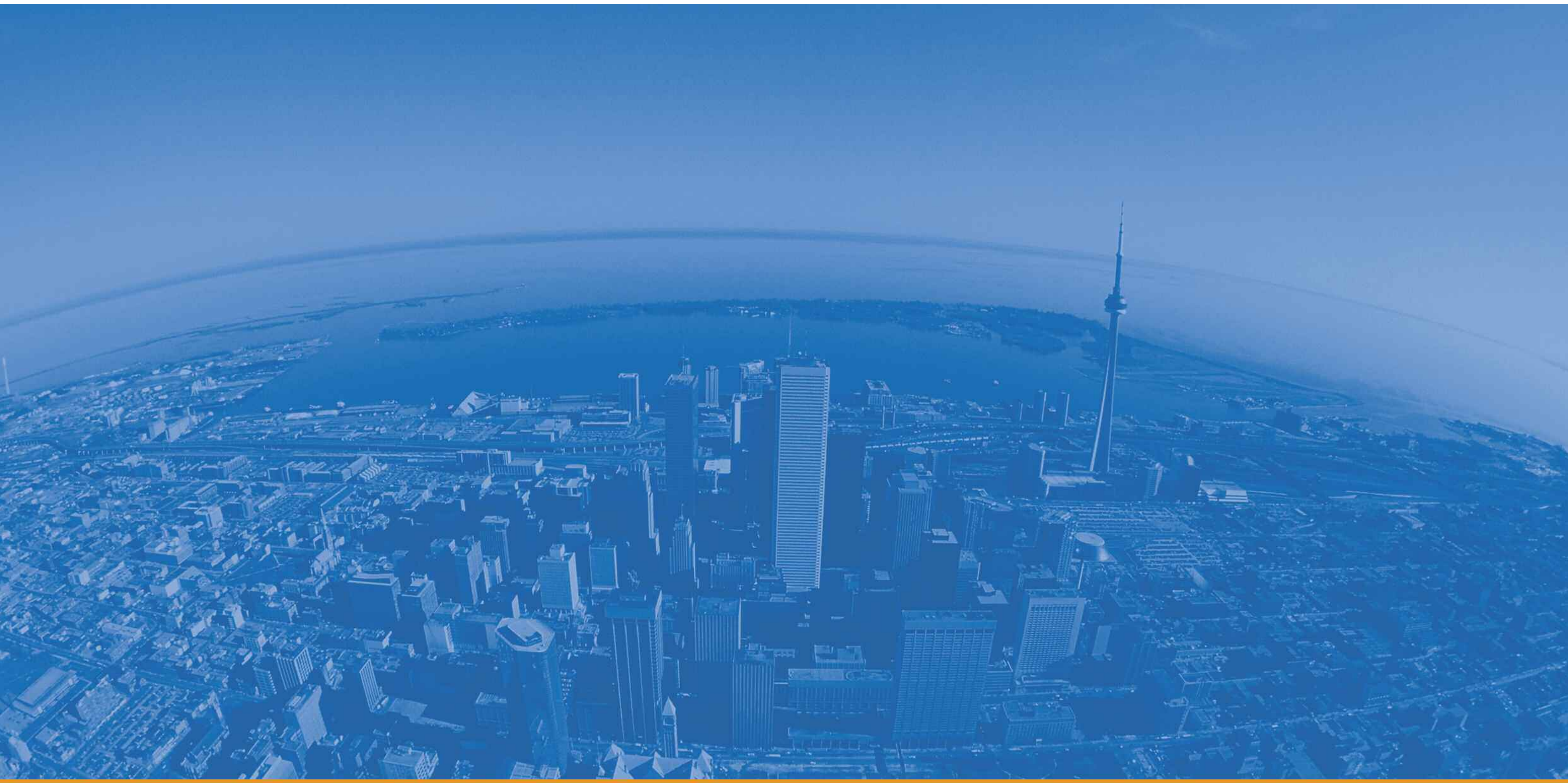

Reference Manual

Ashtech Optimized Messaging

GNSS Receiver Communication Protocol, Vers 1.12

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May 2010 Release Note

Compared to the February 2010 Release, the following changes have been made to this manual:

- Pages 17 and 56: In the Time Tag Presentation table, the time tag presentation type has been corrected: Full time tag is “0” and fine time tag is “1”. It was inverted in the February 2010 Release.
- Page 59: There are two additional notes at the bottom of the page for RNX signal data.
- Page 63: In the Extended Signal Data table (Table 16), more comments are now available for the “Smoothing Residual”.

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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-3 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

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

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	CRC
8 bits	6 bits	10 bits	Variable length, integer number of bytes. **Message 4095 is here**.	24 bits
11010011	Not defined, set to 000000	Message length in bytes	0-1023 bytes	QualComm Definition CRC-24Q

If the original 4095 message does not contain an integer number of bytes, then the needed number of zero bits 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	Units/Scale	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 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 MES, PVT, ATR, NAV, DAT, RNX, BAS, 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 89*.
– <CR><LF> are respectively the carriage return and line feed.

Short ATOM Overview

To date, ATOM vers.1 supports the following primary groups of GNSS data:

Group Type	Group ID	Message Clarifier	Standardized Counterparts	Group Configuration
GNSS measurements	4095,2 or ATOM,MES	0010	RTCM-3 1001-1006, 1009-1012	Not a configurable message
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-3.0	Group of independent messages or single, composite, configurable message
GNSS RTK base corrections	4095,8 or ATOM,BAS	1000	RTCM-2 20, 21, 24	Group of independent messages or single, composite, configurable message
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

Groups MES, RNX and BAS refer to ATOM observables. In most cases, they output the same data but presented in slightly different forms. Depending on the desired application and personal preferences, any of these groups may be used. A short overview of these groups is given below.

Group PVT delivers positioning results such as position, velocity, clock offset, 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 16*.

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 ephemeris and almanac data as well as some other valuable information, like broadcast GPS 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, PPS time-tagging or some internal receiver alarms, such as receiver reset.

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

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

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

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

While the general organization of all the ATOM groups is similar, there are however some differences. Messages or groups ATR, NAV, DAT, STA and EVT are always generated independently of each other. At the same time, messages of groups MES, RNX, BAS and PVT can be output differently. Each of these groups contains a unique header 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 16*):

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

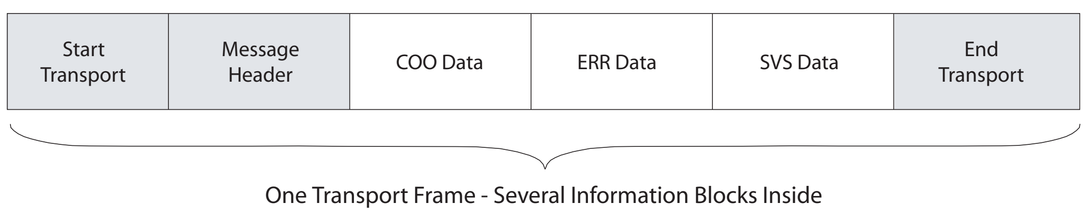
Note that multiple-GNSS receivers make an assumption about the primary GNSS system used (default is usually GPS). When a primary GNSS system is specified, then the ATOM message time tag and position datum refer to that primary system.

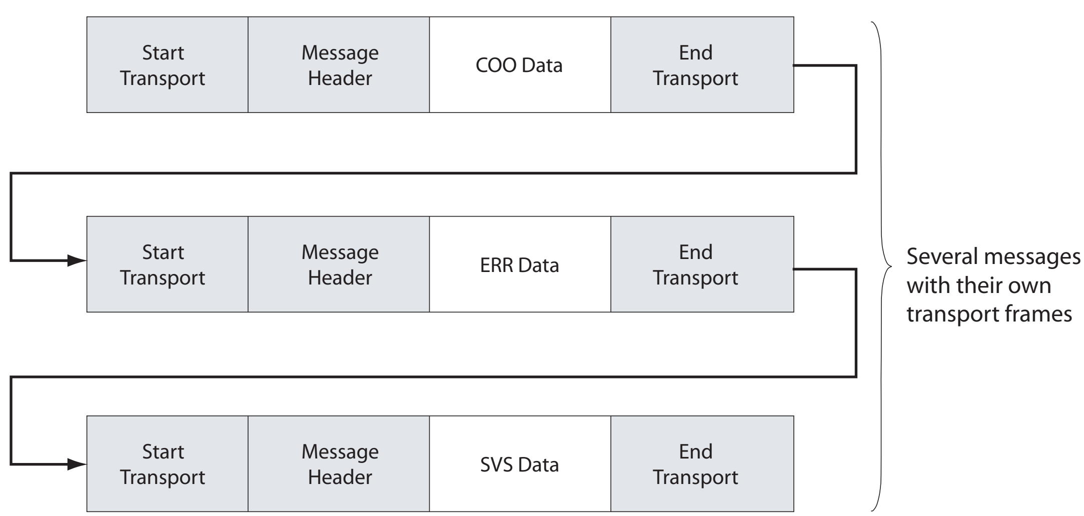
Currently the following PVT data sub-blocks are supported.

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
Pseudo Range Residuals (L1)	PRR	3+5*Nsat_used
Satellites status	SVS	Depends on tracking status

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

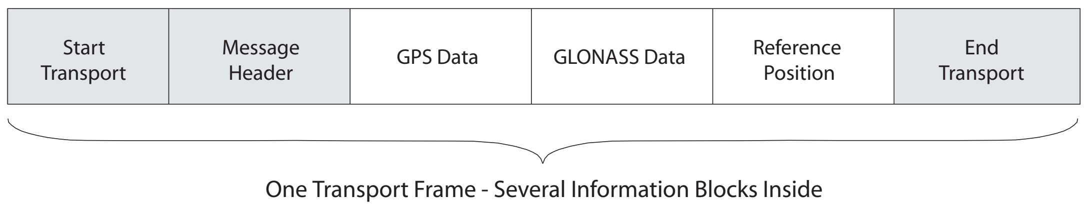
The two diagrams below show different transmission strategies applicable to ATOM PVT messages (3 sub-blocks are given as examples).

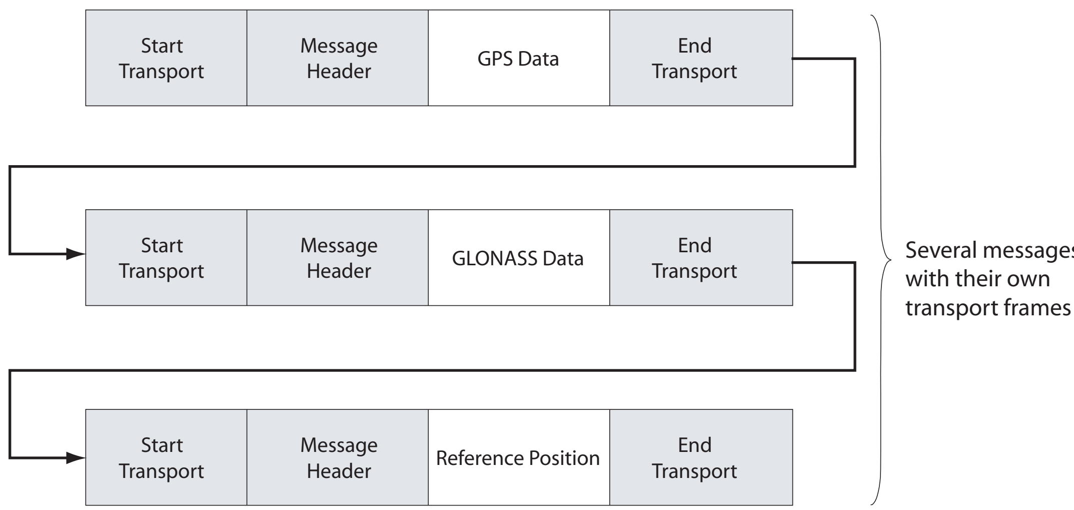




An Overview of ATOM Observation Messages (MES, RNX and BAS)

A quick look at these messages show they are similar. Each contains blocks of GPS, GLONASS, etc. observables as well as optional reference position. Presentation of observables in each message is exactly the same for each GNSS. This allows the same source code to be used to construct and parse each GNSS observation block in a given message. Each of these blocks can be transmitted inside a single message, or can be spread among several transmissions as shown below.





Although the MES, RNX and BAS messages are generally the same, they are not equally effective, depending on which application is using them. The table below tentatively presents their differences.

Feature	MES	RNX	BAS
Raw data generation	Y	Y	Needs special conversion
Differential data generation	Not effective	Y	Y
Compatibility with RTCM-3	Y	Y	Probably with future RTCM-3 messages
Compatibility with RINEX-3	N	Y	Needs special conversion
Customization possibility	N	Y	Y
Throughput optimization	N	Y	Y
Open for future multiple signals and GNSS	Relatively weak	Y	Y

Group MES refers to GNSS raw measurements. The presentation is very similar to existing RTCM-3 messages (MT 1001-1004, 1009-1012), but allows all the data (GPS, GLONASS, SBAS, reference position) to be sent inside a single message thereby making easy the restoring of a complete raw data epoch. This group is recommended for use in raw data recording only. No special customization of this message is possible. It is intended to output all the raw data and supplementary information a receiver can provide.

Group RNX is similar to MES, but allows more flexibility to present receiver data directly in RINEX-3.0 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 (like MES) and as an effective differential protocol (like BAS).

Group BAS refers to GNSS differential corrections (computed range – measured range). This group is recommended for use in RTK base mode only to generate GNSS reference data to RTK rover(s). This group includes a number of different options that can noticeably save the data link throughput.

RNX and BAS use the same data presentation allowing almost the same source code to be used for constructing and parsing these messages.

It must be noted that RNX can be used as a differential protocol with the same throughput efficiency as BAS. The possibility to use RNX or BAS as differential protocol is similar to the possibility to use either RTCM-2 MT 18, 19 (raw observables) or RTCM-2 MT 20, 21 (differential corrections). Each of these approaches has its own advantages and disadvantages. Choosing one rather than the other is left to the user's choice. Formally speaking, corrections can easily be computed from observations provided reference position and ephemeris data are available. Reciprocally, corrections can be converted into observations, but this requires a little more complicated computations.

One of the advantages of corrections over observations as differential protocol is fewer computations required on rover side. This can be very important for cheap rovers with limited computation capability. Another example is high-rate corrections (e.g. 10 Hz) processing on rover side when extra float point operations (such as converting base observations into base corrections) cost much.

Since ATOM RNX and BAS messages allow different customization and optimization scenarios to be implemented, a number of additional explanations/clarifications are provided in *Appendices C, D and E* from *page 93*. These Appendices allow users to understand in more details what algorithmic background is behind these observation messages.

ATOM observation messages can generate the following primary observables for each tracked signal:

- 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:

- 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 (e.g. RNX) 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 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 receiver and 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.

Chapter 3. ATOM Messages Description

Preamble

This chapter contains the detailed (bit-to-bit) description of messages supported by ATOM format version 1. The following groups are described:

- GNSS measurements: ATOM MES
- Positioning results: ATOM PVT
- Attributes data: ATOM ATR
- Navigation data: ATOM NAV
- Raw binary data: ATOM DAT
- GNSS RINEX observations: ATOM RNX
- GNSS RTK base corrections: ATOM BAS
- Status information: ATOM STA
- Events information: ATOM EVT

It should be noted that ATOM messages described here are not all necessarily supported by all Ashtech receivers and in all firmware versions. 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 71*.

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 of the ATOM messages 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 decoded navigation frame has been updated (i.e. changed).

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 (*on time*) 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 MES, RNX and BAS groups, 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 MES, RNX and BAS groups. 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 MES and PVT groups, GPS is the primary GNSS used and the GPS-UTC time shift is 15 sec (as from January 1, 2009), then MES and PVT will always be output for different time tags:

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

Data Field Conventions

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

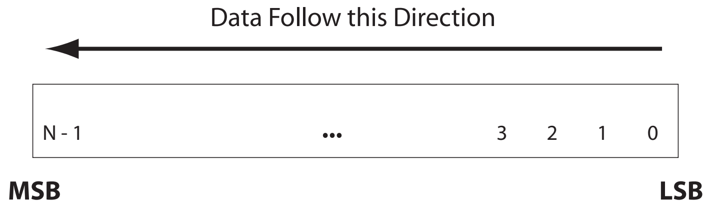
Data Type	Description	Range	Example/Notes
bitX	Bit field, each bit is 0 or 1 X is the length of the bit field	0, 1	bit2: 2-bit field bit11: 11-bit field
uintX	X bit unsigned integer	0 to $(2^x - 1)$	uint8: 8-bit unsigned integer
intX	X bit 2’s complement integer	$\pm(2^{x-1} - 1)$	int8: 8-bit 2`s complement integer
intSX	X bit sign-magnitude integer	$\pm(2^{x-1} - 1)$	intS14: 14-bit sign-magnitude integer (see notes below)
Char(X)	8-bit character set with total length in X chars	Character set with variable length	
utf8(X)	Unicode 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) is presented in the diagram below.



Bit Location in N-bit Integer

To insure quick reference to all ATOM DF, numerical equivalents to some of them are provided. Some ATOM DF are the exact copy of the corresponding standardized RTCM-3 DF, some are unique to the ATOM format. That is why ATOM DF having exact RTCM-3 counterparts are marked as DFxxx. For example, data field "Message Number" (uint12, 4095 reserved for Ashtech) is referenced as DF002. Some other ATOM DF, 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. 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 does not generate these states, but new ATOM versions could. If a newly introduced state can play a vital role in parsing ATOM data, then the version number of the corresponding ATOM message will be increased and the corresponding Manual update (or Amendment) will be issued.

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

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

ATOM MES Message

This message is generated by some Ashtech GNSS receivers when logging raw data.

Processing raw data files from these receivers can be done by first converting them into RINEX data, using for example the bin2std utility (see *Chapter 6. on page 87*).

However, if some users would like to design their own decoders, please contact Ashtech to get more information about the ATOM MES message.

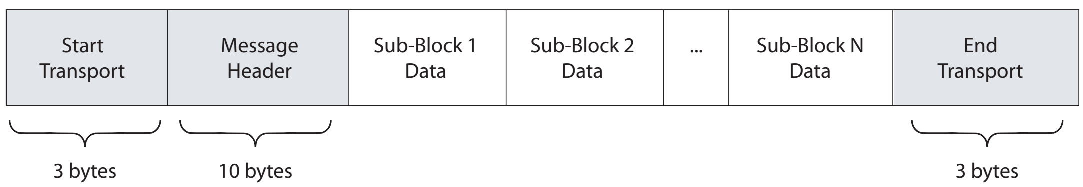
ATOM PVT Message

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 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.

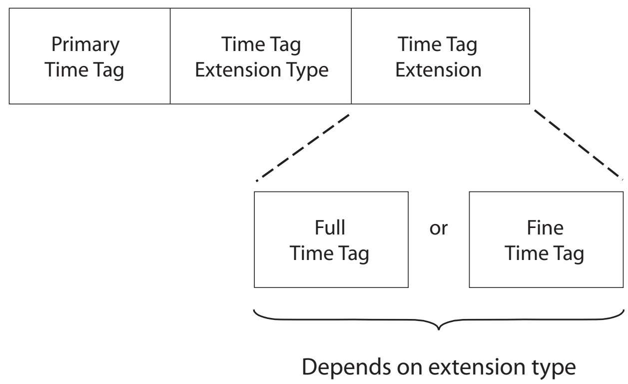


The table below sketches the ATOM PVT message and presents the organization of its header.

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	
Multiple message bit	1	bit1	43		0-1	1: other PVT message(s) corresponding to given PVT solution ID will be output for given time tag 0: no other PVT message corresponding to given PVT solution ID will be output for given time tag	
Reserved	4	uint4	44		0-15	See Appendix G	AF001
PVT engine ID	6	bit6	48		0-63	See Appendix G	AF002
PVT solution ID	2	bit2	54		0-3	See Appendix G	AF009
Reserved	7	bit7	56		0-127	Set to 0…0	
Nsats used	6	uint6	63		0-63	Number of satellites used in position	
Nsats seen	6	uint6	69		0-63	Number of visible satellites	
Nsats tracked	6	uint6	75		0-63	Number of tracked satellites	
Primary GNSS system	2	bit2	81		0-3	0: GPS is primary 1: GLONASS is primary 2-3: reserved	
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.
- Generally, the receiver can compute more than one position at the same time (e.g. more than one PVT engine runs in parallel). In general, the identifier of the position engine can change on-line, depending on environmental conditions and/or the differential data link status.



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 0 for GLONASS	
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) 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 the GPS week number or GLONASS day 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	Comments	Counterpart
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		Reserved		1001		
10		Reserved		1010		
11		Reserved		1011		
12		Reserved		1100		
13	PRR	Pseudo-range Residuals (L1)	3+5*Nsat_used	1101	Pseudo-range Residuals	$GPRRE
14	SVS	Sat status	Depends on tracking status	1110	Satellite tracking/usage information	$PASHR,SAT $GPGSV
15		Special messages		1111		

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 (including debug) specific to 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 including this field	
Block ID	4	uint4	8		0-14	Reserved for general purpose data	
Sub block data			12			Each of blocks 0-14	
Total	8*X						

Special PVT Sub-Blocks:

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SPECIAL SUB-BLOCK DATA							
Block size, X	8	uint8	0		0-255	The size of given block in bytes including this field	
Block ID	4	uint4	8		15	Reserved for a variety of special data	
Special block sub-ID	8	uint8	12		0-255	Special data block ID	
Special sub block data			20			Each of blocks 15,0-255	
Total	8*X						

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

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. ATOM is open to outputting position on a custom datum (see clarifying bit in the MIS block). 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	
GPS used	1	bit1	16		0-1	1: GPS is used in position	
GLO used	1	bit1	17		0-1	1: GLO is used in position	
Reserved	2	bit2	18		0-3	Set to 00	
Reserved	4	bit4	20		0-15	See Appendix G	AF004
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	0-100	Corresponds to satellites used (102.3 if not defined or invalid)	
HDOP	10	uint10	44	0.1	0-100	Corresponds to satellites used (102.3 if not defined or invalid)	
X coordinate	38	int38	54	0.1 mm	±13743.9 km		DF025
Y coordinate	38	int38	92	0.1 mm	±13743.9 km		DF026
Z coordinate	38	int38	130	0.1 mm	±13743.9 km		DF027
Differential age	10	uint10	168	1 sec	0-1023	Age of differential corrections (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	bit4	190		0-15	See Appendix G	AF003
Reserved	14	bit18	194			Set to 0…0	
Total	208						

NOTES:

- With at least one GPS or GLONASS 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 (120-138)
- 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 is provided to specify in more details what is behind the standardized GGA-type position flag.

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.

$$S = \begin{bmatrix} s11 & s12 & s13 \\ & s22 & s23 \\ & & s33 \end{bmatrix}$$

Where s11, s22 and s33 are always positive. All other terms can be negative. Here, indexes 1, 2, and 3 refer to the latitude, longitude, and altitude components 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	int20	12	0.001 m	0-1000 m	1048.575 if not defined or invalid.	
k1	7	uint7	32	1/128	0…1		
k2	7	uint7	39	1/128	0…1		
k3	7	uint7	46	1/128	0…1		
r12	8	int8	53	1/128	-1…1		
r13	8	int8	61	1/128	-1…1		
r23	8	int8	69	1/128	-1…1		
Reserved	3	bit3	77		0-7	Set to 000	
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)

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

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 m/s	- 1677.7216 if not defined or invalid	
Y velocity	25	int25	37	0.0001 m/s	± 1677 m/s	- 1677.7216 if not defined or invalid	
Z velocity	25	int25	62	0.0001 m/s	± 1677 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	Set to 0000	
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,&CLC
- **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	±500000 m	- 536870.911 if not defined or invalid	
Receiver clock drift	22	int22	44	0.001 m/s	± 2000 m/s	- 2097.151 if not defined or invalid	
TDOP	10	uint10	66	0.1	0-100	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 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.

Latency This sub-block contains receiver position latency.

- **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 ATM,PVT 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	56	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	bit2	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 m	1.023 means not defined or invalid	
BRMS	10	uint10	74	0.001 m	0-1 m	1.023 means not defined or invalid	
Reserved	4	bit4	84		0-15	Set to 0000	
Total	88						

NOTES:

- For the description of fields MRMS and BRMS, see ATT message definition in the documentation of the receiver used.
- The BRMS field is reported invalid if the lengths of baselines are not known a priori.

Baseline This sub-block contains baseline estimates. These estimates are applicable only to differential operation.

- **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	bit3	12		0-7	0: XYZ 1: rectilinear ENU centered on rover 2: rectilinear ENU centered on base 3-7: reserved	
Base motion	2	bit2	15		0-3	0: static base 1: moving base 2: reserved 3: unknown	
Base accuracy	2	bit2	17		0-3	0: exact base coordinate 1: approximate base coordinates 2: reserved 3: unknown	
Baseline flag	2	bit2	19		0-3	0: invalid baseline 1: code differential 2: RTK float 3: RTK fixed	
Reserved	1	bit1	21		0-1	Set to 0	
Baseline 1st component	35	int35	22	0.0001 m	± 1717986.9183 m	Edge states mean that actual value is outside specified range	
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	
Reserved	1	bit1	127		0-1	Set to 0	
Total	128						

NOTES:

- Baseline components are expressed according to the value of "Baseline coordinate frame".
- Baseline refers to the distance 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.

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	bit3	44		0-7	0: Antenna reference point 1: L1 phase center 2-5: Reserved 6: Ground mark 7: unknown	
Reserved	2	bit2	47		0-3	See Appendix G	AF006
Antenna height	16	uint16	49	0.0001 m	0-6.5535	6.5535 if not defined or invalid	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	± 300	-327.67 if not defined or invalid	
Time tag ambiguity	12	uint12	88		0-4095	4095 if not defined or invalid	D076
GPS-UTC time shift	6	uint6	100	1 s	0-63	63 if not defined or invalid	
Magnetic variation	16	int16	106	0.01 degree	±180	-327.68 if not defined or invalid	
Local zone time offset	11	uint11	122	1 min	0-1439	2047 if not defined or invalid	
Type of used ephemeris	3	bit3	133		0-15	0: almanac used 1: broadcast L1(CA) ephemeris used 2-6: reserved 7: unknown	
Firmware version	32	Char(4)	136			Same as in $PASHR,POS message	
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). The receiver can also potentially report position tagged to some local datum. ATOM allows this possibility by setting the datum field to "custom". If the datum is custom, then an extra ATOM message (block) can be generated to specify this datum. Such functionality is not supported yet in ATOM v.1.
- For Geoid height, local zone time offset, magnetic variation, please refer to *NMEA-3.0 definitions*.
- Time tag ambiguity is GPS week number if GPS is primary, or GLONASS day number if GLONASS is primary.

Pseudo-Range Residuals

This section is intentionally left blank.

Satellite Information

This sub-block contains the status of each visible (by almanac, above 0 degrees) satellite. No SNR, elevation and other masks are applied to output satellites status. One SVS sub-block describes the status of a single GNSS. If a receiver tracks GPS, GLONASS and SBAS, then 3 SVS sub-blocks will be generated sequentially under the same ATOM PVT header. The organization of SVS data is very similar to data organization in the ATOM RNX message (see *page 54* and *Appendix E* on *page 99*).

- **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:

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 3-7: reserved	
Satellite mask	40	bit40	15			See Appendix E	
Signal mask	24	bit24	55			See Appendix E	
Cell mask	64	bit64	79			See Appendix E	
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 most significant bits in the Cell mask have sense. All the remaining bits are set to zero.
- If a satellite is seen by almanac but not tracked, it is marked as having virtually only the 1C signal.

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 2-15: corrections applied See Appendix G	AF007
Sat usage status	5 Nsat times	uint5 (Nsat)			0-31	0: Sat is not tracked 1-3: Sat is used in position 4-15: Reserved 16-31: Sat is not used in position See Appendix G	AF008
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.
- 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.
- SNR=0 and/or Smooth count=0 does not 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.

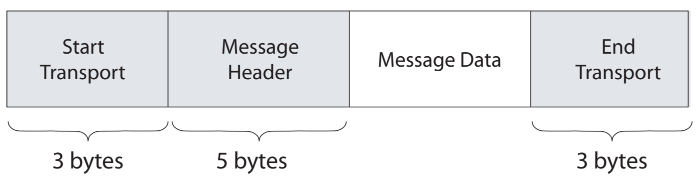
ATOM ATR Messages

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 in the diagram 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
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

NOTES:

- The observables generated in the ATOM MES, RNX and BAS messages always correspond to the antenna name specified in ATR message type 1. At the same time, this name can correspond to either a physical antenna (e.g. MAG990596) or a virtual antenna (e.g. ADVNULLANTENNA) for which raw receiver data can be optionally adjusted before being output.

  In the latter case, the receiver can additionally generate ATR message type 3, indicating the physical antenna name. If the antenna names specified in ATR message types 1 and 3 are the same, this means that no receiver raw data was adjusted to a virtual antenna. If the antenna names in ATR message types 1 and 3 are different, this means that receiver raw data (corresponding to ATR message type 3) were adjusted to the virtual antenna (specified in ATR message type 1).
- Both ATR messages type 1 and type 3 are requested through the same serial command.
- When processing ATOM MES, RNX and BAS data, these should be corrected using the PCO table, corresponding to the antenna name presented in ATR message type 1. ATR message type 3 is only informative.

Antenna attributes

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

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

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

This message contains information about site occupation.

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

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 23	
MESSAGE DATA							
Time tag	21	bit21				GPS time tag. See Time Tag description for PVT message.	
Occupation type	3	bit3			0-3	0: static 1: quasi-static 2: dynamic 3: reserved	
Occupation event	1	bit1			0-1	0: begin 1: end	
Reserved	7	bit7			0	Set to 0000000	
Occupation name coun-ter, N	8	uint8			0-255	Number of characters in occupation name field	
Occupation name	8*N	Char(N)				Standard ASCII characters describe occupation name	
Occupation description counter, M	8	uint8			0-255	Number of characters in occupation description field	
Occupation description	8*M	Char(M)				Standard ASCII characters describe occupation description	
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

External Sensors Data

This section is intentionally left blank.

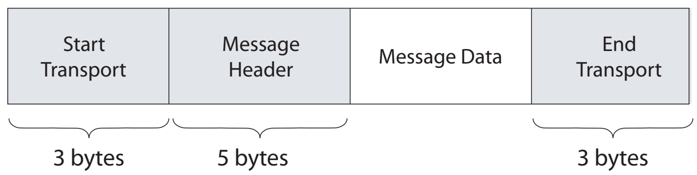
ATOM NAV Messages

Messages of the NAV (NAVigation data) group contain selected information which can be extracted from GPS, GLONASS, SBAS 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 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	Copy of standardized message RTCM-3 type 1019	RTCM-3 MT 1019
2	EPH	GLO ephemeris	Copy of standardized message RTCM-3 type 1020	RTCM-3 MT 1020
3	EPH	SBAS ephemeris	Copy of SNW message, but in compact presentation	$PASHR,SNW
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
21	GIT	GPS ionosphere and time shift parameters	Copy of ION message, but in compact presentation	$PASHR,ION
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	2^{4}		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
Dn	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	2^{4}		Reference ephemeris time	DF093
Cic	16	int16	368	2^{-29}		Harmonic correction term (radians)	DF094
w0	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
w	32	int32	480	2^{-31}		Argument of perigee (semicircles)	DF099
w 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						

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						

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 angle at reference time (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			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	7	int7	180	2^{-9}		Correction to mean value of Draconic period (seconds)	
Reserved	12	bit12	202			Af1=d(Af0)/dt(sec/sec)	
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						

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							
$\alpha0$	8	int8	64	2^{-30}		Ionospheric parameter (seconds)	
$\alpha1$	8	int8	72	2^{-27}		Ionospheric parameter (seconds/semi-circle)	
$\alpha2$	8	int8	80	2^{-24}		Ionospheric parameter (seconds/semi-circle)	
$\alpha3$	8	int8	88	2^{-24}		Ionospheric parameter (seconds/semi-circle)	
$\beta0$	8	int8	96	2^{11}		Ionospheric parameter (seconds)	
$\beta1$	8	int8	104	2^{14}		Ionospheric parameter (seconds/semi-circle)	
$\beta2$	8	int8	112	2^{16}		Ionospheric parameter (seconds/semi-circle)	
$\beta3$	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	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						

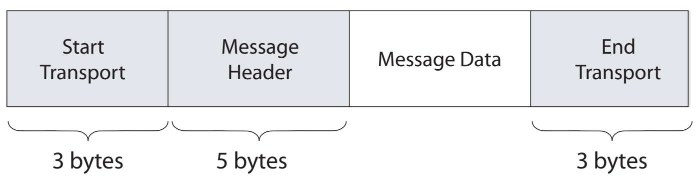
ATOM DAT Messages

Messages of the DAT (raw DATa) group contain original binary data. Particularly, this group contains GPS, GLONASS and SBAS raw navigation data (streams). Processing raw navigation data, users can extract any navigation information, particularly that from ATOM NAV messages. All DAT messages can be requested independently of each other. For each navigation system, DAT messages are always of fixed length. For messages of this group, there is no need to specify intervals between messages. A message is output after a new frame has been decoded.

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 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.

NAV message type	ASCII identifier	Attribute description	Comments	Counterpart
1	GPS	GPS raw navigation data	All raw data from GPS signal	N/A
2	GLO	GLO raw navigation data	All raw data from GLONASS signal	N/A
3	SBA	SBAS raw navigation data	All raw data from SBAS signal	$PASHR,SBD
11	EXT	Original binary stream	Data entering (flowing inside) receiver via internal/external port(s) / sockets	N/A

GPS Raw Subframe

This message contains a GPS raw subframe. A raw GPS subframe is 300 bits in total. For detailed information about the structure of GPS raw subframes, please refer to *ICD-GPS-200*. Note that any bit inversion in subframe data has been removed, so the first byte in the data buffer will be 0x8B (Hex) - TLM word preamble.

- **Output logic**: on change
- **Message binary size**: 52 bytes (416 bits)
- **How to request?** $PASHS,ATM,DAT,<Port Name>,ON,&GPS
- **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. Set to 46 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 1	
MESSAGE DATA							
Sat ID	6	uint6	64		1-32	Satellite PRN number 0: Sat ID is not defined	DF009
Signal ID	3	uint3	70		0-7	Type of signal 0: Signal is not defined 1: L1CA signal	
Channel number	8	uint8	73		0-255	Receiver channel number 0: channel number is unknown	
Subframe	3	uint3	81		1-5	GPS subframe number	
Reserved	4	bit4	84			Set to 0000	
Subframe data	300	bit300	88			GPS raw subframe	
Reserved	4	bit4	388			Set to 0000	
END TRANSPORT							
CRC	24	uint24	392			24-bit Cyclic Redundancy Check (CRC)	
Total	416						

GLONASS Raw String

This message contains GLONASS raw string data. A GLONASS raw string is 100 bits in total. For detailed information about the structure of GLONASS raw strings, please refer to the *GLONASS ICD*.

- **Output logic**: on change
- **Message binary size**: 28 bytes (224 bits)
- **How to request?** $PASHS,ATM,DAT,<Port Name>,ON,&GLO
- **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. Set to 22 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 2	
MESSAGE DATA							
Sat ID	5	uint5	64		1-24	GLONASS satellite number 0: Sat ID is not defined	DF038
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	
Frequency Channel number	5	uint5	80		0-31	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
String Number	4	uint4	85		1-15	GLONASS string number	
Reserved	7	bit7	89			Set to 0000000	
String data	100	bit100	96			GLONASS string	
Reserved	4	bit4	196			Set to 0000	
END TRANSPORT							
CRC	24	uint24	200			24-bit Cyclic Redundancy Check (CRC)	
Total	224						

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*.

- **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		0-19	SBAS satellite number 0: Sat ID is not defined 1 -> PRN#120 2 -> PRN#121 ..... 19 -> PRN#138	
Signal ID	3	bit3	69		0-7	Type of signal 0: Signal is not defined 1: L1CA signal	
Channel number	8	uint8	72		0-255	Receiver channel number 0: channel number is unknown	
Message Type	6	uint6	80		0-63	SBAS subframe number	
Receiver time (GPS)	20	uint20	86	1 sec	0-604799	GPS second within GPS week, 2^{20-1} if not defined	DF004
Reserved	6	bit6	106			Set to 000000	
Subframe data	250	bit250	112			SBAS subframe data	
Reserved	6	bit6	362			Set to 000000	
END TRANSPORT							
CRC	24	uint24	368			24-bit Cyclic Redundancy Check (CRC)	
Total	392						

EXTernal Port Data This message contains the binary data entering (and traveling inside) the receiver via one of its ports. Particularly this message can contain incoming differential corrections and/or commands used to configure the receiver.

- **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
3-22	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), it allows users to spy all the data entering the receiver via its 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 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 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.

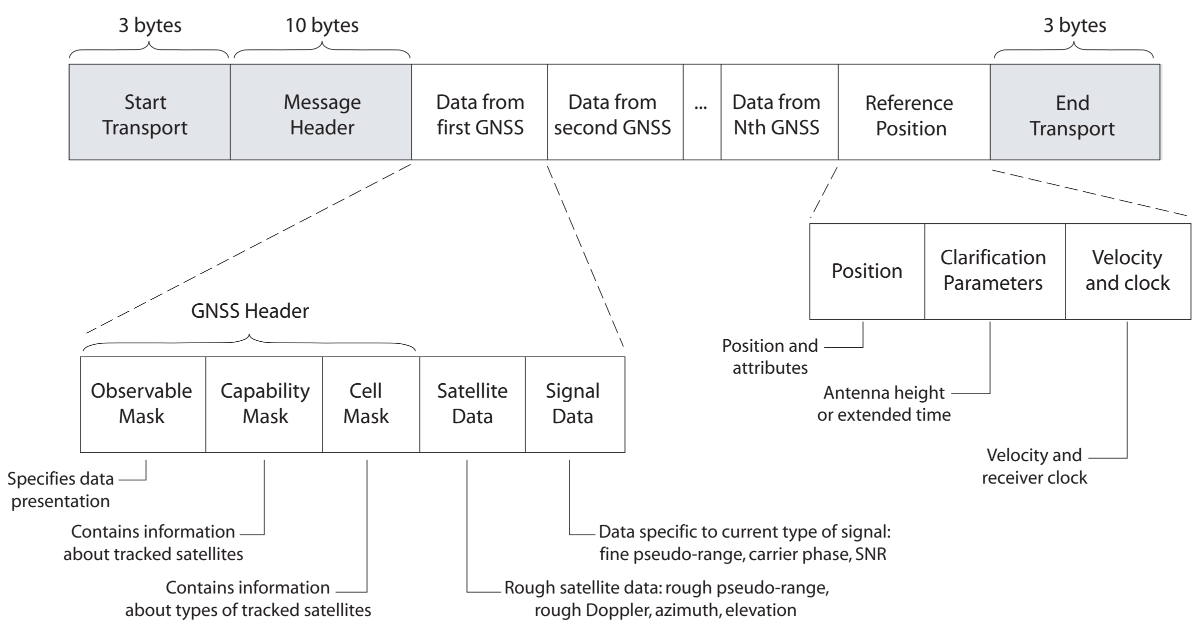
The particularities that stand behind generating, presenting and restoring the ATOM RNX message can be found in *Compression Options for ATOM RNX and BAS Observables on page 77* and Appendices C, D, E and F from *page 93*.

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

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	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	7 is reserved for ATOM RNX	
Version	3	uint3	40		0-7	ATOM version number, set to 1	
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	
Reserved	6	bit6	56		0-63	Set to 000000	
Position presentation	2	bit2	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 Bit4-8: reserved for other GNSS	
Primary GNSS system	3	bit3	72		0-7	0: GPS is primary 1: reserved for other GNSS 2: GLONASS is primary 2-7: reserved for other GNSS	
Time tag	21	bit21	75			See *Table 2*, *Table 3* and *Table 4*.	
Reserved	8	bit8	96		0-255	Set to 00000000	
FIRST GNSS BLOCK DATA (see GNSS mask in the message header)							
Observables Mask	16					See *Table 5*.	
Capability Mask	[72]					See *Table 6*.	
Cell Mask	[<64]					See *Table 7*.	
Satellite Data	[ ]					See *Table 8*.	
Signal Data	[ ]					See *Table 9*.	
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 10*, *Table 11* and *Table 12*.	
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) 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 physical receiver time.

Fig. 2. Time Tag Organization

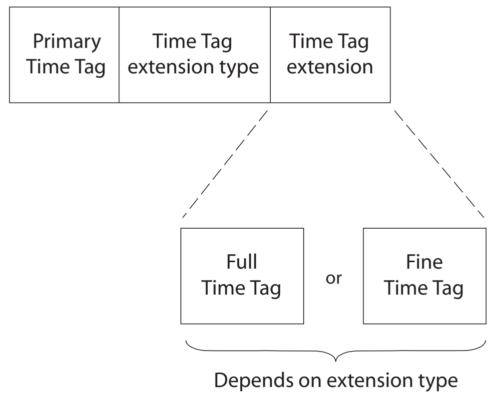


Table 2. Time Tag Presentation

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 0 for GLONASS	
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) 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 the GPS week number or GLONASS day 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.

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 each time the content of capability or cell mask is changed	
Data ID follow	1	bit1	5		0-1	0: no capability&cell mask follow 1: capability&cell mask follow	
N_{ms} follow	1	bit1	6		0-1	0: no N_{ms} follow 1: N_{ms} follow	
Supplementary follow	2	bit2	7		0-3	0: no supplementary data follow 1: compact supplementary data follow 2: full supplementary data follow 3: reserved	
Pseudo-range follow	2	bit2	9		0-3	0: no pseudo-range follow 1: fine pseudo-range follow 2: full pseudo-range follow 3: reserved	
Carrier phase follow	2	bit2	11		0-3	0: no carrier phase follow 1: fractional carrier phase follow 2: full carrier phase follow 3: reserved	
Reserved	3	bit3	13		0-7	Set to 000	
Total	16						

Table 6. Capability Mask Description (inserted if "Data ID follow"=1 in Observable mask)

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
CAPABILITY MASK							
Satellite mask	40	bit40	0			See Appendix E	
Signal mask	24	bit24	40			See Appendix E	
Reserved	8	bit8	64			Set to 000000000	
Total	72						

Table 7. Cell Mask Description (inserted if "Data ID follow"=1 in Observable mask)

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

NOTES:

- The Cell mask is of float size, but its size is known after decoding the capability mask (see *Table 6*).
- 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.

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 8. 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	DF014
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	
Extended Satellite supplementary data	32 x Nsat times	bit32(N_{sat})				Inserted if full supplementary data follow (See *Extended ATOM RNX Data on page 63*).	
Total							

NOTE:

- 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.

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 9. Signal Data

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 fractional or full carrier phase follows	
SNR	6 Ncell times	uint6(N_{cell})		1dBHz	0-63 dBHz	Inserted if compact or full supplementary data follow	
Extended supplementary data	56 Ncell times	bit56(N_{cell})				Inserted if full supplementary data follow (see *Extended ATOM RNX Data on page 63*)	
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.
- Each cell in the “integer cycle carrier phase data” field actually includes a 4-bit cumulative loss of continuity indicator, followed by the 12-bit integer cycle carrier phase as such.
- The Cumulative loss of continuity indicator is incremented by 1 each time a non-recovered carrier cycle slip occurs for this particular signal. The indicator takes values from 0 to 15 (and then back to 0 after 15 has been reached).
- 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 always 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 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 to it, thereby inserting a negligible error not affecting the final performance.

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 10*)
- Compact reference position + clarification data (see *Table 11*)
- Compact reference position + clarification data + velocity & clock (see *Table 12*)

Table 10. 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	bit3	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) 5-6: reserved 7: unknown	
Reserved	7	bit7	4		0-127	Set to 0000000	
Position tagging	3	bit3	11		0-7	0: Antenna reference point 1-7: other	
X coordinate	38	int38	14	0.0001 m	±13743895.3472 m		DF025
Y coordinate	38	int38	52	Ditto	Ditto		DF026
Z coordinate	38	int38	90	Ditto	Ditto		DF027
Total	128						

Table 11. 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	bit3	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) 5-6: reserved 7: unknown	
Reserved	7	bit7	4		0-127	Set to 0000000	
Position tagging	3	bit3	11		0-7	0: Antenna reference point 1-7: other	
X coordinate	38	int38	14	0.0001 m	±13743895.3472 m		DF025
Y coordinate	38	int38	52	Ditto	Ditto		DF026
Z coordinate	38	int38	90	Ditto	Ditto		DF027
Clarifier switch	2	bit2	128		0-3	0: ITRF year and antenna height follow 1: GPS-UTC time offset and GPS week number follow 2-3: reserved	
Clarification data	22	bit22	130			See *Table 13* and *Table 14*.	
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 REF data, antenna height and ITRF epoch year are generated. In the next epoch of REF data, GPS-UTC time offset and GPS week number are generated.

Table 12. 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	bit3	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) 5-6: reserved 7: unknown	
Reserved	7	bit7	4		0-127	Set to 0000000	
Position tagging	3	bit3	11		0-7	0: Antenna reference point 1-7: other	
X coordinate	38	int38	14	0.0001 m	±13743895.3472 m		DF025
Y coordinate	38	int38	52	Ditto	Ditto		DF026
Z coordinate	38	int38	90	Ditto	Ditto		DF027
Clarifier switch	2	bit2	128		0-3	0: ITRF year and antenna height follow 1: GPS-UTC time offset and GPS week number follow 2-3: reserved	
Clarification data	22	bit22	130			See *Table 13* and *Table 14*.	
X velocity	25	int25	152	0.0001 m/s	±1677.7216	-1677.7216 if not defined or invalid	
Y velocity	25	int25	177	0.0001 m/s	±1677.7216	-1677.7216 if not defined or invalid	
Z velocity	25	int25	202	0.0001 m/s	±1677.7216	-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	±500000 m	-536870.911 if not defined or invalid	
Receiver clock drift	22	int22	258	0.001 m/s	±2000 m/s	-2097.151 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.

Table 13. 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		DF028
Total	22						

Table 14. 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
GPS week number	12	uint12	6	1 week	0-4095	4095 means undefined or invalid	DF076
Reserved	4	Bit4	18		0-15	Set to 0000	
Total	22						

NOTE:

- Official RTCM field “DF021” is actually reserved for the ITRF epoch year, but not claimed as usable. ATOM follows the same strategy. Once RTCM claims that DF021 is usable, ATOM will use it as well.

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 15. 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	±8192 m/s	Value -8192 means invalid	
Full range available	1	bit1	29		0-1	0: Full Sat range available 1: No full Sat range available	
Sat status	2	bit2	30		0-3	0: Sat is used in position 1: Sat is not used (no ephemeris) 2: Sat is not used (other cause) 3: Reserved	
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 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.

Table 16. Extended Signal Data

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	±1.6384 m/s	Value -1.6384 means invalid	
Smoothing residual	11	int11	23	0.02 m	±20.48 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 17*).	

Table 16. Extended Signal Data

Total	56	

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 17. Signal Warnings

Data item	Bits	Data type	Offset	Scale	Range	Comments	DF Number
SIGNAL WARNINGS (one signal portion)							
Fractional carrier bias	2	bit2	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	bit2	3		0-3	0: OK 1: satisfactory 2: admissible 3: bad	Same as MPC warning (bits 3-4). See notes below.
Doppler quality	1	bit1	5		0-1	0: Smoothed Doppler 1: Not smoothed Doppler	
Cycle Slip possible	1	bit1	6		0-1	0: no cycle slip suspected 1: cycle slip is possible	Same as MPC warning (bit 6)
Loss of Continuity	1	bit1	7		0-1	0: continuous carrier tracking 1: loss of lock occurred	Same as MPC warning (bit 7)
Reserved	6	Bit6	8		0-63	See Appendix G	AF005
Total	14						

NOTES:

- The bits in the MPC warning byte are counted from 0 to 7.
- 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.
- 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.
- "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 18. 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

This section is intentionally left blank.

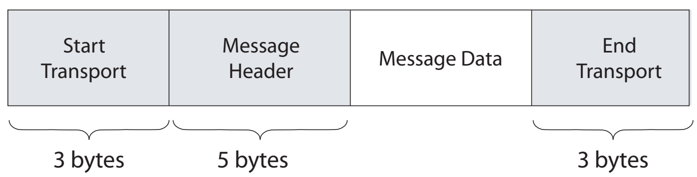
ATOM EVT Messages

Messages of the EVT (EVenTs) group contain various information for some particular events occurring in the receiver firmware. This information can include precise time tags for event pulses the receiver generates or gets from an external equipment. Also this group can contain the description of some events internal to the receiver, such as receiver reset or initialization. Different alarms that the receiver generates (e.g. exceptions, overflow, etc.) can also be inserted inside this EVT group.

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

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

The general organization of the EVT message is presented on the diagram below.



EVT 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	14 is reserved for ATOM EVT messages	
Version	3	Uint3	40		0-7	ATOM version number, set to 1	
Reference station ID	12	uint12	43		0-4095	Reference station ID	DF003
EVT type	9	Uint9	55		0-511	Specifies which EVT message follows	
MESSAGE DATA							
Event information						See sub-sections below	
END TRANSPORT							
CRC	24	uint24				24-bit Cyclic Redundancy Check (CRC)	
Total							

The currently supported EVT messages are presented in the table below.

EVT message type	ASCII identifier	Attribute description	Comments	Counterpart
1	TTT	External event time tag		$PASHR,TTT
2	PTT	PPS time tag		$PASHR,PTT

NOTE:

- For more information about how to generate the TTT and PTT messages, please see the documentation relevant to the receiver used.

External Event Time Tag

This message contains the precise GPS time tag for an external event pulse.

- **Output logic**: on detection of a pulse at the event input
- **Message binary size**: 18 bytes (144 bits)
- **How to request?** $PASHS,ATM,EVT,<Port Name>,ON,&TTT
- **Permissible intervals x (sec)**: N/A (not processed)
- **See also**: $PASHR,TTT

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.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	14 is reserved for ATOM EVT 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
EVT type	9	uint9	55		0-511	Set to 1 for this message	
MESSAGE DATA							
Day	3	uint3	64	1 day	1-7	1 is Sunday, ...7 is Saturday	
Hour	5	uint5	67	1 hour	0-23		
Minute	6	uint6	72	1 minute	0-59		
Second	6	uint6	78	1 second	0-59		
Fractional Second	30	uint30	84	1 nano second	0-99999999		
Reserved	6	uint6	114		0-63	Set to 0…0	
END TRANSPORT							
CRC	24	uint24	120			24-bit Cyclic Redundancy Check (CRC)	
Total	144						

PPS Time Tag This message contains the precise GPS time tag of the PPS pulse the receiver generates.

- **Output logic**: On each occurrence of a 1PPS pulse
- **Message binary size**: 18 bytes (144 bits)
- **How to request?** $PASHS,ATM,EVT,<Port Name>,ON,&PTT
- **Permissible intervals x (sec)**: N/A (not processed)
- **See also**: $PASHR,PTT

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.	
MESSAGE HEADER							
Message number	12	uint12	24		1001-4095	4095 is reserved for Ashtech	DF002
Message sub-number	4	uint4	36		0-15	14 is reserved for ATOM EVT 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
EVT type	9	uint9	55		0-511	Set to 2 for this message	
MESSAGE DATA							
Day	3	uint3	64	1 day	1-7	1 is Sunday, …7 is Saturday	
Hour	5	uint5	67	1 hour	0-23		
Minute	6	uint6	72	1 minute	0-59		
Second	6	uint6	78	1 second	0-59		
Fractional Second	30	uint30	84	1 nano second	0-99999999		
Reserved	6	uint6	114		0-63	Set to 0…0	
END TRANSPORT							
CRC	24	uint24	120			24-bit Cyclic Redundancy Check (CRC)	
Total	144						

ATOM STA Messages

This section is intentionally left blank.

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 PVT, ATR, NAV, DAT, STA and EVT. Then we show how to customize ATOM observables messages (RNX and BAS) 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 (MES, PVT, ATR, NAV, DAT, RNX, BAS, 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
GNSS observables	2	MES	not configurable	1 second
Positioning results	3	PVT	COO,ERR,LCY,SVS	1 second for all
Receiver attributes	4	ATR	ANM,RNM	30 seconds for all
Navigation information	5	NAV	EPH,GIT,GFT	300 seconds for all
Binary data frames	6	DAT	EXT	N/A
GNSS RINEX observables	7	RNX	SCN,4	1 second
GNSS RTK base corrections	8	BAS	SCN,4	1 second
Receiver status	13	STA	BLA	N/A
Receiver events	14	EVT	TTT,PTT	N/A

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).

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 (PVT, ATR, NAV, DAT, STA, EVT), and those configurable by scenario (RNX, BAS). 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 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 [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 port B and port A simultaneously, and generally with different periods and sub-blocks/sub-messages. 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 setup for <Port Name>:

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

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

– PVT: COO, ERR, VEL, CLK, LCY, HPR, BLN, MIS, PRR, SVS (see also *Appendix G*)
– ATR: ANM, RNM, UEM, AOP, OCC, SNS
– NAV: EPH, ALM, GIT, GFT

– DAT: GPS, GLO, SBA, EXT
– STA: BLA
– EVT: TTT, PTT

It should be noted that when requesting the EPH sub-message, one actually gets EPH for multiple GNSS (GPS,GLO,SBA 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 B with different intervals (600 and 300 seconds respectively):

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

- Enable ATOM DAT (GPS,GLONASS,SBAS) data on port C:

  $PASHS,ATM, DAT,C,ON,&GPS,GLO,SBA

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).

Unlike the other ATOM messages, RNX and BAS have an extra-feature: they 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/BAS messages can then be enabled/disabled through a single command:

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

The table below shortly describes the scenarios currently supported (for more details please refer to *Compression Options for ATOM RNX and BAS Observables on page 77* and *Appendices C through F from page 93*).

User case	SCN,x	Comment
Raw data recording		
	0	All available raw data in full presentation, full computed reference position follows each epoch
'Standard' differential protocols		
	1	L1 pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs; the analog of RTCM-3 MT 1001,1009,1006
	2	L1 SNR, pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs, the analog of RTCM-3 MT 1002,1010,1006
	3	L1&L2 pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs, the analog of RTCM-3 MT 1003,1011,1006
	4	L1 &L2 SNR, pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs, the analog of RTCM-3 MT 1004,1012,1006
Compact differential protocols		
	100	L1&L2 compact pseudo-range and full carrier phase, extended fixed position follows each 12 epochs, all the data are decimated in 5 times compared to L1 carrier phase
	101	L1&L2 compact pseudo-range and compact carrier phase, extended fixed position follows each 12 epochs, all the data are decimated in 5 times compared to L1 carrier phase. **This scenario cannot be used with moving receiver**.
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 (or BAS) message can be requested on the same receiver port.
- RNX (or BAS) messages with different scenarios/intervals can be requested on different receiver ports.
- The default RNX (or BAS) 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.

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

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 response (user readable) will be available through the same port. An example of ATOM setup is provided below.

```
MES:
A:  1.0,-T-
B:  OFF,---
C:  OFF,---

PVT: COO    ERR    VEL     CLK    LCY     HPR    BLN     MIS     PRR     SVS
A:  1.0,-T-   1.0,-T-  OFF,--- OFF,--- 1.0,-T-  OFF,--- OFF,--- OFF,--- OFF,--- 1.0,-T-
B:  OFF,---   OFF,--- OFF,--- OFF,--- OFF,--- OFF,--- OFF,--- OFF,--- OFF,--- OFF,--
C:  OFF,---   OFF,--- OFF,--- OFF,--- OFF,--- OFF,--- OFF,--- OFF,--- OFF,--- OFF,---

ATR: ANM    RNM     ANM    UEM
A:    030,-T-  030,-T-  030,-T- OFF,---
B:    OFF,---  OFF,---  OFF,--- OFF,---
C:    OFF,--- OFF,---   OFF,--- OFF,---

NAV: EPH      ALM    GIT       GFT
A:     300,-TN OFF,--- 300,-TN  300,-T-
B:     OFF,---  OFF,--- OFF,---   OFF,---
C:     OFF,---  OFF,--- OFF,---   OFF,---
```

```
DAT: GPS     GLO     SBA       EXT
A:     OFF,---  OFF,--- OFF,---  ON,--N
B:     OFF,---  OFF,--- OFF,---  OFF,---
C:     OFF,---  OFF,--- OFF,---  OFF,---
```

```
RNX:          SETTINGS
A:   1.0,-T-  SCN,004
B:   OFF,--- SCN,004
C:   OFF,--- SCN,004
 EVT: TTT     PTT
A:    ON,--N  ON,--N
B:    OFF,--- OFF,---
C:    OFF,--- OFF,---
```

Chapter 5. Compression Options for ATOM RNX and BAS Observables

Messages RNX and BAS can serve two important cases of use:

- Data recording for further post-processing, and/or
- Data generation from base to rover for RTK function

Each of them can correspond to a static or moving receiver. In each case, it is desirable to apply special configurations allowing the size of the ATOM messages to be extended or reduced very effectively. These configurations are available for end users as a set of supported scenarios (SCN). Each RNX/BAS message includes two quite independent parts:

- Receiver observables/corrections as such
- Receiver reference position, which can optionally be disabled.

Receiver observables can be sorted using the so-called “observables table”. Receiver position can also be described through the so-called “reference position table”.

Receiver Observables Table

The data a receiver generates can be represented in the so-called receiver observables table, which uses the RINEX-3.0 naming convention. An example of this table, for most of the currently existing GPS+GLONASS+SBAS signals, is shown below.

	GPS	GPS	GPS	GPS	GPS	GPS	GLO	GLO	GLO	GLO	SBA
	1C	1P	2P	2S	2L	2X	1C	1P	2C	2P	1C
C											
L											
S											
D											

The letters in the first column have the following meaning:

- C refers to pseudo-range observable
- L refers to carrier phase observable
- S refers to signal strength (SNR)
- D refers to Doppler observable

Each of the 2-symbol signal names in the second row refers to a particular GNSS signal the receiver tracks. The first symbol (a digit) refers to the frequency band. The second symbol refers to the type of signal (and the method to process it). Particularly, 1C means L1CA signal for each of the GNSS. Names 2S, 2L, 2X refer to different signals the receiver generates when tracking GPS L2C.

To simplify the writing conventions, 1P and 2P for GPS can actually be substitutes for each of the letters P, W, Y referring to different Y code processing techniques (e.g. W refers to Z-tracking or similar cross-correlation methods).

Some receivers can track all signals simultaneously, some others can also track all signals, but not simultaneously. The latter case is illustrated in the table below.

	GPS 1C	GPS 1P	GPS 2P|2S	GLO 1C	GLO 2C:2P	SBA 1C
C						
L						
S						
D						

In the above table, writing 2C:2P for GLONASS means that a receiver can track L2C signal for some GLONASS satellites and L2P signal for other GLONASS satellites (e.g. L2C for new GLONASS-M and L2P for old GLONASS). Writing 2P|2S for GPS means that a receiver tracks either 2P for all GPS, or tracks 2S for all GPS (depending on receiver option).

Any of the observables a receiver can generate may be represented in a cell in the table above. If some observable is generated, then the corresponding cell is marked with a Y, if some observable is not generated, then the corresponding cell is marked with an N or left empty. For C (pseudo-range) and L (carrier phase) observables, ATOM can generate the so-called compact presentation (see below the description of the OPT choice), in which case Y is replaced with C.

An example is given below (only L1CA data are generated for each of the three GNSS: pseudo-range, carrier phase and SNR; carrier phase is generated in compact form).

	GPS 1C	GPS 1P	GPS 2P|2S	GLO 1C	GLO 2C:2P	SBA 1C
C	Y			Y		Y
L	C			C		C
S	Y			Y		Y
D						

ATOM also allows different data presentations for different epochs (see below the description of the DEC option). In this case, each cell in the observables table contains as many letters as needed to reflect the complete period of the transmission scenario. An example for one possible transmission can be as follows.

	GPS 1C	GPS 1P	GPS 2P|2S	GLO 1C	GLO 2C:2P	SBA 1C
C	YN			YN		YN
L	YY		NY	YY	NY	YY
S	YN			YN		YN
D						

Here the complete scenario period is 2 epochs. The first symbol (Y or N) refers to the 1st, 3rd, 5th, etc. epochs, while the second symbol (Y or N) refers to the 2nd, 4th, 6th, etc. epochs. For example with 1 Hz data generation:

- Each odd epoch generates L1 pseudo-range, carrier phase and SNR data
- Each even epoch generates only L1&L2 carrier phase data
- Doppler data are not generated
- L1P GPS data are not generated.

Reference Position Table

When processing receiver observables, it is often essential to know the corresponding receiver position. There are at least two good reasons for that:

- Precise receiver (base) position is needed on rover side to compute accurate RTK position.
- Rough receiver position is needed on decoding side to restore the complete observables if they are generated in compact form.

RNX and BAS messages can generate static or moving reference position. When RNX and/or BAS is used as differential protocol generated by a static base receiver, this reference position is usually entered at the base and generated in RNX or BAS with its own update rate (usually lower than the observables update rate).

When RNX or BAS is used for receiver raw data recording or as differential protocol generated by a moving base receiver, this reference position is typically a receiver-computed position with an update rate usually equal to that of the observables.

Additionally RNX and BAS allow three different types of reference position presentation, from the most compact to the fullest. Also, the reference position can optionally be disabled if it is known a priori that it is not needed on decoding side.

The table below summarizes all the types of reference position that can be found in RNX/BAS messages.

Receiver motion	Position type	Position interval
Static, or Moving	No position, or Compact position, or Extended position, or Full position	Position decimation against observables (1-999)

Internal Options Used to Customize Scenarios

To customize receiver observations, the ATOM generator internally supports the following options:

- Shape (SPE)
- Optimization (OPT)
- Decimation (DEC)

Any reasonable combination of these options can graphically be presented in the receiver observable table (see *Receiver Observables Table on page 77*).

Option SPE best refers to the high-level observable table view. This option defines the “shape” of the table, i.e. the potentially available signals/observables in RNX/BAS messages. The following four tables clarify what is behind the choices SPE=1, 2, 3, 4 in general, and what SPE represents for a particular receiver/firmware.

SPE=1	GPS	GLO	SBA
General	1?	1?	1C
Particular	1C	1C	1C
C			
L			

SPE=2	GPS	GLO	SBA
General	1?	1?	1C

SPE=2	GPS	GLO	SBA
Particular	1C	1C	1C
C			
L			
S			

SPE=3	GPS	GPS	GLO	GLO	SBA
General	1?	2?	1?	2?	1C
Particular	1C	2P|2S	1C	2C:2P	1C
C					
L					

SPE=4	GPS	GPS	GLO	GLO	SBA
General	1?	2?	1?	2?	1C
Particular	1C	2P|2S	1C	2C:2P	1C
C					
L					
S					

Choice SPE=0 is receiver type and firmware version dependent. The table below shows what SPE=0 can be for a particular receiver.

SPE=0	GPS	GPS	GPS	GLO	GLO	SBA
Particular	1C	1P	2P|2S	1C	2C:2P	1C
C						
L						
S						
D						

Option OPT allows pseudo-range (C) and carrier phase (L) observables to be presented in different forms. Internally each C or L observable can be presented in one of three forms:

- No observable at all
- Compact presentation
- Full presentation

These 3*3=9 choices are mapped to particular values for OPT, as shown in the table below.

	No C	Compact C	Full C
No L	0	1	2
Compact L	3	4	5
Full L	6	7	8

To see how the different choices for OPT appear in the ATOM presentation, please refer to *Appendix C* on *page 93*.

Option DEC allows all requested observables (except L1CA carrier) to be decimated with time. The value given to DEC represents the decimation parameter (unitless), which can take values DEC=1, 2, 5, 10, 20, 50. Decimation is a very useful option when observables are requested at high speed (e.g. 10 Hz) while keeping the throughput at a reasonable level.

The Decimation option allows dramatic saving of the mean throughput while not reducing data performance, because all the decimated data can be restored easily with L1CA carrier data, provided continuous tracking is achieved over the needed interval. For more details regarding decimation, please see *Appendix D* on *page 97*.

To customize the presentation of the receiver reference position, the ATOM generator internally supports the following options:

- Mode (MOD)
- Position interval (XYZ)

The **MOD option** allows the mapping of the receiver motion and position type to an integer value from 0 to 6. The mapping table is given below.

Type \ Motion	Static	Moving
No	0	0
Compact	1	4
Extended	2	5
Full	3	6

The **XYZ option** allows the decimation applied to the reference position to be specified in comparison with observables. XYZ is unitless and can take any integer value from 1 to 999.

Supported Scenarios

The supported RNX/BAS scenarios are presented in the table below.

User case	SCN	SPE	DEC	OPT	XYZ	MOD	Comment	Approximate relative mean throughput (GPS+GLONASS)
Raw data recording								
	0	0	1	8	1	6	All available raw data in full presentation, full computed reference position follows each epoch	k*200% (k depends on receiver configuration, k=1 if one signal for L1 and one signal for L2 are generated)
'Standard' differential protocols								
	1	1	1	8	12	2	L1 pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs; the analog of RTCM-3 MT 1001,1009,1006	55%
	2	2	1	8	12	2	L1 SNR, pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs, the analog of RTCM-3 MT 1002,1010,1006	60%
	3	3	1	8	12	2	L1&L2 pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs, the analog of RTCM-3 MT 1003,1011,1006	95%
	4	4	1	8	12	2	L1 &L2 SNR, pseudo-range and carrier phase in full presentation, extended fixed position follows each 12 epochs, the analog of RTCM-3 MT 1004,1012,1006	100% ~ 300 bytes/epoch
Compact differential protocols								
	100	3	5	4	12	2	L1&L2 compact pseudo-range and full carrier phase, extended fixed position follows each 12 epochs, all the data are decimated in 5 times compared to L1 carrier phase	50%
	101	3	5	7	12	2	L1&L2 compact pseudo-range and compact carrier phase, extended fixed position follows each 12 epochs, all the data are decimated in 5 times compared to L1 carrier phase. **This scenario cannot be used with moving receiver**.	27%
Differential protocols for moving base								
	201	1	1	8	1	5	Same as scenario 1, but extended computed reference position follows each epoch	57%
	202	2	1	8	1	5	Same as scenario 2, but extended computed reference position follows each epoch	62%
	203	3	1	8	1	5	Same as scenario 3, but extended computed reference position follows each epoch	96%
	204	4	1	8	1	5	Same as scenario 4, but extended computed reference position follows each epoch	101%
	300	3	5	4	1	5	Same as scenario 100, but extended computed reference position follows each epoch	53%

The table above is a copy of the table from *Using the Extended Serial Interface For Observables Scenario Cutomization on page 74*, in which the chosen value for each of the different customization options (see *Internal Options Used to Customize Scenarios on page 79*) is provided in the description of each scenario. The provided throughput figures are approximate and can vary depending on the number of satellites from the different constellations. *Appendix F*, on *page 103*, provides a comparison table showing the different ATOM throughputs obtained in the same typical case of use, but with different customization options.

Once more, it should be noted that if the size of a single ATOM message exceeds 1023 bytes (say too many GNSS signals to generate), then more than one ATOM,RNX message will be generated for the same time tag (M-bit will be managed correspondingly).

Special emphasis should be put on the fact that any of the supported scenarios can potentially serve either raw data recording or real time differential protocol. In other words, one can use, say, SCN,100 or SCN,300 for raw data recording, and SCN,0 as a differential protocol. But the available spectrum of supported scenarios allows users to select the best way to serve the targeted application, with constrained or unconstrained data link and/or storage device.

The universality of ATOM often makes it possible to easily serve raw data recording and differential operation through the same scenario. In this case SCN,4 is the most preferable. This scenario is the best choice if the recorded ATOM raw data corresponding to a static receiver are to be used by third-party processing software. Because in this case third-party users will first convert ATOM to RINEX, thus resulting in the loss of most of the extra data generated in SCN,0 (compared to SCN,4), there is no advantage in using SCN,0 instead of SCN,4.

It should also be noted that each ATOM scenario is “self-optimized” in regard to “ghost data”. For example, SCN,4 is designed to send as maximum GPS L1/L2, GLONASS L1/L2 and SBAS L1. Yet, if a receiver can only track L1, SCN,4 will stay as effective as SCN,2 in terms of throughput, because no “ghost L2 data” are generated. This is one of the advantages of ATOM compared to standardized RTCM-3, where message 1004 cannot generate L1-only data with the same throughput efficiency as message 1002. So in most cases, SCN,4 can be used regardless of the receiver capability. On the other hand, the availability of SCN,2 gives users the possibility to generate L1-only data while the receiver tracks L1&L2.

Observables tables for all supported scenarios are presented below.

Table 19. SCN=1, 201

	GPS	GLO	SBA
	1?	1?	1C
C	Y	Y	Y
L	Y	Y	Y

Table 20. SCN=2, 102

	GPS	GLO	SBA
	1?	1?	1C
C	Y	Y	Y
L	Y	Y	Y
S	Y	Y	Y

Table 21. SCN=3, 203

	GPS	GPS	GLO	GLO	SBA
	1?	2?	1?	2?	1C
C	Y	Y	Y	Y	Y
L	Y	Y	Y	Y	Y

Table 22. SCN=4, 204

	GPS	GPS	GLO	GLO	SBA
	1?	2?	1?	2?	1C
C	Y	Y	Y	Y	Y
L	Y	Y	Y	Y	Y
S	Y	Y	Y	Y	Y

Table 23. SCN=0

	GPS	GPS	GPS	GLO	GLO	SBA
	1C	1P	2P|2S	1C	2C:2P	1C
C	Y	Y	Y	Y	Y	Y
L	Y	Y	Y	Y	Y	Y
S	Y	Y	Y	Y	Y	Y
D	Y	Y	Y	Y	Y	Y

Table 24. SCN=100, 300

	GPS	GPS	GLO	GLO	SBA
	1?	2?	1?	2?	1C
C	CNNNN	CNNNN	CNNNN	CNNNN	CNNNN
L	YYYYY	YNNNN	YYYYY	YNNNN	YYYYY

Table 25. SCN=101

	GPS	GPS	GLO	GLO	SBA
	1?	2?	1?	2?	1C
C	CNNNN	CNNNN	CNNNN	CNNNN	CNNNN
L	CCCCC	CNNNN	CCCCC	CNNNN	CCCCC

Reference position tables for all supported scenarios are presented below.

Table 26. SCN=0

Receiver motion	Position type	Position interval
Moving	Full position	1

Table 27. SCN=1, 2, 3, 4, 100, 101

Receiver motion	Position type	Position interval
Static	Extended position	12

Table 28. SCN=201, 202, 203, 204, 300

Receiver motion	Position type	Position interval
Moving	Extended position	1

The overall trade-off between throughput and data quality for different ATOM scenarios primarily depends on the presentation of observables. The reference position usually plays a secondary role. Let us consider in more details the rover RTK performance that can be expected from different ATOM scenarios used as differential protocol. In general, all existing and future ATOM scenarios can be divided among three principal groups:

- Complete observables (scenarios 0, 2, 4, 202, 204)
- Incomplete observables (1, 3, 201, 203)
- Compact observables (100, 101, 300)

Complete observables are those containing complete observation epoch and for this reason do not require any extra information or memory from the previous epoch to process a given epoch. As a result they are the most bandwidth consuming. They are customarily used either for raw data recording or as differential protocols when there are no constraints of data link bandwidth or traffic cost.

Incomplete observables are those either not containing all the required observables (e.g. no SNR), or only containing observables presented in reduced form (e.g. pseudo-range modulo 1ms only). Usually processing these data requires approximate reference position and ephemeris data to make these observations complete on receiving side. Absence of SNR can be not so critical if the incomplete scenario is generated by a static reference station. In this case, the SNR information usually brings nothing valuable to the rover. As a result, incomplete observables give some small improvements in the final throughput without any loss in the final differential performance.

The mean throughput can be reduced dramatically by using compact observables. Restoring compact observables on rover side requires the following:

- Knowing reference position and ephemeris to restore complete observables from (super) compact presentation
- Applying some kind of ingenious decoded data processing which includes memorizing the previously processed epochs (i.e. filter is needed).

When a base generates compact observables to save the data link, users should be aware that it can affect the final rover performance. If the data link is ideal, i.e. no data epochs are missing or corrupted, then the final rover performance with compact observations is the very same as that with complete observations.

However, when data are lost through the data link, then the final performance with compact data can be impaired. This is caused by the fact that compact observables have some kind of “between epochs” memory. So missing one epoch can result in the inability to restore some others that follow, even if they are decoded correctly. However, it must be noted that the presentation of compact ATOM observations is designed in such a robust way that these “additional losses of epochs” would not be dramatic in most cases, especially when compact data are generated by static open sky receivers.

More details can be found in the paper entitled *ATOM: Super Compact and Flexible Format to Store and Transmit GNSS Data* by I. Artushkin, A. Boriskin and D. Kozlov. This paper was presented at the ION GNSS International Conference in 2008.

Chapter 6. ATOM Utilities

There are a number of existing PC tools that help view ATOM messages and their transformations into other presentation forms. These are:

- bin2txt
- bin2std
- DATAVIEW (+ areader.dll)

Bin2txt is a command line utility allowing users to read any log file with arbitrary ATOM content and generate the ASCII equivalent of each ATOM message/field in a user-readable form. Please note that the original log file can contain not only ATOM messages, but also any other messages, which will not interfere with the binary-to-ASCII transformation process.

The bin2std utility allows users to read any log file with arbitrary ATOM content and generate different standardized messages/files, provided ATOM messages are properly formed. This utility has an entry-level self-explanatory GUI.

The DATAVIEW tool allows users to read any log file with arbitrary ATOM content and plot the most valuable ATOM message/field using standard DATAVIEW screens.

These three tools not only allow ATOM messages to be processed, but also any binary streams other receivers support. These include RTCM-2/3 and CMR/CMR+ data.

Each utility has its own short description available separately.

Appendix A. $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. 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				

Appendix C. Decomposition for ATOM RNX and BAS Observables

This Appendix describes in detail the principles of breaking down ATOM observables (RNX and BAS), thus providing a bridge between the different choices for the OPT optimization option (see *page 79*) and the corresponding ATOM presentations (see *page 54* and *page 66*).

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)

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

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

where K is the integer to be determined. The resolution is 655.36 meters for pseudo-ranges and 4096 cycles for carrier phases. The integer value K 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.

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

The table below (to be compared to the 6th table in *Internal Options Used to Customize Scenarios on page 79*) shows which components of the original observables are generated depending on the choice made for the OPT (optimization) option. The generated rough_range can either be full rough_range or rough_range modulo 1 ms. The generation of the number of integer ms in rough_range is not controlled by the OPT setting. In contrast, this value can be generated, or not generated, depending on the choice made for the SCN option.

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

Appendix D. Decimation for ATOM RNX and BAS 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 E*). In static open sky conditions, this identification information does not usually change very quickly. This gives a convenient possibility to freeze most of this information (i.e. decimate headers). Although a simple idea, it is not however trivial to implement, because irregular constellation changes as well as short-term data link blockage have to be taken into account. The careful implementation of the "header freezing" process in ATOM avoids degrading RTK performance against a static open sky reference receiver. Since header data can be considered as an observable along with pseudo-range and carrier phase, then it was decided that the DEC setting would affect header decimation in the same manner as it affects decimated pseudo-ranges and carrier phases

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

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

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

Appendix E. Data Identifiers for ATOM RNX and BAS 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 40 positions for each GNSS. Currently:

- GPS occupies 32 positions (theoretically there can be up to 39 PRN for GPS)
- GLO occupies 24 positions (24, but probably 28 slots, can be available)
- SBAS reserves 19 positions
- Probably Galileo will not reserve more than 40 positions (current estimate is 36).

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 24 bits. Each bit is representative of a specific GNSS signal. The definition of the Signal mask bits for each GNSS is given below (already existing signals are shaded). 1M and 1N for GPS L1 and 2M, 2N and 2D for GPS L2 are not mentioned just to make the table clearer. Besides, there is a sufficient number of reserved positions in Signal mask to make these signals available.

Rank	GPS, RINEX code	SBAS, RINEX code	GLONASS, RINEX code	Galileo, RINEX code	Comment
1					
2	1C	1C	1C	1C	
3	1P		1P	1A	
4	1W			1B	
5	1Y			1X	
6				1Z	
7					
8	2C		2C	6C	
9	2P		2P	6A	
10	2W			6B	
11	2Y			6X	
12				6Z	
13					
14				7I	
15	2S			7Q	
16	2L			7X	
17	2X				
18				8I	
19				8Q	
20				8X	
21					
22	5I	5I		5I	
23	5Q	5Q		5Q	
24	5X	5X		5X	

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 too sparse and so can effectively be presented by the Capability mask, i.e. by two independent masks:

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

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

Signals \ Sats	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	…	32	…	40	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
…																				…
24																				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 40-bit Satellite mask
- Fixed-size 24–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 100*.

Let us decode the Satellite mask as the following 40-bit sequence:

1010011000001010000000000000000100000000

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 24-bit sequence:

010100000100001000000000

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 99*).

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 F. Throughput Figures for ATOM RNX and BAS Observables

The main feature of RNX and BAS messages is their scalability, i.e. the possibility to configure them to save message sizing. A lot of different configurations can be generated using the following options (see also *Internal Options Used to Customize Scenarios on page 79*):

- 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 MES	791	400	538	Not configurable
ATOM RNX (SCN,0)	829	425	561	Fullest presentation
ATOM RNX (SCN,4)	317	205	193	Standard presentation
RTCM-3	338 (MT 1004,10012)	214 (MT 1002,1010)	202 (MT 1004)	RTCM scenarios matched to ATOM RNX (SCN,4)
ATOM RNX (SCN,100)	159*	140*	98*	Compact presentation
ATOM RNX (SCN,101)	86*	75*	70*	Super compact presentation, only applicable to static receivers

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

NOTES:

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

SPE=3 refers to sending L1 and L2 (one signal per band) pseudo-range and carrier phase data modulo 1 ms, and not sending SNR.

DEC=5 refers to decimating all the data in 5 times compared to L1 carrier data.

OPT=7 refers to compact pseudo-range and full carrier phase.

OPT=4 refers to compact pseudo-range and compact carrier phase.

These figures show that:

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

Appendix G. Description of Extra Specific Messages and AFxxx Fields

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Index

Ashtech Contact Information:
In USA +1 408 572 1103 ▪ Fax +1 408 572 1199
In South America +1 786 220 2579

In France +33 2 28 09 38 00 ▪ Fax +33 2 28 09 39 39
In Russia +7 495 980 5400 ▪ Fax +7 495 981 4840

In Singapore +65 9838 4229 ▪ Fax +65 6777 9881
In China +86 10 5802 5174 ▪ Fax +86 10 5802 5135

www.ashtech.com

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