ashtech

Reference Manual

ATOM, GNSS Receiver Communication Protocol

Second Edition
Revision October 2013

October 2013 issue.

Ashtech reserves the right to make changes to the specifications of the ATOM protocol without notice.

October 2013 Release Note

Compared to the May 2010 Release, this edition is a major upgrade with the introduction of ATOM ver.2. Beyond this significant technical step forward in the evolving ATOM messaging protocol, we would like to emphasize some other crucial advents that give ATOM even more legitimacy:

- “GNS6” (for the existing 6 GNSS: GPS+GLO+GAL+QZS+BDS+SBA) is now functioning and, as anticipated, the ATOM messaging protocol simply fits in with the simultaneous use of all these constellations.
- RTCM-3 MSM messages, which are in fact re-using the ATM,RNX concept, are now officially released, which proves the great value of ATOM in the GNSS world.
- A lot of customers have already integrated the processing of ATOM data into their applications, which proves the maturity of ATOM and the efficiency of its Reference Manual.

NOTICE:

The following ATOM messages are intentionally not described in this manual:

- ATM,SUP
- ATM,EVT
- ATM,STA
- ATM,ALR

Should you need information on these messages, please contact Technical Support.

More generally speaking, the ATOM protocol being constantly evolving, each new edition of this ATOM Reference Manual picks the essential user-oriented information from the core of the ATOM development program at the moment of the publication. That’s why some messages may be mentioned in this manual, but not described. This is made knowledgeably. In fact, we are quite sure the supposedly missing information wouldn’t not be useful to you. However:

- At your personal request, we can provide additional information about many of the messages or fields mentioned but not described.
- The design or implementation of any extra ATOM groups, messages or fields required in your applications is possible, provided we can count upon your active collaboration.

Table of Contents

Chapter 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 third-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.

Chapter 2. ATOM Organization Overview

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 may be unknown to older ATOM versions.**	24 bits
11010011	Not defined, set to 000000	Message length in bytes	0-1023 bytes, as specified in the Message Length block		QualComm Definition CRC-24Q

Similarly to RTCM-3, ATOM reserves a possibility for potential future extensions 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:

- The actual message length (as decoded from the message header) may not match (i.e. may be greater than) the minimum required message length, as dictated by the content of any given ATOM message).
- The decoding software should omit (ignore) any extra block of data at the end of the ATOM message. The availability of such extra data should be considered as a normal event and so should not raise a warning flag.
- The encoding software should NOT however use this possibility for undocumented proprietary data transmissions. No extra information whatsoever should be added to the end of an ATOM message by the encoding software unless this information complies with the next releases of the ATOM documentation.

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	Less than or equal to 8165		

Wrapping Basic ATOM

Optionally, each basic ATOM message can be wrapped into legacy Ashtech transport as follows:

$PASHR,<group_type>,<atom_length>,<atom_data><cc><CR><LF>

Where:

– <group_type> stands for either ALR, SUP, PVT, ATR, NAV, DAT, RNX, STA or EVT, which is a human-readable message group (see below) for quick reference.
– <atom_length> is a 16-bit integer value (2-byte BIG ENDIAN format) indicating the length, in bytes, of the ATOM data that follow.
– <atom_data> is a single ATOM message in basic ATOM transport including preamble and CRC.
– <cc> is a binary checksum calculated as the sum of 2-byte integers (BIG ENDIAN), starting after “$PASHR,<group_type>,”. The final checksum is two least-significant bits (BIG ENDIAN). This is the checksum used in most of legacy Ashtech binary messages. If the length of <atom_data> is not even, a zero byte should be added at the end of the buffer when computing the checksum. See example in *Appendix A on page 107*.
– <CR><LF> are respectively the carriage return and line feed.

To date, ATOM vers.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			Group of independent messages or single, composite, configurable message. 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 a transport layer used to pack any other message. Not described in this manual.

Most of the existing ATOM groups are available for third-party users. There are also reserved, proprietary groups and their respective message numbers that are not available to end users. If some third-party equipment happens to detect such groups or messages, then it should 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 described on *page 18*.

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 the 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 and 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 useful to identify receiver problems. ALR messages are intended to inform end users of receiver problems or incorrect setups. For each of the alarms, end users are informed of all the steps taken to restore normal receiver operation. ALR messages are part of the Ashtech Trouble Log, known as the atl.log file, which customers can request from their Ashtech receivers in case of a problem.

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

There is also a special group (4095,15) –not described in this manual– for which intentionally no 3-letter name has been assigned. This group acts as a simple packing frame used 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 multiple satellite information (i.e. Nsat dependent) contained in the message. 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.

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 *ATOM PVT Message on page 18*):

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 this 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

The position delivered by the ATM,PVT message may be tagged to one of the following points: L1 antenna phase center, antenna reference point or ground mark. An identifier provided in the message body tells users which point the position is tagged to. The antenna height (i.e. the height of the antenna reference point above the ground mark) being usually provided, users can change the tagging of the position at their convenience by correcting the computed position accordingly. After having requested the antenna name, users can also easily correct the position delivered to be tagged either to the L1 antenna phase center or to the antenna reference point.

The position delivered by block COO in ATM,PVT refers to some datum. This datum, which can be reported as the "default" one, is defined as follows:

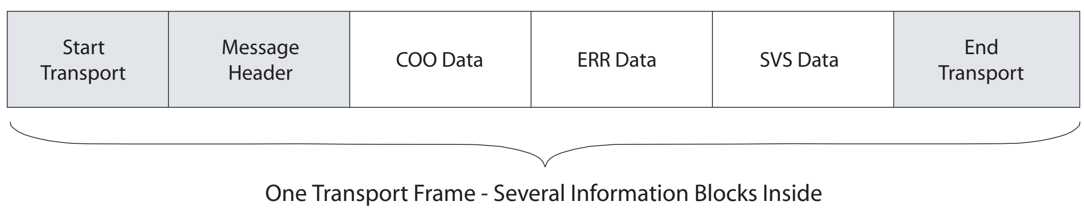
- The datum of the broadcast ephemeris data (i.e. IGS05 realization of ITRF2005 on current epoch, if GPS is defined as the primary system used)
- Or the datum the reference position is tagged to, for all RTK and DGNSS positions

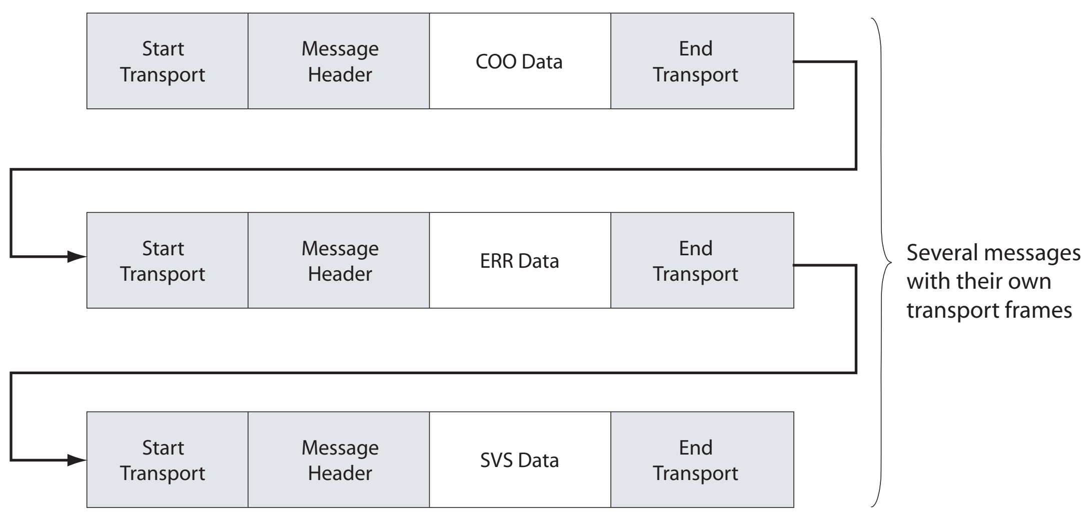
Note that often, the datum of the reference position is unknown a priori. In this case, the MIS block in ATM,PVT reports the datum used as being the "default" one, which is true only if the reference position is tagged to the same datum as the one used by the broadcast ephemeris data. If the reference position is expressed in another datum, the allegedly "default" datum will in fact be an "unknown" one for all the RTK or DGNSS positions delivered.

Users may be interested in getting the position in some specific local datum and/or projection. A rule is used in ATM,PVT stipulating that block COO always delivers the originally computed position (reported as the "default" or "custom" one in the MIS block). Extra blocks can however be output to deliver block LDP (Local Datum Position) and/or LMP (Local Map Projection). See the complete ATM,PVT description for detailed formats.

ATM,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 ATM,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 ATM,PVT transmission. In the latter case, the multiple-message bit in the ATM,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 a network provider delivers additional information about the source datum, local datum and map projections, extra ATM,PVT blocks can supplement the original position delivered in block COO. In general, these extra blocks provide:

- The name of the datum in which the position delivered in block COO is expressed (block CDC)
- The coordinates of the position delivered in block COO, as expressed in a local datum (block LDP)

- The coordinates of the position delivered in block COO, as expressed in a local map projection (block LMP)

Sometimes, clarification information is known a priori about the reference position datum (e.g. source datum name from the so-called RTCM-3 coordinate transformation messages). In this case, block MIS in ATM,PVT will indicate the "custom" datum. An additional CDC (for Custom Datum Clarification) block in ATM,PVT will then be generated to clarify the name and parameters of this "custom" datum.

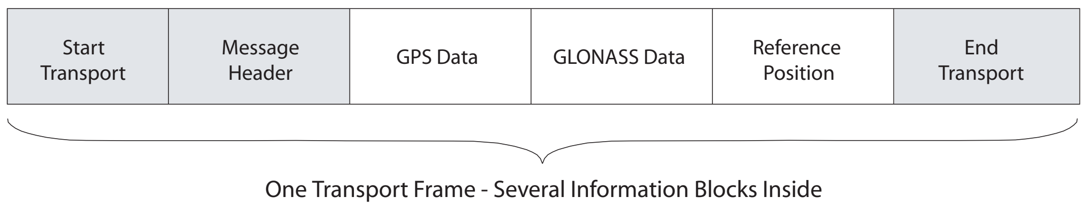
More needs to be said about multiple ATOM PVT output. In most user cases, a complete GNSS solution refers to one receiver antenna and one dedicated correcting data stream. In this case, all sub-blocks inside ATOM PVT are tagged to this unique GNSS solution. However, Ashtech GNSS receivers can deliver advanced GNSS solutions including more than one single antenna and one correcting source.

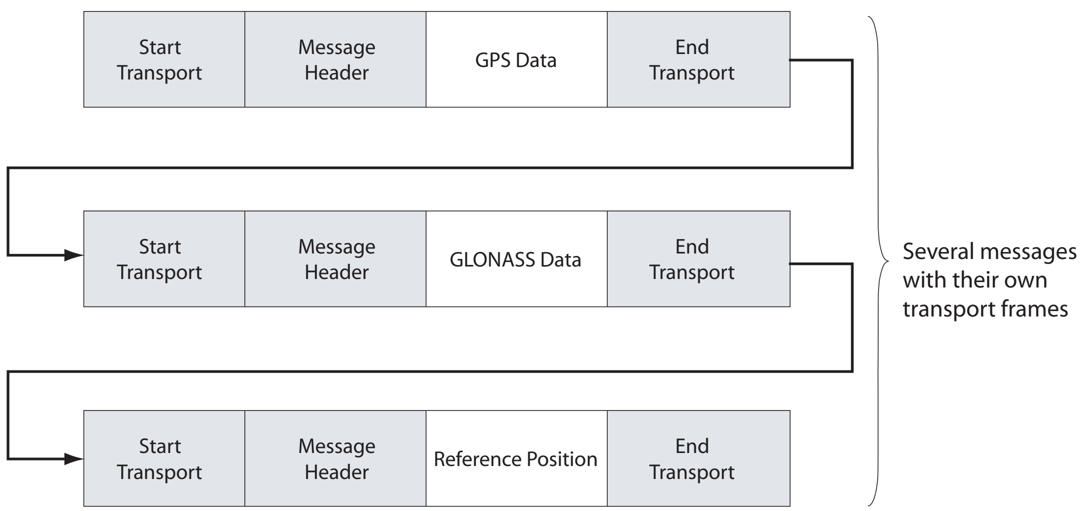
For example, Ashtech supports RTK + Heading solution, or RTK + full attitude solution, where obviously more than a single antenna and its corresponding corrections/ observations are used. For such advanced GNSS solutions, users can be provided with more than one PVT message, each of them carrying a particular GNSS solution.

Thanks to the generic structure of ATOM PVT messages, these multiple PVT outputs can be decoded using the same parser, but the receiving entity should however be able to correctly interpret these multiple PVT messages. To make that possible, the ATOM PVT generator provides special information (Request ID) in the ATOM PVT header.

An Overview of ATOM RNX Observation Messages

Each RNX message 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 the latter case, the decoding equipment should be able to process the Multiple Message Bit properly (it is available in the header of each observation message). It should also be 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 also be spread among several sequential transmissions. In this case, the Multiple Message Bit is also set accordingly in order to allow complete epoch compiling.





The RNX message delivers 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 messages allow different customization and optimization scenarios to be implemented, a number of additional explanations/clarifications are provided in*Appendix B*, *Appendix C* and *Appendix D*. These Appendices allow users to understand in more details what algorithmic background is behind RNX observation messages.

ATOM RNX observation messages 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 observations:

- 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 specific receiver biases. On the other hand, GLONASS receiver observations can be corrected to conform with the Golden Ashtech receiver type. Through this process, GLONASS double-difference observations from the concerned receiver are made unbiased compared to the golden receiver.

The optional reference position, which can be generated inside ATOM observation messages, is assumed to refer to the correct ITRF epoch year, this information being usually indicated in the body of the ATOM message. In ATOM RNX, the reference position can be tagged to different points, including L1 phase center, antenna reference point or ground mark. Usually, the antenna height (i.e. the height of the antenna reference point above the ground mark) is provided together with the reference position, so that users can convert the position of the reference point into the position of the ground mark, or vice versa. The antenna name can also be requested from the receiver allowing transformation between the L1 antenna phase center and the antenna reference point.

The reference position in ATOM RNX may be either a static one (i.e. as entered), or a kinematic one (i.e. moving receiver) which the receiver determines every epoch. In the latter case, RNX can be used as the differential data generated by the moving receiver. An accuracy indicator for the reference position can be provided as well.With multiple GNSS tracking, the definitions of the receiver clock offset and clock steering must be clarified. Internally, the receiver can estimate its own clock offset in reference to each of the available GNSS time scales. Each epoch, a GNSS is selected as the “primary” one. The choice of primary GNSS will impact the following:

- Time tag representation for some messages
- Default datum for output position
- Reference time system when generating the receiver clock offset estimate and making clock steering.

The receiver clock offset estimate delivered in the PVT and RNX messages always refers to the primary GNSS system specified in the header of these messages. The clock steering procedure applies this clock equally to all GNSS observables. The receiver clock estimates, in reference to all the GNSS scales that the receiver can currently support, are output via the STA messages group.

Chapter 3. ATOM Messages Description

Preamble

This chapter contains the detailed (bit-to-bit) description of messages supported by ATOM format versions 1 and 2. A short summary of the main differences between V1 and V2 is provided in *Appendix F.* 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 not all Ashtech receivers or all firmware versions can support the ATOM messages described here. Some of the 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 *ATOM Serial Interface on page 97*.

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 even*t 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 the corresponding data has been updated (i.e. changed). In order to have a unified user interface pattern, the output interval for DAT messages can be specified, but be aware 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 the corresponding data has been updated, i.e. changed. However, users may want to see STA messages with some preset interval. That’s why Ashtech also implemented this strategy. In this case, users will miss some status updates if more than one internal update occurs between any two consecutive STA messages, or they will get identical information in two consecutive STA messages if no internal update occurs in between.

Most of the ATOM NAV messages are output by combining the *on new*, *on change* and *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 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 and 0.5 sec. If a receiver supports higher update rates, then intervals of 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 seconds). 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. and 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 the 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 such a way 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 requested ATOM messages will be generated regardless of whether their content is valid or not. For example, ATM,PVT,COO data will be generated even if the receiver cannot compute a position, or the computed position is internally found invalid. In this case, the position components will take pre-specified, invalid values while the other fields in ATM,PVT,COO may still deliver valid values.

Conversely, some other requested ATOM messages will no longer be output if their content is found invalid or no longer refreshed. For example the NAV message will stop being output if the age of the EPH data in this message is no longer valid. Messages from the STA group (e.g. differential decoder status) will stop being output if their content has not been updated for some time.

Data Field Conventions

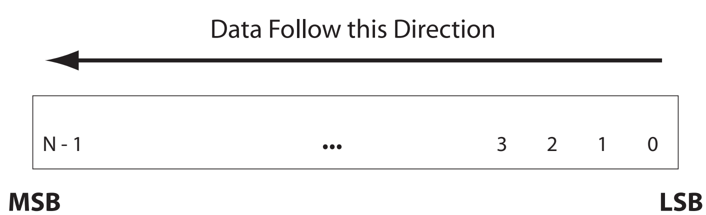
Each of the binary Data Fields (DF) described below fits one of the types presented in the following table.

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 note below)
Char(X)	8-bit character set with total length in X chars	Character set with variable length	
utf8(X)	Unicode UTF-8 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 Significant and Least Significant Bits (MSB and LSB) for signed and unsigned data is presented in the diagram below.



Bit Location in N-bit Integer

ATOM uses a number of bit masks (indicated as field bitX) referring to the GNSS set being transmitted (GNSS mask), the satellites being present (Satellite mask), the signals available (Signal mask) and many others. In all these masks, the first bit is the one that goes first into the binary stream, and the last bit is the one that goes last into the binary stream.

To insure quick reference to all 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 referring to a data field is given in the form “see DF...”, then it means that the described field has something in common with the standardized data field but is not exactly the same. 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 third-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. Third-party users should ignore all these fields. With ATOM development, some initially reserved fields (usually defined as zero) can become meaningful. Since third-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 messages, ATOM generates field DF003 (reference station ID). This is the correct name if a receiver is used as a reference station. However, if a receiver is not used as a reference station, the DF003 field is still used as a generalized indicator for a receiver.

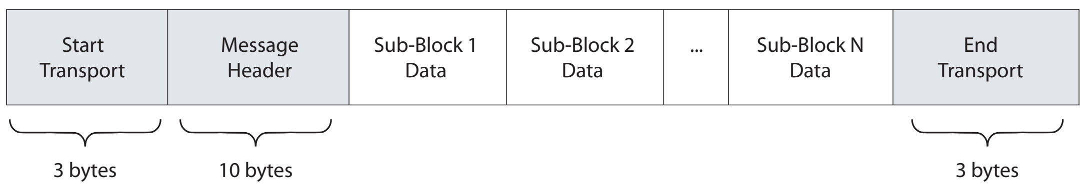
ATOM PVT Message

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 the diagram below.



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

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		AF019
Engine ID	6	uint6	48		0-63		AF002
Request ID	4	uint4	54		0-15		AF020
Reserved	5	bit5	58		0-31	Set to 00000	
Nsats used	6	uint6	63		0-63	Number of satellites used, “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 the next three tables below)	
MESSAGE DATA							
Sub-blocks of PVT message						See sub-sections below	
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

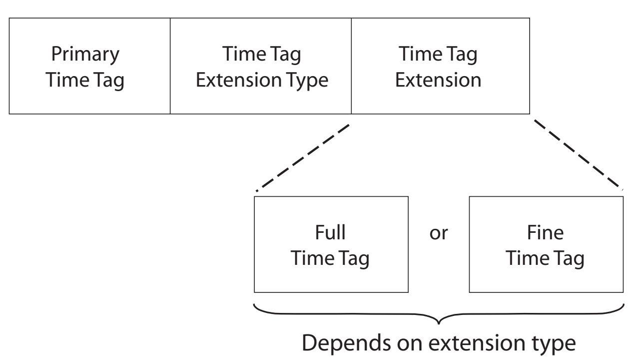
NOTES:

- Unlike with other ATOM groups, the station ID is not provided in the ATM,PVT header. But it can be available in extended form in the ATM,PVT MIS block.
- Only the SVS block (see below) is affected by the change from ATOM version 1 to ATOM version 2.
- The receiver usually features a number of basic PVT sub-engines. Each of them (or some of their combinations) can deliver a user position at a given epoch. Field AF002 identifies the combination of PVT sub-engine(s) providing the position solution,. In general, the AF002 field can change with epochs, depending on the environmental conditions and/or the differential data link status (for a too long data link loss for example, AF002, initially reported as equal to "9" will switch to "6").
- ATM,PVT is a generic message. In some specific cases, you may request different PVT-like messages. If several ATM,PVT messages are generated for a given time tag, you should be able to identify the messages corresponding to the serial commands you sent to issue those messages. Field AF020 allows you to match each decoded message with the corresponding request ($PASHS,ATM,*** command).
- It is assumed that more than one antenna connector can serve a particular GNSS board. That's why the antenna ID (AF019) is provided. For each hardware configuration, each antenna connector can have its own, unique index.

  For the MB500 or MB800 GNSS board, only antenna connector #1 is available.

  For the MB100 GNSS board, two antenna connectors are available: Antenna connector #1 refers to the so-called "external" antenna and can process L1/L2 signals; Antenna connector #2 refers to the so-called "internal" antenna and can only process the L1 signal.

  In future Ashtech boards, the relationship between available antenna connectors and their indexes will be provided in the corresponding manuals. The antenna name, which is reported in the ATM,ATR,ANM message, always refers to the antenna corresponding to the connector mentioned in the message header. The complete status of each potentially available antenna is supposed to be seen via another message (see ATM,STA,AST).
- Usually all the data corresponding to the same antenna ID, engine ID, and request ID are generated within a 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, the M-bit is set as described to help the PVT listener compile the complete PVT epoch corresponding to a particular set of antenna ID, engine ID and request ID.



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	0: full time tag extension follows 1: fine time tag extension follows	
Time tag extension	8		13			Primary time tag extension (see table below)	
Total	21						

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. set to BDS day (0...6) within BDS week, 0 is Sunday, 1 is Monday, etc. In all cases, “7” refers to an unknown day.	
Total	8						

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 + NIs (where NIs 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 the 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 the table below.

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	Miscella-neous	23	1000	Position supplementary data	$GPRMC $GPGGA $GPZDA
9	ROT	Extended Atti-tude Parame-ters	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		Reserved		1101		
14	SVS	Sat status	Depends on ATM,PVT version and tracking sta-tus	1110	Satellite tracking/usage information	$PASHR,SAT $GPGSV
SPECIAL BLOCKS (1111)						
15,0		Reserved		00000000		
15,1	LDP	Local Datum Position	Depends on message content	00000001	Position from block COO expressed in local user datum	N/A
15,2	CDC	Custom Datum Clarifi-cation	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 carto-graphic 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 some particular GNSS receiver/firmware. The organization of general-purpose and special blocks is presented in the tables below.

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, includes 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						

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, includes 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.

Position

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

Structure & 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 Bits7-8: 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	-13743895.3472m if not defined or invalid	DF025
Y coordinate	38	int38	92	0.1 mm	±13743895.3471	-13743895.3472m if not defined or invalid	DF026
Z coordinate	38	int38	130	0.1 mm	±13743895.3471	-13743895.3472m 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		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				AF023
Total	208						

NOTES:

- If an invalid fix is reported, some supplementary fields can still have some sense (e.g. Base ID or differential age).
- If the position is invalid, the position type clarifier (AF003) will tell you why it is so.

- With at least one GPS, GLONASS, GALILEO, QZSS, SBAS (ranging) or BeiDou 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. For example, it helps make the distinction between DGNSS and DSBAS.
- All DOP figures are computed assuming an independent clock offset for each GNSS. With three GNSS systems used (GPS+GLONASS+GALILEO), the GDOP matrix will be a 6 x 6 matrix.
- The reported "Differential position age" refers to the difference between the current time tag and the time tag of the original differential corrections being applied (i.e. correction project time). Note that in some cases, the last received corrections cannot be applied. That's why an increasing "Differential position age" does not necessarily mean there's a problem with the data link, but just indicates the degree of degradation of the position.
- In contrast, the reported "Differential link age" refers to the difference between the current time tag and the time tag of the last decoded corrections. So a growing differential link age DOES mean base failure or communication failure.
- The position is reported as a Cartesian position. Users can compute the geodetic position by applying the suitable ellipsoid parameters. The default or custom datum bit is provided in the MIS block. If the datum has been set to "Default", then users should apply the corresponding default ellipsoid parameters that are unique to the GNSS chosen as the primary system. If the datum has been set to "Custom", then the name of the custom datum and its ellipsoid parameters can be found in the additional CDC (Custom Data Clarification) block.
- There is no guarantee that the reported differential position be tagged to the default datum (which depends on which GNSS has been chosen as the primary system), even if claimed to be so. In fact the datum used will be the one in which the reference position is expressed. It was established that some providers generate reference positions tagged to the local datum without explicitly mentioning it. This is the case in the US where some network providers generate reference positions in NAD83 but don't communicate this information to their users.

Accuracy This sub-block always 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 the 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 the 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

Structure & 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	Meaningful 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		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 (in meters):

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

- k1, k2, k3 (all unitless):

$$k1 = \frac{\sqrt{s11}}{sigma} \qquad k2 = \frac{\sqrt{s22}}{sigma} \qquad k3 = \frac{\sqrt{s33}}{sigma}$$

- r12, r13, r23 (all “square” unitless)

$$r12 = \frac{s12}{\sqrt{s11 \times s22}} \qquad r13 = \frac{s13}{\sqrt{s11 \times s33}} \qquad r23 = \frac{s23}{\sqrt{s22 \times s33}}$$

- The reported covariance matrix does not need any additional scaling because actually it’s one-sigma accuracy figures that are reported.
  The random variable ratio1=err1/sqrt(s11) should theoretically follow the Gaussian (0,1) distribution.

Velocity 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

Structure & 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 below.	
Reserved	4	bit4	92		0-15		AF022
Total	96						

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.

Clock 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

Structure & 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.
- The reported receiver clock offset and drifts (as well as the TDOP value) are given with respect to the primary GNSS system specified in the PVT message header.
- It should be noted that, for highly dynamic receivers, the clock steering procedure affects the reported position (COO block). In this case, users who would like to return to the original receiver status (i.e. not steered) will have to correct the reported position (COO) using the knowledge of the reported receiver velocity (VEL block) and the internal clock offset (in the current block).

Latency This sub-block contains the latency of a 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

Structure & 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 below.	
Total	24						

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

NOTES:

- 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 a given ATM,PVT message and may differ from the latency reported in the $PASHR,LTN message.

Attitude 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

Structure & 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		AF024
Total	88						

NOTES:

- 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 is set to “1”, “2” or “3”, the reported angles refer to the platform attitude (i.e. the platform on which the antennas are installed). When Antenna setup=0, the reported heading refers to the baseline azimuth, the reported pitch refers to the baseline elevation, and the roll is reported as invalid.
- When a single baseline is applied for attitude estimation (only two antennas used), either the pitch or roll -or both- are unavailable. When two or more baselines (three or more antennas used) are applied for attitude estimation, all angles can generally be available. But in some singular cases, some of the three angles may be unavailable, even with three or more antennas used.
- In case of a single baseline, the HPR block being transmitted with the BLN block, under the same PVT header, indicates that the HPR content is based on the BLN estimate.

Baseline This sub-block contains baseline estimates. These estimates are applicable only to “MS” differential operation. “MS” stands for “Measurement Space” and “MS differential operation” refers to Measurement Space corrections, in contrast to State Space (SS) corrections for which the 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

Structure & 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 to be different 1: Base and rover clock drifts assumed to be the same	
Total	128						

NOTES:

- 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 blocks COO and BLN being tagged to the same PVT solution ID, source ID and antenna ID are related to each other by the simple formula: *position=base+baseline*, where base is the coordinates of the reference receiver (whether static or moving, physical or virtual).
- Being expressed in XYZ, the baseline does not depend on the reported primary GNSS system, i.e. on the primary datum. Converting an XYZ baseline to any rectilinear ENU system always relies on the use of the default ellipsoid model corresponding to the primary GNSS system used.
- The Arrow option refers to using or not using an “a priori” knowledge of a fixed and known baseline length. If the fixed baseline length is not known yet (an Arrow calibration sequence is in progress), then “0” is reported for this indicator.
- The common clock drift indicator can be valuable for the so-called internal heading configuration, or when base and rover boards are driven by an external oscillator.

Miscellaneous 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

Structure & 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		AF006
Antenna height	16	uint16	49	0.0001 m	0-6.5535	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	
Number of GNSS time cycles	12	uint12	88		0-4095	For GPS wn modulo 4095 cycle For GLONASS, day number in 4-year cycle (DF129) 4095 means defined 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	2047 if not defined or invalid	
Type of ephemeris used	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 should be noted that field DF028 is still not declared as mandatory in the RTCM document. It is now reserved to output ITRF epoch year. For this reason, users are advised to ignore its content.
- If the “Datum” field is set to “custom”, then an extra ATM,PVT,CDC (Custom Data clarification) block can be generated to identify the custom datum and read its parameters.
- Additionally, the receiver can also report position tagged to some local datum. See ATM,PVT,LDP (Local Datum Position) block for details.

- For more information on geoid height, local zone time offset and magnetic variation, please refer to *NMEA-4.0 definitions*.
- The number of GNSS time cycles refers to the GPS week number if GPS is the primary system (0-4095; 0 starts midnight Jan 5/Jan 6, 1980, rolls from 4095 to 0).
- The number of GNSS time cycles refers to the GLONASS day number if GLONASS is the primary system (1-1461; day 1 corresponds to Jan 1, 1996; rolls from 1461 to 1; "0" means unknown day; values 1462-4095 are not used).
- The number of GNSS time cycles refers to the BDS week number if BDS is the primary system (0-4095; 0 starts midnight Jan 1, 2006 (Sunday), rolls from 4095 to 0).
- In all cases, the "Antenna height" field refers to the vertical distance between Antenna Reference Point and Ground Mark.

Supplementary Attitude Data

This sub-block contains supplementary information to HPR sub-block, such as attitude rate, attitude accuracy and some other valuable indicators. Users can in addition request this sub-block if they need more than the HPR data for their applications.

- **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

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	0.01 d/s	±327.67 d/s	-327.68 means invalid	
Pitch speed	16	int16	28	0.01 d/s	±327.67 d/s	-327.68 means invalid	
Roll speed	16	int16	44	0.01 d/s	±327.67 d/s	-327.68 means invalid	
Heading rms	10	uint10	60	0.01 d	0-10.23 d	10.22 means 10.22+ 10.23 means invalid	
Pitch rms	10	uint10	70	0.01 d	0-10.23 d	10.22 means 10.22+ 10.23 means invalid	
Roll rms	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	Bit14	100				AF017
Total	104						

NOTE:

- Sign conventions for angular speed need to be specified.
- Accuracy reported to be "0" (zero) does not mean an invalid estimate. For example, with a very long baseline (e.g. >100 meters), the accuracy of the heading estimate is better than the resolution used. In that case, the reported "0" accuracy should be understood as an accuracy actually ranging between 0 and 0.01 degree rms.
- The "Extrapolation interval" field is considered to be true even if the associated angles and their derivatives are reported to be invalid.

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. Users can in addition request this sub-block if they need more than the BLN data for their applications.

- **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

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	Meaningful only if Sigma 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 the base coordinates are quite accurate and do not insert extra error into the 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 the first, second and third baseline components respectively, as defined by the coordinate frame used, as reported in the BLN sub-block. The equations below provide the correspondence between the elements of the covariance matrix and the BSD fields (these are the same as those in the 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 (in meters):

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

- k1, k2, k3 (all unitless):

$$k1 = \frac{\sqrt{s11}}{sigma} \qquad k2 = \frac{\sqrt{s22}}{sigma} \qquad k3 = \frac{\sqrt{s33}}{sigma}$$

- r12, r13, r23 (all “square” unitless)

$$r12 = \frac{s12}{\sqrt{s11 \times s22}} \qquad r13 = \frac{s13}{\sqrt{s11 \times s33}} \qquad r23 = \frac{s23}{\sqrt{s22 \times s33}}$$

- The reported covariance matrix does not need any additional scaling because actually it’s one-sigma baseline accuracy figures that are reported.

  The random variable ratio1=err1/sqrt(s11) should theoretically follow the Gaussian (0,1) distribution.

Additionally, the block reports baseline extrapolation information interval (if extrapolation applied), with a resolution of 10 ms, and the Base station ID. A significant number of bits have been reserved to allow more data to be added into this sub-block in the future.

Satellite Information

The content of this block depends on the version of the ATM,PVT message. This sub-block contains the status of each visible satellite (by almanac). 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 the size of the PVT message remains below 1023 bytes. The organization of SVS data is very similar to data organization in the ATOM RNX message (see *ATOM RNX Message on page 81* and *Appendix D on page 119*).

- **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

SVS Header (ATM,PVT Vers. 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 D.*	DF394
Signal mask	32	Bit32	79			See *Appendix D.*	DF395
Cell mask	64	bit64	111			See *Appendix D.*	See DF396
Reserved	9	bit9	175		0-511	Set to 000000000	
Total	184						

SVS Header (ATM,PVT Vers. 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 D.*	See DF394
Signal mask	24	bit24	55			See *Appendix D.*	See DF395
Cell mask	64	bit64	79			See *Appendix D.*	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.
- In ATOM Ver. 1, the size of Satellite Mask is 40 bits, and Signal Mask, 24 bits. With ATOM Ver. 2, Sat Mask is 64 bits long, and Signal Mask, 32 bits long. In Ver. 2, the first 40 bits in Satellite Mask have the same meaning as in Ver. 1, and the first 24 bits in Signal Mask have the same meaning as in Ver. 1. The decoding equipment should be able to analyze the version number of ATM,PVT and process all the other fields accordingly.
- If the Cell Mask happens to exceed 64 bits (e.g. 14 satellites and 5 signals, i.e. 14*5=70>64), then the tracking status for the given GNSS can be provided as two

or more sequential SVS blocks that are complementary to each other. The decoding equipment should be ready for such a possibility.

- For a satellite that is visible but not tracked, a *ghost* –because not tracked yet– signal may be reported in the signal mask. This is usually signal 1C. Such a satellite can however report no signal, in which case the ATOM PVT SVS parser will knowingly deal with the case of satellite data available, but no signal data available for this satellite.

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: Unknown status	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: Unknown status 16-31: Sat is not used in position	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. By visible satellites, we mean here those currently tracked (they may have negative elevation in some specific cases), and also those not tracked but seen above the horizon as indicated in the 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 from 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.

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 SNR's 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 description of warnings in the ATOM 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.

Position Expressed in Local Datum

This sub-block contains the same position as in the COO block, but expressed in a local datum. The description (i.e. the name) of the local datum is also provided. This block needn't be requested specifically. Each time a COO block is generated and transformation parameters corresponding to COO positions are available, block LDP is generated.

In absence of transformation parameters for a given COO position at a given epoch, block LDP will not be generated. For example, there may be some transformation parameters that are valid only for differential (e.g. RTK) position. In cases where the receiver switches to standalone or SBAS differential position (e.g. data link lost), block LDP may not be generated.

- **Output logic**: on time
- **Sub-block binary size**: Depends on the 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**: N/A

Structure & 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 value or a higher value.	
Reserved	20	bit20	239		0-	Set to 0...0	
Utilized trans-formation source	3	uint3	259		0-7	0: unknown source 1: RTCM-3 2-7: reserved	
Source clarifi-cation	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 local datum name used	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, the reported Cartesian coordinates may be invalid while the Geographic coordinates are valid, or vice versa. The decoding equipment should be able to track this kind of situation by checking the fields for validity.
- The utilized transformation source and its clarification currently support RTCM-3 transformation messages. But these fields can be used in the future to indicate other sources or clarifiers.
- Field DF148 contains information about some specific RTCM transformation messages (1023 through 1027) used for the position reported in that block.

Custom Datum Clarification

This sub-block contains the clarification (name) and parameters of the datum in which the COO position is expressed. This block needn't be requested specifically; each time the "datum" field in the MIS block is set to 1 (custom), all clarification parameters are generated in the block.

- **Output logic**: on time
- **Sub-block binary size**: Depends on the 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**: N/A

Structure & 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 provide the custom datum name and ellipsoid parameters relevant to the position provided in the COO block and allow the latitude, longitude and altitude components of the Cartesian COO position to be output as well.

Position Expressed in Local Cartographic Projection

The LMP (Local Map Projection) sub-block is deduced from the position held in the COO block. This sub-block needn't be requested specifically; each time a COO block is generated and the projection parameters corresponding to the COO positions are available, block LMP is generated.

In absence of projection parameters for a given COO position at a given epoch, block LMP will not be generated, or it will be generated with an indication that all (or some of) the fields are invalid. For example, there may be some projection parameters that are valid only for differential (e.g. RTK) position. In cases where the receiver switches to standalone or SBAS differential position (e.g. data link lost), block LMP may not be generated.

- **Output logic**: on time
- **Sub-block binary size**: Depends on the 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**: N/A

Structure & 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	±109951162.7775m	- 109951162.7776 m if not defined or invalid	
Easting	41	int41	61	0.1 mm	±109951162.7775m	- 109951162.7776 m if not defined or invalid	
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							

NOTE:
- See NMEA $GPGMP message description for more details.

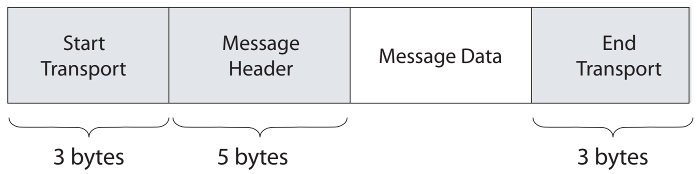
ATOM ATR Messages

Messages from the ATR (for “ATtRibutes”) group contain different additional and service information such as antenna and receiver description, antenna offset parameters with respect to 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 on the diagram and in the table below.



ATR Message 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 the table below.

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 the receiver supports	Signals the receiver can potentially track	$PASHR,CFG
8	CPB	GLONASS Code-Phase Bias value	The reported values make it possible to adjust Ashtech raw data to "golden" standard.	RTCM-3 MT1230
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 etc	N/A
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 ATOM RNX 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 RNX 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 the SNS message is primarily used for recording data to a file for further post-processing, the more compact MET message on the other hand is more intended for being inserted into a differential stream to inform a real-time rover of the meteo conditions at the base, thereby allowing it to mitigate the residual tropospheric error.

Antenna attributes

This message contains antenna attributes. The generated ATOM observables (RNX) 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

Structure & 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 corre-sponds 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							

Receiver attributes

This message contains receiver attributes. It is a copy of standardized RTCM-3 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

Structure & 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	DF0002
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	DF0003
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							

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>,ON,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

Structure & 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							

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

Structure & 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						

Site Occupation Information

(Not described)

Meteo Data

This message contains information about local meteo parameters (corresponding to an area of reasonable size located in the vicinity of the GNSS antenna). This message allows the troposphere error to be mitigated.

It is supposed that the message can be generated together with other attributive information (receiver/antenna names) from base to rover, although the latter information will be available at a lower rate. The message can also be used as a source for RINEX meteo files.

It is supposed that the meteo information is either made available to the MET message generator automatically (meteo sensors stream their readings directly to the MET generator), or local meteo parameters enter the receiver at some regular intervals via the available serial interface. The meteo data generated in the 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

Structure & 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						

GLONASS Code-Phase Bias

This message generates the so-called “GLONASS Code-Phase bias values” for up to all FDMA GLONASS observations. It is an extended copy of RTCM-3 MT 1230. For CPB value-to-GLONASS FDMA observations applicability, see the description of *RTCM-3 MT 1230*.

The message content is equally applicable to all raw/differential proprietary/standardized data generated by Ashtech receivers, 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

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							

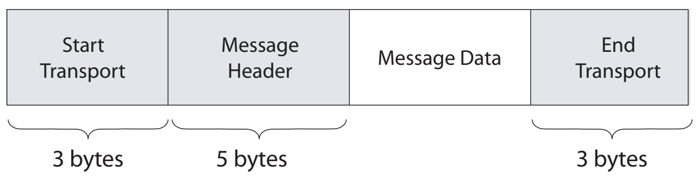
ATOM NAV Messages

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 the diagram and in the table below.



NAV Message 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							

The supported NAV messages are presented in the table below.

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 standardized yet)
4	EPH	GAL ephemeris (I/NAV) from E1b/E5b signal data	Modified copy of RTCM-3 type 1045	RTCM-3 MT 1045
5	EPH	QZSS ephemeris from L1CA signal data	Modified copy of EPH (GPS)	RTCM-3 MT 1044 (not standardized yet)
6	EPH	BDS ephemeris from 1I signal data		RTCM-3 MT ? (not standardized yet)
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

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

Structure & 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/sec2)	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
A1/2	32	uint32	320	2^{-19}		Square root of semi-major axis (meters1/2)	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						

NOTE: See decoding sample in *Appendix A.*

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 vers. 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

Structure & 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 coordinates in PZ-90 datum	DF115
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 and UTC	DF133
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 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.

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

Structure & 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						

Galileo Ephemeris This message contains Galileo ephemeris data for a given Galileo satellite. These data can be extracted from the Galileo E1b or E5b Signal. For detailed information about Galileo ephemeris data, please refer to the *GALILEO OS SIS ICD*. The content of this message is the extended copy of *RTCM-3 MT1045*.

- **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 1045

Structure & 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 mess. No.	12	uint12	64			Reserved for future usage. Can take arbitrary value.	DF002
GALILEO Satellite ID	6	uint6	76	1	1-64	The GALILEO SVID parameter is coded with 6 bits. However, the max constellation which can be accommodated within the I/NAV and F/NAV frames is 36 satellites (3 planes of 12 satellites each).	DF252
GALILEO Week Number (WN)	12	uint12	82	1 week	0 - 4095	Galileo week number. Roll-over every 4096 weeks (about 78 years). Galileo System Time (GST) is defined in OS SIS ICD, Issue 1.1, September 2010. The GST start epoch shall be 00:00 UT on Sunday 22 August 1999 (midnight between 21st and 22nd August).	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, Issue 1.1, September 2010 (reserved)	DF291
GALILEO IDOT	14	int14	112	2^{-43}	See Note 1	Rate of inclination. Unit: semi-circles/s	DF292
GALILEO toc	14	uint14	126	60	983,040	Clock reference time. Galileo System Time (GST) is defined in OS SIS ICD, Issue 1.1, September 2010. The GST start epoch shall be 00:00 UT on Sunday 22 August 1999 (midnight between 21st and 22nd Aug). At the start epoch, GST shall be ahead of UTC by thirteen (13) leap seconds. Since the next leap second was inserted at 01 January 2006, this implies that as of 01 January 2006 GST is ahead of UTC by fourteen (14) leap seconds.	DF293
GALILEO af2	6	int6	140	2^{-59}	See Note 1	Clock correction. Unit: s/s^2	DF294
GALILEO af1	21	int21	146	2^{-46}	See Note 1	Clock correction. Unit: s/s	DF295
GALILEO af0	31	int31	167	2^{-34}	See Note 1	Clock correction. Unit: seconds	DF296

GALILEO Crs	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 M0	32	int32	230	2^{-31}	See Note 1	Mean anomaly at reference time. Unit: semi-circles	DF299
GALILEO Cuc	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 Cus	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 toe	14	uint14	356	60	983,040	Ephemeris reference time. Galileo System Time (GST) is defined in OS SIS ICD, Issue 1.1, September 2010. The GST start epoch shall be 00:00 UT on Sunday 22 August 1999 (midnight between 21st and 22nd August). At the start epoch, GST shall be ahead of UTC by thirteen (13) leap seconds. Since the next leap second was inserted at 01 January 2006, this implies that as of 01 January 2006 GST is ahead of UTC by fourteen (14) leap seconds.	DF304
GALILEO Cic	16	int16	370	2^{-29}	See Note 1	Amplitude of the cosine harmonic correction term to the angle of inclination. Unit: radians	DF305
GALILEO Ω0	32	int32	386	2^{-31}	See Note 1	Longitude of ascending node of orbital plane at weekly epoch. Unit: semi-circles	DF306
GALILEO Cis	16	int16	418	2^{-29}	See Note 1	Amplitude of the sine harmonic correction term to the angle of inclination. Unit: radians	DF307
GALILEO i0	32	int32	434	2^{-31}	See Note 1	Inclination angle at reference time. Unit: semi-circles	DF308
GALILEO Crc	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 OMEGADOT	24	int24	516	2^{-43}	See Note 1	Rate of right ascension. Unit: semi-circles/sec	DF311
GALILEO BGDE5a/E1	10	int10	540	2^{-32}	See Note 1	Broadcast Group Delay E5a/E1	DF312
GALILEO BGDE5b/E1	10	int10	550	2^{-32}	See Note 1	Broadcast Group Delay E5b/E1 (reserved)	DF313
E5a SIGNAL HEALTH STATUS	2	bit(2)	560			The Signal Health Status Bit Values are: 0 Signal OK 1 Signal out of service 2 Signal will be out of service 3 Signal Component currently in Test Note: These values are still marked as to be confirmed in the current document (OS SIS ICD, Issue 1.1, September 2010). In case of any changes in the definition of later ICD version these values might change their meaning.	DF314
E5a DATA VALIDITY STATUS	1	bit(1)	562			The navigation data validity status transmitted on E5a. The signal health status and data validity status refer to the transmitting satellite. These status flags are used as service performance level notification (e.g. notification of satellite non-availability).	DF315
Reserved	7	bit(7)	563			Set to 0.. 0	
Reserved	22	bit(22)	570			Set to 0.. 0	
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: This message is the extended copy of RTCM MT 1045.

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 the QZSS ephemeris message is a copy of the corresponding GPS ephemeris message (same size), yet with some fields set to fixed values or with slightly different meanings.

- **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

Structure & 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/sec2)	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
⊿n	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 (meters1/2)	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 and L2C	DF101
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						

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**: NA

Structure & 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/sec2)	
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	
⊿n	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 (meters1/2)	
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						

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

Structure & 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	int16	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-circle)	
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.

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

Structure & 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						

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

Structure & 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						

Galileo Almanac This message contains GAL almanac data for a given GAL satellite, as extracted from the 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**: NA

Structure & 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 SVID 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 i0 = 56° (semi-circles per sec)	
Ω0	16	int16	105	2^{-15}		Right ascension (semi-circles)	
(Ω0)’	11	int11	121	2^{-33}		Rate Right ascension. (semi-circles per sec)	
ω	16	int16	132	2^{-15}		Argument of Perigee (semi-circles)	
M0	16	int16	148	2^{-15}		Mean anomaly at reference time (semi-circle)	
af0	16	int16	164	2^{-19}		Satellite clock correction bias “truncated” (sec)	
af1	13	int13	180	2^{-38}		Satellite clock correction linear “truncated” (sec/sec)	
IODa	4	uint4	193				
t0a	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						

QZSS Almanac

This message contains QZSS almanac data for a given QZSS satellite. For detailed information about QZSS almanac, please refer to the *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

Structure & 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.

Beidou Almanac

This message contains Beidou almanac data for a given Beidou 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

Structure & 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, i_0=0.30 semi-circles; for GEO satellites, i_0=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 *Δ*i generated from field i_0 (Inclination Angle at Reference Time) from BDS ephemeris data is scaled by 0.1 and 0.

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

Structure & 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							
$\alpha 0$	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			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						

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

Structure & 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 week number modulo 4095 cycle 4095 means undefined or invalid	DF076
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						

GAL Ionosphere & 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

Structure & 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)	
⊿tLS	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	
⊿tLSF	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						

QZSS Ionosphere & 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

Structure & 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						

BDS Ionosphere & 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

Structure & 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							
$\alpha 0$	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)	
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						

ATOM DAT Messages

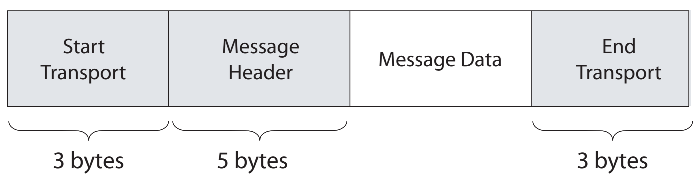
Messages of the DAT (raw DATa) group contain original binary data. Particularly, this group contains GPS, GLONASS, Galileo, QZSS, BDS and SBAS raw navigation data (streams). Processing raw navigation data streams, users can extract any navigation information, particularly that contained in ATOM NAV messages. Also, the DAT group contains very valuable, generalized EXT and INT messages capable of outputting almost any data existing or traveling inside the 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 this can still be specified for universality reasons, although ignored).

A message is output after a new frame has been decoded. DAT,EXT messages are requested through a single command and output every time data is entering the GNSS receiver, i.e. DAT,EXT contains spied data packed into convenient frames. DAT,INT messages are also requested through a single command. For each hardware target and firmware version, there may be different sets 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 the diagram and in the table below.



DAT Message 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 the table below.

DAT message type	ASCII identifier	Attribute description	Comments	Counterpart
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 traveling inside the receiver	Data traveling inside receiver via internal pipes	N/A
11	EXT	Original binary stream entering the receiver	Data enteringthe receiver via physical/ virtual port(s) and sockets	N/A

NOTE: Message FRM is a generic substitute for legacy messages GPS/GLO/SBA/GAL. Only this generic message will be supprted in the future by adding support of new GNSS's and their signals (e.g. QZSS).

SBAS Subframe

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*. Should the parity check fail, the corresponding sub-frame would not be 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

Structure & 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		0-38	SBAS satellite number 0: Sat ID is not defined 1 -> PRN#120 2 -> PRN#121 ….. 38 -> PRN#158	
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						

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 data created by an external device, which means the GNSS receiver outputting DAT,EXT messages is not responsible for their content. Packed data may have a known structure in which case users can process them using their own algorithms or tools. Packed data may also have unknown structure, implying users should inquire about the source that originally generated the 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

Structure & 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		

Adding Number 2 (examples):

Original byte	Converted byte
0x13	0x15
0xAF	0xB1
0xFE	0x00
0xFF	0x01

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.

ATOM DAT (EXT) can be used for creating the so-called "virtual ports". This can be useful if some application is talking to a GNSS receiver via a single physical port (e.g. port A),but at the same time wants to get more than one fully independent data stream.

For example, some receiver data can be requested on port A, and some other (or the same data with other parameters) on port Z. Both streams will be output via the same physical port A, but the data stream corresponding to virtual port Z will additionally be packed inside ATM,DAT,EXT with source ID=25 (port Z).

This packing does not necessarily mean that each message is packed separately, but on the contrary, the stream can be cut off quite arbitrarily. The only need is having some application software capable of parsing the ATM,DAT,EXT transport to be able to split both streams. Any software supporting RTCM-3 transport decoding can easily implement ATM,DAT,EXT parsing.

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. This message can be considered as a generic substitute for 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

Structure & 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 *Appendix G.*	
Signal ID	5	uint5	73		0-31	The rank-1 in Signal mask, see DF395 in *Appendix G.*	
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.	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						

NOTES:

- The proper number of zero bits (0 to 7) is inserted before the CRC in order to make sure the complete message contains an integer number of bytes.
- Only the data that were successfully synchronized/decoded are generated.
- The numbers representing respectively Satellite ID and Signal IDs actually refer to the position (rank) of the corresponding bit in the Satellite and Signal Mask (see *Satellite, Signal and Cell Masks on page 129*. For example, ID=0 refers to the first bit in the corresponding Mask, ID=1 refers to the second bit in the corresponding Mask, etc.

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 that sense, the RNX message does the same job as BINEX, but with much better throughput efficiency, flexibility and compatibility.

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 trade-off 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.

To match general RTCM-3 standards, observables presented in the ATOM RNX messages are always 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 *Appendix B* to *Appendix E.*

Understanding the organization of ATM,RNX may be made easier by reading the *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 a simplified copy of ATOM RNX messages.

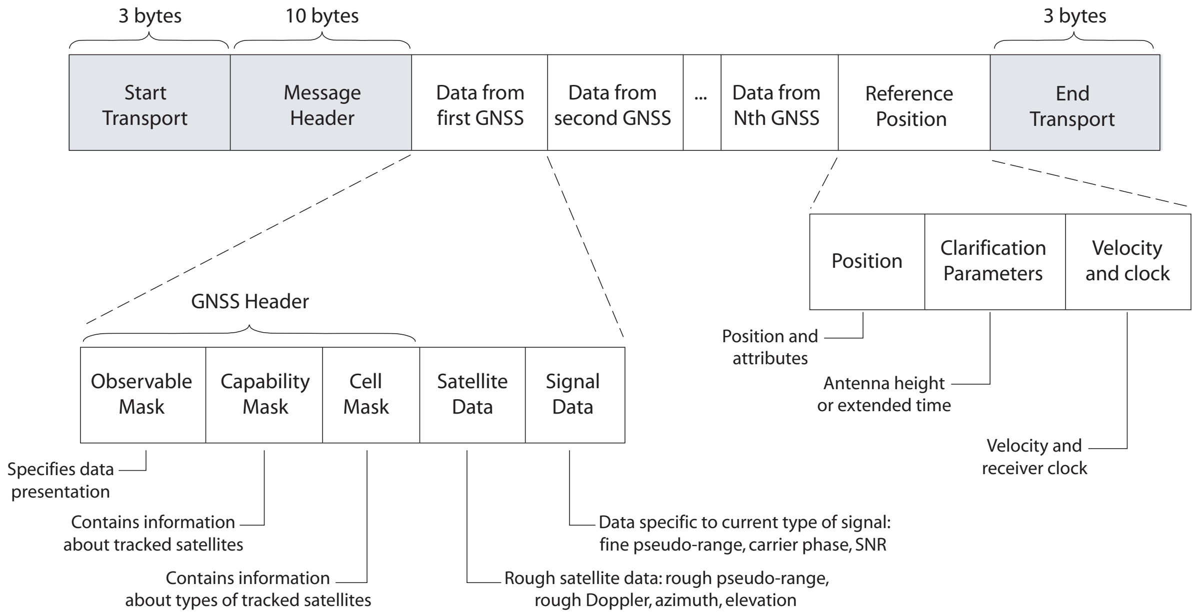
The basic principles behind ATOM RNX messages are in fact those of the standardized RTCM-3 generic MSM data. These are messages 1071-1077 (GPS), 1081-1087 (GLONASS), 1091-1097 (Galileo), etc. This means that there are many similarities in generating and processing Ashtech proprietary ATOM RNX messages and standardized RTCM-3 MSM data.

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.

Fig. 1. ATOM RNX Message Organization



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 1. ATOM RNX Message Structure & 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	DF393
IODS	3	uint3	56		0-7	Reserved for Issue Of Data Station; Set to 000	DF409
Smoothing interval	3	uint3	59		0-7	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	

Table 1. ATOM RNX Message Structure & Content

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 *Table 2*, *Table 3* and *Table 4*.	
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 5*.	
Capability Mask	[ ]					See *Table 6* and *Table 7*.	Depends on ATOM RNX version
Cell Mask	[≤64]					See *Table 8*.	
Satellite Data	[ ]					See *Table 9*.	
Signal Data	[ ]					See *Table 10*.	
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 12*, *Table 13* and *Table 14*.	
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, then SBAS, then GLONASS, then GALILEO, then QZSS, then 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.
- The reported code-carrier smoothing parameters (smoothing interval and divergence free indicator) are copies of the SMI parameters specified by the user through serial commands sent to the receiver. *See the corresponding Ashtech GNSS Boards Reference Manual*.

  Users should understand that single-frequency receivers cannot generate divergence free smoothing. Ashtech default smoothing intervals are typically 600 seconds for single-band receivers, and 1800 seconds for multi-band receivers.

  Note that a 600-second interval for L1-only receivers should not be deemed as a too high value. In fact, Ashtech applies a long-time proven L1 code-carrier smoothing strategy using second-order filtering. While first-order filtering may produce a ionosphere bias, even with a smoothing interval as low as 100 seconds, second-order filtering by Ashtech on the other hand will NOT insert any bias, even with a 600-second smoothing interval.
- At certain time windows, some satellites cannot provide L2 data. Although the receiver can report divergence free smoothing, users should realize this is not applicable to L2-defective data.

- The “Cumulative session transmitting time indicator” field shows the time elapsed since the last ATM,RNX output request was made. Each time the $PASHS,ATM,RNX,<port>,ON,<period>,&SCN,<scenario> command is issued (even with the same parameters as in the previous request), this field is reset to zero. The processing equipment should therefore interpret this field as a cycle slip for all carrier data if its content decreases between any two consecutive epochs received.
- Having two observation messages with the same physical time does not necessarily mean they have the same time tagging. This is because one message can be tagged to one GNSS time while the other can be tagged to another GNSS time.

Fig. 2. Time Tag Organization

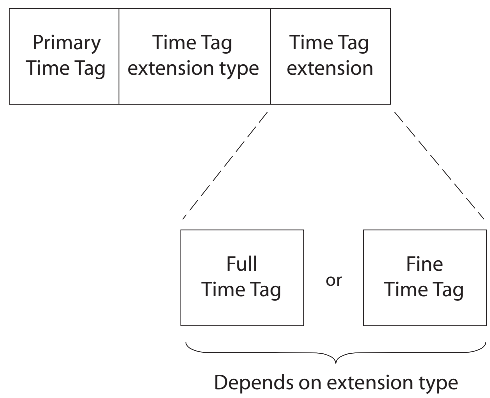


Table 2. Time Tag Presentation

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	0: full time tag extension follows 1: fine time tag extension follows	
Time tag extension	8		13			Primary time tag extension (see *Table 3* and *Table 4*).	
Total	21						

Table 3. 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 all cases, “7” refers to an unknown day	
Total	8						

Table 4. 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 2012) for GPS, and UTC-3 hours for GLONASS.
- The size of the time tag is always fixed.
- For most of the supported ATM,RNX scenarios, the message will not be generated if the selected primary GNSS system is unable to provide a correct time. For example, if GPS is set as the primary system and GPS is not tracked, then no GNSS data (other than the unavailable GPS data) will 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 the 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).

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 5. Observable Mask Description

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 masks follow 1: capability&cell masks follow	
N_{ms} follow	1	bit1	6		0-1	0: no N_{ms} follows 1: N_{ms} follows	
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 follows 1: fine pseudo-range follows 2: full pseudo-range follows 3: reserved	
Carrier phase follow	2	uint2	11		0-3	0: no carrier phase follows 1: fine carrier phase follows 2: full carrier phase follows 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 6. Capability Mask Description for ATOM RNX Version 2 (inserted if "Data ID follow"=1 in Observable mask; see Table 5)

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

Table 7. Capability Mask Description for ATOM RNX Version 1 (inserted if "Data ID follow"=1 in Observable mask; see Table 5)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
CAPABILITY MASK							
Satellite mask	40	bit64	0			See *Appendix D.*	See DF394
Signal mask	24	bit24	40			See *Appendix D.*	See DF 395
Reserved	8	bit32	64			Set to 00000000	
Total	72						

Table 8. Cell Mask Description (inserted if "Data ID follow"=1 in Observable mask; see Table 5)

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

NOTES:

- Bit "Resolution" in the Observable mask is hardcoded to 0 in ATOM Version 1, but can take values 0 or 1 in ATOM Version 2. Depending on this bit value, Signal data will have a different presentation. see *Signal Data on page 87*.
- The Cell mask is of float size, but its size is known after decoding the capability mask (see *Table 6* and *Table 7*).
- 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 1*).
- 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.
- In ATOM RNX Version 1, Sat mask is 40 bits in size and Signal mask is 24 bits. The first 40 bits in Sat mask are the same in ATOM RNX Version 1 and Version 2. Likewise, the first 24 bits in Signal mask are the same in ATOM RNX Version 1 and Version 2. The decoding equipment must be capable of analyzing the ATOM RNX version number and process all the other fields accordingly.

Satellite Data Satellite data have three optional blocks that can be inserted in the message, depending on configuration bits in the Observable mask (see *Table 5*). These blocks contain the information common to each signal from the same satellite.

In each of these three 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 6*).

Table 9. Satellite Data

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SATELLITE 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 unknown.	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 *Extended ATOM RNX Data on page 92*).	
Total							

NOTES:

- Considering “Integer number of ms in Satellite range” for example, “repeating” this field means that the value of the field will be provided in succession for each of the satellites for which the Satellite mask is “1” (see *Table 6*). With 10 tracked satellites for example, the field size will finally be 80=10 x 8 bits.
- Full rough range (in ms) is just the sum of the first two fields above. In case the integer number of milliseconds is not available, it is the decoding equipment’s responsibility to restore this number using the known, approximate position and the available navigation data.

Signal Data Signal data have five optional blocks that can be inserted in the message, depending on configuration bits in the Observable mask (see *Table 5*). These blocks contain information specific to each signal.

In each of these five 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 7*).

Table 10. Signal Data for Resolution= 0 (Standard)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SIGNAL DATA							
Fine pseudo-range data	15 Ncell times	uint15(N_{cell})		0.02m	0-655.34 m	Inserted if fine or full pseudo-range follows	
Integer cycle carrier phase data	16=4+12 Ncell times	uint16(N_{cell})		1 cycle	0-4095 cycle	Inserted if full carrier phase follows (see notes below)	
Fractional cycle carrier phase data	8 Ncell times	uint8(N_{cell})		1/256 cycle	0-(255/256) cycle	Inserted if fine or full carrier phase follows	
SNR	6 Ncell times	uint6(N_{cell})		1dBHz	0-63 dBHz	Inserted if compact or full supplementary data follow	DF403
Extended supplementary data	56 Ncell times	bit56(N_{cell})				Inserted if full supplementary data follow (see *Extended ATOM RNX Data on page 92*)	
Total							

Table 11. Signal Data for Resolution= 1 (Extended)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SIGNAL DATA							
Fine pseudo-range data	20 Ncell times	uint20(N_{cell})		0.02m	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	uint8(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 *Extended ATOM RNX Data on page 92*)	
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 7*). With 20 available cells, the field size will finally be 300=20x15 bits (or 20x20 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.
- The full fine carrier phase data are the sum of the integer cycle carrier phase and the fractional carrier phase. In some cases, the integer cycle carrier phase is not transmitted (compact data transmission scenarios for static GNSS receiver) so the decoding equipment should be capable of restoring the full fine carrier phase or operating with the fractional carrier only.
- The Cumulative loss of continuity indicator is incremented by 1 each time at least non-recovered carrier cycle slip occurs for this particular signal in the interval between the currently generated epoch and the previously generated one. The indicator takes values from 0 to 15 or 1023 (and then back to 0 after 15 or 1023 has been reached). The ATM,RNX data generator makes sure not to allow a full indicator range cycle to occur over 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 the pseudo-range for some signal is invalid, then its corresponding fine pseudo-range field is reported as zero. If the pseudo-range for some signal is valid and the corresponding fine pseudo-range field actually takes the value “zero”, then the ATOM generator adds 0.02 m (or 0.02/32 m for extended resolution) to it, thereby inserting a negligible error not affecting the final performance.
- If the carrier phase for some signal is invalid, then the corresponding integer cycle carrier phase and fractional cycle carrier phase are both set to zero. If the carrier phase for some signal is valid but actually takes the value “zero”, then the ATOM generator adds 1/256 cycle (or 1/1024 cycle for extended resolution) to it, thereby inserting a negligible error not affecting the final performance.

- The observables reported for different resolution options are actually the same. To toggle from Extended to Standard resolution, simply discard the 2 LSB for the fractional carrier, the 5 LSB for the fine range and the 4 LSB for the SNR. The cumulative loss of continuity indicator for Standard resolution consists of the 4 LSB from the corresponding 10-bit indicator in Extended resolution.
- With incorrect initialization and/or singular ionosphere conditions, the carrier phase can diverge over time from the respective pseudo-range by a large value which prevents effective data packing into ATM,RNX without re-initializing the new integer value in the carrier phase.

  In these cases, the ATM,RNX generator can apply the new integer value (i.e. introduce a cycle slip in the respective carrier). This integer value is either 1024 or (-1024) cycles of the respective wavelength but this will not be indicated in the cumulative loss of continuity indicator. The decoding equipment must be aware about such a possibility and foresee the necessary actions either to reset the corresponding carrier processing, or to "sew" the respective carrier measurements.

Reference Position

Reference position refers to the "default" datum associated with the GNSS indicated as primary in the Message header (see *Table 1*). Depending on the position presentation flag in the Message header (see *Table 1*), the reference position can be generated in one of the following four different forms:

- No reference position
- Compact reference position (see *Table 12*)
- Compact reference position + clarification data (see *Table 13*)
- Compact reference position + clarification data + velocity & clock (see *Table 14*)

Table 12. 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 of meters 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:

- To date (Sep 2013), the reserved bits are planned to be used in the 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) and External Clock indicator (DF412, 2 bits).
- The Motion Flag should be interpreted as follows: If indicating a moving receiver, the processing equipment should consider this epoch of RNX observables and the next ones (if not containing reference position data) as pertaining to a moving receiver. It is recommended to generate reference position data at each observation epoch.

  If the Motion Flag indicates a static receiver, the processing equipment should consider this epoch of RNX observables and the next ones (if not containing reference position data) as pertaining to a static receiver. It is sufficient to generate the reference position with admissible decimation (e.g. in 10-30 times) compared to RNX observables. The decoding equipment should not make any a priori assumptions regarding time intervals between reference position epochs and changes reported in the Motion Flag from one epoch to another.
- Because it is not possible to indicate the reference position quality flag in all cases, the default quality flag is often unknown.

Table 13. 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 of meters 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 *Table 15* and *Table 16.*	
Total	152						

NOTE:

- 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 14. 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 of meters accu-racy) 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 *Table 15* and *Table 16*.	
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						

NOTE:

- “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 third-party users to restore original (not steered) receiver observables.
- The reported receiver clock offset and drifts refer to the time scale of the primary GNSS system, as specified in the RNX message header. This value is used for clock steering in all GNSS observables.
- Please note that the clock steering procedure affects not only observables but also the reference position when this position is that of a very-high-dynamics receiver. In this case, if you wish to return to not-steered data, you will have not only to correct original observables, but also the original reference position.

Table 15. 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 16. 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	DF054
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	
Receiver time status	4	uint4	18		0-8		AF010
Total	22						

NOTES:

- 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 the GPS Week Number (0-4095; 0 starts midnight January 5/January 6, 1980, rolls from 4095 to 0) if GPS is the primary system.
- The number of GNSS time cycles refers to the GLONASS Day Number (1-1461; 1 corresponds to January 1, 1996, rolls from 1461 to 1; “0” means unknown day, values 1462-4095 are not used) if GLONASS is the primary system.
- The receiver time status refers to the time scale of the primary GNSS system.

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 17. 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 (Sat) 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 may not be used because healthy ephemeris data are not available in the receiver or for some other reason (e.g. satellite under elevation mask). A satellite not used in internal receiver position does not imply that its observables are bad.
- A satellite can be recognized internally as unhealthy. This does not generally stop the output of its observables. It should be noted that a satellite can be set internally as unhealthy for different reasons (almanac data, satellite's ephemeris data, SBAS integrity data, external integrity flags, etc.). If a satellite has no ephemeris and is marked as unhealthy, then Status=3 is reported.

Table 18. 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 than or equal to (-20.46) Value 20.46 means greater than or equal to 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 20*).	
Total	56						

Table 19. 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	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	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 than or equal to (-20.46) Value 20.46 means greater than or equal to 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 20*).	
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 20. 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		AF005
Total	14						

NOTES:

- Having invalid smoothing residuals does not necessarily mean an invalid value for the 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 in Signal Mask (signals 1W and 2W). MPC bits 0-1 are not reflected here, but in the 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, when the fractional carrier bias field changes state, and if the carrier bias has actually been changed (when resolving polarity), or is suspected to have changed (when losing data synchronizations), then indications of carrier cycle slip and loss of lock will also occur. However, if the polarity is correctly resolved and no half-cycle correction has been introduced, then the cycle slip and loss of lock indicators will not be set following the transition from 1 to 0 of the fractional carrier bias.
- 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 Integer Cycle Carrier Phase Data field).

- "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:

Table 21. 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

Chapter 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.

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

At each receiver reset, the configuration of each group (i.e. their sub-blocks/sub-messages and intervals) is reset to its default values.

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

$PASHS,ATM,ALL,<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.

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

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

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

Once again, it should be noted that some sub-messages/sub-blocks cannot be supported by the 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 data (raw navigation data for all tracked GNSSs) 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 new 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).

You should also remember that a GNSS receiver can operate with a different internal update rate, which is controlled by receiver options and the POP setting. Depending on the internal update rate used, not all the output rates are possible. For example, with an internal update rate of 5 Hz, you can only use 0.2 and 1 sec as “fast” intervals, and not 0.5, 0.1 and 0.05 seconds.

Using the Extended Serial Interface For Observables Scenario Cutomization

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 *Appendix B* through *Appendix E*).

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	Single-band pseudo-range and carrier phase in full presentation. Nms in ranges does not follow, extended fixed position follows every 12 epochs.	The generalized analog of RTCM-3 MT 1001, 1009, 1006. Can support L1-only, L2-only, L5-only, etc. generation.
	2	Single-band SNR, pseudo-range and carrier phase in full presentation, extended fixed position follows every 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 every 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 every 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 every 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 every 12 epochs, all the data are decimated in 5 times compared to a pilot carrier phase. **This scenario cannot be used with a moving receiver**.	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 message 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 are generated for each GNSS&Sat&Band. This means that generating simultaneously 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.

Encapsulation

To allow each ATOM message to be wrapped into the Ashtech $PASHR frame, the following command should be used:

$PASHS,ENC,<Port Name>,ASH

Where ENC stands for ENCapsulation, and ASH for ASHtech.

To return ATOM presentation to the basic RTCM-3 frame, one of the following commands should be used:

$PASHS,ENC,<Port Name>,RT3
or
$PASHS,ENC,<Port Name>,NTV

Where RT3 stands for RTcm-3, and NTV for NaTiVe (default). It must be noted that the ENC setting affects equally all the messages (ATOM and non-ATOM) enabled through a given physical port.

Output to Virtual Port

Ashtech receivers can output any ATOM message (or any other supported message) via physical ports (A, B, C, etc.) as well as via virtual ports (Z, Y, X, etc.). To do this, additional encapsulation of the original ATOM data into an ATOM DAT EXT message is applied (see *ATOM DAT Messages on page 75*).

Virtual port Z for example can be created via physical port A using the command:

$PASHS,VIP,Z,A

(To deactivate the virtual port, you would use the command:

$PASHS,VIP,Z,OFF
)

With such a defined virtual port, the receiver can output two similar ATOM messages for two different recipients via the same physical port. For example, physical port A can be used to generate ATOM RNX SCN,101 as differential data to be re-directed to the GSM module. At the same time, virtual port Z created for physical port A, can be used to generate ATOM RNX SCN,0 as raw data to be re-directed to a recording device.

Through this mechanism, you are given the ability to use the same physical port as a source of *compact* differential corrections and a source of *extended* raw data for post processing.

RNX Messages Split Into Different Transmissions

The RNX group includes some data which can be generated under the same header (thus inside the same transport frame), or under their own headers (and thus inside separate transport frames).

A high-level example is given in *An Overview of ATOM RNX Observation Messages on page 10*.

The appearance of RNX messages may be different, depending on the following:

- Hardware target
- GNSS firmware version and options
- Receiver configuration
- Size of the data to be transmitted
- Cell mask size, i.e. the number of satellites tracked and the number of signals supported.

In all cases however, RNX messages will comply with the standard. This particularly means that:

- The size of a single transmission cannot exceed the permissible value (1023 bits)
- The size of the Cell Mask for each GNSS cannot exceed the permissible value (64 bits)
- If the original data are split into more than one transmission, then the M-bit should be set accordingly.
- The epoch data, which are spread over more than one ATM,RNX transmissions, are complementary to each other, that is, the GNSS&Sat&Sig observation data is presented only once.

It is very important to mention here that there are no specific commands that exist that would let you schedule ATM,RNX data over one or more messages.

ATOM Version

The receiver firmware that supports the latest ATOM version (e.g. Ver.2) can be configured to generate ATOM data in any of the existing former versions. This is achievable using the following command:

$PASHS,ATM,VER,x

Where x can potentially take any integer value from 1 to 7. To date (September 2013), only x=1 or 2 are supported. All other choices will be NAKed.

Differences between versions only exist for new ATOM messages/blocks. The difference between Ver.1 and Ver.2 is applicable only to ATM,RNX and ATM,PVT,SVS data.

Once Ver.2 or Ver.1 is selected through the command, both ATM,RNX and ATM,PVT,SVS will be generated accordingly.

Querying ATOM Setup

The current ATOM setup for each available receiver port can be read using the following command sent to any of the receiver ports:

$PASHQ,PAR,ATM

The receiver will return a user-readable response through the same port.

The content of the response is self-explanatory for users who understand general ATOM organization. It is not intended for automatic parsing, may vary from one hardware target to another and depend on the firmware version and available options.

Multiple ATOM PVT Generation

When a receiver is configured to operate in an advanced positioning mode (e.g. RTK+Heading or RTK+Attitude) where more than one single solution is available, you can still request the primary position solution with a standard setting:

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

Request ID=0 will be reported in the header of the resulting message.

The secondary solution (heading, attitude and associated baseline) will be delivered by requesting an additional message:

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

The content of this message refers to the PVT of the secondary solution. Request ID=1 will be reported in the header of the resulting message.

Chapter 5. ATOM Utilities

There are four primary Ashtech PC tools that help view and process ATOM messages. These are:

- AshCom: PC terminal program to communicate with GNSS receivers and view their statuses
- DataView/AtlView: PC tool used to process and view precollected GNSS data files
- WhatIs: Console executable used to get ASCII content as well as statistics of most binary GNSS data
- Bin2std: Console converter used to convert ATOM RNX data into standardized messages or files.

Each tool has its own description available separately. Please contact Technical Support to get these tools.

Appendix A. Decoding Samples

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

Different parts of the message:

- Start Transport (3 bytes):

  D3 00 42

- Message Header (5 bytes):

  FF F5 20 3E 01

- Message Data (61 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

- End Transport (3 bytes):

  D8 82 21

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
w0	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
ωdot	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				

$PASHR Transport Decoding Sample

Below is a raw ATOM message in hex format. Each byte is represented as a 2-byte hex number:

24 50 41 53 48 52 2C 41 54 52 2C 00 15 D3 00 0F FF F4 20 3E 01 07 55 4E 4B 4E 4F 57 4E 00 00 00 D0 5B 6C 42

Where:

24 50 41 53 48 52 2C 41 54 52 2C = $PAHSR,ATR

00 15 = 21 bytes in length

D3 00 0F FF F4 20 3E 01 07 55 4E 4B 4E 4F 57 4E 00 00 00 D0 5B = ATOM message

6C 42 = binary checksum

Computing Check Sum:

00 15 +
D3 00 +
0F FF +
F4 20 +
3E 01 +
07 55 +
4E 4B +
4E 4F +
57 4E +
00 00 +
00 D0+
5B <here, virtual 00 is added>, because length is not even
= 36C42

0x36C42 & 0xFFFF = 6C42, which is indeed the value of checksum found at the end of the message.

Appendix B. Decomposition for ATOM RNX Observables

General Principles Used 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 two 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 with the “cumulative loss of continuity” indicator representing a 4-bit field incremented by 1 each time the original full carrier integer ambiguity is re-initialized (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:

$$Full \equiv Specific + (N \times resolution)$$

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 below for more 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.

Explicit Algorithm Used to Restore Original Observables

Regardless of their absolute values, all original receiver measurements (pseudo-range and carrier phase observables, expressed in meters) pertaining to a given satellite and made at a given time appear as some compact cloud of various size.

Let *Mmax* and *Mmin* be respectively the maximum and minimum values found in the cloud.

We can then write:

$$Mmax - Mmin < dM$$

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

Remember that each carrier phase is aligned with the corresponding pseudo-range at the initialization time after the required integer number of cycles has been adjusted.

For observables to be unambiguously packed into ATOM RNX messages, we must have:

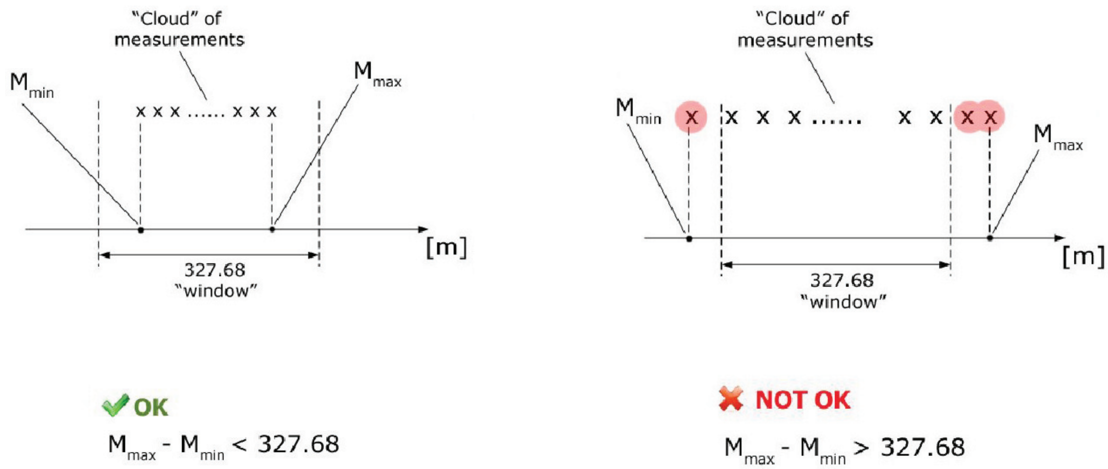
$$dM = 327.68[m]$$

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

In most cases, the above requirement is met. In theory however, there are some singular cases (super-high ionosphere conditions, very specific receiver hardware biases, obviously incorrect carrier phase initialization) where this requirement is not met.

It should be noted that this type of requirement is not specific to ATOM RNX data. In fact, all compact data protocols (e.g. standardized RTCM-3 observation messages) are to some degree limited because of a certain level of divergence not to be exceeded in observations. For example, abs (L1 pseudo-range - L2 pseudo-range) should not exceed some 163 meters.

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



If the cloud contains outlying pseudo-ranges, the ATOM RNX generator will remove them before packing the message. The generator is entirely responsible for determining which pseudo-ranges should be removed.

If the cloud contains outlying carrier phases, the ATOM RNX generator will reinitialize them by introducing a new integer number of cycles before packing. In this particular case, the ATOM RNX generator can add or subtract an a priori known number of cycles (1024 cycles rollover), which can be applied on decoding side to reconstitute the carrier phase data. There again, the generator has the entire responsibility for determining which carrier phases should be corrected. Similar rollover procedures exist in standardized RTCM-3 messages.

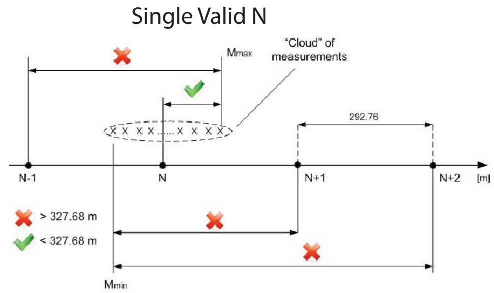
Again, it should be emphasized that Rough_Range is not generally associated with any single observable (pseudo-range or phase). Instead it is associated with the cloud of observables for a given satellite. The reported Rough_Range (1/1024 ms resolution) is not some rounded-off float value, but on the contrary, is selected among several admissible candidates.

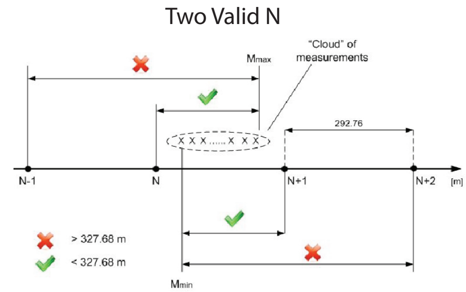
Let integer N be the number of 1/1024 ms intervals in Rough_Range. Typically it is in the range 60000-80000, except for SBAS, QZSS and other similar systems with "exclusive" orbits. There exists the only single limitation when selecting the N value for packing:

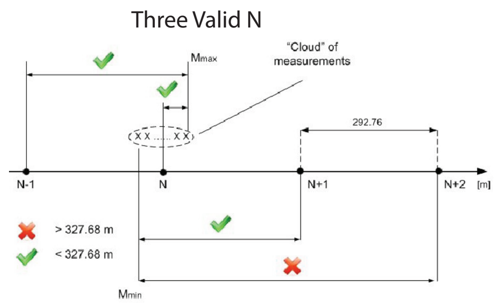
$$\forall i |Mi - N \times Const| < 327.68[m]$$

$$Const = 292.76607226562498[m]$$

In theory, there can be up to three different N values, as shown on the three diagrams below, depending on the cloud size and location.







With multiple N opportunities, **it does not matter** which N value the ATOM generator selects. If the cloud of satellite data to be packed does not fit the required conditions, then the ATOM generator can do either of the following:

- Split transmission by signal and use multiple RNX generation
- Decide not to generate any outlier data at all
- Generate all the data, still modulo 327.68 meters, and provide extra indication in the extended supplementary data.

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

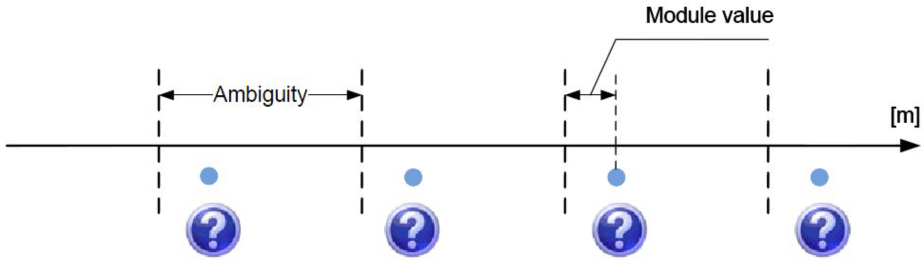
It is a well known task to restore a full measurement value using its two samples:

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

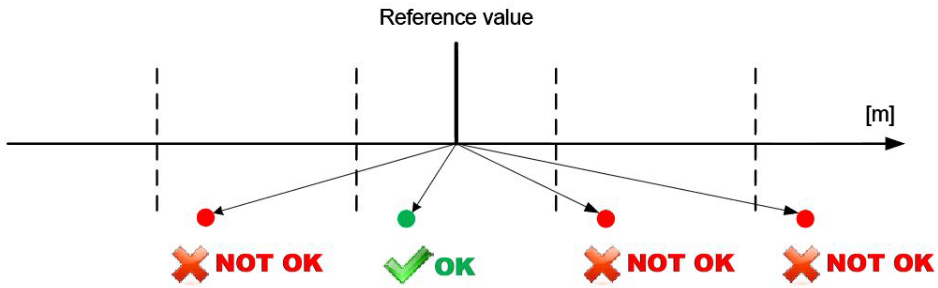
NOTE: If you have already dealt with RTCM3- 1001, 1003, 1009 and 1011 messages, you know what the problem is. The full raw range may be restored from the raw range modulo 1 ms with the help of the calculated rough range (using ephemeris). See examples below to understand the mechanism:

CalcRange=70.56 ms, RangeModulo 1 ms=0.52 ms, Full Range=70.52
CalcRange=70.97 ms, RangeModulo 1 ms=0.03 ms, Full Range=71.03
CalcRange=70.01 ms, RangeModulo 1 ms=0.99 ms, Full Range=69.99

When we only have the ambiguity part, there is an unlimited number of solutions (see blus circles below)



To choose the best one, we add some low-precision reference value. The best solution is the one the closest to the reference.



An adequate reference range is needed to restore the original receiver observables. In ATOM RNX, this reference depends on the type of range presentation used.

- Range presentation= 2 (Rough range R follows) and Nms is available (e.g. SCN,0,2,4). In this case, no a priori information is needed. The 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, ephemeris and reference position must be used to calculate the distance between base and satellite (CalcRange). The permitted error on this value compared to the real measurement can be ±0.5 ms maximum. If this condition is met, the value can 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, ephemeris and reference position must be used to calculate the distance between base and satellite (CalcRange). The permitted error on this value compared to the real measurement can be ±327.68 m maximum. If this condition is met, the value can be used to restore the full range and phase.

$$Reference = CalcRange$$

Note that using receiver clock-steered data allows us to guarantee that the reference will be adequate to restore an error-free full range.

Below is an example of C++ source code used to restore full pseudo-range and carrier phase data from ATM,RNX fields. The example is provided just to illustrate the procedure. Please do not use that code in 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 C. 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 and L1 and L2 pseudo-ranges can be generated with a 5-second interval, resulting in 5 times decimation. On decoder side, the decimated data can be restored easily, 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 D*). 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.

Appendix D. Data Identifiers for ATOM RNX Observables

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 the future)
- GLO occupies 24 positions (but theoretically, 28 slots can be available for FDMA, even more for CDMA)
- SBAS reserves 39 positions (but obviously, this will be extended)
- Galileo reserves 36 positions (but this cannot be guaranteed)
- QZSS reserves 10 positions (5 by other sources)
- BeiDou reserves 37 positions (but this cannot be guaranteed).

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. Refer to Satellite, Signal and Cell Masks in *Satellite, Signal and Cell Masks on page 129* for the definition of the Signal mask bits for each GNSS. See also composite compact table below for reference, which can be considered as an example only.

In addition to RINEX definitions, the following choices were also reserved: 1?, 2? and 5?. These are very useful 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 whose type is unknown.

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	1A		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	

Capability Mask

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

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.

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 two 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	•		•			•	•						•		•		•			1
3																				0
4	•		•			•							•				•			1
5																				0
6																				0
7																				0
8																				0
9																				0
10	•		•			•							•				•			1
11																				0
12																				0
13																				0
14																				0
15	•						•								•		•			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 four 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 seven 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”.

Signals \ Sats	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 three 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).

Example of Interpreting Satellite, Signal and Cell Masks

Consider the example of GPS data described in *Example of Building Satellite, Signal and Cell Masks on page 120*.

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 on *page 119*).

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 four different types of signals, the Cell mask should be split into seven equal parts (Sub-BITSET):

$$\underbrace{1111}_{1}\underbrace{1110}_{2}\underbrace{1110}_{3}\underbrace{1001}_{4}\underbrace{1110}_{5}\underbrace{1001}_{6}\underbrace{1111}_{7}$$

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 E. 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:

- 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 three 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 1004,1012)	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:

- 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 the 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 F. Summary of Differences Between ATOM Ver.1 and ATOM Ver.2

Remember Ashtech decoders supporting some ATOM version X will automatically support older ATOM versions. The reverse is not true.

Each ATOM generator supporting some ATOM version X can be configured to generate ATOM in any of the older versions (to insure backward compatibility) with legacy decoders.

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

All ATOM messages described in this manual refer to ver.1 with the exception of the ATM,PVT (SVS block) and ATM,RNX (GNSS observables block) messages. These can be generated as ATOM ver.1 and ATOM ver.2 messages. The differences are summarized below.

Satellite and Signal Masks in ATM,PVT (SVS Block)

The sizes of the Satellite and Signal masks are extended from 40 and 24 (in ver.1) to 64 and 32 (in ver.2) respectively. See tables in *Baseline Supplementary Data on page 33*.

Satellite and Signal Masks in ATM,RNX (GNSS Observables Block)

The size of the Satellite mask is extended from 40 (in ver.1) to 64 (in ver.2). Initially the reserved 8 bits (in ver.1) are added to the Signal mask (in ver.2) thus changing its size from 24 bits (ver.1) to 32 bits (ver.2). See *Table 6 on page 86* and *Table 7 on page 86*.

Extended Data Resolution in ATOM,RNX (GNSS Observables Block)

Extended resolution is supported starting from ATOM RNX ver.2. It's not supported in ATOM RNX ver.1. See *Table 5 on page 85*, *Table 10 on page 87* and *Table 11 on page 88*.

Appendix G. Satellite, Signal and Cell Masks

These three masks are so important that we describe them in a separate section. Their description follows ATOM V2, while ATOM V1 uses truncated versions for the satellite mask (40 bits) and the signal mask (24 bits).

These three masks are used in the ATM,RNX message, as well as in the ATM,PVT message, but with a slightly changed Cell mask for the latter. These are twins of standardized RTCM-3 fields DF394, DF395 and DF396 used to generate the so-called Multiple Signal Messages (MSM). The table below provides a complete description of the three masks.

Mask Name	Equivalent RTCM-3 Data field	Size	Description
GNSS Satellite mask	DF394	bit(64)	Sequence of bits specifying those GNSS satellites for which data are available in the 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. The Least Significant Bit (LSB), or the last encoded bit corresponds to GNSS satellite with ID=64. The exact mapping of GNSS satellites (PRNs for GPS, “slot number” for GLONASS, etc.) to satellite mask IDs is specific to each GNSS (see corresponding tables for each particular GNSS in the description of the MSM message). Some ID values may refer to specific satellites, while some others may be indicated as “Reserved” in this standard. These IDs may be used in the future for other satellites. So the decoding software should not skip these bits but instead use them to decode the complete GNSS Satellite Mask and the corresponding observables, as if they referred to known satellites. It should however refrain from using them, unless a new satellite mapping table is made available to map the corresponding ID to a specific satellite. If any data for satellite with ID=n follow, then the corresponding bit (bit number n) is set to 1. If data for satellite with ID=m do not follow, then the corresponding bit (bit number m) is set to 0.
GNSS Signal mask	DF395	bit(32)	Sequence of bits specifying those GNSS signals for which data are available in the message. Each bit corresponds to a particular signal type (observable) for a 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. The Least Significant Bit (LSB), or the last encoded bit corresponds to signal with ID=32. The exact mapping of the actual signal identifiers to signal mask IDs is specific to each GNSS (see corresponding tables for each particular GNSS in the description of the MSM message), and is in correspondence with the RINEX 3.01 signal naming convention. Some ID values may refer to specific signals, while some others may be indicated as “Reserved” in this standard. These IDs may be used in the future for other signals. So the decoding software should not skip these bits but instead use them to decode the complete GNSS Signal Mask and the corresponding observables, as if they referred to known signals. It should however refrain from using them, unless a new signal mapping table is made available to map the corresponding ID to a specific signal. If signal (observable) with ID=n is available for at least one of the transmitted satellites, then the corresponding bit (number n) is set to 1, otherwise it is set to 0.

Mask Name	Equivalent RTCM-3 Data field	Size	Description
GNSS Cell mask	DF396	bit(X)	This field represents a two-dimensional table that determines signal availability for each transmitted satellite. This field is of variable size. X=Nsig*Nsat, where Nsat is the number of satellites (i.e the number of bits set to 1 in the satellite mask, DF394), and Nsig is the number of available signals (i.e. the number of bits set to 1 in the Signal mask, DF395). The first row of this rectangular table corresponds to the signal with the smallest ID, taken among those for which the corresponding bit in Signal Mask is set to 1. The second row corresponds to the signal with the second smallest ID, taken among those for which the corresponding bit in Signal Mask is set to 1. The last row corresponds to the signal with the highest ID, taken among those for which the corresponding bit in Signal Mask is set to 1. The first column of this rectangular table corresponds to the satellite with the smallest ID, taken among those for which the corresponding bit in Satellite Mask is set to 1. The second column corresponds to the satellite with the second smallest ID, taken among those for which the corresponding bit in Satellite Mask is set to 1. The last column corresponds to the satellite with the highest ID, taken among those for which the corresponding bit in Satellite Mask is set to 1. If observable data for a given satellite and a given signal follow, then the 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 corresponding to the smallest satellite ID. Each column is Nsig bits in size. It is packed starting from the cell corresponding to the smallest signal ID. Each cell in the table is packed in 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 masks are provided in *Appendix D*.

The table below gives an overview of the 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 in the same band are aligned with each other by a proper fractional part of cycle (usually 0.25).

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+k9*/16	L1C
	G2	1246+k7*/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 note that some locations in the signal mask are reserved for unknown signals on particular bands. Such an indication makes it possible to transfer 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
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 the 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
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	
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 SAIF 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	
17	L2	L2C(M+L)	2X	
18-21				Reserved
22	L5	I	5I	
23	L5	Q	5Q	
24	L5	I+Q	5X	
25-32				Reserved

BeiDou Signal ID Mapping

Signal ID in Signal Mask (DF395)	Frequency Band	Signal	BeiDou 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

Index

ATOM, GNSS Receiver Communication Protocol

Reference Manual

Contact Information:

Americas & Asia
Ashtech OEM only
+1.408.481.8560 Phone
+1.408.481.8984 Fax
GNSSOEMSupport@trimble.com
www.ashtech.com

EMEA
Ashtech OEM only
+33.2.28.09.3800 Phone
+33.2.28.09.3939 Fax
GNSSOEMSupport@trimble.com