SNG, which do not contain some important fields.
- The “intS” data type refers to a sign-magnitude value. Sign-magnitude representation records the number's sign and magnitude. MSB is 0 for positive numbers and 1 for negative numbers. The rest of the bits represents the number’s magnitude. For example, for 8-bit words, the representations of the numbers "-7" and "+7" in a binary form are 10000111 and 00000111, respectively. Negative zero is not used.

3.6.3 ATOM NAV Message / SBAS Ephemeris

This message contains SBAS ephemeris data for a given SBAS satellite. For detailed information about SBAS ephemeris data, please refer to the WAAS ICD document.

Output Logic: on time / on change / on new
Message Binary size: 39 bytes (312 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&EPH
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SNW

Table 3.6.3.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number

START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 33 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 3	
MESSAGE DATA							
SVPRN	8	uint8	64			SBAS satellite number	
Iode	8	uint8	72			Issue of data	
T_0	13	uint13	80	16		Ephemeris data reference time within the day expressed in the SBAS time scale (seconds)	
Accuracy	4	uint4	93			Accuracy	
Rx	30	int30	97	0.08		Satellite ECEF X coordinates (meters)	
Ry	30	int30	127	0.08		Satellite ECEF Y coordinates (meters)	
Rz	25	int25	157	0.4		Satellite ECEF Z coordinates (meters)	
Vx	17	int17	182	0.000625		Satellite ECEF velocity X' coordinates (m/s)	
Vy	17	int17	199	0.000625		Satellite ECEF velocity Y' coordinates (m/s)	
Vz	18	int18	216	0.004		Satellite ECEF velocity Z' coordinates (m/s)	

Ax	10	int10	234	0.0000125		Satellite ECEF acceleration X''' (m/s^2)	
Ay	10	int10	244	0.0000125		Satellite ECEF acceleration Y'' (m/s^2)	
Az	10	int10	254	0.0000625		Satellite ECEF acceleration Z'' (m/s^2)	
aGf0	12	int12	264	2^{-31}		Time offset between satellite time scale and SBAS system time scale (seconds)	
aGf1	8	int8	276	2^{-40}		Time drift between satellite time scale and SBAS system time scale (seconds)	
Reserved	4	bit4	284			Set to 0000	
END TRANSPORT							
CRC	24	uint24	288			24-bit Cyclic Redundancy Check (CRC)	
Total	312						

3.6.4 ATOM NAV Message / Galileo Ephemeris

This message contains Galileo I/NAV ephemeris data for a given Galileo satellite. These data are extracted from Galileo E1b or E5b signal. For detailed information about Galileo ephemeris data please refer to the GALILEO OS SIS ICD. The content of given message is the extended copy of RTCM-3 MT 1046 draft.

Output Logic: on time / on change / on new
Message Binary size: **77** bytes (616 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&EPH
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: RTCM-3 Message 1046

Table 3.6.4.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	

Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 71 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message set to 4	
MESSAGE DATA							
Standardized message number	12	uint12	64			If 1046 then the content below is valid. Otherwise the content is wrong.	DF002
GALILEO Satellite ID	6	uint6	76	1	1-64	The GALILEO SV_{ID} parameter is coded with 6 bits. However, the max constellation which can be accommodated within the I/NAV frames is 36 satellites (3 planes of 12 satellites each).	See DF252
GALILEO Week Number (WN)	12	uint12	82	1 WEEK	0 - 4095	GALILEO week number. Roll-over every 4096 weeks (about 78 years). The start time for Galileo System Time (GST) is (TBD)	DF289
GALILEO IODnav	10	uint10	94	1	0-1023	Issue of data - unitless	DF290
GALILEO SV SISA (SIS Accuracy)	8	uint8	104			SIS Accuracy, data content definition not given in GALILEO OS SIS ICD (reserved)	DF291
GALILEO $\dot{i}$ (IDOT)	14	int14	112	2^{-43}	*See Note 1*	Rate of inclination. Unit: semi-circles/s	DF292
GALILEO t_{oc}	14	uint14	126	60	983,040	Clock reference time. Unit: semi-circles/sec The start time for Galileo System Time (GST) is (TBD)	DF293
GALILEO a_{f2}	6	int6	140	2^{-59}	*See Note 1*	Clock correction. Unit: s/s^2	DF294
GALILEO a_{f1}	21	int21	146	2^{-46}	*See Note 1*	Clock correction. Unit: s/s	DF295

GALILEO a_{f0}	31	int31	167	2^{-34}	*See Note 1*	Clock correction. Unit: seconds	DF296
GALILEO C_{rs}	16	int16	198	2^{-5}	*See Note 1*	Amplitude of the sine harmonic correction term to the orbit radius. Unit: meters	DF297
GALILEO Δn	16	int16	214	2^{-43}	*See Note 1*	Mean motion difference from computed value. Unit: semi-circles/s	DF298
GALILEO M_0	32	int32	230	2^{-31}	*See Note 1*	Mean anomaly at reference time. Unit: semi-circles	DF299
GALILEO C_{uc}	16	int16	262	2^{-29}	*See Note 1*	Amplitude of the cosine harmonic correction term to the argument of latitude. Unit: radians	DF300
GALILEO e	32	uint32	278	2^{-33}	0.03	Eccentricity - unitless	DF301
GALILEO C_{us}	16	int16	310	2^{-29}	*See Note 1*	Amplitude of the sine harmonic correction term to the argument of latitude. Unit: radians	DF302
GALILEO $a^{1/2}$	32	uint32	326	2^{-19}	*See Note 1*	Square root of the semi-major axis. Unit: $meters^{1/2}$	DF303
GALILEO t_{oe}	14	uint14	356	60	983,040	Ephemeris reference time. Unit: seconds	DF304
GALILEO C_{ic}	16	int16	370	2^{-29}	*See Note 1*	Amplitude of the cosine harmonic correction term to the angle of inclination. Unit: radians	DF305
GALILEO Ω_0	32	int32	386	2^{-31}	*See Note 1*	Longitude of ascending node of orbital plane at weekly epoch. Unit: semi-circles	DF306
GALILEO C_{is}	16	int16	418	2^{-29}	*See Note 1*	Amplitude of the sine harmonic correction term to the angle of inclination. Unit: radians	DF307
GALILEO i_0	32	int32	434	2^{-31}	*See Note 1*	Inclination angle at reference time. Unit: semi-circles	DF308
GALILEO C_{rc}	16	int16	468	2^{-5}	*See Note 1*	Amplitude of the cosine harmonic correction term to the orbit radius. Unit: meters	DF309
GALILEO ω	32	int32	484	2^{-31}	*See Note 1*	Argument of Perigee. Unit: semi-circles	DF310
GALILEO $\dot{\Omega}_0$ (OMEGADOT)	24	int24	516	2^{-43}	*See Note 1*	Rate of right ascension. Unit: semi-circles/sec	DF311
GALILEO $BGD_{E5a/E1}$	10	int10	540	2^{-32}	*See Note 1*	Broadcast Group Delay E5a/E1	DF312
GALILEO $BGD_{E5b/E1}$	10	int10	550	2^{-32}	*See Note 1*	Broadcast Group Delay E5b/E1	DF313

GALILEO NAV SIGNAL HEALTH STATUS (OSHS)	2	bit(2)	560			Unitless (reserved)	DF316
GALILEO NAV DATA VALIDITY STATUS (OSDVS)	1	bit(1)	562			Unitless (reserved)	DF317
Transmission Time of GALILEO Orbit	20	uint20	563	1s	0-604799	Full seconds since the beginning of the Galileo week. Note: a bit pattern equivalent to fffffh in this field indicates the given Galileo time of week is invalid respectively not set	DF397
Reserved	1	bit(1)	583				Set to 0
E1b Signal Health Status	2	bit(2)	584			Unitless	
E1b Data Validity Status	1	bit(1)	586			Unitless	
E5b Signal Health Status	2	bit(2)	587			Unitless	
E5b Data Validity Status	1	bit(1)	589			Unitless	
The Source of decoded ephemeris	2	uint2	590		0-3	0: E1b 1: E5b 2: E1b & E5b 3: unknown	
END TRANSPORT							
CRC	24	uint24	592			24-bit Cyclic Redundancy Check (CRC)	
Total	616						

Note 1: Effective range is the maximum range attainable with the indicated bit allocation and scale factor.
Note 2: The message is extended copy of RTCM MT 1046 draft as appears on February 2012

3.6.5 ATOM NAV Message / QZSS Ephemeris

This message contains QZSS ephemeris data for a given QZSS satellite. For detailed information about QZSS ephemeris data, please refer to the IS-QZSS_13[E] document. The content of QZSS ephemeris message is a copy of corresponding GPS ephemeris message (the same size) with some fields set to fixed values or with slightly another meaning.

Output Logic: on time / on change / on new
Message Binary size: 72 bytes (576 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&EPH
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SNV; RTCM-3 Message 1019

Table 3.6.5.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 66 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message set to 5	
MESSAGE DATA							
Reserved	12	uint12	64			Set to 0…0	
SVPRN	6	uint6	76		1-5	Satellite PRN number, original ID 193 corresponds to 1, 194 corresponds to 2 etc	

Wn	10	uint10	82		0-1023	GPS week number	DF076
Accuracy	4	uint4	92			User range accuracy	DF077
Code on L2	2	bit2	96			10 = C/A code ON (fixed value)	DF078
Idot	14	int14	98	2^{-43}		Rate of inclination (semicircles/sec)	DF079
Iode	8	uint8	112			Orbit data issue	DF071
Toc	16	uint16	120	16		Clock data reference time (sec)	DF081
af2	8	int8	136	2^{-55}		Clock correction (sec/sec^2)	DF082
af1	16	int16	144	2^{-43}		Clock correction (sec/sec)	DF083
af0	22	int22	160	2^{-31}		Clock correction (sec)	DF084
Iodc	10	uint10	182			Clock data issue	DF085
Crs	16	int16	192	2^{-5}		Harmonic correction term (meters)	DF086
Δn	16	int16	208	2^{-43}		Mean anomaly correction (semicircles/sec)	DF087
m0	32	int32	224	2^{-31}		Mean anomaly at reference time (semicircles)	DF088
Cuc	16	int16	256	2^{-29}		Harmonic correction term (radians)	DF089
E	32	uint32	272	2^{-33}		Eccentricity	DF090
Cus	16	int16	304	2^{-29}		Harmonic correction term (radians)	DF091
$A^{1/2}$	32	uint32	320	2^{-19}		Square root of semi-major axis (meters$^{1/2}$)	DF092
Toe	16	uint16	352	16		Reference ephemeris time	DF093
Cic	16	int16	368	2^{-29}		Harmonic correction term (radians)	DF094
ω0	32	int32	384	2^{-31}		Longitude of ascending node (semicircles)	DF095
Cis	16	int16	416	2^{-29}		Harmonic correction term (radians)	DF096
i0	32	int32	432	2^{-31}		Inclination angle (semicircles)	DF097
Crc	16	int16	464	2^{-5}		Harmonic correction term (meters)	DF098
ω	32	int32	480	2^{-31}		Argument of perigee (semicircles)	DF099
ω dot	24	int24	512	2^{-43}		Rate of right ascension (semicircles/sec)	DF100
Tgd	8	int8	536	2^{-31}		Group delay (sec) SV group delay differential between L1C/A	DF101

						and L2C	
Health	6	uint6	544			The MSB shall indicate a summary of the health of the NAV data. The five LSBs shall indicate the health of the signal components.	DF102
L2 P data flag	1	bit1	550			As there is no L2P code, bit is fixed at "1"	DF103
Fit Interval	1	bit1	551			When the curve fit interval is set to "0", the Ephemeris data are effective for 2 hours. When the curve fit interval is "1", the Ephemeris data are effective for more than 2 hours	DF137
END TRANSPORT							
CRC	24	uint24	552			24-bit Cyclic Redundancy Check (CRC)	
Total	576						

Notes:

-

3.6.6 ATOM NAV Message / Beidou Ephemeris

This message contains Beidou ephemeris data for a given Beidou satellite. For detailed information about Beidou ephemeris data, please refer to the Beidou ICD (IOpen Service Signal B1I Version 1.0, December 2012) document.

Output Logic: on time / on change / on new
Message Binary size: 76 bytes (608 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&EPH
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also:

Table 3.6.6.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							

Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 70 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message set to 6	
MESSAGE DATA							
Reserved	12	uint12	64			Set to 0…0	
SVPRN	6	uint6	76		1-???	Satellite PRN number, starting from 1	
SatH1	1	bit	82			Autonomous Satellite Health flag	
AODC	5	uint5	83			Age of Data, Clock	
URAI	4	uint4	88			User Range Accuracy Index	
Wn	13	uint13	92		0-1023	Beidou week number	
toc	17	uint17	105	8		Reference time of clock parameters	
Bgd1	10	int10	122	0.1		Equipment Group Delay Differential (nanosec)	
reserved	10	int10	132			// For future Equipment Group Delay Differential 2	
a2	11	int11	142	2^{-66}		Clock correction (sec/sec^2)	
a0	24	int24	153	2^{-33}		Clock correction (sec)	
a1	22	int22	177	2^{-50}		Clock correction (sec/sec)	
AODE	5	uint5	199			Age of Data, Ephemeris	

Δn	16	int16	204	2^{-43}		Mean motion difference from computed value (semicircles/sec)	
Cuc	18	int18	220	2^{-31}		Amplitude of cosine harmonic correction term to the argument of latitude (radians)	
m0	32	int32	238	2^{-31}		Mean anomaly at reference time (semicircles)	
e	32	uint32	270	2^{-33}		Eccentricity	
Cus	18	int18	302	2^{-31}		Harmonic correction term (radians)	
Crc	18	int18	320	2^{-6}		Harmonic correction term (meters)	
Crs	18	int18	338	2^{-6}		Harmonic correction term (meters)	
$A^{1/2}$	32	uint32	356	2^{-19}		Square root of semi-major axis (meters$^{1/2}$)	
toe	17	uint17	388	8		Reference ephemeris time (sec)	
i0	32	int32	405	2^{-31}		Inclination angle (semicircles)	
Cic	18	int16	437	2^{-31}		Harmonic correction term (radians)	
ω dot	24	int24	455	2^{-43}		Rate of right ascension (semicircles/sec)	
Cis	18	int16	479	2^{-31}		Harmonic correction term (radians)	
IDOT	14	int14	497	2^{-43}		Rate of inclination (semicircles/sec)	
ω0	32	int32	511	2^{-31}		Longitude of ascending node (semicircles)	
ω	32	int32	543	2^{-31}		Argument of perigee (semicircles)	
reserved	9	bit9	575				
END TRANSPORT							
CRC	24	uint24	584			24-bit Cyclic Redundancy Check (CRC)	
Total	608						

Notes:

-

3.6.7 ATOM NAV Message / GPS Almanac

This message contains GPS almanac data for a given GPS satellite. For detailed information about GPS almanac data, please refer to the ICD-GPS-200 document.

Output Logic: on time / on change / on new
Message Binary size: 36 bytes (288 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&ALM
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SAL

Table 3.6.7.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 30 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 11	
MESSAGE DATA							
SVPRN	5	uint5	64		0-31	Satellite PRN number	
Health	8	uint8	69			Satellite Health	
E	16	uint16	77	2^{-21}		Eccentricity	

Toa	8	uint8	93	2^{12}		Reference time of almanac	
Δi	16	int16	101	2^{-19}		Inclination at reference time relative to i_0 = 0.3 semi-circles	
OMEGADOT	16	int16	117	2^{-38}		Rate of right Asc. (semi-circles per sec)	
ROOT_A	24	uint24	133	2^{-11}		Square root of semi-major axis (meters$^{1/2}$)	
OMEGA0	24	int24	157	2^{-23}		Longitude of ascending node (semicircles)	
Ω	24	int24	181	2^{-23}		Argument of Perigee (semi-circles)	
M0	24	int24	205	2^{-23}		Mean anomaly at reference time (semi-circle)	
Af0	11	int11	229	2^{-20}		Clock correction (sec)	
Af1	11	int11	240	2^{-38}		Clock correction (sec/sec)	
Wna	8	uint8	251	1	0-255	Almanac week number	
Reserved	5	bit5	259			Set to 00000	
END TRANSPORT							
CRC	24	uint24	264			24-bit Cyclic Redundancy Check (CRC)	
Total	288						

Note:

- The value of Δi generated from field i_0 (Inclination Angle at Reference Time) from GPS Ephemeris data is scaled by 0.1

3.6.8 ATOM NAV Message / GLONASS Almanac

This message contains GLONASS almanac data for a given GLONASS satellite. For detailed information about GLONASS almanac data, please refer to the GLONASS ICD ver.5 document.

Output Logic: on time / on change /on new
Message Binary size: 31 bytes (248 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&ALM
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SAG

Table 3.6.8.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 24 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 12	
MESSAGE DATA							
SatNum	5	uint5	64		1-24	GLONASS satellite number	
Frequency Channel Number	8	uint8	69			The GLONASS Satellite Frequency Channel Number identifies the frequency of the GLONASS satellite. 0 indicates channel number –07 1 indicates channel number –06 ….. 13 indicates channel number +6 31 indicates invalid channel number	
Health	1	bit1	77			Satellite Health, 0 – bad, 1 – good	

E	15	uint15	78	2^{-20}		Eccentricity	
Na	11	uint11	93			Reference day number	
Di	18	int18	104	2^{-20}		Correction to inclination (semicircles)	
La	21	int21	122	2^{-20}		Longitude of first ascension node (semicircles)	
Ta	21	uint21	143	2^{-5}		Reference time of longitude of first node (seconds)	
W	16	int16	164	2^{-15}		Argument of perigee (semicircles)	
Dta	22	int22	180	2^{-9}		Correction to mean value of Draconic period (seconds)	
dDta	7	int7	202	2^{-14}		Speed of Draconic period change (sec/curcuit)	
Reserved	5	bit5	209			Af1=d(Af0)/dt(sec/curcuit^2)	
Clock Offset	10	int10	214	2^{-18}		Clock offset (seconds)	
END TRANSPORT							
CRC	24	uint24	224			24-bit Cyclic Redundancy Check (CRC)	
Total	248						

3.6.9 ATOM NAV Message / SBAS Almanac

This message contains SBAS almanac data for a given SBAS satellite. For detailed information about SBAS almanac data, please refer to the WAAS ICD document.

Output Logic: on time / on change / on new
Message Binary size: 21 bytes (168 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&ALM
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SAW

Table 3.6.9.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number

START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 16 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 13	
MESSAGE DATA							
Data ID	2	uint2	64			Data ID	
SVPRN	8	uint8	66		1-19	SBAS satellite number	
Health	8	bit8	74			Satellite Health&Status bitwise meaning is: Bit0 – Ranging On(0), Off(1) Bit1 – Corrections On(0), Off(1) Bit2 – Broadcast Integrity On(0), Off(1) Bit3 – Reserved Bit4-7 – SBAS provider ID (0-15): 0 – WAAS, 1 – EGNOS, 2 – MSAS, 3-13 – Not assigned yet, 14-15 – Reserved	
X	15*	int15	82	2600		Satellite ECEF X coordinates (meters)	
Y	15*	int15	97	2600		Satellite ECEF Y coordinates (meters)	
Z	9*	int9	112	26000		Satellite ECEF Z coordinates (meters)	

Vx	3*	int3	121	10		Satellite ECEF velocity X' coordinates (m/s)	
Vy	3*	int3	124	10		Satellite ECEF velocity Y' coordinates (m/s)	
Vz	4*	int4	127	60		Satellite ECEF velocity Z' coordinates (m/s)	
t0	11	uint11	131	64		Almanac data reference time within the day expressed in the SBAS time scale (seconds)	
Reserved	2	bit2	142			Set to 00	
END TRANSPORT							
CRC	24	uint24	144			24-bit Cyclic Redundancy Check (CRC)	
Total	168						

3.6.10 ATOM NAV Message / Galileo Almanac

This message contains GAL almanac data for a given GAL satellite extracted from I/NAV signal. For detailed information about GALILEO almanac data, please refer to the GALILEO OS SIS ICD (September 2010) document.

Output Logic: on time / on change / on new
Message Binary size: 37 bytes (296 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&ALM
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also:

Table 3.6.10.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 31 for this message	

MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 14	
MESSAGE DATA							
SVPRN	6	uint6	64		1-36	The GALILEO SV_{ID} parameter is coded with 6 bits. However, the max constellation which can be accommodated within the I/NAV frames is 36 satellites (3 planes of 12 satellites each).	See DF252
$\Delta a^{(1/2)}$	13	int13	70	2^{-9}		Difference with respect to the square root of the nominal semi-major axis (meters$^{1/2}$)	
e	11	uint11	83	2^{-16}		Eccentricity (dimensionless)	
Δi	11	int11	94	2^{-14}		Inclination at reference time relative to $i_0 = 56^{\circ}$ (semi-circles per sec)	
Ω_0	16	int16	105	2^{-15}		Right ascension (semi-circles)	
$(\Omega_0)'$	11	int11	121	2^{-33}		Rate Right ascension. (semi-circles per sec)	
ω	16	int16	132	2^{-15}		Argument of Perigee (semi-circles)	
M_0	16	int16	148	2^{-15}		Mean anomaly at reference time (semi-circle)	
a_{f0}	16	int16	164	2^{-19}		Satellite clock correction bias “truncated” (sec)	
a_{f1}	13	int13	180	2^{-38}		Satellite clock correction linear “truncated” (sec/sec)	
IODa	4	uint4	193				
t_{0a}	10	uint10	197	600		Almanac reference time	sec
Wna	2	uint2	207	1		Almanac reference week number	week

Reserved	8	Bit(8)	209				
E1-B Signal Health Status	2	bit(2)	217			Unitless	
Reserved	1	bit(1)	219			Because in GAL,ALM there is no data validity bits	
E5b Signal Health Status	2	bit(2)	220			Unitless	
Reserved	1	bit(1)	222			Because in GAL,ALM there is no data validity bits	
Source of decoded ephemeris	2	uint2	223			0 – from E1-B, 1- from E5b, 2 – used booth, 3 - unknown	
Reserved	7	bit(7)	225				
END TRANSPORT							
CRC	24	uint24	232			24-bit Cyclic Redundancy Check (CRC)	
Total	256						

3.6.11 ATOM NAV Message / QZSS Almanac

This message contains QZSS almanac data for a particular satellite. For detailed information about QZSS almanac one should refer to IS-QZSS_13[E] document.

Output Logic: on time / on change / on new
Message Binary size: 36 bytes (288 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&ALM
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SAL

Table 3.6.11.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	

Message Length	10	unt10	14			Message length in bytes. Set to 30 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 15	
MESSAGE DATA							
SVPRN	5	uint5	64		0-4	Satellite PRN number, original ID 193 corresponds to 0, ID 194 corresponds to 1 etc	
Health	8	uint8	69			This 8-bit Almanac health is divided into the first 3 bits (NAV Data Health Indications) and the last 5 bits (indicate the health of the signal components)	
E	16	uint16	77	2^{-21}		Eccentricity	
Toa	8	uint8	93	2^{12}		Reference time of almanac	
Δi	16	int16	101	2^{-19}		Inclination at reference time relative to i_0 = 0.3 semi-circles	
OMEGADOT	16	int16	117	2^{-38}		Rate of right Asc. (semi-circles per sec)	
ROOT_A	24	uint24	133	2^{-11}		Square root of semi-major axis (meters$^{1/2}$)	
OMEGA0	24	int24	157	2^{-23}		Longitude of ascending node (semicircles)	
Ω	24	int24	181	2^{-23}		Argument of Perigee (semi-circles)	
M0	24	int24	205	2^{-23}		Mean anomaly at reference time (semi-circle)	
Af0	11	int11	229	2^{-20}		Clock correction (sec)	
Af1	11	int11	240	2^{-38}		Clock correction (sec/sec)	
Wna	8	uint8	251	1	0-255	Almanac week number	

Reserved	5	bit5	259			Set to 00000	
END TRANSPORT							
CRC	24	uint24	264			24-bit Cyclic Redundancy Check (CRC)	
Total	288						

Note:

- The value of Δi generated from field i_0 (Inclination Angle at Reference Time) from GPS Ephemeris data is scaled by 0.1

3.6.12 ATOM NAV Message / Beidou Almanac

This message contains Beidou almanac data for a particular satellite. For detailed information about Beidou almanac please refer to the Beidou ICD (IOpen Service Signal B1I Version 1.0, December 2012) document.

Output Logic: on time / on change / on new
Message Binary size: 38 bytes (304 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&ALM
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,SAL

Table 3.6.12.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 32 for this message	
MESSAGE HEADER							

Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 16	
MESSAGE DATA							
SVPRN	6	uint6	64		0-???	Satellite PRN	
ROOT_A	24	uint24	72	2^{-11}		Square root of semi-major axis (meters$^{1/2}$)	
a1	11	int11	96	2^{-38}		Clock correction (sec/sec)	
a0	11	int11	107	2^{-20}		Clock correction (sec)	
OMEGA0	24	int24	118	2^{-23}		Longitude of ascending node (semicircles)	
E	17	uint17	142	2^{-21}		Eccentricity	
Δi	16	int16	159	2^{-19}		For MEO/IGSO satellites, i0=0.30 semi-circles; for GEO satellites, i0=0.00. semi-circles	
OMEGADOT	17	int17	175	2^{-38}		Rate of right Asc. (semi-circles per sec)	
Ω	24	int24	192	2^{-23}		Argument of Perigee (semi-circles)	
M0	24	int24	216	2^{-23}		Mean anomaly at reference time (semi-circle)	
Wna	8	uint8	240	1	0-255	Almanac week number	
Toa	8	uint8	248	2^{12}		Reference time of almanac	
Health	9	uint8	256			The satellite health information	
Reserved	7	bit7	265			Set to 00000	
END TRANSPORT							
CRC	24	uint24	272			24-bit Cyclic Redundancy Check (CRC)	
Total	304						

Note:

- The value of Δi generated from field i_0 (Inclination Angle at Reference Time) from BDS Ephemeris data is scaled by 0.1 and 0

3.6.13 ATOM NAV Message / GPS ionosphere and time shift parameters

This message contains GPS ionosphere and time-shift parameters. For detailed information about these parameters, please refer to the ICD-GPS-200 document.

Output Logic: on time / on change / on new
Message Binary size: 32 bytes (256 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&GIT
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,ION

Table 3.6.13.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 26 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 21	

MESSAGE DATA							
α0	8	int8	64	2^{-30}		Ionospheric parameter (seconds)	
α1	8	int8	72	2^{-27}		Ionospheric parameter (seconds/semi-circle)	
α2	8	int8	80	2^{-24}		Ionospheric parameter (seconds/semi-circle)	
α3	8	int8	88	2^{-24}		Ionospheric parameter (seconds/semi-circle)	
β0	8	int8	96	2^{11}		Ionospheric parameter (seconds)	
β1	8	int8	104	2^{14}		Ionospheric parameter (seconds/semi-circle)	
β2	8	int8	112	2^{16}		Ionospheric parameter (seconds/semi-circle)	
β3	8	int8	120	2^{16}		Ionospheric parameter (seconds/semi-circle)	
A1	24	int24	128	2^{-50}		First order terms of polynomial	
A0	32	int32	152	2^{-30}		Constant terms of polynomial	
Tot	8	uint8	184	2^{12}		Reference time for UTC data	
Wnt	8	uint8	192		0-255	UTC reference week number	
ΔtLS	8	int8	200			GPS-UTC differences at reference time	
WnLSF	8	uint8	208		0-255	Week number when leap second became effective	
DN	8	uint8	216		0-7	Day number when leap second became effective	
ΔtLSF	8	int8	224			Delta time between GPS and UTC after correction	
END TRANSPORT							
CRC	24	uint24	232			24-bit Cyclic Redundancy Check (CRC)	
Total	256						

3.6.14 ATOM NAV Message / GPS full time parameters

This message contains the full set of GPS time parameters.

Output Logic: on time
Message Binary size: 16 bytes (128 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&GFT
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: RTCM-3 MT 1013

Table 3.6.14.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 10 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 22	
MESSAGE DATA							
TOW	20	uint20	64	0 - 604799	sec	GPS time of week	DF004
WN	12	uint12	84	0 - 4095	week	GPS wn modulo 4095 cycle	

						4095 means underfined or invalid	
GPS-UTC	6	uint6	96	0 - 63	sec	GPS-UTC time shift, 63 means unknown	DF054
Reserved	2	bit2	102			Set to 00	
END TRANSPORT							
CRC	24	uint24	104			24-bit Cyclic Redundancy Check (CRC)	
Total	128						

3.6.15 ATOM NAV Message / GAL ionosphere and time shift parameters

This message contains Galileo ionosphere and time-shift parameters. For detailed information about these parameters, please refer to the GALILEO OS SIS ICD (September 2010) document.

Output Logic: on time / on change / on new
Message Binary size: 34 bytes (272 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&GIT
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,ION

Table 3.6.15.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 28 for this message	

MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 24	
MESSAGE DATA							
$\alpha0$	11	uint11	64	2^{-2}		Effective ionisation level 1-st order parameter (sfu)	
$\alpha1$	11	int11	75	2^{-8}		Effective ionisation level 2-st order parameter (sfu/degree)	
$\alpha2$	14	int14	86	2^{-15}		Effective ionisation level 3-st order parameter (sfu/degree^2)	
SF1	1	bit1	100			Ionospheric disturbance Flag for region 1	
SF2	1	bit1	101			Ionospheric disturbance Flag for region 2	
SF3	1	bit1	102			Ionospheric disturbance Flag for region 3	
SF4	1	bit1	103			Ionospheric disturbance Flag for region 4	
SF5	1	bit1	104			Ionospheric disturbance Flag for region 5	
A0	32	int32	105	2^{-30}		Constant terms of polynomial (s)	
A1	24	int24	137	2^{-50}		First order terms of polynomial (s/s)	
ΔtLS	8	int8	161			GAL-UTC differences at reference time	
Tot	8	uint8	169	3600		Reference time for UTC data	
Wnt	8	uint8	177		0-255	UTC reference week number	
WnLSF	8	uint8	185		0-255	Week number when leap second became effective	
DN	3	uint3	193		0-7	Day number when leap second became effective	
ΔtLSF	8	int8	196			Delta time between GAL and UTC after correction	

A0G	16	int16	204	2^{-35}		Constant terms of polynomial for GAL ->GPS	
A1G	12	int12	220	2^{-51}		First order terms of polynomial for GAL->GPS	
TotG	8	uint8	232	3600		Reference time for GAL->GPS	
WntG	6	uint6	240		0-255	reference week number for GAL->GPS	
reserved	2	uint2	246				
END TRANSPORT							
CRC	24	uint24	248			24-bit Cyclic Redundancy Check (CRC)	
Total	272						

3.6.16 ATOM NAV Message / QZS ionosphere and time shift parameters

This message contains QZSS ionosphere and time-shift parameters. For detailed information about these parameters, please refer to the IS-QZSS_13[E] document.

Output Logic: on time / on change / on new
Message Binary size: 32 bytes (256 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&GIT
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,ION

Table 3.6.16.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 26 for this message	

MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 25	
MESSAGE DATA							
$\alpha 0$	8	int8	64	2^{-30}		Ionospheric parameter (seconds)	
$\alpha 1$	8	int8	72	2^{-27}		Ionospheric parameter (seconds/semi-circle)	
$\alpha 2$	8	int8	80	2^{-24}		Ionospheric parameter (seconds/semi-circle)	
$\alpha 3$	8	int8	88	2^{-24}		Ionospheric parameter (seconds/semi-circle)	
$\beta 0$	8	int8	96	2^{11}		Ionospheric parameter (seconds)	
$\beta 1$	8	int8	104	2^{14}		Ionospheric parameter (seconds/semi-circle)	
$\beta 2$	8	int8	112	2^{16}		Ionospheric parameter (seconds/semi-circle)	
$\beta 3$	8	int8	120	2^{16}		Ionospheric parameter (seconds/semi-circle)	
A1	24	int24	128	2^{-50}		First order terms of polynomial	
A0	32	int32	152	2^{-30}		Constant terms of polynomial	
Tot	8	int8	184	2^{12}		Reference time for UTC data	
Wnt	8	uint8	192		0-255	UTC reference week number	
ΔtLS	8	int8	200			QZS-UTC differences at reference time	
WnLSF	8	uint8	208		0-255	Week number when leap second became effective	
DN	8	uint8	216		0-7	Day number when leap second became effective	
ΔtLSF	8	int8	224			Delta time between QZS and UTC after correction	

END TRANSPORT							
CRC	24	uint24	232			24-bit Cyclic Redundancy Check (CRC)	
Total	256						

3.6.17 ATOM NAV Message / BDS ionosphere and time shift parameters

This message contains BDS ionosphere and time-shift parameters. For detailed information about these parameters, please refer to the Beidou ICD (IOpen Service Signal B1I Version 1.0, December 2012) document..

Output Logic: on time / on change / on new
Message Binary size: 44 bytes (352 bits)
How to request? $PASHS,ATM,NAV,<Port Name>,ON,x,&GIT
Permissible intervals x (sec): 1/2/3/etc each integer second but less than 999
See also: $PASHR,ION

Table 3.6.17.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 38 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	5 is reserved for ATOM NAV message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
NAV message type	9	uint9	55		0-511	Specifies which NAV message follows. For this message, set to 26	

MESSAGE DATA							
α0	8	int8	64	2^{-30}		Ionospheric parameter (seconds)	
α1	8	int8	72	2^{-27}		Ionospheric parameter (seconds/semi-circle)	
α2	8	int8	80	2^{-24}		Ionospheric parameter (seconds/semi-circle)	
α3	8	int8	88	2^{-24}		Ionospheric parameter (seconds/semi-circle)	
β0	8	int8	96	2^{11}		Ionospheric parameter (seconds)	
β1	8	int8	104	2^{14}		Ionospheric parameter (seconds/semi-circle)	
β2	8	int8	112	2^{16}		Ionospheric parameter (seconds/semi-circle)	
β3	8	int8	120	2^{16}		Ionospheric parameter (seconds/semi-circle)	
A0 GPS	14	int14	128	0.1		Const terms clock bias relative to GPS (ns)	
A1 GPS	16	int16	142	0.1		First order clock bias relative to GPS (ns/s)	
A0 Gal	14	int14	158	0.1		Const terms clock bias relative to Gal (ns)	
A1 Gal	16	int16	172	0.1		First order clock bias relative to Gal (ns/s)	
A0 GLO	14	int14	188	0.1		Const terms clock bias relative to GLO (ns)	
A1 GLO	16	int16	202	0.1		First order clock bias relative to GLO (ns/s)	
ΔtLS	8	int8	218			BDS-UTC differences at reference time	
ΔtLSF	8	int8	226			Delta time between BDS and UTC after correction	
WnLSF	8	uint8	234		0-255	Week number when leap second became effective	
A0	32	int32	242	2^{-30}		Const terms clock bias relative to UTC (s)	
A1	24	int24	274	2^{-50}		First order clock bias relative to UTC(s/s)	
DN	8	uint8	298		0-7	Day number when leap second became effective	
Reserved	22		306			For future t0t and wnt	
END TRANSPORT							
CRC	24	uint24	328			24-bit Cyclic Redundancy Check (CRC)	

Total	352	

3.7 ATOM DAT Messages

Messages of the DAT (raw DATa) group contain original binary data. Particularly this group contains GPS, GLONASS, Galileo, QZSS, BDS and SBAS raw navigation data (streams). Processing raw navigation data streams, users can extract any navigation information, particularly that contained in ATOM NAV messages. Also group DAT contains very valuable generalized message EXT and INT capable to output almost any data existing/travelling inside GNSS receiver. All DAT messages containing navigation streams can be requested independently of each other. For messages of this group, there is no need to specify intervals between messages (while it still can be specified by universality reasons in which case it will be ignored). A message is output after a new frame has been decoded. DAT,EXT messages are requested by single command and output every data entering GNSS receiver, i.e. DAT,EXT contains spied data packed into convenient frames. DAT,INT messages are also requested by single command. For each hardware target and firmware version there can be different set of DAT,INT messages.

The set of default ATOM DAT messages can be enabled/disabled using the following command:

$PASHS,ATM,DAT,<Port Name>,ON/OFF

The general organization of the DAT message is presented on Figure 3.7.a and in Table 3.7.a.

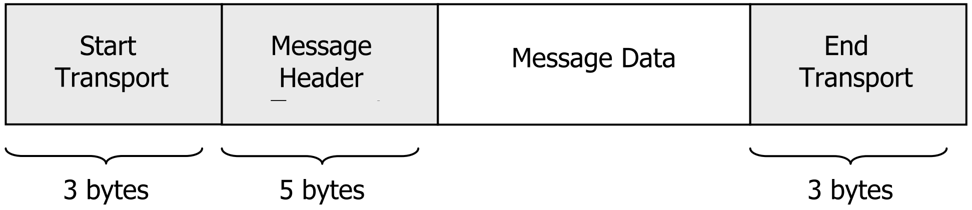


Figure 3.7.a. *DAT messages organization*

Table 3.7.a. *DAT messages organization*

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	

Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	6 is reserved for ATOM DAT message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
DAT message type	9	uint9	55		0-511	Specifies which DAT message follows	
MESSAGE DATA							
Raw Data content						See sub-sections below	
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

The supported DAT messages are presented in Table 3.7.b.

Table 3.7.b. Supported DAT messages

DAT message type	ASCII identifier	Attribute description	Comments	Counterpart
0				RESERVED
1	GPS	GPS raw navigation data	All raw data from L1 CA GPS signal	N/A
2	GLO	GLO raw navigation data	All raw data from L1 CA GLONASS signal	N/A
3	SBA	SBAS raw navigation data	All raw data from L1 CA SBAS signal	$PASHR,SBD

4	GAL	GAL raw navigation data	All raw data from Galileo E1b signal	N/A
9	FRM	Universal GNSS raw data frames	Raw navigation data from all tracked GNSS, Satellites, Signals	N/A
10	INT	Original binary data travelling inside receiver	Data travelling inside receiver via internal pipes	N/A
11	EXT	Original binary stream entering receiver	Data entering receiver via physical/virtual port(s) and sockets	N/A

It must be noted that message FRM is generic substitute of legacy messages GPS/GLO/SBA/GAL. Only given generic message will be supported in future by adding support of new GNSS and their signals (e.g. QZSS).

3.7.1 ATOM DAT Message / GPS Raw Sub Frame

3.7.2 ATOM DAT Message / GLONASS Raw String

3.7.3 ATOM DAT Message / SBAS Sub Frame

This message contains an SBAS raw subframe. A raw SBAS subframe is 250 bits in total. For detailed information about the structure of SBAS raw subframes, please refer to the WAAS ICD. If parity check failed then corresponding sub-frame is not output.

Output Logic: on change
Message Binary size: 49 bytes (392 bits)
How to request? $PASHS,ATM,DAT,<Port Name>,ON,&SBA
Permissible intervals x (sec): N/A
See also: $PASHR,SBD

Table 3.7.3.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	

Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes. Set to 43 for this message	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	6 is reserved for ATOM DAT message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
DAT message type	9	uint9	55		0-511	Specifies which DAT message follows. For this message, set to 3	
MESSAGE DATA							
Sat ID	5	uint5	64		0-19	SBAS satellite number 0: Sat ID is not defined 1 -> PRN#120 2 -> PRN#121 ….. 19 -> PRN#138	
Signal ID	3	bit3	69		0-7	Type of signal 0: Signal is not defined 1: L1CA signal	
Channel number	8	uint8	72		0-255	Receiver channel number 0: channel number is unknown	
Message Type	6	uint6	80		0-63	SBAS subframe number	
Receiver time (GPS)	20	uint20	86	1 sec	0-604799	GPS second within GPS week, 2^{20-1} if not defined	DF004
Reserved	6	bit6	106			Set to 000000	
Subframe data	250	bit250	112			SBAS subframe data	
Reserved	6	bit6	362			Set to 000000	
END TRANSPORT							

CRC	24	uint24	368			24-bit Cyclic Redundancy Check (CRC)	
Total	392						

3.7.4 ATOM DAT Message / Galileo Raw Pages

3.7.5 ATOM DAT Message / EXTernal port data

This message contains the binary data entering the receiver via one of its ports/sockets. Particularly this message can contain incoming differential corrections and/or commands used to configure the receiver. Packed data are the data created by an external device, that is why GNSS receiver which outputs DAT,EXT messages is not responsible for their content. Packed data can be of known structure and user can process them by own algorithms/tools. At the same time packed data can be of unknown structure in which case user must inquire which source created the original data packed into DAT,EXT.

Output Logic: on change
Message Binary size: depends on buffer organization
How to request? $PASHS,ATM,DAT,<Port Name>,ON,&EXT
Permissible intervals x (sec): N/A
See also: N/A

Table 3.7.5.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	unt10	14			Message length in bytes.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	6 is reserved for ATOM DAT message	

Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
DAT message type	9	uint9	55		0-511	Specifies which DAT message follows. For this message set to 11	
MESSAGE DATA							
Source identifier	16	uint16			0-65535	The port/socket original data come from. 65535 means no source defined	
Reserved	16	Bit16			0-65535	Set to 0…0	
Cumulative data counter	8	uint8			0-255	Incremented with each new data portion corresponding to the same source identifier	
Type of data packing	6	uint6			0-63	Specifies original data packing method 0: Original binary data 1: Inverted original binary data 2: Adding number 2 to each byte 3-62: reserved 63: unknown type of packing	
Length of data, X	10	uint10			0-1000	The length of data (in bytes) which follow. Length > 1000 is invalid	
The data	8*X	char(X)				The spied data themselves. Each byte is converted with “Type of data packing” algorithm	
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

Table 3.7.5.b Examples of adding number 2

Original byte	*Converted byte*
0x13	*0x15*
0xAF	*0xB1*
0xFE	*0x00*

0xFF	*0x01*

Table 3.7.5.c Source identifiers

Code	Source description	Comment
0	Port A	The data from physical port A are packed
1	Port B	The data from physical port B are packed
2	Port C	The data from physical port C are packed
3	Port D	The data from physical port D are packed
4-6	Reserved for other physical ports	
7	Port H	In MB100 refers to internal heading mode pipe
8-22	Reserved for other physical or virtual ports	
23	Port X	The data from virtual port X are packed
24	Port Y	The data from virtual port Y are packed
25	Port Z	The data from virtual port Z are packed
26-65535	Reserved for other sources identifiers	

The ATOM DAT (EXT) message is universal. Referring to physical receiver ports (source description 0,1,2 etc), it allows users to spy all the data entering the receiver via its physical ports A,B,C etc. There is no need to parse the incoming data. The ATOM coder just takes the appropriate part from the input stream (buffer), wraps it into an ATOM DAT (EXT) message which is then output via the desired receiver port(s). Thus ATOM DAT (EXT) is a very effective transport to do the following:

- Spy all receiver configuration oriented commands (from whichever port) without the need to parse them
- Spy incoming differential stream(s) without the need to decode them

It is worth noting that, being requested to be output via a given receiver port, ATOM DAT (EXT) will not interfere with any other receiver message requested on the same port (data packing methods are applied to additionally guarantee that the content of the spied data will not be recognized mechanically by other procedures). The composite log file can then be easily processed to extract all the spied data, for example to create a reference station raw data file.

The ATOM DAT (EXT) can be used for creating so called virtual ports. It can be useful if some application is talking to GNSS receiver via single physical port (e.g. port A), but wants to get more than one fully independent data streams. E.g. some receiver data can be requested to port A, some other receiver data (or the same data with other parameters) can be requested to port Z. Both streams will be output via the same physical port A, but the data stream corresponding virtual port Z will be additionally packed inside ATM,DAT,EXT with source ID=25 (port Z). This packing does not obligatory mean that each message is packed separately, on contrary the stream can be cut off quite arbitrarily. The only application s/w need is supporting parsing ATM,DAT,EXT transport to split both streams. Any s/w which supports decoding RTCM-3 transport, can easily implement ATM,DAT,EXT parsing.

3.7.6 ATOM DAT Message / INTernal receiver data

3.7.7 ATOM DAT Message / Universal GNSS raw data frames

This message contains raw frames decoded from each tracked GNSS signal with data (not pilots). The message is universal and applicable to each currently known GNSS signal. Given message can be considered as a generic substitute of particular messages DAT,GPS/GLO/SBA/GAL.

Output Logic: on change
Message Binary size: depends on GNSS and signal type
How to request? $PASHS,ATM,DAT,<Port Name>,ON,&FRM
Permissible intervals x (sec): N/A
See also: N/A

Table 3.7.7.a Message structure and content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	bit6	8			Set to 000000	
Message Length	10	uint10	14			Message length in bytes	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	6 is reserved for ATOM DAT message	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
DAT message type	9	uint9	55		0-511	Specifies which DAT message follows. For this message, set to 9	
MESSAGE DATA							
GNSS ID	3	uint3	64		0-7	0: GPS 1: SBAS	

						2: GLONASS 3: GALILEO 4: QZSS 5: Beidou 6-7: reserved for other GNSS	
Satellite ID	6	uint6	67		0-63	The rank-1 in Satellite mask, see DF394 in section 3.3	
Signal ID	5	uint5	73		0-31	The rank-1 in Signal mask, see DF395 in section 3.3.	
Channel ID	8	uint8	78		0-255	The receiver channel number tracking given signal	
GNSS specific field	4	uint4	86		0-15	GLONASS: it is freq number indicator (see also message STA,GFN) SBAS: it is time of message (TOW) Other GNSS: set to 0	
Overlap flag	1	uint1	90		0-1	User must skip this message if the flag is set to 1. See Appendix G.	AF024
Reserved	9	bit9	91			Set to 0…0	
Subframe data length, K	12	uint12	100	1 bit	0-4096	The number of bits in subframe data which follow	
Subframe data	K	bitK	112			Frame data themselves	
END TRANSPORT							
CRC	24	uint24	112+K			24-bit Cyclic Redundancy Check (CRC)	
Total	136+K						

Note:

- The proper number (0 to 7) of zero bits is inserted before CRC to make complete message to contain integer number of bytes
- Only data which were successfully synchronized/decoded are generated
- The numbers representing Satellite ID and Signal IDs respectively refers actually to the position (rank) of corresponding bit in Satellite and Signal Mask (see Section 3.3). E.g. ID=0 refers to the first bit in corresponding Mask, ID=1 refers to the second bit in corresponding Mask etc.

3.8 ATOM RNX Message

The ATOM RNX (RiNeX) message is intended to generate receiver observations to allow their future, effective, unambiguous conversion to RINEX-3. In most cases, this message can also be used as differential protocol between RTK base and RTK rover. The RNX message can contain observables from more than one GNSS and (optionally) receiver reference position (stationary or moving). The RNX message can be customized using the existing serial interface. Customization may range from fully expanded to fully compacted, allowing users to select the desired tradeoff between message size and data availability. The RNX message supports the generation of different GNSS (as well as reference position) inside separated ATOM transmissions, as well as inside a single ATOM transmission. The description below is focused on the latter case while staying a general description of the message. Observables presented in the ATOM RNX messages are steered for the receiver clock offset. At the same time, an optional ATOM RNX block provides the original receiver clock offset and clock drift. So the decoding equipment can restore original (i.e. not steered) observables if needed. The particularities that stand behind generating, presenting and restoring the ATOM RNX message can be found in Section 5 and Appendixes C, D, E and F.

The understanding of ATM,RNX organization can be helped with Ashtech ION GNSS 2012 paper.

Session D5: Multi-Constellation User Receivers

The RTCM Multiple Signal Messages: A New Step In GNSS Data Standardization

A. Boriskin, D. Kozlov, G. Zyryanov, Ashtech, Russia

The paper deals with standardized RTCM-3.2 Multiple Signal Messages (MSM) which are simplified copy of ATOM RNX messages

The basic principles of ATOM RNX messages originated standardized RTCM-3.2 generic MSM data. These are the messages 1071-1077 (GPS), 1081-1087 (GLONASS), 1091-1097 (GALILEO) etc. This means that generating and processing Ashtech proprietary ATOM RNX messages and standardized RTCM-3.2 MSM data has very much in common.

The default ATOM RNX message can be enabled/disabled using the following command:

$PASHS,ATM,RNX,<Port Name>,ON/OFF

The general organization of the RNX message is presented below.

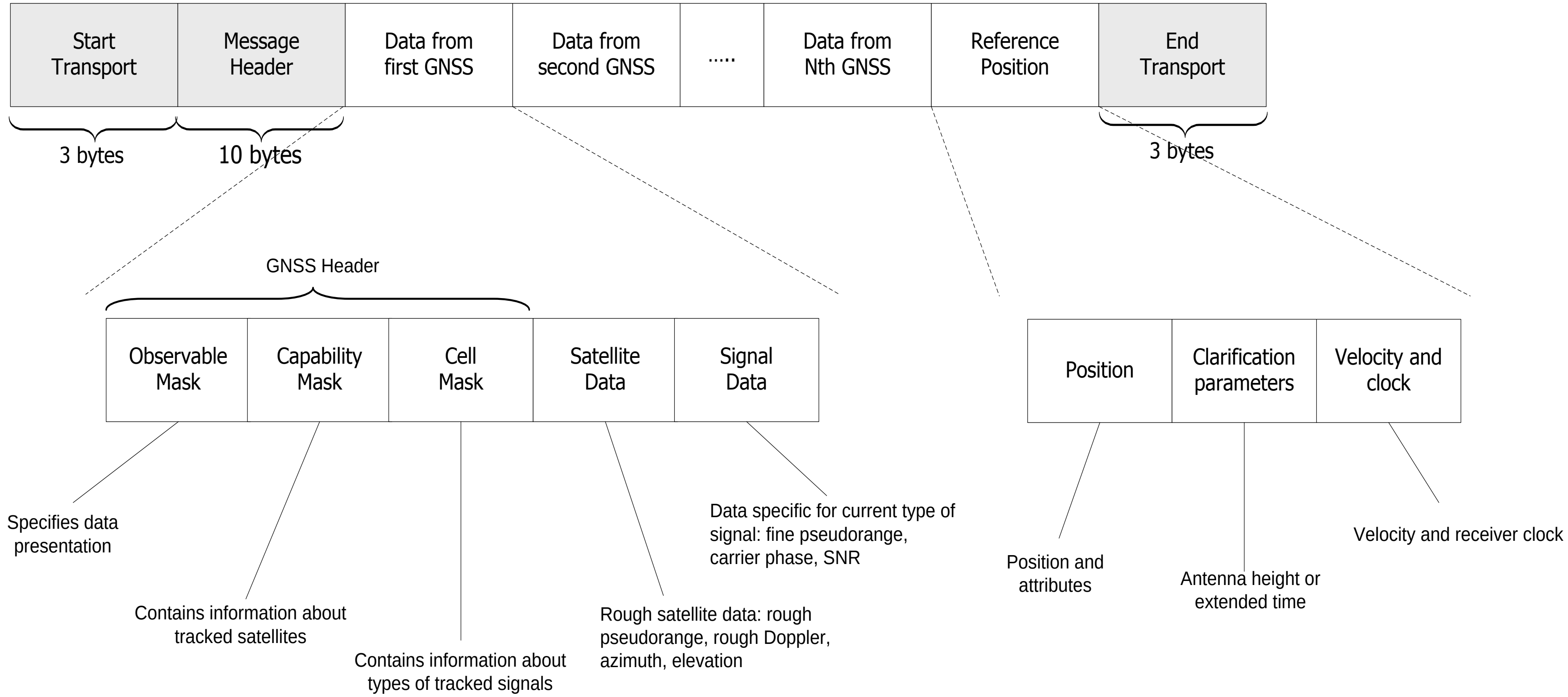


Figure 3.8a Organization of RNX message

3.8.1 Message structure and header

Output Logic:	on time
Message binary size:	depends on message content
How to request?	$PASHS,ATM,RNX,<Port Name>,ON,x
Permissible intervals x (sec):	0.05/0.1/0.2/0.5/1/2/3/4/5/6/10/12/15/20/30/60/120 etc each integer minute but less than 15 min
See also:	$PASHR,MPC; $PASHR,PBN; RTCM-3 MT 1001-1006, 1009-1012; RTCM-2 MT 18,19,24; RTCM-3 MSM

Table 3.8.1.a Message structure and header content

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
START TRANSPORT							
Transport Preamble	8	uint8	0			Set to 0xD3 (HEX Code)	
Reserved	6	Bit6	8			Set to 000000	
Message Length	10	uint10	14			Message length in bytes	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	7 is reserved for ATOM RNX	
Version	3	uint3	40		0-7	ATOM version number, set to 1 or 2	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
Multiple message bit	1	Bit1	55		0-1	1, if more ATOM RNX data follow tagged to the same physical time and reference station ID	See DF393
IODS	3	uint3	56		0-7	Reserved for Issue Of Data Station. Set to 000	DF409
Smoothing interval	3	uint3	59		0-7	The code-carrier smoothing interval	DF415
Position presentation	2	uint2	62		0-3	0: position does not follow 1: compact position follows 2: extended position follows 3: full position follows	
GNSS mask	8	Bit8	64		0-255	Bit1: GPS data follow Bit2: SBAS data follow Bit3: GLONASS data follow Bit4: GALILEO data follow Bit5: QZSS data follow Bit6: BEIDOU data follow Bit7-8: reserved for other GNSS	

Primary GNSS system	3	uint3	72		0-7	0: GPS is primary 2: GLONASS is primary 6: BEIDOU is primary 1,3,4,5,7: reserved for other GNSS	
Time tag	21	bit21	75			See Tables 3.8.1b, c, d	
Divergence free smoothing indicator	1	bit1	96		0-1	Indicates if more than one carrier was used for code-carrier smoothing	DF414
Cumulative session transmitting time indicator	7	uint7	97		0-127		
FIRST GNSS BLOCK DATA (see GNSS mask in the message header)							
Observables Mask	16					See Table 3.8.2a	
Capability Mask	[]					See Tables 3.8.2b,c	Depends on ATOM RNX version
Cell Mask	[<=64]					See Table 3.8.2d	
Satellite Data	[ ]					See Table 3.8.3a	
Signal Data	[ ]					See Table 3.8.4a	
SECOND GNSS BLOCK DATA (see GNSS mask in the message header)							
Meanings of data packing and fields are the same for each GNSS							
N-th GNSS BLOCK DATA (see GNSS mask in the message header)							
Meanings of data packing and fields are the same for each GNSS							
REFERENCE POSITION (see position presentation flag in the message header)							
Reference position						See Table 3.8.5a,b,c	

END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

Notes:

- The sequence of GNSS data is fixed and always follows “GNSS mask” (GPS->SBAS->GLONASS->GALILEO->QZSS->BEIDOU) regardless of the primary GNSS used.
- Reference position is always last and can be presented in different forms as indicated by the “Position presentation” flag
- The Multiple message bit allows the complete GNSS data epoch (including reference position) to be compiled from different ATOM RNX messages tagged to the same receiver time and reference station ID.
- Reported code-carrier smoothing parameters (smoothing interval and divergence free indicator) are the copies of SMI parameters user specified by receiver serial commands. See Ashtech OEM products User Manuals. User must understand that single frequency receivers cannot generate divergence free smoothing. Typical Ashtech default smoothing intervals are 600 sec for single band receivers and 1800 sec for multiple band receivers. Note 600 seconds for L1-only receiver it not so high value as one can think. In fact Ashtech applies years-proven L1 code-carrier smoothing strategy using second order filtering. That is why when first order filter can produce ionosphere bias even with 100 sec smoothing, Ashtech second order filtering inserts no bias even with 600 sec smoothing.
- Some Satellites at some time windows cannot provide L2 data. While receiver can report divergence free smoothing, user must realize that it cannot be applicable for ‘L2-defective’ data.
- Field “Cumulative session transmitting time indicator” shows the time elapsed since requesting given ATM,RNX output. Each time when command $PASHS,ATM,RNX,<port>,ON,<period>,&SCN,<scenario> is issued (even with the very same parameters as previously), this field is reset to zero. Processing equipment should interpret decreasing this indicator between 2 consecutive received epochs as a cycle slip for all carrier data.
- The same physical time of two observation messages does not obligatory mean the very same time tagging because one message can be tagged to one GNSS time, while the other message can be tagged to another GNSS time.

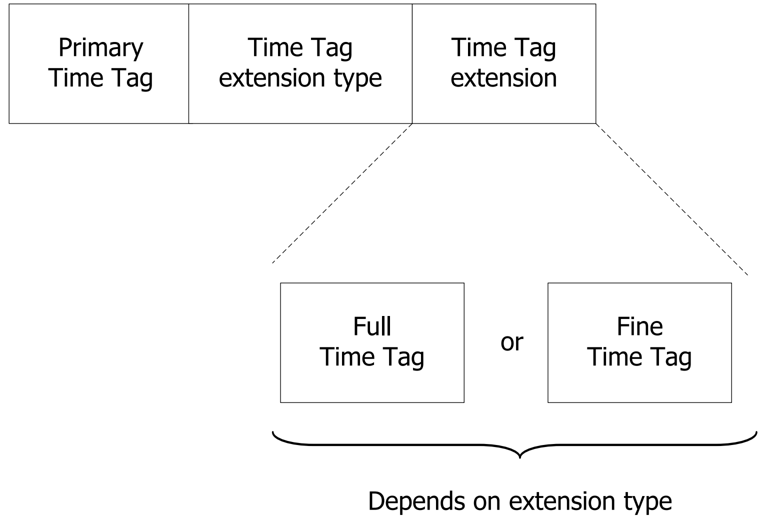


Figure 3.8.1a Time tag organization

Table 3.8.1.b Time tag presentation

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
Primary time tag	12	uint12	0	1 second	0-3599	GNSS time modulo 1 hour, 4095 means invalid time	
Time tag extension type	1	bit1	12		0-1	1: fine time tag extension follows 0: full time tag extension follows	
Time tag extension	8		13			Primary time tag extension (see the tables 3.8.1c, d)	
Total	21						

Table 3.8.1.c FULL Time tag presentation

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
Hour	5	uint5	0	1 hour	0-23	GNSS hour within GNSS day	

Day	3	uint3	5	1 day	0-6	Set to GPS day (0…6) within GPS week (0 is Sunday, 1 is Monday etc) Set to GLONASS day (0…6) within GLONASS week (0 is Sunday, 1 is Monday etc) Set to BDS day (0…6) within BDS week (0 is Sunday, 1 is Monday etc) In each case, 7 refers to unknown day	
Total	8						

Table 3.8.1.d FINE Time tag presentation

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
Fractional second	8	uint8	0	5 ms	0-995	GNSS time modulo 1 sec	
Total	8						

Notes:

- The time tag always refers to the time scale of the primary GNSS system used, e.g. UTC + Nls (where Nls is the number of leap seconds, i.e.15 as from Jan 1 2009 and 16 as from July 2012) for GPS, and UTC+3 hours for GLONASS.
- The size of the time tag is always fixed.
- In the most of the cases (i.e. for the most of supported ATM,RNX scenarios) the message is not generated if correct primary GNSS time is not known. For example, GPS can be set as primary system, but GPS can be not tracked. In this case, correct primary system time can be not available and other (than GPS) GNSS data will not be generated.
- Using the switchable time tag presentation, users can cover a full range of GNSS time tags with fine resolution. If the time tag is an integer second, the ATOM generator will insert full extension information to reduce whole time tag ambiguity down to a week number. If the time tag is a fractional second, then the ATOM generator will insert a fine time tag extension thus allowing data to be generated at up to 200 Hz.
- If a leap second occurs, the primary time tag is set to 3600 (if GPS is primary).

3.8.2 GNSS header

The GNSS header is described below by sequentially introducing the description of the Observable mask (fixed size), the optional Capability mask (fixed size), and the optional Cell mask (float size).

Table 3.8.2.a Observable mask

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
OBSERVABLE MASK							
Data ID change counter	5	uint5	0		0-31	Incremented by 1 each time the content of capability or cell mask is changed; rolls from 31 to 0.	
Data ID follow	1	bit1	5		0-1	0: no capability&cell mask follow 1: capability&cell mask follow	
N_{ms} follow	1	bit1	6		0-1	0: no Nms follow 1: Nms follow	
Supplementary follow	2	uint2	7		0-3	0: no supplementary data follow 1: compact supplementary data follow 2: full supplementary data follow 3: reserved	
Pseudo-range follow	2	uint2	9		0-3	0: no pseudo-range follow 1: fine pseudo-range follow 2: full pseudo-range follow 3: reserved	
Carrier phase follow	2	uint2	11		0-3	0: no carrier phase follow 1: fine carrier phase follow 2: full carrier phase follow 3: reserved	
Resolution	1	bit1	13		0-1	0: standard resolution 1: extended resolution	
Reserved	2	bit2	14		0-3	Set to 00	
Total	16						

Table 3.8.2.b Capability mask for ATOM RNX version 2 (inserted if 'Data ID follow'=1 in observable mask, see Table 3.8.2a)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
CAPABILITY MASK							
Satellite mask	64	bit64	0			See Appendix E	DF394
Signal mask	32	bit32	64			See Appendix E	DF395
Total	96						

Table 3.8.2.c Capability mask for ATOM RNX version 1 (inserted if 'Data ID follow'=1 in observable mask, see Table 3.8.2a)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
CAPABILITY MASK							
Satellite mask	40	bit64	0			See Appendix E	See DF394
Signal mask	24	bit24	40			See Appendix E	See DF395
Reserved	8	bit32	64			Set to 00000000	
Total	72						

Table 3.8.2.d Cell mask (inserted if 'Data ID follow'=1 in observable mask, see Table 3.8.2a)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
CELL MASK							
Cell mask	X= Nsat x Nsig	bitX				See Appendix E	DF396
Total	X<=64						

Notes:

- Bit 'Resolution' in Observable mask is hardcoded to 0 for ATOM v.1, but can take values 0 and 1 for ATOM v.2. Depending on this bit, the presentation of Signal data can be different. See Section 3.8.4.
- The Cell mask is of float size, but its size is known after decoding the capability mask (see Table 3.8.2b,c)
- Nsat is the number of tracked satellites (the number of 1's in Satellite mask), Nsig is the number of available signals (the number of 1's in Signal mask)
- The ATOM generator checks X, and if it is actually >64, then ATOM RNX data are to be split into more than one transmission, in which case the Multiple message bit in the ATOM RNX header is set accordingly (see table 3.8.1a).
- The availability of the "Data ID change counter" allows the decimation of the Capability and Cell masks to be applied. For some epochs, observations can come without identification information. In this case, the previously decoded identification information can be used, provided the Data ID change counter has not changed meanwhile.
- ATOM,RNX ver.1 defines Sat mask size 40 bits and Signal mask size 24 bits. The meaning of first 40 bits in Sat mask v.2 and Sat mask v.1 is the same. The meaning of first 24 bits in Signal mask v.2 and Signal mask v.1 is the same. Decoding equipment must analyze ATOM,RNX version number and process all the other fields accordingly.

3.8.3 Satellite data

Satellite data have 3 optional blocks that can be inserted in the message, depending on configuration bits in the Observable mask (see Table 3.8.2a). These blocks contain information common to each signal from the same satellite. In each of these 3 blocks, the field(s) having the same meaning for each of the satellites from a given GNSS are internally repeated Nsat times in order to output the value(s) of this or these fields for each of the satellites. The value of Nsat is known after decoding the Capability mask (see Table 3.8.2b).

Table 3.8.3.a Satellite data

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
STELLITE DATA							
Integer number of ms in Satellite ranges	8 x Nsat times	uint8(N_{sat})		1 ms	0-255 ms	Inserted if Nms follows Set to 255 if not known	DF397
Satellite rough range modulo 1 ms	10 x Nsat times	uint10(N_{sat})		1/1024 ms	0-(1023 / 1024) ms	Inserted if full pseudo-range follows	See DF398
Extended Satellite supplementary data	32 x Nsat times	bit32(N_{sat})				Inserted if full supplementary data follow (See section 3.8.6)	
Total							

Notes:

- Considering 'Integer number of ms in Satellite range' for example, "repeating" this field means that the value of this field will be provided in succession for each of the satellites for which the Satellite mask is "1" (see Table 3.8.2b). With 10 tracked satellites for example, the field size will finally be 80=10x8 bits.
- Full rough range (in ms) is just the sum of the first 2 fields above. In case when integer number of ms is not available, it is responsibility of decoding equipment to restore it using known approximate position and available navigation data

3.8.4 Signal data

Signal data have 5 optional blocks that can be inserted in the message, depending on configuration bits in the Observable mask (see Table 3.8.2a). These blocks contain information specific to each signal. In each of these 5 blocks, the field(s) having the same meaning for each of the signals from a given GNSS are internally repeated Ncell times in order to output the value(s) of this or these fields for each of the signals. The value of Ncell is known after decoding the Cell mask (see Table 3.8.2c).

Table 3.8.4.a Signal data for resolution = 0 (standard)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SIGNAL DATA							
Fine pseudorange data	15 Ncell times	uint15(N_{cell})		0.02m	0-655.34 m	Inserted if fine or full pseudo-range follows	
Integer cycle carrier	16=4+12					Inserted if full carrier phase	

Table 3.8.4.b Signal data for resolution = 1 (extended)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SIGNAL DATA							
Fine pseudorange data	20 Ncell times	uint20(N_{cell})		0.02	0-655.34 m	Inserted if fine or full pseudo-range follows	
Integer cycle carrier phase data	22=10+12 Ncell times	uint22(N_{cell})		1 cycle	0-4095 cycle	Inserted if full carrier phase follows (see notes below)	
Fractional cycle carrier phase data	10 Ncell times	uint10(N_{cell})		1/1024 cycle	0-(1023/1024) cycle	Inserted if fine or full carrier phase follows	
SNR	10 Ncell times	uint10(N_{cell})		1/16 dBHz	0-63 dBHz	Inserted if compact or full supplementary data follow	DF408
Extended supplementary data	64 Ncell times	bit64(N_{cell})				Inserted if full supplementary data follow (see section 3.8.6)	
Total							

Notes:

- Considering 'Fine pseudo-range data' for example, "repeating" this field means that the value of this field will be provided in succession for each of the signals for which the Cell mask is "1" (see Table 3.8.2c). With 20 available cells, the field size will finally be 300=20x15 bits (or 20*20 bits for extended resolution)
- Each cell in the 'integer cycle carrier phase data' field actually includes a 4-bit cumulative loss of continuity indicator (10 bits for extended resolution), followed by the 12-bit integer cycle carrier phase as such.

- Full fine carrier phase data is just a sum of integer cycle carrier phase and fractional cycle carrier phase. In some cases, integer cycle carrier phase is not transmitted (compact data transmission scenarios for static GNSS receiver), so decoding equipment must take proper care to restore full fine carrier phase or operate with fractional carrier only.
- The Cumulative loss of continuity indicator is incremented by 1 each time when at least one non recovered carrier cycle slip occured for this particular signal on interval between currently generated and previously generated epoch. The indicator takes values from 0 to 15 or 1023 (and then back to 0 after 15 or 1023 has been reached). ATM,RNX data generator insures needed provision in order not to allow full indicator range cycle to occur during less than 2 minutes.
- All reported carrier phases of different signals belonging to the same band are aligned with each other, i.e. a ¼ cycle correction is possibly applied.
- Fine pseudo-range data are usually smoothed properly. Optional parameters (smooth count and smoothing residuals) are used to indicate the smoothing status and restore the unsmoothed fine pseudo-range, if needed.
- If pseudo range for some signal is invalid then its corresponding fine pseudo range field is reported as zero. If pseudo range for some signal is valid and corresponding fine pseudo range field actually takes zero value, then ATOM generator adds 0.02 m (or 0.02/32 m for extended resolution) to it inserting thereby this negligible error which does not affect the final performance.
- If carrier phase for some signal is invalid then corresponding integer cycle carrier phase and fractional cycle carrier phase are both set to zero. If carrier phase for some signal is valid but actually takes zero value, then ATOM generator adds 1/256 (or 1/1024 cycle for extended resolution) cycle to it inserting thereby this negligible error which does not affect the final performance.
- The observables reported for different resolution options are actually the same. To transit from Extended to Standard resolution one simply ignores 2 LSB for fractional carrier, 5 LSB for fine range and 4 LSB for SNR. At the same time cumulative loss of continuity indicator for Standard resolution is 4 LSB of corresponding 10 bits indicator with Extended resolution.
- With incorrect initialization and/or singular ionosphere conditions, carrier phase can diverge with time against respective pseudo range by large value which can no longer allow effective data packing into ATM,RNX w/o reinitializing new integer value in carrier phase. In these cases, ATM,RNX generator can apply new integer value (i.e. introduce cycle slip in respective carrier). This integer value is either 1024 or (-1024) cycles of respective wavelength and it can be not indicated by cumulative loss of continuity indicator. Decoding equipment must be aware about such a possibility and foresee the actions either to reset corresponding carrier processing or to 'sew' respective carrier measurements.

3.8.5 Reference position

Reference position refers to the ‘default’ datum associated with the GNSS indicated as primary in the Message header (see Table 3.8.1a). Depending on the position presentation flag in the Message header (see Table 3.8.1a), the reference position can be generated in one of the following 4 different forms:

- No reference position
- Compact reference position (see table 3.8.5a)
- Compact reference position + clarification data (see table 3.8.5b)
- Compact reference position + clarification data + velocity & clock (see table 3.8.5c)

Table 3.8.5.a Compact reference position

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
REFERENCE POSITION							
Motion flag	1	bit1	0		0-1	0: stationary 1: moving	
Position quality flag	3	uint3	1		0-7	0: precise (mm accuracy) 1: RTK fixed (cm accuracy) 2: RTK float (dm accuracy) 3: DGNSS (sub-meter accuracy) 4: Standalone (a few meters accuracy) 5: Rough (hundreds meter accuracy) 6: Approximate (km level accuracy) 7: unknown	
Reserved	7	bit7	4		0-127	Set to 0000000	
Position tagging	3	uint3	11		0-7	0: Antenna reference point 1: L1 phase center 2-5: reserved 6: Ground mark 7: Unknown	
X coordinate	38	int38	14	0.0001 m	+/- 13743895.3472 m	-13743895.3472 if not defined or invalid	DF025

Y coordinate	38	int38	52	Ditto	Ditto	Ditto	DF026
Z coordinate	38	int38	90	Ditto	Ditto	Ditto	DF027
Total	128						

Notes:

- At the moment, reserved bits are planned to be used in future for the following standardized RTCM-3 indicators: VRS indicator (DF141, 1 bit), Reference Oscillator Indicator (DF142, 1 bit), Clock Steering Indicator (DF411, 2 bits), External Clock Indicator (DF412, 2 bits)
- Motion flag must be interpreted as following. If it indicates moving receiver, then processing equipment must consider this and each next (if it does not contain reference position data) epoch of RNX observables as corresponding to moving receiver. It is recommended to generate reference position each observation epoch. If motion flag indicates static receiver, then processing equipment should consider this and each next (if it does not contain reference position data) epoch of RNX observables as corresponding to static receiver. It is sufficient to generate reference position with admissible decimation (e.g. in 10-30 times) compared to RNX observables. Decoding equipment must not make any a priori assumptions regarding time intervals between reference positions epochs and changes in reported motion flag from epoch to epoch.
- It is not possible to indicate reference position quality flag in all the cases; that is why very often the default quality flag is unknown.

Table 3.8.5.b Compact reference position + clarification data

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
REFERENCE POSITION							
Motion flag	1	bit1	0		0-1	0: stationary 1: moving	
Position quality flag	3	uint3	1		0-7	0: precise (mm accuracy) 1: RTK fixed (cm accuracy) 2: RTK float (dm accuracy) 3: DGNSS (sub-meter accuracy) 4: Standalone (few meters accuracy) 5: Rough (hundreds meter accuracy) 6: Approximate (km level accuracy) 7: unknown	

Reserved	7	bit7	4		0-127	Set to 0000000	
Position tagging	3	uint3	11		0-7	0: Antenna reference point 1: L1 phase center 2-5: reserved 6: Ground mark 7. Unknown	
X coordinate	38	int38	14	0.0001 m	+/- 13743895.3 471 m	-13743895.3472 if not defined or invalid	DF025
Y coordinate	38	int38	52	Ditto	Ditto	Ditto	DF026
Z coordinate	38	int38	90	Ditto	Ditto	Ditto	DF027
Clarifier switch	2	uint2	128		0-3	0: Extended position data follow 1: Extended time data follow 2-3: reserved	
Clarification data	22	bit22	130			See tables 3.8.5.d,e.	
Total	152						

Notes:

- The Clarifier switch allows the different clarification data provided in the next 22 bits to be used. For example, a typical transmission scenario can be as follows. In one epoch of reference position data, antenna height and ITRF epoch year are generated. In the next epoch of reference position data, GPS-UTC time offset and GPS week number are generated.

Table 3.8.5.c Compact reference position + clarification data + velocity&clock

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
REFERENCE DATA							
Motion flag	1	Bit1	0		0-1	0: stationary 1: moving	
Position quality flag	3	uint3	1		0-7	0: precise (mm accuracy) 1: RTK fixed (cm accuracy) 2: RTK float (dm accuracy) 3: DGNSS (sub-meter accuracy)	

						4: Standalone (few meters accuracy) 5: Rough (hundreds meter accuracy) 6: Approximate (km level accuracy) 7: unknown	
Reserved	7	Bit7	4		0-127	Set to 0000000	
Position tagging	3	uint3	11		0-7	0: Antenna reference point 1: L1 phase center 2-5: reserved 6: Ground mark 7: Unknown	
X coordinate	38	int38	14	0.0001 m	+/-13743895.3471 m	-13743895.3472 if not defined or invalid	DF025
Y coordinate	38	int38	52	Ditto	Ditto	Ditto	DF026
Z coordinate	38	int38	90	Ditto	Ditto	Ditto	DF027
Clarifier switch	2	uint2	128		0-3	0: Extended position data follow 1: Extended time data follow 2-3: reserved	
Clarification data	22	bit22	130			See tables 3.8.5.d,e.	
X velocity	25	int25	152	0.0001 m/s	+/-1677.7215	-1677.7216 if not defined or invalid	
Y velocity	25	int25	177	0.0001 m/s	+/-1677.7215	-1677.7216 if not defined or invalid	
Z velocity	25	int25	202	0.0001 m/s	+/-1677.7215	-1677.7216 if not defined or invalid	
Reserved	1	Bit1	227		0-1	Set to 0	
Receiver clock offset	30	int30	228	0.001 m	+/-536870.911 m	-536870.912 if not defined or invalid	

Receiver clock drift	22	int22	258	0.001 m/s	+/-2097.152 m/s	-2097.152 if not defined or invalid	
Total	280						

Notes:

- "Receiver clock offset" and "Receiver clock drift" refer to the original receiver observables the clock of which is typically kept within +/-1 ms. By contrast, observables reported in ATOM RNX are clock steered. The availability of the receiver clock offset and clock drift allows 3rd party users to restore original (not steered) receiver observables**.**

- Reported receiver clock offset and drifts refers to the time scale of primary GNSS system specified in RNX message header. This value is used for clock steering in all GNSS observables

- It must be noted that clock steering procedure affects not only observables but also reference position when this position corresponds to very high dynamic receiver. In this case, user who desires to return to not steered data will have not only to correct original observables, but also original reference position.

Table 3.8.5.d Clarification data for reference position (clarifier = 0)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
REFERENCE POSITION CLARIFICATIONS DATA							
ITRF epoch year	6	uint6	0		0-63		DF021
Antenna height	16	uint16	6	0.0001 m	0-6.5535	Value 6.5535 means 6.5535+	DF028
Total	22						

Table 3.8.5.e Clarification data for reference position (clarifier = 1)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
REFERENCE POSITION CLARIFICATIONS DATA							
GPS-UTC time offset	6	uint6	0	1 sec	0-63	63 means undefined or invalid	See DF054
The number of GNSS time cycles	12	uint12	6		0-4095	For GPS, wn modulo 4095 cycle For BDS, wn modulo 4095 cycle For GLO, day number of 4 year period (DF129)	

						4095 means underfined or invalid	
Receiver time status	4	uint4	18		0-8	See Appendix G	AF010
Total	22						

Note:

- Official RTCM field “DF021” is actually reserved for the ITRF epoch year, but not claimed as usable. ATOM follows the same strategy. Once RTCM claims that DF021 is usable, ATOM will use it as well.
- The number of GNSS time cycles refers to GPS Week number (0-4095; 0 starts midnight January5/January 6 1980, rolls from 4095 to 0) if GPS is primary system.
- The number of GNSS time cycles refers to GLONASS day number (1-1461, day 1 corresponds to January 1 1996, rolls from 1461 to 1, zero means unknown day, values 1462-4095 are not used) if GLONAS is primary system.
- Receiver time status refers to time scale of primary GNSS system.

3.8.6 Extended ATOM RNX data

This section describes the extended observation data. The generation of extended satellite and signal data is controlled by the 'supplementary follow' field in the GNSS header.

Table 3.8.6.a Extended Satellite data

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
EXTENDED SATELLITE DATA (one Satellite portion)							
Azimuth	8	uint8	0	2 degrees	0-358	>358 means invalid azimuth	
Elevation	7	uint7	8	1 degree		0-90 means true positive elevation 91 means true elevation -1 degree 92 means true elevation -2 degree etc. 126 means true elevation less or equal to -36 degree 127 means invalid elevation	
Rough Doppler	14	int14	15	1 m/s	+/-8191 m/s	Value -8192 means invalid	DF399
Full range available	1	bit1	29		0-1	0: Full Sat range available 1: No full Sat range available	
Satellite status	2	uint2	30		0-3	0: Sat is used in position 1: Sat is not used (no ephemeris) 2: Sat is not used (other cause) 3: Sat is not used (unhealthy)	
Total	32						

Notes:

- No "Full Sat range available" means that the original receiver pseudo-range contains an unknown integer number of milliseconds, but pseudo-range is still valid modulo 1 ms.
- A satellite is considered as used in internal receiver position if at least one satellite observable (code, carrier or Doppler) was used in position computation. A satellite not used in internal receiver position does not imply that its observables are bad.
- A satellite can be internally recognized as unhealthy. This does not generally prevent to output its observables. It must be noted that Sat can be set internally unhealthy by different reasons (almanac data, own ephemeris data, SBAS integrity data, external integrity flags etc). If a Sat has no ephemeris and marked as unhealthy, then Status =3 is reported.

Table 3.8.6.b   Extended Signal data if resolution = 0

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
EXTENDED SIGNAL DATA (one Signal portion)							
Channel number	8	unt8	0		0-255	Value 0 means not defined	
Fine Doppler	15	int15	8	0.0001 m/s	+/-1.6383 m/s	Value -1.6384 means invalid	
Smoothing residual	11	int11	23	0.02 m	+/-20.46 m	To be added to pseudo-range to get unsmoothed value. The copy of MPC smooth correction, but with opposite sign. Value (-20.48) means invalid Value (-20.46) means less or equal (-20.46), value 20.46 means more or equal 20.46	
Smooth count	8	uint8	34	1 sec	0-255	The copy of MPC smooth count. Value 255 means 255+	
Signal warnings	14	bit14	42			Original channel warnings (see table 3.8.6d)	
Total	56						

Table 3.8.6.c   Extended Signal data if resolution = 1

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
EXTENDED SIGNAL DATA (one Signal portion)							
Channel number	8	uint8	0		0-255	Value 0 means not defined	
Fine Doppler	15	int15	8	0.0001 m/s	+/-1.6383 m/s	Value -1.6384 means invalid	DF404
Smoothing residual	16	int16	23	0.002/32 m	+/-20.46 m	To be added to pseudo-range to get unsmoothed value. The copy of	

						MPC smooth correction, but with opposite sign. Value (-20.48) means invalid Value (-20.46) means less or equal (-20.46), value 20.46 means more or equal 20.46	
Reserved	3	Bit3	39			Set to 000	
Smooth count	8	uint8	42	1 sec	0-255	The copy of MPC smooth count. Value 255 means 255+	
Signal warnings	14	bit14	50			Original channel warnings (see table 3.8.6d)	
Total	64						

Notes:

- Full Doppler(j) for each Signal(j) is restored as FullDoppler(j)=RoughDoppler+FineDoppler(j)
- "MPC" refers to the legacy output message $PASHR,MPC containing the GNSS measurement from one satellite for one epoch.

Table 3.8.6.d Signal warnings

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SIGNAL WARNINGS (one signal portion)							
Fractional carrier bias	2	uint2	0		0-3	0: zero fractional bias (polarity known) 1: possible half a cycle bias (polarity not resolved) 2: arbitrary carrier bias 3: reserved	Similar to MPC polarity byte
Carrier quality	1	Bit1	2		0-1	0: carrier tracking is OK 1: possible carrier drift	Same as MPC warning (bit 2)
Pseudo-range quality	2	uint2	3		0-3	0: OK 1: satisfactory 2: admissible 3: bad	Same as MPC warning (bits 3-4). See notes below.

Doppler quality	1	Bit1	5		0-1	0: Smoothed Doppler 1: Not smoothed Doppler	
Cycle Slip possible	1	Bit1	6		0-1	0: no cycle slip suspected 1: cycle slip is possible	Same as MPC warning (bit 6)
Loss of Continuity	1	Bit1	7		0-1	0: continuous carrier tracking 1: loss of lock occurred	Same as MPC warning (bit 7)
Reserved	6	Bit6	8		0-63	See Appendix G	AF005
Total	14						

Notes:

- Invalid smoothing residuals do not obligatory mean invalid value of corresponding pseudo-range
- The bits in the MPC warning byte are counted from 0 to 7.
- MPC bit 5 (Z-tracking) is not reflected here, but it is reflected in Signal Mask (signals 1W and 2W). MPC bits 0-1 are not reflected here, but they are reflected in Satellite status field in Extended Satellite data.
- A special state for "fractional carrier bias" was reserved to allow a "not fixable" carrier to be generated (applicable to carriers from some consumer receivers such as SiRF). This state indicates that the carrier can have an arbitrary float bias during its continuous tracking. Because of that, its Double-Difference ambiguity can never be fixed to integers.
- In general, transitions between states of "fractional carrier bias" field are accompanied by carrier cycle slip and loss of lock indicators if carrier bias has been actually changed (when resolving polarity) or suspected to be changed (when losing data synchronizations) . However, if resolved polarity is correct and no half a cycle correction introduced, then cycle slip and loss of lock indicators are not set with transition from 1 to 0.
- Indicators relating to carrier phase (carrier quality, cycle slip possible and loss of continuity) actually refer to the interval between the current and previously generated ATOM RNX epoch, and not to the receiver time tag. Cumulative twin of loss of continuity bit is available in the field 'integer cycle carrier phase data'.
- "Smoothed Doppler" means that is was derived from carrier phase samples through appropriate filtering. "Not smoothed Doppler" refers to Doppler extracted directly from the carrier/frequency tracking loop (NCO)
- Matching table for pseudo-range quality:

Pseudo-range quality	Pseudo-range quality value	MPC bit 3	MPC bit 4
Good	0	0	0
Satisfactory	1	1	0
Admissible	2	0	1

Bad	3	1	1

3.9 ATOM SUP Messages

3.10 ATOM EVT Messages

3.11 ATOM STA Messages

3.12 ATOM ALR Messages

4. ATOM SERIAL INTERFACE

This chapter is organized as follows. First we describe the simplest ways to request each group of ATOM messages. Second we describe how to request each particular ATOM sub-message or sub-block from groups SUP, PVT, ATR, NAV, DAT, STA and EVT. Then we show how to customize ATOM observables messages (RNX) for user-specific needs.

4.1 Getting started

To request the output of any of the ATOM groups on a specified port with its default parameters, use the following command:

$PASHS,ATM,<Group type>,<Port Name>,ON

where:

<Group type> is any of the available messages (ALR, SUP, PVT, ATR, NAV, DAT, RNX, STA, or EVT)
<Port Name> is any of the supported receiver ports (A, B, etc.)

Using this type of request, default data outputs will be available. Examples of default outputs are given in the table below (defaults may be receiver/firmware dependent).

Group type	4095 subID	ATM subID	Default sub-messages/sub-blocks or scenario	Default intervals
Receiver Alarms	0	ALR	USR	N/A
Supplementary data	1	SUP	CPI	1 second
Positioning results	3	PVT	COO,ERR,LCY,SVS	1 second for all
Receiver attributes	4	ATR	ANM,RNM, CPB	30 seconds for all
Navigation information	5	NAV	EPH,GIT,GFT	300 seconds for all
Binary data frames	6	DAT	EXT,FRM	N/A
Receiver observables	7	RNX	SCN,4	1 second
Receiver status	13	STA	BLA,DDS,GFN	5 seconds for all
Receiver events	14	EVT	TTT,PTT	N/A

With each receiver reset, the configuration (sub-blocks/sub-messages and their intervals) of each group is set to respective defaults.

To request the output of any ATOM message on a specified port at the desired output rate (period), use the following command:

$PASHS,ATM,<Group type>,<Port Name>,ON,<Per>

where:

<Per> is the period (in sec) of the group (i.e. of each default sub-message or sub-block). The period specified for ALR and DAT messages is ignored.

To disable particular ATOM group on a given port, use the following command:

$PASHS,ATM, <Group type>,<Port Name>,OFF

To disable all the ATOM messages on a given port, use the following command:

$PASHS,ATM,ALL,<Port Name>,OFF

The existing ATOM groups can be divided into two categories: those configurable by sub-messages or sub-blocks (ALR, SUP, PVT, ATR, NAV, DAT, STA, EVT), and those configurable by scenario (RNX). The way ATOM messages are output is under the control of the "ATOM setup". Users can configure the ATOM setup using the extended serial interface described in the sections below.

4.2 Using the Extended Serial Interface for Sub-Message & Sub-Block Customization

ATOM messages ALR, SUP, PVT, ATR, NAV, DAT, STA and EVT contain different sub-messages/sub-blocks which users can choose to generate (with their own period) or not. "Sub-block" means a data block inserted under a message header, i.e. generated within the same transmission, together with other sub-blocks. "Sub-message" means independently generated data belonging to a given group type. To customize these groups, the extended serial interface should be used:

$PASHS,ATM, <Group type>,<Port Name>,ON[,Per],&mm1,mm2,mm3,…

or

$PASHS,ATM, <Group type>,<Port Name>,OFF[,Per],&mm1,mm2,mm3,…

where:

mm1,mm2,mm3, … are sub-message/sub-group identifiers
[Per] is the optional period in seconds

Users can request sub-messages/sub-groups one by one, or multiplex them into a single string. For example, the first command line below describes the same ATOM setup as the next three command lines, provided the same Group Type, Port name ,and Per is specified in all four command lines:

$PASHS,ATM, <Group type>,<Port Name>,ON[,Per],&mm1,mm2,mm3

$PASHS,ATM, <Group type>,<Port Name>,ON[,Per],&mm1

$PASHS,ATM, <Group type>,<Port Name>,ON[,Per],&mm2
$PASHS,ATM, <Group type>,<Port Name>,ON[,Per],&mm3

The receiver stores the ATOM setup independently for each <Port Name>. This means for example that users can enable a PVT message on virtual port Z and physical port A simultaneously, and generally with different periods and sub-blocks. When configuring the ATOM setup, each new setup command adds (or modifies) particular settings to the already existing (previous) setup, but does not reset it. That is why before requesting a setup update, it may be convenient first to disable all the ATOM outputs, using the following command:

$PASHS,ATM,ALL,<Port Name>,OFF

Any command in the form:

$PASHS,ATM, <Group type>,<Port Name>,ON

will initialize the corresponding default ATOM Group setup for <Port Name>.

Currently the following sub-messages/sub-blocks are supported:

ALR: USR, DBG

SUP: CPI, EPI, CVE, EVE

PVT: COO, ERR, VEL, CLK, LCY, HPR, BLN, MIS, ROT, BSD, PRR, SVS, LDP, CDC, LMP

ATR: ANM, RNM, UEM, AOP, OCC, SNS, MET, SAH, RIO, CFG, CPB

NAV: EPH(6), ALM(6), GIT(4), GFT

DAT: GPS, GLO, SBA, GAL, EXT, INT, FRM

STA: BLA, DDS, DPS, RSA, RSP, EGB, DLS, GCO, SHI, AST, SSC, GFN

EVT: TTT, PTT

It must be noted once more that some sub-messages/sub-blocks can be not not supported by Ashtech GNSS firmware. But they can be supported by Ashtech field and/or office application software.

Also some sub-blocks (e.g. LDP, CDC, and LMP) cannot be requested separately and are generated automatically in some conditions as a supplement to other sub-blocks (e.g. COO).

It should be noted that when requesting the EPH sub-message, one actually gets EPH for multiple GNSS (GPS, GLO, SBA, GAL, QZS, BDS if all are tracked). There is no way to request EPH data separately for each GNSS. The same is true for ALM data. Also, if a user requested raw data reduction to the virtual antenna (e.g. ADVNULLANTENNA) and asks for the ANM sub-message, two different ANM messages will result: one for the physical antenna and the other for the virtual antenna the reported observables data correspond to.

Below are typical examples to enable some ATOM data outputs. All the examples suppose that the **$PASHS,ATM, ALL,<Port name>,OFF** command has been run previously.

Enable ATOM PVT data on port A with position, followed by accuracy, both at 0.1-second interval, and by satellite status at 1-second interval:

$PASHS,ATM, PVT,A,ON,0.1,&COO,ERR
$PASHS,ATM, PVT,A,ON,1,&SVS

Enable ATOM NAV (EPH) data on port A and port Z (virtual port) with different intervals (600 and 300 seconds respectively):

$PASHS,ATM, NAV,A,ON,600,&EPH
$PASHS,ATM, NAV,Z,ON,300,&EPH

Enable ATOM DAT (raw navigation data for all tracked GNSS) data on port C:

$PASHS,ATM, DAT,C,ON,&FRM

The following rules should be known when applying customization to sub-messages/sub-blocks:

- Requesting a sub-message without specifying its period will result in a sub-message output with the default period
- Requesting several sub-messages through a single string that contains at least one syntax error will result in no setting applied at all
- Requesting several sub-messages with different periods will result in each of the sub-messages output with its specific period.
- Disabling all previously enabled sub-messages will put an end to the generation of the complete group (message).

User must also realize the following. GNSS receiver can operate with different internal update rate which is controlled by receiver options and POP setting. Depending on internal update rate, not all the output rates are permissible. E.g. with 5 Hz internal update rate, one can utilize only 'fast' intervals: 0.2 and 1 sec, but not 0.5, 0.1 and 0.05 sec.

4.3 Using the Extended Serial Interface for Observables Scenario Customization

Unlike the other ATOM messages, RNX has an extra-feature: it can generate the same observation data in different forms, thereby allowing some trade-off between data quality/availability and message throughput. These different forms of data presentation can be available through the so-called SCN,x scenario, where integer x stands for the scenario number.

RNX messages can then be enabled/disabled through a single command:

$PASHS,ATM, RNX,<Port Name>,ON/OFF,<Per>,&SCN,x

The table below shortly describes the scenarios currently supported (for more details please refer to Section 5 and **Appendixes C** through **F**)

User case	SCN,x	Comment	Notes
Raw data recording			
	0	All available raw data in full presentation, full computed reference position follows each epoch	
‘Standard’ differential protocols			
	1	Singe band pseudo-range and carrier phase in full presentation, Nms in ranges does not follow, extended fixed position follows each 12 epochs	The generalized analog of RTCM-3 MT 1001,1009,1006 Can support L1-only, L2-only, L5-only etc generation
	2	Singe band SNR, pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs	The generalized analog of RTCM-3 MT 1002,1010,1006 Can support L1-only, L2-only, L5-only etc generation
	3	Dual band pseudo-range and carrier phase in full presentation, Nms in ranges does not follow, extended fixed position follows each 12 epochs	The generalized analog of RTCM-3 MT 1003,1011,1006 Can support L1&L2 as well as L1&L5 or any other dual band combination
	4	Dual band SNR, pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs	The generalized analog of RTCM-3 MT 1004,1012,1006 Can support L1&L2 as well as L1&L5 or any other dual band combination
Compact differential protocols			
	100	Dual band compact pseudo-range and full carrier phase, extended fixed position follows each 12 epochs, all the data are decimated in 5 times compared to a pilot carrier phase	Can support L1&L2 as well as L1&L5 or any other dual band combination By default, pilot carrier is L1
	101	Dual band compact pseudo-range and compact carrier phase, extended fixed position follows each 12 epochs, all the data are decimated in 5 times compared to a pilot carrier phase. **<u>This scenario cannot be used with moving receiver.</u>**	Can support L1&L2 as well as L1&L5 or any other dual band combination By default, pilot carrier is L1
Differential protocols for moving base			
	201	Same as scenario 1, but extended computed reference position follows each epoch	
	202	Same as scenario 2, but extended computed reference position follows each epoch	
	203	Same as scenario 3, but extended computed reference position follows each epoch	
	204	Same as scenario 4, but extended computed reference position follows each	

		epoch	
	300	Same as scenario 100, but extended computed reference position follows each epoch	

Notes:

- Receiver port, scenario and interval can be set independently
- No more than one RNX scenario can be requested on the same receiver port
- RNX messages with same or different scenarios/intervals can be requested on different receiver ports
- The default RNX scenario and interval can be receiver type and/or firmware version dependent
- As the ATOM protocol continues to evolve, more available scenarios will be published
- Scenario SCN,0 depends on receiver capability, firmware version and/or available options
- All scenarios except SCN,0 suppose that only single signal data is generated for each GNSS&Sat&Band. For example, simultaneous generation of L2P(Y) and L2C(pilot) data (or 2W and 2L in RINEX convention) for the same Satellite is possible only for SCN,0
- Each newly specified scenario or interval overwrites the previous setup for a given port

4.4 Encapsulation

4.5 Output to virtual port

4.6 ATOM RNX scheduling among different transmissions

4.7 ATOM version

4.8 Querying ATOM Setup

4.9 Multiple ATOM PVT generation

When GNSS receiver is configured into advanced positioning modes (e.g. RTK+Heading or RTK+Attitude) where more than single solution is available then user still can request the primary position solution with standard setting:

$PASHS,ATM, PVT,<Port Name>,ON/OFF,<Per>

Given message reports Request ID=0 in the header.

At the same time, secondary solution (heading, attitude, and associated baseline) result should be requested with additional message request:

$PASHS,ATM, ANG,<Port Name>,ON/OFF,<Per>

This message content is PVT content but it refers to secondary solution. Given message reports Request ID=1 in the header.

5. COMPRESSION OPTIONS FOR ATOM RNX OBSERVABLES

6. ATOM UTILITIES

There are four primary Ashtech PC tools which help viewing/processing ATOM messages.

- AshCom: PC terminal program to talk to GNSS receivers and view its status
- DataView/AtlView: PC tool to process/view precollected GNSS data files
- WhatIs: console executable to get ascii content and statistic of most of binary GNSS data
- Bin2Std: console converter of ATOM RNX data to standardized messages/files

Each tool has own description available separately. Ask Ashtech Technical Support for corresponding tools.

Appendix A: *$PASHR transport decoding sample*

Appendix B: ATOM message decoding sample

Using an example of ATOM NAV / GPS ephemeris message, this Appendix gives the method to decode an ATOM message from binary to ASCII.

Full binary message content:

D3 00 42 FF F5 20 3E 01 3F B2 1D 90 03 03 2A 72 42 00 FF F1 E9 A0 54 2A FC 95 2A 94 14 A6 F0 58 FC 8B 05 69 B3 06 13 E2 A1 0D C9 32 72 42 00 59 29 D9 CF 58 FF E4 28 22 18 45 19 F5 76 70 BA D7 FF AB 27 F8 02 D8 82 21

Parts of the message:

D3 00 42 – Start Transport (3 bytes)

FF F5 20 3E 01 – Message Header (5 bytes)

3F B2 1D 90 03 03 2A 72 42 00 FF F1 E9 A0 54 2A FC 95 2A 94 14 A6 F0 58 FC 8B 05 69 B3 06 13 E2 A1 0D C9 32 72 42 00 59 29 D9 CF 58 FF E4 28 22 18 45 19 F5 76 70 BA D7 FF AB 27 F8 02 – Message Data (61 bytes)

D8 82 21 – End Transport (3 bytes)

Resulting ASCII presentation:

Data item	# Bits	Offset	Binary (HEX)	Scale	ASCII (Decimal)
START TRANSPORT					
Transport Preamble	8	0	D3		211
Reserved	6	8	00		0
Message Length	10	14	42		66
MESSAGE HEADER					
Message number	12	24	0F FF		4095
Message sub-number	4	36	05		5
Version	3	40	01		1

Reference station ID	12	43	00 1F		31
NAV message type	9	55	00 01		1
MESSAGE DATA					
Standardized message number	12	64	03 FB		1019
SVPRN	6	76	08		8
Wn	10	82	01 D9	**	1497
Accuracy	4	92	00		0
Code on L2	2	96	00		0
Idot	14	98	03 03	2^{-43}	8.765255E-011
Iode	8	112	2A		42
Toc	16	120	72 42	16	468000
af2	8	136	00	2^{-55}	0.000000E+000
af1	16	144	FF F1	2^{-43}	-1.705303E-012
af0	22	160	3A 68 15	2^{-31}	-1.706979E-004
Iodc	10	182	2A		42
Crs	16	192	FC 95	2^{-5}	-2.734375E+001
Δn	16	208	2A 94	2^{-43}	1.239187E-009
m0	32	224	14 A6 F0 58	2^{-31}	1.613446E-001
Cuc	16	256	FC 8B	2^{-29}	-1.648441E-006
E	32	272	05 69 B3 06	2^{-33}	1.057205E-002
Cus	16	304	13 E2	2^{-29}	9.480864E-006
$A^{1/2}$	32	320	A1 0D C9 32	2^{-19}	5.153723E+003
Toe	16	352	72 42	16	468000
Cic	16	368	00 59	2^{-29}	1.657754E-007
$\omega 0$	32	384	29 D9 CF 58	2^{-31}	3.269595E-001

Cis	16	416	FF E4	2^{-29}	-5.215406E-008
i0	32	432	28 22 18 45	2^{-31}	3.135405E-001
Crc	16	464	19 F5	2^{-5}	2.076563E+002
ω	32	480	76 70 BA D7	2^{-31}	9.253152E-001
ω dot	24	512	FF AB 27	2^{-43}	-2.469392E-009
Tgd	8	536	F8	2^{-31}	-3.725290E-009
Health	6	544	00		0
L2 P data flag	1	550	01		1
Fit Interval	1	551	00		0
END TRANSPORT					
CRC	24	552	D8 82 21		
Total	576				

Appendix C: Decomposition for ATOM RNX observables

This Appendix describes in detail the principles of breaking down ATOM RNX observables, thus providing a bridge between the different choices for the OPT optimization option (see section 5.3) and the corresponding ATOM presentations (see sections 3.8 and 3.9).

C.1. General principles to decompose original observables

With proper receiver design, basic observables (pseudo-range and carrier phase) always appear as being controlled by the same receiver clock. As a result, the 'dynamic' of all pseudo-ranges and carrier phases corresponding to the same satellite is almost the same. Only ionosphere divergence, receiver biases and some other negligible factors can cause the divergence of one observable against another. This fact is used when generating compact observations. It was initially introduced in the Trimble CMR format and later appeared as a primary concept in standardized RTCM-3 observation messages. Being quite attractive at that time, it has now become some kind of showstopper. The problem is that some signal (L1 pseudo-range) is selected as 'primary' observable, while all the other ('secondary') signals (e.g. L2 pseudo-range, L1&L2 carrier phase) are generated as the difference against this primary signal.

With the multiple signals we now get from each GNSS, it seems that such a 'primary-secondary' concept is not convenient. It has at least the following disadvantages:

- Invalid L1 pseudo-range (for whatever reason) automatically leads to inability to present all the other data.
- There is no possibility to send L2 data without sending L1 data. Earlier this was not so important, but with the current and future availability of L2C and L5, such L1 centered scheme can be ineffective (L5-only receivers can be manufactured in future)
- There is no possibility to send carrier phase data without sending pseudo-range. Carrier phase data have some interest primarily for precise applications, while [well smoothed] pseudo-range data are usually not needed with the same update rate as the carrier phase.

Of course, there already exists some actions to mitigate the negative effect of the L1 pseudo-range centered scheme. However, all of them are not so effective compared to the rough/fine range concept used in ATOM..

The idea behind the rough/fine range concept used in ATOM is very simple: each GNSS observable contains a 'regular term' and a 'specific term':

- Under 'regular term', we mean approximate range to a given satellite from a given position at a given receiver time. This regular term is the same for any type of observable corresponding to a given satellite. Moreover it does not contain site-specific information because it can be estimated (restored) easily providing, ephemeris and reference position are available.
- Under 'specific term', we mean 'thin' components including site-specific information, such as local ionosphere/troposphere conditions, receiver biases and multipath. This information cannot be restored.

That is why it is often possible to generate only the 'specific term' and not the 'regular term', as the latter can be restored on decoding side. To apply effectively this concept, the reference receiver should apply the following obvious principles:

- The carrier phase observable must be 'matched' to the corresponding pseudo-range by proper adjustment of the integer number of cycles

- All receiver observables must be receiver clock steered to guarantee minimum possible receiver clock error

These 2 principles are general for each standardized RTCM-3 observable.

ATOM RNX can generate the 'regular term' as the so-called "rough_range, which has not exactly a physical meaning, but is rather some technological value that will be used on the decoding side to restore the complete observable. There can be different algorithms to generate rough_range, based on:

- Some particular pseudo-range (e.g. L1CA)
- The mean value of all available pseudo-ranges
- Computed range

Rough_range is generated with a resolution of 1/1024 ms (about 300 meters) and is broken down into two components:

- The number of integer milliseconds in rough_range (8 bits covering the interval 0 to 255 ms)
- The rough_range modulo 1 millisecond (10 bits covering the interval 0 to (1023/1024) ms)

The receiver can generate the following:

- Full rough_range (18 bits)
- Fractional rough_range (10 bits)
- No rough_range at all (0 bits)

ATOM RNX can generate 'specific terms' for each observable as follows:

- Fine pseudo-range as original full pseudo-range modulo 655.36 meters with a resolution of 0.02 meters (15 bits covering the interval 0 to 655.34 meters)
- Fractional carrier phase as original carrier phase modulo 1 cycle with a resolution of 1/256 cycles (8 bits covering the interval 0 to (255/256) cycles)
- Integer cycle carrier phase as original carrier phase modulo 4096 cycles with a resolution of 1 cycle (12 bits covering the interval 0 to 4095 cycles)

If generated, the integer cycle carrier phase is supplemented by the "cumulative loss of continuity" indicator representing a 4-bit field incremented by 1 each time the original full carrier integer ambiguity is reinitialized (re-computed) to match the corresponding full original pseudo-range.

The general algorithm to restore any "Full" observable (pseudo-range or carrier phase) from the 'specific term' should be based on the following formula:

Full=Specific + N* resolution

where N is the integer to be determined. The resolution is 655.36 meters for pseudo-ranges and 4096 cycles for carrier phases. The integer value N can be found with the help of rough _range (if it is provided by ATOM) or can be restored (if rough_range is not provided by ATOM) using the knowledge of the reference position and the availability of ephemeris data. See section C.2 for additional details.

Some applications can work with the fractional carrier phase only. That is why ATOM allows such an option: sending only the fractional carrier phase. Also, there is a possibility to restore the full carrier phase from the fractional carrier. However, this is only possible if it is known a priori that the receiver generating the fractional carrier is a static receiver.

The table below (to be compared to the 6th table in section 5.3) shows which components of the original observables are generated depending on the choice made for the OPT (optimization) option. The generated rough_range can either be full rough_range or rough_range modulo 1 ms. The generation of the number of integer ms in rough_range is not controlled by the OPT setting. In contrast, this value can be generated, or not generated, depending on the choice made for the SCN option.

	No C	Compact C	Full C
No L	0: Not any data	1: Fine pseudo-range	2: Fine pseudo-range Rough_range (same for all satellites)
Compact L	3. Factional carrier	4: Fine pseudo-range Fractional carrier	5: Fine pseudo-range Fractional carrier Rough_range (same for all satellites)
Full L	6: Fractional carrier Integer cycle carrier	7: Fine pseudo-range Fractional carrier Integer cycle carrier	8: Fine pseudo-range Fractional carrier Integer cycle carrier Rough_range (same for all satellites)

C.2. Explicit algorithm to restore original observables

Regardless absolute value, all original receiver measurements (pseudo-range and carrier phase observables expressed in meters) corresponding to each particular Satellite at each particular instant appear as some compact cloud of a size:

$$Mmax-Mmin < dM$$

where dM is mainly defined by dispersive components, such as ionosphere.

Remind that each carrier phase is aligned to corresponding pseudo-range at the initialization moment using the adjustment of needed integer number of cycles.

For observables to be unambiguously packed into ATOM,RNX we require:

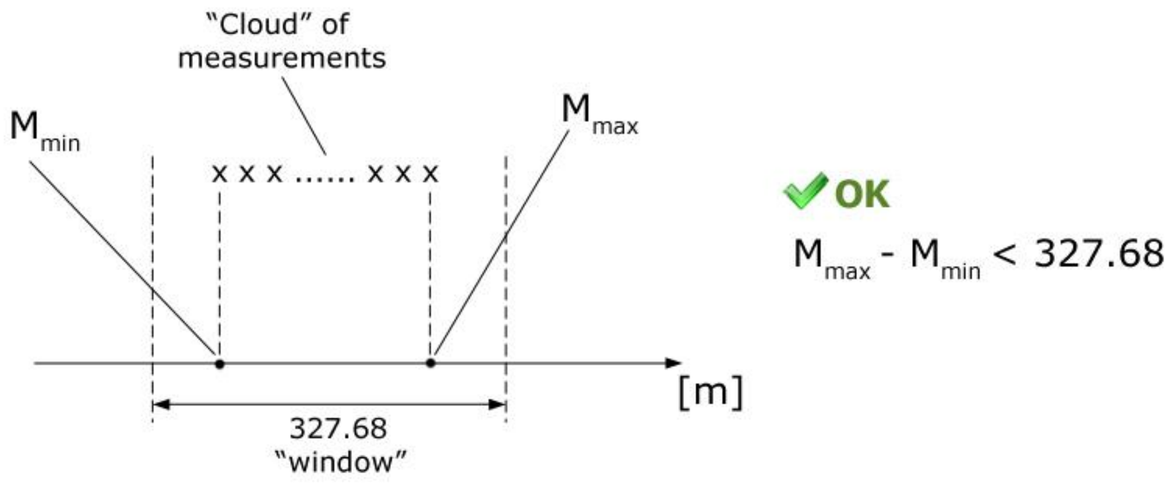
$$dM = 327.68\ [m]$$

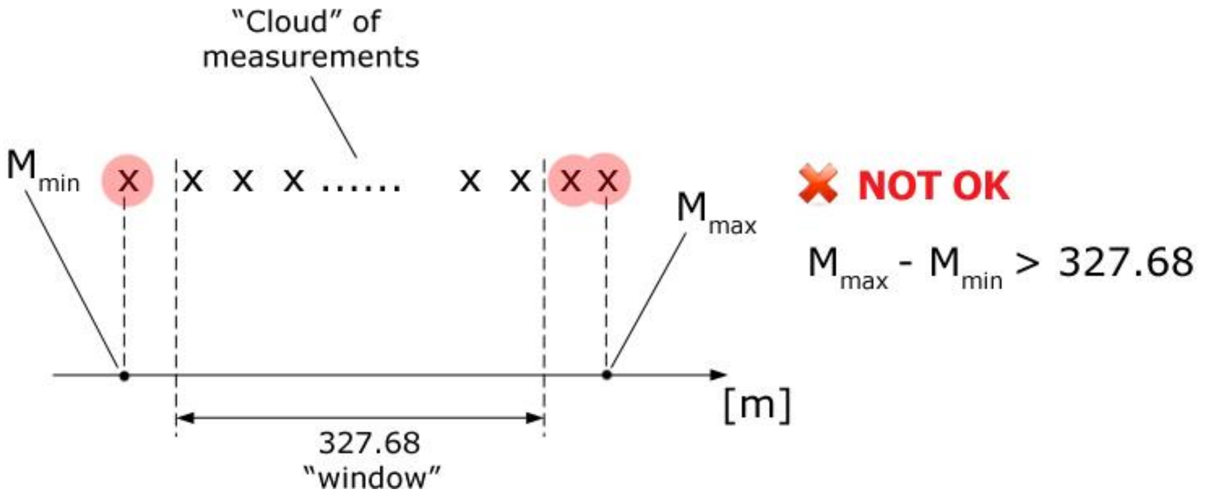
Carrier data can be a little bit more outside this area.

In the most of the cases, the condition above is valid, but there can be theoretically some singular cases (super high ionosphere conditions, very specific receiver hardware biases, obviously incorrect carrier phase initialization) where this condition is not held.

It must be noted that such a cloud size limitation is not an exclusive attribute of ATOM RNX data. In fact, all compact data protocols (e.g. standardized RTCM-3 observation messages) are in some degree limited by admissible observations divergence. For example, abs (L1 pseudo-range – L2 pseudo-range) must not exceed about 163 meters.

The diagrams below show good and bad examples of raw data.





In case when the cloud contains outlying pseudo-ranges, ATOM RNX generator will remove them before packing. It is full ATOM RNX generator responsibility to determine which pseudo-ranges should be removed.

In case when the cloud contains outlying carrier phases, ATOM RNX generator will reinitialize them by introducing new integer number of cycles before packing. In this case, ATOM generator can add/subtract a priori known number of cycles (1024 cycles rollover) which can be applied on decoding site to 'sew' carrier phase data. It is full ATOM RNX generator responsibility to determine which carrier phases should be corrected. Similar rollover procedures exist in standardized RTCM-3 messages.

It must be emphasized once more that generally Rough_Range is not associated with any single observable (pseudo-range or phase). On contrary, Rough_Range is associated with the cloud of observables for given Satellite. And reported Rought_Range (1/1024 ms resolution) is not actually computed as round-off of some float value; on contrary it is selected among up to several admissible candidates.

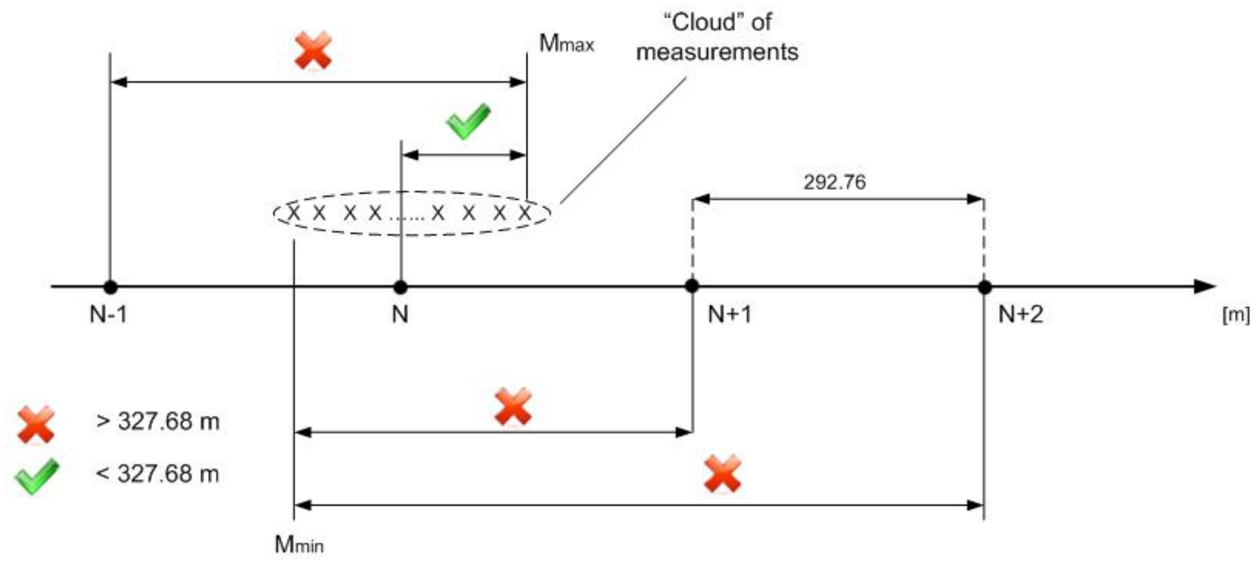
Let integer N be the number of 1/1024 ms intervals in Rough_Range. Typically it is in the range 60000…80000, except SBAS, QZSS and similar systems with 'exclusive' orbits. There exists the only single limitation when selecting N value for packing:

$$\forall i \quad |Mi - N*Const| < 327.68\ [m]$$

$$Const = 292.76607226562498\ [m]$$

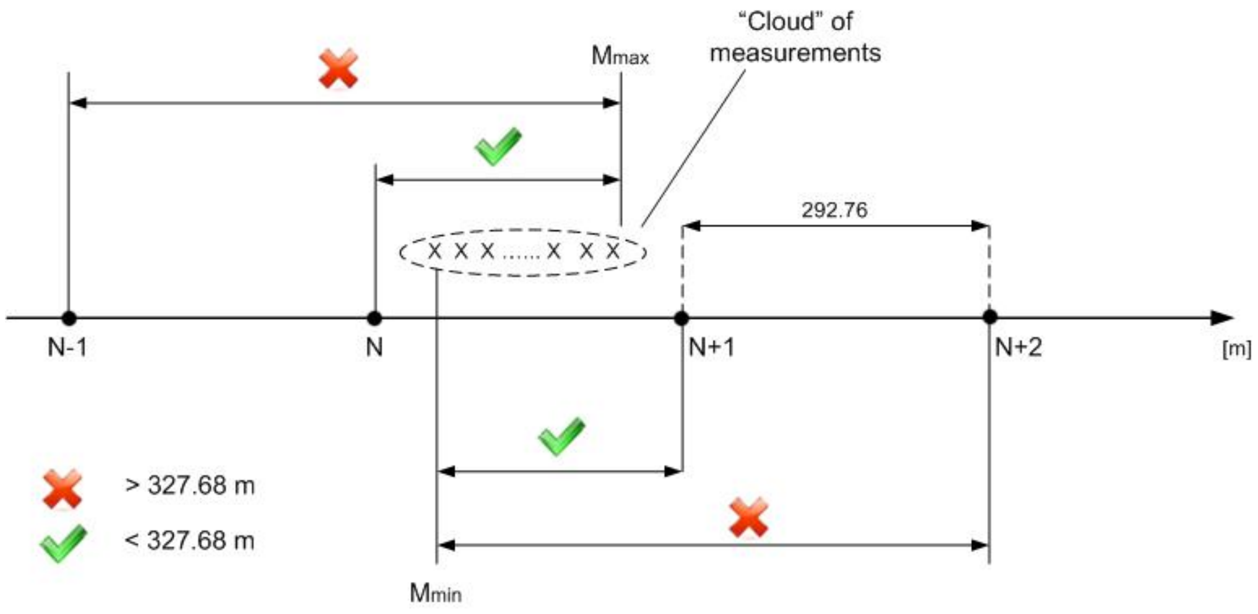
In theory there can be up to 3 different N values depending on cloud size and location. The diagrams below show all possible cases.

Single valid N

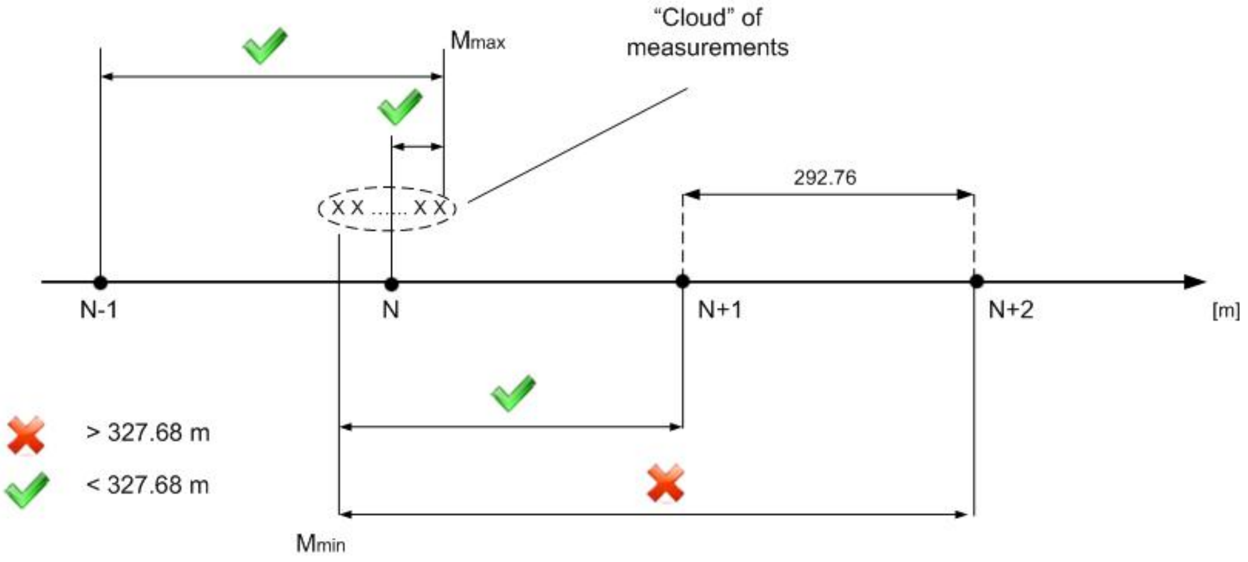


"Cloud" of measurements
Mmax
292.76
X X X X ...... X X X X
N-1
N
N+1
N+2
[m]
> 327.68 m
< 327.68 m
Mmin

Two valid N



Three valid N



With multiple N-opportunity **IT DOES NOT MATTER** which N ATOM generator selects.

If the cloud of Sat data to be packed does not fit favorite conditions, then ATOM generator can:

- Split transmission by Signals and use multiple RNX generation, or
- Do not generate outlier data at all
- Generate all the data still by modulo 327.68 meters and provide extra indication in extended supplementary data

Depending on hardware target and firmware version, ATOM RNX generator can apply any combinations of the above strategies. Under no circumstances ATOM RNX generator will adjust one signal to another to make a cloud compact.

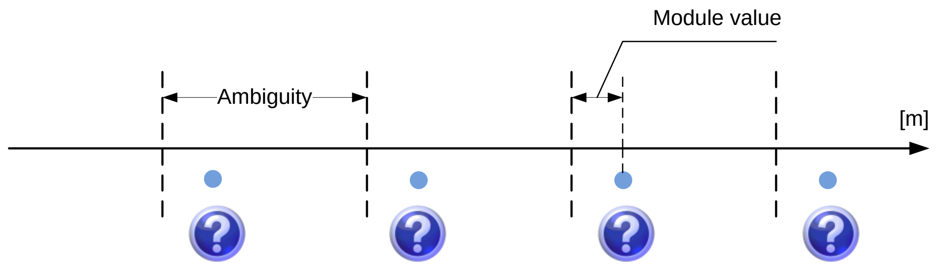
It is a well known task to restore full measurement (value) using its two samples:

High precision, but ambiguous part
Low precision, but fully known part

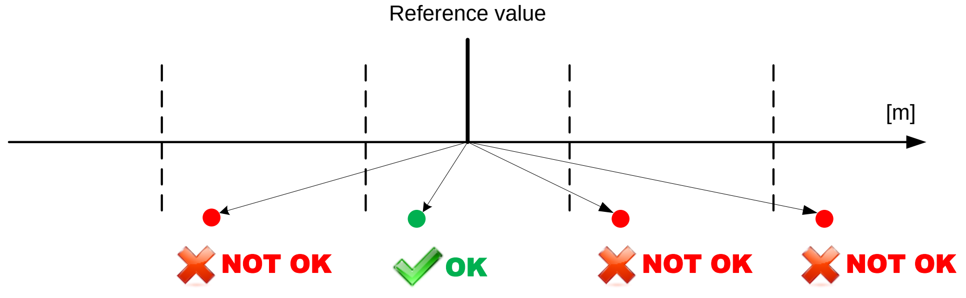
If somebody has dealt with RTCM3 1001,1003,1009,1011 messages, he/she also faced this problem. Here one should restore full raw range from raw range modulo 1 ms with the help of calculated rough range (using ephemeris).
Let us see some examples, to understand the physics:
CalcRange = 70,56 ms, RangeModulo1ms = 0,52 ms, Full Range = 70,52

CalcRange = 70,97 ms, RangeModulo1ms = 0,03 ms, Full Range = 71,03
CalcRange = 70,01 ms, RangeModulo1ms = 0,99 ms, Full Range = 69,99

When we have only ambiguity part we have unlimited number of solutions (blue circles)



To choose only one (the best) we add some reference (low precision) value. The best solution is that which is closest to reference.



Adequate reference range is needed to restore original receiver observables. In ATOM RNX, this reference depends on type of range presentation:

- Range presentation = 2 (Rough range R follows) and Nms is available (e.g. SCN,0,2,4). In this case we do not need any a priori information. Reference value can be computed as:

  Reference = Nms+R/1024 ms

- Range presentation = 2 (Rough range R follows) and Nms is not available (e,g. SCN,1,3). In this case, one must use ephemeris and reference position to calculate the distance between base and Satellite (CalcRange). This value can have admissible error against real measurement up to about (+/-0.5 ms) to be used to restore Nms.

  Nms =Function(CalcRange, R/1024 ms)

Reference = Nms+R/1024 ms

- Range presentation = 1 (Rough range R does not follow) and Nms is not available (e,g, SCN,100). In this case, one must use ephemeris and reference position to calculate the distance between base and satellite (CalcRange). This value can have admissible error against real measurement up to (+/-327.68 m) to be used to restore full range and phase.

  Reference =CalcRange

Note, that using receiver clock steered data we always guarantee that reference will be adequate to restore full range w/o errors.

The below is an example of C++ source code which restores full pseudo-range and carrier phase from ATM,RNX fields. This source code is provided only for illustration: do not copy it to your application.

```
// Nms               - number of ms
// dFineRange        - fine range within 0-655.36[m]
// dFinePhase        - fine phase within 0-4096[cycles]
// dRoughRange       - satellite rough range within 0-1023/1024 [ms]
// dFullRange        - Full restored range [m]
// dFullPhase        - Full restored phase [m]
// dCalcRange        - Calculated using ephemerids range (the same as used in
//                  RTCM3,1001/1003/1009/1011 range restoring) [m]
// eRangePresent     - 1. Compact, 2. Compact+Rough, 3. Compact+Rough+Nms
// dLyambda          - wave length [m] (about 0.19 for L1)
// ePhasePresent     - phase presentation is always full (modulo 4096 [cycles])

if(eRangePresent == 3)
{
  dReference = (Nms+ dRoughRange)*F64_LIGHT_MSEC; //moving from ms->meter scale
}
else if(eRangePresent == 2)
{
  dReference = dCalcRange;
  fAmbiguity = F64_LIGHT_MSEC; //1msec
  fModulo = dRoughRange;
  dReference = RestoreFullMeas(dReference, fAmbiguity, fModulo);
}
else if(eRangePresent == 1)
{
  dReference = dCalcRange;
}
fAmbiguity = 655.36;
```

```
fModulo = dFineRange;
dFullRange = RestoreFullMeas(dReference, fAmbiguity, fModulo);

fAmbiguity = 4096*dLyambda;
fModulo = dFinePhase;
dFullPhase = RestoreFullMeas(dReference, fAmbiguity, fModulo);

//*********************************************************************************************
float64 RestoreFullMeas(float64 dReference, float64 fAmbiguity, float64 fModulo)
{
  float64 dClosest = ROUND(dReference/fAmbiguity)*fAmbiguity; //find nearest on ambiguity scale
  float64 dFull = dClosest + fModulo; //full range which can have error +-fAmbiguity
  float64 dDelta = (dFull - dReference); //Find how far restored range from Rough part
  if     (dDelta > fAmbiguity /2)  dFullRange -= fAmbiguity; //make minus correction
  else if(dDelta < -fAmbiguity /2) dFullRange += fAmbiguity; //make plus correction
}
```

Appendix D: Decimation for ATOM RNX observables

The idea of decimation is well known. It comes from the simple fact that the ‘dynamic’ of all the basic observables (pseudo-ranges and carrier phases) corresponding to a given satellite is almost the same. Their divergence due to the ionosphere and some other factors is usually a slow process. This means that having acquired only one precise observable (e.g. L1 carrier phase) for all the epochs allows the observables that are missing at some epochs to be restored.

Decimation for ATOM observations refers to a special scenario in which all the data, except the L1 carrier phase, are generated at a slower rate. For example, with the L1 carrier phase generated at 1 second, the L2 carrier phase, L1 and L2 pseudo-ranges can be generated with a 5-sec interval, resulting in 5 times decimation. On decoder side, the decimated data can be easily restored provided the continuous tracking of the L1 carrier phase is achieved. Restoring pseudo-ranges is trivial even for 10-to-30 seconds decimation. Restoring a decimated L2 (or L5) carrier is different as a second-order estimator has to be applied to more precisely eliminate ionosphere divergence. In all cases, the rover must monitor the continuity indicator of the received L1 carrier phase to prevent the decimated data from being restored incorrectly.

The decimation (DEC) option can be applied to static and moving receivers equally. However, with moving receivers, performance degradation is foreseeable (higher percentage of missing data on rover side). This is because moving receivers are usually more affected by cycle slips and constellation changes than static open sky receivers. In combination with possible short-term data link outages, this can lead to potentially more unavailable epochs on rover side.

It must be noted that pseudo-range and carrier phase data are not the only data that can be decimated. There is one extra ‘observable’ in ATOM, which consists of the data identifiers represented by the Satellite, Signal, and Cell masks (see Appendix E). In static open sky conditions, this identification information does not usually change very quickly. This gives a convenient possibility to freeze most of this information (i.e. decimate headers). Although a simple idea, it is not however trivial to implement, because irregular constellation changes as well as short-term data link blockage have to be taken into account. The careful implementation of the “header freezing” process in ATOM avoids degrading RTK performance against a static open sky reference receiver. Since header data can be considered as an observable along with pseudo-range and carrier phase, then it was decided that the DEC setting would affect header decimation in the same manner as it affects decimated pseudo-ranges and carrier phases.

It must be emphasized that the decimation option is implemented in an ‘adaptive’ way, i.e. it does not use fixed decimation/freezing intervals. On the contrary, it applies some flexible strategy depending on the current situation at the reference site. As for the decoder (on rover side), it does not make any a priori assumptions regarding the data decimation scenario used on reference side. On the contrary, all the information about the data presentation form is extracted from the ATOM message itself.

Although the decimation option allows the reduction of the mean throughput, it does not however allow the reduction of the peak throughput. However, for many data links (e.g. GPRS), it is the mean throughput that really matters.

The decimation technique described above for RNX (observations) data is equally applicable to BAS (corrections) data.

Appendix E: Data identifiers for ATOM RNX observables

E.1. Satellite mask

Satellite mask is a bitset indicating which satellites from a given GNSS provide at least one signal (it does not matter which). The Satellite mask contains 64 positions for each GNSS. Currently:

- GPS occupies 32 positions (but up to 63 PRNs are claimed for future)
- GLO occupies 24 positions (but theoretically 28 slots for FDMA can be available, for CDMA there can be even more)
- SBAS reserves 19 positions (but it will be obviously extended)
- Galileo reserves 36 positions (but it cannot be guaranteed)
- QZSS reserves 10 positions, (5 by other sources)
- BeiDou reserves 36 positions (but it cannot be guaranteed)

E.2. Signal mask

Signal mask is a bitset indicating which signals from a given GNSS are available from at least one of the multitude of tracked satellites. The Signal mask includes 32 bits. Each bit is representative of a specific GNSS signal. The definition of Signal mask bits for each GNSS is given in Section 3. 3. Below is combined compact table for more clear reference.

It must be noted that additionally to RINEX definitions we reserved choices 1?, 2? and 5?. They are very useful in cases when some legacy data are converted into ATOM while the exact type of signal is known. In other words, 1? stands for any L1 signal which type is not known.

Rank	GPS, RINEX code	SBAS, RINEX code	GLONASS, RINEX code	Galileo, RINEX code	QZSS, RINEX code	BeiDou, RINEX code
1	1?	1?	1?	1?	1?	

2	1C	1C	1C	1C	1C	1I
3	1P		1P			1Q
4	1W			1B		
5						
6						
7	2?		2?		2?	
8	2C		2C	6C		
9	2P		2P	6A		
10	2W			6B		
11				6X		
12				6Z		
13						
14				7I		7I
15	2S			7Q	2S	7Q
16	2L				2L	
17	2X				2X	
18				8I		
19				8Q		
20						

21	5?	5?		5?	5?	
22	5I	5I		5I	5I	
23	5Q	5Q		5Q	5Q	
24						
25						
26						
27						
28						
29						
30	1S				1S	
31	1L				1L	
32	1X				1X	

E.3. Capability mask

The Capability mask is the combination of the Satellite mask and Signal mask for a given GNSS at a given time.

E.4. Cell mask

For quite a long time to come (or even forever), some satellites from a given GNSS will transmit some set of signals while some other satellites from the same GNSS will continue to transmit another set of signals. The Satellite and Signal masks described above can contain a number of ‘cross-cells’ that cannot correspond to the actual signal available, or the signal cannot be acquired in the given environmental conditions. To save room in the ATOM observation messages, the Cell mask has been introduced.

The Cell mask is a bitset the length of which is Nsat*Nsig, where Nsat is the number of satellites (= the number of 1's in the Satellite mask) and Nsig is the number of signals (= the number of 1's in the Signal mask). The Cell mask indicates if the 'cross-cell' for a given satellite & signal combination actually contains any data (Cell mask=1 means it does).

Signal data are generated only for those satellite & signal combinations where Cell mask=1.

E.5. Example of building Satellite, Signal and Cell Masks

Let us consider building masks for the GPS (it works similarly for all the other GNSS). For the current epoch, let the L1&L2&L5 GPS tracking status be as follows: Sats 1, 3, 6, 7, 13, 15, 32 are tracked and provide the following signals:

2=1C=L1CA (highest availability)

4=1W=L1P with Z tracking (cannot always be tracked because of the Y code)

10=2W=L2P with Z tracking (cannot always be tracked because of the Y code)

15=2S=L2C(M) (currently not available)

The table below shows the status of the observables in terms of Satellite and Signal masks. It is seen that the number of Sats is 7, and the number of different signals is up to 4. It is clear that such a 'status table' gives a full vision of all the available signals. But generating a complete table can lead to a huge bit consumption. On the other hand, in most cases, the 'tracking table' is sparsely filled and so can effectively be presented by the Capability mask, i.e. by 2 independent masks:

- Signal mask (marked red)
- Satellite mask (marked blue)

So the potential number of Sat data blocks in this example is 28=4*7.

Sats / Signals	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	…	32	…	64	Signal mask
1																				0

2	X		X			X	X						X		X		X			1
3																				0
4	X		X			X							X				X			1
5																				0
6																				0
7																				0
8																				0
9																				0
10	X		X			X							X				X			1
11																				0
12																				0
13																				0
14																				0
15	X						X								X		X			1
16																				0
…																				…
32																				0
Satellite mask	1	0	1	0	0	1	1	0	0	0	0	0	1	0	1	…	1	...	0	

At the same time, not all 4 signals are tracked for every satellite. It is seen that actually there are only 21 cells to generate. In order not to occupy empty room for 7 untracked (shaded) cells, the Cell mask is additionally created, as shown below.

The first table is a copy of the previous one in which all the columns not containing any signal, as well as all the rows not containing any satellite have been removed. The resulting binary table (in green) is what we call the “Cell mask”.

Sats Signals	1	3	6	7	13	15	32
2	1	1	1	1	1	1	1

4	1	1	1	0	1	0	1
10	1	1	1	0	1	0	1
15	1	0	0	1	0	1	1

The table below shows the same mask but presented by a single bitset as it must be interpreted by coding/decoding equipment. The size of the cell mask is Nsig*Nsat=4*7=28 while the number of available cells with observables is Ncell=21.

Signal ID	2	4	10	15	2	4	10	15	2	4	10	15	2	4	10	15	2	4	10	15	2	4	10	15	2	4	10	15
Sat ID	1	1	1	1	3	3	3	3	6	6	6	6	7	7	7	7	13	13	13	13	15	15	15	15	32	32	32	32
Cell mask	1	1	1	1	1	1	1	0	1	1	1	0	1	0	0	1	1	1	1	0	1	0	0	1	1	1	1	1

The above tables show how the complete (24*40 bits) but too sparse ‘status table’ can be presented by 3 bitsets:

- Fixed-size 64-bit Satellite mask
- Fixed-size 32–bit Signal mask
- Float-size Nsig*Nsat Cell mask (4*7 bits in the above example)

E.6. Example of interpreting Satellite, Signal and Cell Masks

Consider the example of GPS data described in E.5.

Let us decode the Satellite mask as the following 64-bit sequence: 1010011000001010000000000000000100000000000000000000000000000000 . This means that the receiver generates data for Nsat=7 satellites with Sat IDs: 1, 3, 6, 7, 13, 15 and 32.

Then the Signal mask is decoded as the following 32-bit sequence: 01010000010000100000000000000000. This means that the receiver generates up to Nsig=4 signals of types: 2, 4, 10 and 15 (see signal types definition in the table in section E.2).

Then, the size of the Cell mask that follows is known to be 28=4x7.

And finally the Cell mask is decoded as the following 28-bit sequence (BITSET): 1111111011101001111010011111. After that, the satellite and signal data that follow should be identified correctly. To do this, the following steps should be taken:

1. With 7 satellites received for up to 4 different types of signals, the Cell mask should be split into seven equal parts (Sub-BITSET):

1111111011101001111010011111

1 2 3 4 5 6 7

First: 1111

Second: 1110

Third: 1110

Fourth: 1001

Fifth: 1110

Sixth: 1001

Seventh: 1111

One can see that the length of each Sub-BITSET is equal to the number of the different tracked signals (Nsig=4).

2. The first Sub-BITSET tells us that satellite 1 provides signals: 2, 4, 10, 15
3. The second Sub-BITSET tells us that satellite 3 provides signals: 2, 4, 10
4. The third Sub-BITSET tells us that satellite 6 provides signals: 2, 4, 10
5. The fourth Sub-BITSET tells us that satellite 7 provides signals: 2, 15
6. The fifth Sub-BITSET tells us that satellite 13 provides signals: 2, 4, 10
7. The sixth Sub-BITSET tells us that satellite 15 provides signals: 2, 15

8. The seventh Sub-BITSET tells us that satellite 32 provides signals: 2, 4, 10, 15

Appendix F: Throughput figures for ATOM RNX observables

The main feature of RNX messages is their scalability, i.e. the possibility to configure them to save message sizing. A lot of different configurations can be generated using the following options (see Section 5.3):

- Shape
- Optimization
- Decimation

Size-optimized configurations can be needed for compact raw data recording. However, in most cases, optimization is applied to reference data generation (RTK base mode) to allow the use of low-band data links or to save throughput in traffic-paid links (e.g. GPRS).

Consider below one typical case of reference data generation:

- Observables generated at 1 Hz
- Reference position is not generated
- The number of GPS+GLONASS satellites is 20 (12+8)
- SBAS is not generated

The throughput estimates for the following 3 different constellations are provided in the table below:

- GPS+GLONASS L1/L2 data
- GPS L1/L2 data
- GPS+GLONASS L1 data

Throughput includes transport layer as well. In the case of ATOM, it is assumed that the basic (RTCM-3) transport is used.

Protocol/scenario	Mean throughput for GPS+GLO L1/L2, bytes/sec	Mean throughput for GPS+GLO L1(L1CA only), bytes/sec	Mean throughput for GPS L1/L2, bytes/sec	Comments
Ashtech legacy	108*20 = 2160 (MPC)	50*20 = 1000 (MCA)	108*12 = 1296 (MPC)	
ATOM RNX (SCN,0)	829	425	561	Fullest presentation
ATOM RNX (SCN,4)	317	205	193	Standard presentation
RTCM-3	338 (MT 1004,10012)	214 (MT 1002,1010)	202 (MT 1004)	RTCM scenarios matched to ATOM RNX (SCN,4)
ATOM RNX (SCN,100)	159*	140*	98*	Compact presentation
ATOM RNX (SCN,101)	86*	75*	70*	Super compact presentation, only applicable to static receivers

* - The worst case. Usually, in normal conditions, 4 bytes can be subtracted for each system.

Notes:

- The throughput for ATOM RNX is the same for the same scenario used.
- Scenario 100 stands for the triplet SPE=3, DEC=5 and OPT=7
- Scenario 101 stands for the triplet SPE=3, DEC=5 and OPT=4

SPE=3 refers to sending L1 and L2 (one signal per band) pseudo-range and carrier phase data modulo 1 ms, and not sending SNR
DEC=5 refers to decimating all the data in 5 times compared to L1 carrier data
OPT=7 refers to compact pseudo-range and full carrier phase
OPT=4 refers to compact pseudo-range and compact carrier phase

These figures show that:

- Using RNX message in its full presentation (SCN,0) instead of legacy MPC/MCA data can reduce size by 2-3 times without loss of any legacy fields.
- Standard RNX scenario (SCN,4) shows approximately the same throughput as their RTCM-3 counterparts
- Applying admissible (i.e. not leading to performance degradation) RNX optimization scenarios allows dramatic reduction of data throughput

Appendix G: *Miscellaneous*

Appendix H: *The summary of ATOM v.1/v2 differences*

It must be emphasized once more that Ashtech decoders supporting some ATOM version X can automatically support ATOM of each lower version. But not vice versa.

Each ATOM generator supporting some ATOM version X can be configured to generate ATOM of each lower version (say to insure backward compatibility) with legacy decoders.

3rd party equipment can also effectively support each ATOM version by analyzing ATOM version number field provided in each ATOM message (in the header). Legacy decoding equipment must not process the data if unknown ATOM version number is detected in the header of these messages.

All the ATOM messages described in given Manual refer to ver.1 with the only exception for ATM,PVT (block SVS) and ATM,RNX (block GNSS observables) messages. They can be generated as ATOM ver.1 and as ATOM ver.2 messages. The subsections below summarize the difference

H.1. Satellite and Signal Masks in ATOM,PVT (SVS block)

The size of Satellite and Signal mask is extended from 40 and 24 (in v.1) to 64 and 32 (in v.2) respectively. See Section 3.4.10 and Tables 3.4.10.a and b

H.2. Satellite and Signal Masks in ATOM,RNX (GNSS observables block)

The size of Satellite mask is extended from 40 (in v.1) to 64 (in v.2). Initially reserved 8 bits (in v.1) are added to Signal mask (in v.2) converting it from 24 bit (v.1) to 32 bit (v.2). See Section 3.8.2 and Tables 3.8.2.b and c.

H.3. Extended data resolution in ATOM,RNX (GNSS observables block)

Extended resolution is supported for ATOM RNX v.2, but it is not supported for ATOM RNX v.1. See:

- Section 3.8.2 and Table 3.8.2.a
- Section 3.8.4 and Table 3.8.4.a,b
- Section 3.8.6 and Table 3.8.6.b,c

Appendix I: Satellite, Signal and Cell Masks

These three masks are so important so we describe them in separate section. Their description follows ATOM v.2, while ATOM v.1 uses truncated versions of Satellite (40 bits) and Signal (24 bits) mask.

These masks are used in ATM,RNX message and (with smallest modification for Cell Mask) in ATM,PVT message. They are twins of standardized RTCM-3 fields DF394, DF395 and DF396 used for generation so called Multiple Signal Messages (MSM). The table below provides complete description.

DF394	GNSS Satellite mask	bit(64)	The sequence of bits, which specifies those GNSS satellites, for which there is available data in this message. The Most Significant Bit (msb), or the first encoded bit corresponds to GNSS satellite with ID=1, the second bit corresponds to GNSS satellite with ID=2, etc. And the Least Significant Bit (lsb), or the last ecoded bit corresponds to GNSS satellite with ID=64. Exact mapping of actual GNSS satellites (PRNs for GPS, “slot number” for GLONASS, etc.) to satellite mask IDs is specific for each GNSS (see corresponding tables in MSM description for each particular GNSS). Some ID values may refer to specific satellites, while some ID values may be indicated as “Reserved” in this standard. These IDs may be used in the future for other satellites and thus decoding software shall ensure, that it does not skip these bits, but decodes complete GNSS Satellite mask, decodes corresponding observables as if they refer to known satellites, but should refrain from using them, unless new satellite mapping table becomes available to map corresponding ID to a specific satellite. If any data for satellite with ID=n follows, then corresponding bit (bit number n) is set to 1, if data for satellite with ID=m do not follow, then corresponding bit (bit number m) is set to 0.

DF395	GNSS Signal mask	bit(32)	The sequence of bits, which specifies those GNSS signals, for which there is available data in this message. Each bit corresponds to particular signal (observable) type for given GNSS. The Most Significant Bit (msb), or the first encoded bit corresponds to signal with ID=1, the second bit corresponds to signal with ID=2, etc. And Least Significant Bit (lsb), or the last ecoded bit corresponds to signal with ID=32. Exact mapping of actual signal identifier (in correspondence with RINEX 3.01 signal naming convention) to signal mask IDs is specific for each GNSS (see corresponding tables in MSM description for each particular GNSS). Some ID values may refer to specific signals, while some ID values may be indicated as “Reserved” in this standard. These IDs may be used in the future for other signals and thus decoding software shall ensure, that it does not skip these bits, but decodes complete GNSS Signal mask, decodes corresponding observables as if they refer to known signals, but should refrain from using them, unless new signal mapping table becomes available to map corresponding ID to a specific signal. If signal (observable) with ID=n is available for at least one of transmitted satellite, then corresponding bit (number n) is set to 1, otherwise corresponding bit is set to 0.
DF396	GNSS Cell mask	bit(X)	This filed represents a two-dimensional table, which determines signal availability for each transmitted satellite. This field is of variable size. X=Nsig*Nsat, where Nsat is the number of Satellites (the number of those bits, which are set to 1 in Satellite mask, DF394) and Nsig is the number of available signals (the number of those bits, which are set to 1 in Signal mask, DF395). The first row of this rectangular table corresponds to the Signal with the smallest ID among those, for which corresponding bit in Signal Mask is set to 1. The second row corresponds to the Signal with the second smallest ID among those, for which corresponding bit in Signal Mask is set to 1. The last row corresponds to the Signal with the highest ID among those, for which corresponding bit in Signal Mask is set to 1. The first column of this rectangular table corresponds to the Satellite with the smallest ID among those, for which corresponding bit in Satellite Mask is set to 1. The second column corresponds to the Satellite with the second smallest ID among those, for which corresponding bit in Satellite Mask is set to 1. The last column corresponds to the Satellite with the highest ID among those, for which corresponding bit in Satellite Mask is set to 1. If observable data for given Satellite and given Signal follows, then corresponding field in this table is set to 1, otherwise it is set to 0. This bit table is packed by columns, starting from the column, which corresponds to smallest Satellite ID. The size of each column is Nsig bits, and it is packed starting from the cell, which corresponds to the smallest Signal ID.

			Each cell of the table is packed by one bit, which is set to 1 or 0, according to the value in the corresponding cell in the table.

Examples to construct and interpret given masks are given in Appendix E.

The table below gives an overview of GNSS signals currently supported by ATOM. Potentially ATOM can support all known existing and incoming GNSS signals. The number of supported signals can be up to 32 for each GNSS. All carriers corresponding to different signals of the same band are aligned to each other by proper (usually 0.25) fractional part of cycles.

Reference Signal for Phase Alignment

System	Frequency Band	Frequency [MHz]	Reference Signal (RINEX Observation Code)
GPS	L1	1575.42	L1C
	L2	1227.60	L2P
	L5	1176.45	L5I
GLONASS	G1	1602+k*9/16	L1C
	G2	1246+k*7/16	L2C
GALILEO	E1	1575.42	L1B
	E5A	1176.45	L5I
	E5B	1207.140	L7I
	E5(A+B)	1191.795	L8I
	E6	1278.75	L6B
SBAS	L1	1575.42	L1C
	L5	1176.45	L5I
QZSS	L1	1575.42	L1C
	L2	1227.60	L2S
	L5	1176.45	L5I
BeiDou	B1	1561.098	1I
	B2	1207.140	7I
	B3	1268.52	6I

The tables below show the exact content of Satellite and Signal masks for each supported GNSS. Please take a note that some positions in Signal mask are reserved for unknown Signal on particular band. Such an indication allows transferring data from legacy protocols (containing no signal ID or proprietary signal ID) to ATOM.

GPS Satellite ID mapping

Satellite ID in Satellite Mask (DF394)	GPS Satellite PRN
1	1
2	2
…	…
63	63
64	Reserved

GPS Signal ID mapping

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	GPS signal RINEX code	Comments/Notes
1				Reserved
2	L1	C/A	1C	
3	L1	P	1P	
4	L1	Z-tracking	1W	
5-7				Reserved
8	L2	C/A	2C	
9	L2	P	2P	
10	L2	Z-tracking or similar	2W	
11-14				Reserved
15	L2	L2C(M)	2S	
16	L2	L2C(L)	2L	
17	L2	L2C(M+L)	2X	
18-21				Reserved

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	GPS signal RINEX code	Comments/Notes
22	L5	I	5I	
23	L5	Q	5Q	
24	L5	I+Q	5X	
25–29				Reserved
30	L1	L1C-D		
31	L1	L1C-P		
32	L1	L1C-(D+P)		

SBAS Satellite ID mapping

Satellite ID in Satellite Mask (DF394)	SBAS Satellite PRN	Comment
1	120	Original SBAS
2	121	
…	…	
39	158	
40	183	QZSS L1 SAIF
41	184	
…		
44	187	
45-64	Reserved	It can be some BDS in future

SBAS Signal ID mapping

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	GPS signal RINEX code	Comments/Notes
1				Reserved
2	L1	C/A	1C	
3-21				Reserved

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	GPS signal RINEX code	Comments/Notes
22	L5	I	5I	
23	L5	Q	5Q	
24	L5	X	5X	
25–32				Reserved

GLONASS Satellite ID mapping

Satellite ID in Satellite Mask (DF394)	GLONASS Satellite slot number
1	1
2	2
…	…
24	24
25–64	Reserved

GLONASS Signal ID mapping

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	GLONASS signal RINEX code	Comment/Notes
1				Reserved
2	G1	C/A	1C	
3	G1	P	1P	
4-7				Reserved
8	G2	C/A	2C	
9	G2	P	2P	
10-32				Reserved

GALILEO Satellite ID mapping

Satellite ID in Satellite Mask (DF394)	GALILEO Satellite PRN
1	1
2	2
…	…
50	50
51	GIOVE-A
52	GIOVE-B
53-64	Reserved

GALILEO Signal ID mapping

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	GALILEO signal RINEX code	Comments/Notes
1				Reserved
2	E1	C no data	1C	
3	E1	A	1A	
4	E1	B I/NAV OS/CS/SoL	1B	
5	E1	B+C	1X	
6	E1	A+B+C	1Z	
7				Reserved
8	E6	C	6C	
9	E6	A	6A	
10	E6	B	6B	
11	E6	B+C	6X	
12	E6	A+B+C	6Z	
13				Reserved
14	E5B	I	7I	
15	E5B	Q	7Q	
16	E5B	I+Q	7X	
17				Reserved
18	E5(A+B)	I	8I	

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	GALILEO signal RINEX code	Comments/Notes
19	E5(A+B)	Q	8Q	
20	E5(A+B)	I+Q	8X	
21				Reserved
22	E5A	I	5I	
23	E5A	Q	5Q	
24	E5A	X	5X	
25–32				Reserved

QZSS Satellite ID mapping

Satellite ID in Satellite Mask (DF394)	QZSS Satellite PRN
1	193
2	194
…	…
10	202
11-64	Reserved

QZSS Signal ID mapping (signal L1 SAIF is interpreted as SBAS)

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	QZSS signal RINEX code	Comments/Notes
1				Reserved
2	L1	C/A	1C	
3-14				Reserved
15	L2	L2C(M)	2S	
16	L2	L2C(L)	2L	
16	L2	L2C(M+L)	2X	
17-21				Reserved
22	L5	I	5I	

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	QZSS signal RINEX code	Comments/Notes
23	L5	Q	5Q	
24	L5	I+Q	5X	
24–32				Reserved

Beidou Signal ID mapping

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	QZSS signal RINEX code	Comments/Notes
1				Reserved
2	B1	I	1I	
3	B2	Q	1Q	
4-13				Reserved
14	B2	I	7I	
15	B2	Q	7Q	
16-32				Reserved

Appendix J: *Example of ATOM masking table for a particular product*