



RTCM STANDARD 10403.1
FOR
DIFFERENTIAL GNSS
(GLOBAL NAVIGATION SATELLITE SYSTEMS)
SERVICES – VERSION 3

DEVELOPED BY
RTCM SPECIAL COMMITTEE NO. 104

OCTOBER 27, 2006

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PREFACE

This standard has been developed by RTCM SC-104 as a more efficient alternative to the documents entitled "RTCM Recommended Standards for Differential Navstar GPS Service, Version 2.x". Service providers and vendors represented on the SC-104 Committee requested the development of a new standard that would be more efficient, easy to use, and more easily adaptable to new situations. The main complaint was that the Version 2 parity scheme, which uses words with 24 bits of data followed by 6 bits of parity, was wasteful of bandwidth. Another complaint was that the parity was not independent from word to word. Still another was that even with so many bits devoted to parity, the actual integrity of the message was not as high as it should be. Plus, 30-bit words are awkward to handle. The new standard, Version 3, is intended to correct these weaknesses.

Unlike Version 2.x, the Version 3 standards do not include tentative messages. The messages in Version 3 have undergone testing for validity and interoperability, and are considered to be permanent. Future modifications of the standard may change the meaning of reserved bits or provide additional clarifying text, but no changes will be made in the data fields. Changes will require new messages to be developed. In addition to the messages described in this document, the Committee is also developing a number of new messages, which are described in a separate document. As new messages and capabilities have been demonstrated through validity and interoperability testing, they will be incorporated into future versions of the Version 3 standard, either as Supplements or as a new revision of standard 10403.x. Supplements will be made available electronically to those who have purchased the standard. Periodically, accumulated Supplements will be incorporated into a complete revision of standard 10403.x.

The initial release of the new standard, i.e., Version 3.0 (RTCM Paper 30-2004/SC104-STD), consisted primarily of messages designed to support real-time kinematic (RTK) operations. The reason for this emphasis was that RTK operation involves broadcasting a lot of information, and thus benefits the most from an efficient data format. Version 3.0 provided messages that supported GPS and GLONASS RTK operations, including code and carrier phase observables, antenna parameters, and ancillary system parameters.

This release, Version 3.1 – now designated as RTCM Standard 10403.1, incorporates GPS Network Corrections, which enable a mobile receiver to obtain accurate RTK information valid over a large area. In addition, new GPS and GLONASS messages provide orbital parameters to assist in rapid acquisition. A Unicode text message is also provided for the transmission of textual data. Finally, a set of messages are reserved for vendors who want to encapsulate proprietary data in their broadcasts.

RTCM SC-104 believes that the new Standard 10403.1 for DGNSS services will prove useful in supporting highly accurate differential and kinematic positioning as well as a wide range of navigation applications worldwide throughout the next decade.

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1 INTRODUCTION AND SCOPE

1.1 Introduction

The Global Positioning System (GPS) and the GLObal NAVigation Satellite System (GLONASS) are satellite-based positioning systems that are currently providing global service 24 hours each day. Collectively, these two systems, plus other systems currently being designed and implemented, notably Galileo, are called Global Navigation Satellite Systems (GNSS's). GNSS's typically provide navigation and positioning services having accuracies in the 5-40 meter range (2drms). Differential operation provides meter-level accuracy, while Real-Time Kinematic (RTK) operation provides decimeter accuracy or better.

The RTCM Special Committee 104 (SC-104), Differential GNSS Service, has examined the technical and institutional issues and formulated recommendations on the data format and content that are designed to support the most stringent applications in an efficient manner. The Committee has attempted to accommodate the widest possible user community, including not only maritime users, but land-based and airborne users as well. Radiolocation, surveying, and radionavigation applications are supported.

Standard 10403.1 (*i.e.* Version 3.1) describes messages and techniques for supporting GPS and GLONASS operation with one reference station or a network. However, the format is specifically designed to make it straightforward to accommodate new systems that are under development, Galileo in particular, as well as modifications to existing systems (e.g., new L2C and L5 signals). It can also accommodate augmentation systems that utilize geostationary satellites with transponders operating in the same frequency bands. Generically these are called Satellite-Based Augmentation Systems (SBAS's), and they have been designed to be interoperable. The first to be implemented is the Wide-Area Augmentation System (WAAS), which has been developed by the U.S. Federal Aviation Administration to supplement the GPS. The second is the European Geostationary Navigational Overlay System (EGNOS), which will soon be implemented to augment both GPS and GLONASS. The new systems will be accommodated by adding new messages.

Specifically, this document contains four new sets of messages that were not in Version 3.0: (1) GPS Network RTK Corrections, which enable a real-time kinematic rover receiver to accept and process pseudorange and carrier phase observables from a coordinated network of reference stations, (2) a GPS Ephemeris message, which provides a record of the GPS satellite ephemerides in use by the reference station, (3) a GLONASS Ephemeris message, which provides a record of the GLONASS satellite orbit parameters in use by the reference station, (4) a UNICODE message, which provides textual information, and (5) a set of message types reserved for proprietary use by vendors who wish to broadcast special information to their users.

The Committee assumes that Selective Availability has been permanently set to zero on the GPS satellites, so that the GPS signal variations will be dominated by natural causes. No system modifications, augmentations or new systems are considering this kind of intentional accuracy degradation.

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The higher efficiency of the new format, coupled with the absence of Selective Availability, will make it possible to support RTK services with significantly reduced bandwidths. The U.S. Coast Guard's NDGPS-GWEN expansion would be able to support a decimeter-level RTK using the new standard, as well as supporting all existing services with a reduced data broadcast burden. The Committee expects that it will find use in vessel tracking systems as well. Potential land uses include robotic mining, construction, and rapid surveying.

In summary, the Committee expects that the Version 3 format will support the most stringent and unique applications of these high-accuracy positioning techniques.

1.2 Scope

This standard defines a flexible messaging structure to support augmentation of navigation systems. It is the purpose of this structure to provide integrity and capability for existing and future applications an efficient manner. In order to promote these qualities this standard has been designed using a layered approach adapted from the Open System Interconnection (OSI) standard reference model.

- 1) Application Layer
- 2) Presentation Layer
- 3) Transport Layer
- 4) Data Link Layer
- 5) Physical Layer

Application Layer considerations are briefly discussed in Section 2, and include instructions on creating and applying data for navigation and positioning applications. Section 3, which comprises the bulk of the document, addresses the Presentation Layer, and describes the messages, the data elements, and the data definitions. The Transport Layer is described in Section 4, and includes the definition of the message frames, the method of implementing variable-length messages, and the Cyclic Redundancy Check (CRC) that provides message integrity. The Data Link Layer is tailored around the Physical Layer, which defines how the data is conveyed at the electrical and mechanical level.

2 APPLICATION LAYER

The Application Layer defines how the Version 3 messages can be applied for different end user applications. The fundamental feature of Differential Service is that it is a broadcast service, not a 2-way data link. As such, information is developed centrally by a Service Provider, who has an institutional or commercial interest in providing a positioning or navigation service. Recently, point-to-multipoint services using cell phones and Internet connections have become popular, but such services primarily support a one-way flow of information.

In general navigation applications are serviced very well with 1-10 meter horizontal accuracy positioning. (An exception is the GNSS-based aircraft landing system, called the Local Area Augmentation System, or LAAS. A separate standard has been developed for this by RTCM's sister organization, RTCA, Inc., which develops aviation standards.) Conventional differential GNSS service supports these applications nicely, and they utilize broadcast links with relatively low data rates. These low data rates can be supported by low-frequency broadcasts that are received over large areas, and it just so happens that high accuracy is maintained over hundreds of miles.

As innovative engineers and scientists have found uses for sub-meter accuracy positioning, RTK service has increased in importance. RTK service requires the transmission of significantly more data, so that generally line-of-sight broadcasts and point-to-multipoint services that utilize higher bandwidths are employed. Tropospheric and ionospheric variations cause phase and time delay variations in the GNSS signals that limit the area over which a given accuracy can be achieved. For example, relative positioning accuracies of one centimeter or better using single-frequency GNSS signals can be achieved only over distances of 10 kilometers or so (from reference station to user). Using dual-frequency GNSS signals enables one to estimate the ionospheric effects, and water vapor measurements can be made which improve tropospheric delay estimation, so that using these techniques the range can be extended to 50 kilometers or so in certain parts of the world. Dual-frequency RTK is very common, thus is supported by this standard. Because RTK provides relative positioning, the knowledge of the absolute (usually fixed) position of the reference station enables the user to achieve high absolute position accuracies, too.

To achieve the highest accuracy, it is important to account for GNSS antenna variations. Antenna patterns differ slightly from manufacturer to manufacturer and even from model to model. Differential GNSS service supports this by transmitting messages with reference station antenna information. Antenna patterns can also vary between different units of the same model and can vary due to environmental effects, but these can be mitigated by manufacturing design and reference site selection, respectively. Such variations are outside the scope of this document.

The applications of RTK to air, water and land operations are too many to enumerate, but a sampling is useful:

- Marine – Hydrographic surveying, dredge operations, navigation in narrow channels, buoy placement and auditing, even tidal height
- Air – Aerial surveying, landing system testing, calibration of other navigation systems
- Land – Surveying, building and bridge construction, surface mining, agriculture, road construction, asset location and management

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It turns out that the RTK requirements for all these different applications don't vary that much. The broadcast link bandwidth and update rates are primarily determined by the accuracy requirements and the signal blockage environment. Otherwise the required services are similar for air, land and sea applications.

3 PRESENTATION LAYER

3.1 Introduction

3.1.1 Version 3 Database Architecture

RTCM 10403.1 is written in a database format, loosely patterned after the recent NMEA 2000 standard. Whereas the NMEA standard is written for a networked set of different electronic units, the Differential GNSS Version 3 standard is written for a centralized distribution of data. For the Version 3 broadcast every bit counts in the frequently repeated messages, so while lining up on byte boundaries is desirable, forcing each data field to occupy whole numbers of bytes is not practical.

Also, the NMEA 2000 database has a wide disparity between Data Dictionary (DD) and Data Field (DF) records. In the case of RTCM 10403.1 broadcasts, there would be little difference. As a consequence, rather than utilize both DF and DD tables, these are collapsed into one DF definition. Rather than referring to “Parameter Groups”, this document will use the more familiar term “Message Types”.

In the tables below, the GPS and GLONASS RTK messages are defined so as to avoid placing flags in the messages that change the length or the meaning of data elements in the message. There is some variability that can't be avoided, because the number of satellites is not fixed. However, it is possible to determine the number of satellites by examining the message length as defined in the transport layer, because the number of satellites is the only variable quantity employed. For messages whose lengths don't line up with byte boundaries, the reference station designer should use zeros for undefined bits to fill out the last unfilled byte.

3.1.2 Message Groups

Message types contained in the current Version 3 standard (RTCM 10403.1) have been structured in different groups. For proper operation of a particular service the provider needs to transmit messages from each of several groups, as shown in Table 3.1-1. In particular, the provider must transmit at least one message type from each of the following groups: Observations, Station Coordinates, and Antenna Description. The different message types in each group contain messages with similar information content. The shorter ones contain the minimum needed to provide the service, while the other message types contain additional information for enhancing the performance of the service. For example, Message Type 1001 contains the shortest version of a message for GPS Observations, namely L1-only observables. For a broadcast link limited in throughput, use of 1001 might be appropriate. Message Type 1002 contains additional information that enhances performance. If throughput is not limited and the additional information is available, it is recommended to use the longer version of messages. Similarly Message Type 1003 provides minimum data for L1/L2 operation, while Message Type 1004 provides the full data content. The shorter observation messages save throughput, but contain less information. However, since the additional information in the longer observation messages does not change very often, they could be sent less often.

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Table 3.1-1. RTK Message Groups

Group Name	Sub-Group Name	Message Type
Observations	GPS L1	1001
		1002
	GPS L1 / L2	1003
		1004
	GLONASS L1	1009
		1010
	GLONASS L1 / L2	1011
		1012
	Station Coordinates	1005
		1006
Antenna Description		1007
		1008
Network RTK Corrections	Network Auxiliary Station Data Message	1014
	Ionospheric Correction Differences	1015
	Geometric Correction Differences	1016
	Combined Geometric and Ionospheric Correction Differences	1017
Auxiliary Operation Information	System Parameters	1013
	Satellite Ephemeris Data	1019
		1020
	Unicode Text String	1029
Proprietary Information		Currently assigned message numbers 4088 – 4095

The basic types of RTK service supported in this initial version of the standard are (1) GPS, (2) GLONASS, and (3) combined GPS/GLONASS. Since a full GLONASS constellation is not operating at the time of publication, the most likely service types will be GPS and combined GPS/GLONASS. Table 3.1-2 shows various levels of RTK services that could be supported today, with the Message Types that support them. It also provides the appropriate set of messages for both the mobile and reference station receivers for each service.

Table 3.1-2. Message Types Supporting Different RTK Service Levels

Service	Group	Mobile Receiver (minimum decoding requirement)	Reference Station Message Type(s)	
			Minimum Service Operation	Full Service Operation
Precision GPS L1 only	Observations (GPS)	1001-1004	1001	1002
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Antenna Description	1007 and 1008	1007 or 1008	1007 or 1008
	Auxiliary Operation Information			1013
Precision GPS RTK, L1 & L2	Observations (GPS)	1003-1004	1003	1004
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Antenna Description	1007 and 1008	1007 or 1008	1007 or 1008
	Auxiliary Operation Information			1013
Precision GLONASS L1 only	Observations (GLONASS)	1009-1012	1009	1010
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Antenna Description	1007 and 1008	1007 or 1008	1007 or 1008
	Auxiliary Operation Information			1013
Precision GLONASS RTK	Observations (GLONASS)	1011-1012	1011	1012
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Antenna Description	1007 and 1008	1007 or 1008	1007 or 1008
	Auxiliary Operation Information			1013
Precision GPS and GLONASS L1 only	Observations (GPS)	1001-1004	1001	1002
	Observations (GLONASS)	1009-1012	1009	1010
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Antenna Description	1007 and 1008	1007 or 1008	1007 or 1008
	Auxiliary Operation Information			1013

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Service	Group	Mobile Receiver (minimum decoding requirement)	Reference Station Message Type(s)	
			Minimum Service Operation	Full Service Operation
Precision GPS and GLONASS RTK, L1 & L2	Observations (GPS)	1003-1004	1003	1004
	Observations (GLONASS)	1011-1012	1011	1012
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Antenna Description	1007 and 1008	1007 or 1008	1007 or 1008
	Auxiliary Operation Information			1013
Precision GPS Network RTK	Observations (GPS)	1003-1004	1003	1004
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Antenna Description	1007 and 1008	1007 or 1008	1007 or 1008
	Auxiliary Operation Information			1013
	Network RTK Corrections		1014	1014
			1017	1015 and 1016

Service Providers can provide a variety of different services ranging from a basic to a complete service. A basic service would involve, e.g., a GPS single-frequency operation, with no attempt to optimize accuracy or ambiguity resolution time. A complete service would provide dual-frequency operations, possibly involving both GPS and GLONASS, attempting to optimize accuracy, baseline length, and ambiguity resolution time, as well as providing helpful ancillary data for quick startup and post-mission analysis.

Mobile equipment should be designed to decode all the message types in a group, even if all the information is not processed. For example, by decoding a Message Type 1002, the RTK observable data that matches that of Message Type 1001 can be utilized, but the additional information may be ignored. If the mobile equipment only operates on L1, it should still be designed to decode Message Types 1003 and 1004 and to pull out the L1 information.

3.1.3 Operation with Multiple Services

Providing information for multiple GNSS's (e.g., GNSS1=GPS and GNSS2=GLONASS) can be accommodated if guidelines are carefully followed. In particular:

1. The messages for all satellites of a particular system should be grouped in one message. For example, for GPS L1/L2 operation, each 1003 or 1004 message should contain the data for

all GPS satellites that are processed. This ensures that a GPS-only mobile receiver will be certain that all relevant data has been received even if the "Synchronous GNSS Message Flag", which indicates that more GNSS data (e.g., GLONASS) referenced to the same time epoch will be transmitted next, is set to "1".

2. When the "extended" messages, i.e., Message Types 1002, 1004, 1010, and 1012, are transmitted, they should include the entire set of satellites processed.
3. For combined GPS/GLONASS operation, GPS data should be transmitted first. This is because it will reduce latency for GPS-only mobile receivers, while combined GPS/GLONASS mobile receivers will suffer no penalty.
4. If the GNSS1 and GNSS2 data are not synchronous (i.e., the observations are not taken within one microsecond of each other), the "Synchronous GNSS Message Flag" should be set to zero for each set.

When the GLONASS constellation becomes complete and/or the Galileo system becomes operational, these rules may have to be re-examined and modified.

3.1.4 Reference Receiver Time and Observations

The reference receiver shall maintain its clock to align the measurement epoch times to the GNSS system time if possible. This is commonly referred to as Clock Steering. If clock steering is not possible, the observation shall be adjusted to correct for the receiver clock offset

When adjusting for clock offset, the consistency between the observations shall be maintained:

Transmitted Pseudorange =

Raw Pseudorange – (Clock Offset * PhaseRange Rate) – (Clock Offset * Speed of light)

Transmitted PhaseRange =

Raw PhaseRange – (Clock Offset * PhaseRange Rate) – (Clock Offset * Speed of light)

The resulting receiver epoch time should align with the GNSS system epoch time to within $\pm 1 \mu\text{s}$. Note that the PhaseRange has the same sign as the Raw Pseudorange.

For combined GNSS operation, if all GNSS observables are measured at the same instant of receiver time (in other words, if GNSS1 and GNSS2 clocks are based on the same oscillator), the clock offset utilized in the formulas above should be identical for the correction of all observations across both satellite systems and frequencies. The relations of differences between different clock biases in the observations are maintained in their original form. In this case, "Single Receiver Oscillator Indicator" (DF142) should contain "1". Also, "Synchronous GNSS Message Flag" (DF005) should indicate that GNSS measurements are synchronous as described in point 3.1.3. Some reference station installations may not allow for identical clock offsets over all the satellite systems tracked (for example, if two or more independent receiver boards produce the observations). Correspondingly, the "Single Receiver Oscillator Indicator" (DF142) should be set to "0". However, in such a case all GNSS's might be still synchronous, indicating that the observations have been obtained within one microsecond. The "Synchronous GNSS

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Message Flag" (DF005) should identify the proper state. It should be noted that the conditions for DF005 and DF142 refer to the configuration of the reference station equipment, thus do not change during the transmission of a data stream.

3.1.5 *GPS Network RTK corrections*

The fundamental functionality of networking software that combines the information of several permanent reference stations is the determination of integer ambiguities between the reference stations. The resulting integer ambiguities may be used for reducing the original raw reference station observations. This manipulation of the raw observations leaves the general properties of the carrier phase observations (troposphere, ionosphere, phase center variations, etc.) untouched, since only integer numbers have been introduced. This process is named “integer ambiguity-leveling” and the resulting observations of permanent reference stations are “(integer) ambiguity-leveled”.

An application accessing ambiguity-leveled observations of a single reference station will not see any difference. The modeling requirements within the application are identical. However, when an application uses the observations of more than one reference station, the application will no longer have to account for integer ambiguities between the reference stations on the same ambiguity level. Roving user equipment receiving observations of more than one reference station on the same ambiguity level and utilizing the observations in its positioning algorithm may switch from one reference station to another without reinitialization of its filter.

In order to preserve throughput Network RTK messages utilize data fields that extend the approach described above: the raw observations are reduced by the geometric representation of the satellite and receiver distance; and inter-reference station single differences are used (see Appendix A). Network RTK Corrections are designed as additional information for improved performance and precision. A service provider utilizing the network capability will broadcast previously defined Precision GPS RTK messages for the Master Reference Station, but will broadcast Auxiliary Reference Station information as well. Until this version of the standard is revised or a new version published, service providers are advised to limit the data stream to information associated with one single Master Reference Station and its associated Auxiliary Reference Stations. Participating mobile receivers must be designed to accept and process the Network RTK Corrections. Mobile equipment operating close to the Master Reference Station may be designed to use the Observation, Station Description, and Antenna Description information of the Master Reference Station exclusively.

3.1.6 *Proper handling of antenna phase center variation corrections*

Antennas designed for precise RTK operation account for so-called antenna phase center offsets and variations in the centimeter-range. These offsets and variations can be corrected within precise RTK equipment using calibration information. Antenna model type calibrations are available from several sources (e.g. IGS, and NGS). For high precision applications in particular individual antenna calibrations are sometimes performed. Also, within permanent reference station networks individually calibrated antennas are increasingly being used. The proper handling of dissimilar antennas is a pressing issue for the interoperability of RTK network data. Therefore for Network RTK operation adjustments may be made to raw observations for the Master Reference Stations as depicted in messages (1001 – 1004) for antenna biases (phase

center offsets and phase center variations). When corrections of antenna phase center variations are required, one should ensure that consistent sets are used throughout the application. The best way to ensure a consistent set of antenna phase center variations is to use only information from a single source (e.g. IGS, NGS) and ensure that the same form of representation is used consistently throughout each application (note the difference between absolute and relative representations). Note that reference station network software and rover firmware are different applications and thus may use different representations. It is recommended that published antenna parameters be used as they are. It is crucial to avoid mixing different forms of representation, and/or “fine-tuning” given sets of information by assembling a new set out of different sources (e.g. mixing offsets of one calibration with phase center variations with another calibration for one antenna). Offsets and phase center variations comprise a self-consistent set of information for a particular antenna. Both parts of the information are correlated with each other. The shape of one particular antenna phase pattern may be represented in principle by an indefinite number of different consistent sets of information (e.g. the introduction of a different value in the offset will be compensated by the antenna phase center variations).

In the event that it is necessary to change Master Reference Stations within a Precision Network RTK operation, a bias error could occur in the rover position as a consequence of using inconsistent phase center correction sets at the rover (e.g., obtained from different sources). Furthermore, achieving consistency of antenna correction models within large network setups would require storing antenna phase center corrections for dozens of Master Reference Stations, in order to allow use of the most accurate information that would be obtained from individually calibrated antennas. There is another approach to achieving consistent operation of user equipment, which is recommended here: namely, the observation data messages (1001 – 1004) for all Master Reference Stations of a homogenous Network should be referenced to a single antenna (preferably, the ADVNULLANTENNA). The modification of the observation information with respect to antenna phase center variations must be indicated in the disseminated data stream using antenna descriptor messages (1007 or 1008). The antenna descriptor field must then state the descriptor of the antenna (e.g., ADVNULLANTENNA). Note that the reduction to the ADVNULLANTENNA is defined through the correction of the antenna phase center offsets and variations based on the absolute antenna correction representation.

3.1.7 Scheduling of Network RTK messages

Scheduling of the Network RTK messages is a crucial procedure in the rover application. In general the concept chosen for Network RTK messages accommodates a number of different schemes. In order to achieve interoperability, some guidelines are necessary that limit the scheduling but not the resulting performance.

The recommended guidelines for scheduling are:

- First, dissemination of raw observation message (1003 or 1004) containing Master Reference Station data at a high data rate (0.5 – 2 Hz) immediately when information is available (low latency).
- Next, dissemination of ionospheric (dispersive) and geometric (non-dispersive) Correction Difference messages for all Auxiliary Reference Stations ((1015 and 1016) or 1017) at identical epoch time. The chosen epoch time should be identical to an epoch

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time as for raw observations of the Master Reference Station. The update rate may be identical or at a lower data rate than for raw observations. For operation with Correction Difference messages 1015 and 1016, the epoch time of both should be identical. The maximum interval should not exceed 15 seconds. When Correction Differences are updated at a lower rate than the Master Reference Station observations, both the dispersive and the non-dispersive components may be filtered to reduce the effect of noise.

- Next, Station Information messages (1014). The complete set of Station Information messages for all Master and Auxiliary Reference Stations within the data stream may be distributed over time in order to optimize throughput. The dissemination should be completed after a maximum time span of 15 seconds (optimization of start-up time of rover operation).
- Other messages with additional information as needed for proper rover operation (see Table 3.1-2) should be transmitted as for single baseline operation required.

Scheduling schemes within these bounds are recommended for best operation of a Network RTK provider service with Network RTK messages.

These recommended guidelines are based on the scheduling used during interoperability testing, using two different update rates. These rates were chosen to represent typical RTK operations in the field, and are described in Tables 3.1-3 and 3.1-4. Other update rates can be employed, but a Service Provider should be aware that these are the only ones that were actually tested for interoperability.

Table 3.1-3 High Update, for Ease of Comparison Between Different Data Streams

Group Name		Message Type	Update Rate
Observations (GPS)		1004	1 Hz
Station Description		1005 or 1006	As typical in an RTK operation
Antenna description		1007 or 1008	As typical in an RTK operation
Network RTK	Network Auxiliary Station Data	1014	
Network RTK	GPS Ionospheric Correction Difference	1015	1 Hz
Network RTK	GPS Geometric Correction Difference	1016	1 Hz

Table 3.1-4 Update Rate for Typical Operation

Group name		Message Type	Update rate
Observations (GPS)		1004	1 Hz
Station Description		1005 or 1006	As typical in an RTK operation
Antenna description		1007 or 1008	As typical in an RTK operation
Network RTK	Network Auxiliary Station Data	1014	
Network RTK	GPS Ionospheric Correction Difference	1015	Update completed every 10 seconds
Network RTK	GPS Geometric Correction Difference	1016	Update completed every 10 seconds

3.2 Message Type Summary

The message types for supporting RTK GPS and GLONASS operation are shown in Table 3.2-1.

Table 3.2-1. Message Type Table

Message Type	Message Name	No. of Bytes *	Notes
1001	L1-Only GPS RTK Observables	$8.00+7.25*N_s$	N_s = No. of Satellites
1002	Extended L1-Only GPS RTK Observables	$8.00+9.25*N_s$	
1003	L1&L2 GPS RTK Observables	$8.00+12.625*N_s$	
1004	Extended L1&L2 GPS RTK Observables	$8.00+15.625*N_s$	
1005	Stationary RTK Reference Station ARP	19	
1006	Stationary RTK Reference Station ARP with Antenna Height	21	
1007	Antenna Descriptor	5-36	
1008	Antenna Descriptor & Serial Number	6-68	
1009	L1-Only GLONASS RTK Observables	$7.625+8*N_s$	N_s = No. of Satellites
1010	Extended L1-Only GLONASS RTK Observables	$7.625+9.875*N_s$	
1011	L1&L2 GLONASS RTK Observables	$7.625+13.375*N_s$	
1012	Extended L1&L2 GLONASS RTK Observables	$7.625+16.25*N_s$	
1013	System Parameters	$8.75+3.625*N_m$	N_m = Number of Message Types Transmitted
1014	Network Auxiliary Station Data	14.625	
1015	GPS Ionospheric Correction Differences	$9+3.75*N_s$	N_s = Number of Satellites

Message Type	Message Name	No. of Bytes *	Notes
1016	GPS Geometric Correction Differences	$9+4.5*N_s$	N_s = Number of Satellites
1017	GPS Combined Geometric and Ionospheric Correction Differences	$9+6.625*N_s$	N_s = Number of Satellites
1018	RESERVED for Alternative Ionospheric Correction Difference Message		
1019	GPS Ephemerides	62	One message per satellite
1020	GLONASS Ephemerides	45	One message per satellite
1021-1028	RESERVED for Coordinate Transformation Messages		
1029	Unicode Text String	$9+N$	N = Number of UTF-8 Code Units
4001-4095	Proprietary Messages		These message types are assigned to specific companies for the broadcast of proprietary information. See Section 3.6.

* Fill bits (zeros) must be used to complete the last byte at the end of the message data before the CRC in order to maintain the last byte boundary. Thus the total number of bytes must be the next full integer if fill bits are needed. For example, 55.125 computed bytes means 56 bytes total.

3.3 Data Types

The data types used are shown in Table 3.3-1. Note that floating point quantities are not used.

Table 3.3-1. Data Type Table

Data Type	Description	Range	Data Type Notes
bit(n)	bit field	0 or 1, each bit	Reserved bits set to “0”
char8(n)	8 bit characters, ISO 8859-1 (not limited to ASCII)	character set	Reserved or unused characters: [0x00]
int14	14 bit 2's complement integer	-8192 to +8191	
int16	16 bit 2's complement integer	$\pm 32,767$	-32,768 indicates data not available
int17	17 bit 2's complement integer	$\pm 65,535$	-65,536 indicates data not available
int20	20 bit 2's complement integer	-524,288 to +524,287	
int21	21 bit 2's complement integer	$\pm 1,048,575$	-1,048,576 indicates data not available
int22	22 bit 2's complement integer	$\pm 2,097,151$	-2,097,152 indicates data not available
int23	23 bit 2's complement integer	$\pm 4,194,303$	-4,194,304 indicates data not available
int24	24 bit 2's complement integer	$\pm 8,388,607$	-8,388,608 indicates data not available
int30	30 bit 2's complement integer	$\pm 536,870,911$	-536,870,912 indicates data not available
int32	32 bit 2's complement integer	$\pm 2,147,483,647$	-2,147,483,648 indicates data not available
int38	38 bit 2's complement integer	-137,438,953,472 to +137,438,953,471	
uint3	3 bit unsigned integer	0 to 7	
uint4	4 bit unsigned integer	0 to 15	
uint5	5 bit unsigned integer	0 to 31	
uint6	6 bit unsigned integer	0 to 63	
uint7	7 bit unsigned integer	0 to 127	

Data Type	Description	Range	Data Type Notes
uint8	8 bit unsigned integer	0 to 255	
uint10	10 bit unsigned integer	0 to 1023	
uint11	11 bit unsigned integer	0 to 2047	
uint12	12 bit unsigned integer	0 to 4095	
uint16	16 bit unsigned integer	0 to 65,535	
uint17	17 bit unsigned integer	0 to 131,071	
uint18	18 bit unsigned integer	0 to 262,143	
uint20	20 bit unsigned integer	0 to 1,048,575	
uint23	23 bit unsigned integer	0 to 8,388,607	
uint24	24 bit unsigned integer	0 to 16,777,215	
uint25	25 bit unsigned integer	0 to 33,554,431	
uint27	27 bit unsigned integer	0 to 134,217,727	
uint30	30 bit unsigned integer	0 to 1,073,741,823	
uint32	32 bit unsigned integer	0 to 4,294,967,295	
intS5	5 bit sign-magnitude integer	± 15	<i>See Note 1</i>
intS11	11 bit sign-magnitude integer	± 1023	<i>See Note 1</i>
intS22	22 bit sign-magnitude integer	$\pm 2,097,151$	<i>See Note 1</i>
intS24	24 bit sign-magnitude integer	$\pm 8,388,607$	<i>See Note 1</i>
intS27	27 bit sign-magnitude integer	$\pm 67,108,863$	<i>See Note 1</i>
intS32	32 bit sign-magnitude integer	$\pm 2,147,483,647$	<i>See Note 1</i>
utf8(N)	Unicode UTF-8 Code Unit	00h to FFh	8-bit value that contains all or part of a Unicode UTF-8 encoded character

Note 1. 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 the numbers “-5” and “+5” in a binary form are 10000101 and 00000101, respectively. Negative zero is not used.

3.4 Data Fields

The data fields used are shown in Table 3.4-1. Each Data Field (DF) uses one of the Data Types of Table 3.3-1. Note that the Data Field ranges may be less than the maximum possible range allowed by the Data Type.

Table 3.4-1. Data Field Table

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF001	Reserved			bit(n)	All reserved bits should be set to “0”. However, since the value is subject to change in future versions, decoding should not rely on a zero value.
DF002	Message Number	0-4095		uint12	Self-explanatory
DF003	Reference Station ID	0-4095		uint12	<p>The <u>Reference Station ID</u> is determined by the service provider. Its primary purpose is to link all message data to their unique source. It is useful in distinguishing between desired and undesired data in cases where more than one service may be using the same data link frequency. It is also useful in accommodating multiple reference stations within a single data link transmission.</p> <p>In reference network applications the <u>Reference Station ID</u> plays an important role, because it is the link between the observation messages of a specific reference station and its auxiliary information contained in other messages for proper operation. Thus the Service Provider should ensure that the <u>Reference Station ID</u> is unique within the whole network, and that ID's should be reassigned only when absolutely necessary.</p> <p>Service Providers may need to coordinate their <u>Reference Station ID</u> assignments with other Service Providers in their region in order to avoid conflicts. This may be especially critical for equipment accessing multiple services, depending on their services and means of information distribution.</p>

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF004	GPS Epoch Time (TOW)	0-604,799,999 ms	1 ms	uint30	<u>GPS Epoch Time</u> is provided in milliseconds from the beginning of the GPS week, which begins at midnight GMT on Saturday night/Sunday morning, measured in GPS time (as opposed to UTC).
DF005	Synchronous GNSS Message Flag			bit(1)	If the <u>Synchronous GNSS Message Flag</u> is set to “0”, it means that no further GNSS observables referenced to the same Epoch Time will be transmitted. This enables the receiver to begin processing the data immediately after decoding the message. If it is set to “1”, it means that the next message will contain observables of another GNSS source referenced to the same Epoch Time. Note: “Synchronous” here means that the measurements are taken within one microsecond of each other
DF006	No. of GPS Satellite Signals Processed	0-31		uint5	The <u>Number of GPS Satellite Signals Processed</u> refers to the number of satellites in the message. It does not necessarily equal the number of satellites visible to the Reference Station.
DF007	GPS Divergence-free Smoothing Indicator			bit(1)	0= Divergence-free smoothing not used 1= Divergence-free smoothing used
DF008	GPS Smoothing Interval	See Table 3.4-4		bit(3)	The <u>GPS Smoothing Interval</u> is the integration period over which reference station pseudorange code phase measurements are averaged using carrier phase information. Divergence-free smoothing may be continuous over the entire period the satellite is visible.
DF009	GPS Satellite ID	1-63 (See Table 3.4-3)		uint6	A <u>GPS Satellite ID</u> number from 1 to 32 refers to the PRN code of the GPS satellite. Satellite ID's higher than 32 are reserved for satellite signals from Satellite-Based Augmentation Systems (SBAS's) such as the FAA's Wide-Area Augmentation System (WAAS). SBAS PRN codes cover the range 120-138. The Satellite ID's reserved for SBAS satellites are 40-58, so that the SBAS PRN codes are derived from the Version 3 Satellite ID codes by adding 80.
DF010	GPS L1 Code Indicator			bit(1)	The <u>GPS L1 Code Indicator</u> identifies the code being tracked by the reference station. Civil receivers can track the C/A code, and optionally the P code, while military receivers can track C/A, and can also track P and Y code, whichever is broadcast by the satellite. “0” = C/A Code; “1” = P(Y) Code Direct

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF011	GPS L1 Pseudorange	0-299,792.46 m	0.02 m	uint24	<p>The <u>GPS L1 Pseudorange</u> field provides the raw L1 pseudorange measurement at the reference station in meters, modulo one light-millisecond (299,792.458 meters). The GPS L1 pseudorange measurement is reconstructed by the user receiver from the L1 pseudorange field by:</p> $(\text{GPS L1 pseudorange measurement}) = (\text{GPS L1 pseudorange field}) \bmod (299,792.458 \text{ m}) + \text{integer as determined from the user receiver's estimate of the reference station range, or as provided by the extended data set.}$ <p>If DF012 is set to 80000h, this field does not represent a valid L1 pseudorange, and is used only in the calculation of L2 measurements.</p>
DF012	GPS L1 PhaseRange – L1 Pseudorange	$\pm 262.1435 \text{ m}$ (See Data Field Note)	0.0005 m	int20	<p>The <u>GPS L1 PhaseRange – L1 Pseudorange</u> field provides the information necessary to determine the L1 phase measurement. Note that the PhaseRange defined here has the same sign as the pseudorange. The PhaseRange has much higher resolution than the pseudorange, so that providing this field is just a numerical technique to reduce the length of the message. At start up and after each cycle slip, the initial ambiguity is reset and chosen so that the L1 PhaseRange should match the L1 Pseudorange as closely as possible (i.e., within 1/2 L1 cycle) while not destroying the integer nature of the original carrier phase observation.</p> <p>The Full GPS L1 PhaseRange is constructed as follows (all quantities in units of meters):</p> $(\text{Full L1 PhaseRange}) = (\text{L1 pseudorange as reconstructed from L1 pseudorange field}) + (\text{GPS L1 PhaseRange – L1 Pseudorange field})$ <p>Certain ionospheric conditions might cause the <u>GPS L1 PhaseRange – L1 Pseudorange</u> to diverge over time across the range limits defined. Under these circumstances the computed value needs to be adjusted (rolled over) by the equivalent of 1500 cycles in order to bring the value back within the range.</p> <p>See also comments in sections 3.1.6 and 3.5.1 for correction of antenna phase center variations in Network RTK applications.</p> <p>Note: A bit pattern equivalent to 80000h in this field indicates the L1 phase is invalid, and that the DF011 field is used only in the calculation of L2 measurements.</p>

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF013	GPS L1 Lock Time Indicator	See Table 3.4-2		uint7	The <u>GPS L1 Lock Time Indicator</u> provides a measure of the amount of time that has elapsed during which the Reference Station receiver has maintained continuous lock on that satellite signal. If a cycle slip occurs during the previous measurement cycle, the lock indicator will be reset to zero.
DF014	GPS Integer L1 Pseudorange Modulus Ambiguity	0-76,447,076.790 m	299,792.458 m	uint8	The <u>GPS Integer L1 Pseudorange Modulus Ambiguity</u> represents the integer number of full pseudorange modulus divisions (299,792.458 m) of the raw L1 pseudorange measurement.
DF015	GPS L1 CNR	0-63.75 dB-Hz	0.25 dB-Hz	uint8	The <u>GPS L1 CNR</u> measurements provide the reference station's estimate of the carrier-to-noise ratio of the satellite's signal in dB-Hz. The value "0" means that the CNR measurement is not computed.
DF016	GPS L2 Code Indicator			bit(2)	<p>The <u>GPS L2 Code Indicator</u> depicts which L2 code is processed by the reference station, and how it is processed.</p> <p>0= C/A or L2C code 1= P(Y) code direct 2= P(Y) code cross-correlated 3= Correlated P/Y</p> <p>The GPS L2 Code Indicator refers to the method used by the GPS reference station receiver to recover the L2 pseudorange. The GPS L2 Code Indicator should be set to 0 (C/A or L2C code) for any of the L2 civil codes. It is assumed here that a satellite will not transmit both C/A code and L2C code signals on L2 simultaneously, so that the reference station and user receivers will always utilize the same signal. The code indicator should be set to 1 if the satellite's signal is correlated directly, i.e., either P code or Y code depending whether anti-spoofing (AS) is switched off or on. The code indicator should be set to 2 when the reference station receiver L2 pseudorange measurement is derived by adding a cross-correlated pseudorange measurement (Y2-Y1) to the measured L1 C/A code. The code indicator should be set to 3 when the GPS reference station receiver is using a proprietary method that uses only the L2 P(Y) code signal to derive L2 pseudorange.</p>

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF017	GPS L2-L1 Pseudorange Difference	± 163.82 m (See Data Field Note)	0.02m	int14	<p>The <u>GPS L2-L1 Pseudorange Difference</u> field is utilized, rather than the full L2 pseudorange, in order to reduce the message length. The receiver must reconstruct the L2 code phase pseudorange by using the following formula:</p> $(\text{GPS L2 pseudorange measurement}) = (\text{GPS L1 pseudorange as reconstructed from L1 pseudorange field}) + (\text{GPS L2-L1 pseudorange field})$ <p>Note: A bit pattern equivalent to 2000h (-163.84m) means that there is no valid L2 code available, or that the value exceeds the allowed range.</p>
DF018	GPS L2 PhaseRange – L1 Pseudorange	± 262.1435 m (See Data Field Note)	0.0005 m	int20	<p>The <u>GPS L2 PhaseRange - L1 Pseudorange</u> field provides the information necessary to determine the L2 phase measurement. Note that the PhaseRange defined here has the same sign as the pseudorange. The PhaseRange has much higher resolution than the pseudorange, so that providing this field is just a numerical technique to reduce the length of the message. At start up and after each cycle slip, the initial ambiguity is reset and chosen so that the L2 PhaseRange should match the L1 Pseudorange as closely as possible (i.e., within 1/2 L2 cycle) while not destroying the integer nature of the original carrier phase observation.</p> <p>The Full GPS L2 PhaseRange is constructed as follows (all quantities in units of meters):</p> $(\text{Full L2 PhaseRange}) = (\text{L1 pseudorange as reconstructed from L1 pseudorange field}) + (\text{GPS L2 PhaseRange - L1 Pseudorange field})$ <p>Certain ionospheric conditions might cause the <u>GPS L2 PhaseRange - L1 Pseudorange</u> to diverge over time across the range limits defined. Under these circumstances the computed value needs to be adjusted (rolled over) by the equivalent of 1500 cycles in order to bring the value back within the range. Note: A bit pattern equivalent to 80000h in this field indicates an invalid carrier phase measurement that should not be processed by the mobile receiver. This indication may be used at low signal levels where carrier tracking is temporarily lost, but code tracking is still possible.</p> <p>See also comments in sections 3.1.6 and 3.5.1 for correction of antenna phase center variations in Network RTK applications.</p>

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF019	GPS L2 Lock Time Indicator	See Table 3.4-2		uint7	The GPS L2 Lock Time Indicator provides a measure of the amount of time that has elapsed during which the Reference Station receiver has maintained continuous lock on that satellite signal. If a cycle slip occurs during the previous measurement cycle, the lock indicator will be reset to zero.
DF020	GPS L2 CNR	0-63.75 dB-Hz	0.25 dB-Hz	uint8	The GPS L2 CNR measurements provide the reference station's estimate of the carrier-to-noise ratio of the satellite's signal in dB-Hz. The value "0" means that the CNR measurement is not computed.
DF021	ITRF Realization Year			uint6	Since this field is reserved, all bits should be set to zero for now. However, since the value is subject to change in future versions, decoding should not rely on a zero value. The ITRF realization year identifies the datum definition used for coordinates in the message.
DF022	GPS Indicator			bit(1)	0=No GPS service supported 1=GPS service supported
DF023	GLONASS Indicator			bit(1)	0=No GLONASS service supported 1=GLONASS service supported
DF024	Galileo Indicator			bit(1)	0=No Galileo service supported 1=Galileo service supported
DF025	Antenna Ref. Point ECEF-X	± 13,743,895.3471 m	0.0001 m	int38	The antenna reference point X-coordinate is referenced to ITRF epoch as given in DF021.
DF026	Antenna Ref. Point ECEF-Y	± 13,743,895.3471 m	0.0001 m	int38	The antenna reference point Y-coordinate is referenced to ITRF epoch as given in DF021.
DF027	Antenna Ref. Point ECEF-Z	± 13,743,895.3471 m	0.0001 m	int38	The antenna reference point Z-coordinate is referenced to ITRF epoch as given in DF021.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF028	Antenna Height	0-6.5535 m	0.0001 m	uint16	The <u>Antenna Height</u> field provides the height of the Antenna Reference Point above the marker used in the survey campaign.
DF029	Descriptor Counter	0-31		uint8	The <u>Descriptor Counter</u> defines the number of characters (bytes) to follow in DF030, Antenna Descriptor
DF030	Antenna Descriptor			char8 (n)	Alphanumeric characters. IGS limits the number of characters to 20 at this time, but this DF allows more characters for future extension.
DF031	Antenna Setup ID	0-255		uint8	<p>0=Use standard IGS Model 1-255=Specific Antenna Setup ID#</p> <p>The <u>Antenna Setup ID</u> is a parameter for use by the service provider to indicate the particular reference station-antenna combination. The number should be increased whenever a change occurs at the station that affects the antenna phase center variations. While the Antenna Descriptor and the Antenna Serial Number give an indication of when the installed antenna has been changed, it is envisioned that other changes could occur. For instance the antenna might have been repaired, or the surrounding of the antenna might have been changed and the provider of the service may want to make the user station aware of the change. Depending on the change of the phase center variations due to a setup change, a change in the Antenna Setup ID would mean that the user should check with the service provider to see if the antenna phase center variation in use is still valid. Of course, the provider must make appropriate information available to the users.</p>
DF032	Serial Number Counter	0-31		uint8	The <u>Serial Number Counter</u> defines the number of characters (bytes) to follow in Antenna Serial Number
DF033	Antenna Serial Number			char8 (n)	Alphanumeric characters. The <u>Antenna Serial Number</u> is the individual antenna serial number as issued by the manufacturer of the antenna. A possible duplication of the Antenna Serial Number is not possible, because together with the Antenna Descriptor only one antenna with the particular number will be available. In order to avoid confusion the Antenna Serial Number should be omitted when the record is used together with reverse reduction to model type calibration values, because it cannot be allocated to a real physical antenna.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF034	GLONASS Epoch Time (t _k)	0-86,400,999 ms	1 ms	uint27	<u>GLONASS Epoch Time</u> of measurement is defined by the GLONASS ICD as UTC(SU) + 3.0 hours. It rolls over at 86,400 seconds for GLONASS, except for the leap second, where it rolls over at 86,401.
DF035	No. of GLONASS Satellite Signals Processed	0-31	1	uint5	The <u>Number of GLONASS Satellite Signals Processed</u> refers to the number of satellites in the message. It does not necessarily equal the number of satellites visible to the Reference Station.
DF036	GLONASS Divergence-free Smoothing Indicator			bit(1)	0= Divergence-free smoothing not used 1= Divergence-free smoothing used
DF037	GLONASS Smoothing Interval	See Table 3.4-4		bit(3)	The <u>GLONASS Smoothing Interval</u> is the integration period over which reference station pseudorange code phase measurements are averaged using carrier phase information. Divergence-free smoothing may be continuous over the entire period the satellite is visible.
DF038	GLONASS Satellite ID (Satellite Slot Number)	0-63 (See Table 3.4-3)		uint6	A <u>GLONASS Satellite ID</u> number from 1 to 24 refers to the slot number of the GLONASS satellite. A Satellite ID of zero indicates that the slot number is unknown. Satellite ID's higher than 32 are reserved for satellite signals from Satellite-Based Augmentation Systems (SBAS's). SBAS PRN codes cover the range 120-138. The Satellite ID's reserved for SBAS satellites are 40-58, so that the SBAS PRN codes are derived from the Version 3 GLONASS Satellite ID codes by adding 80. <i>Note: For GLONASS-M satellites this data field has to contain the GLONASS-M word “n”, thus the Satellite Slot Number is always known (cannot be equal to zero) for GLONASS-M satellites.</i>
DF039	GLONASS L1 Code Indicator			bit(1)	“0” = C/A Code; “1” = P Code

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF040	GLONASS Satellite Frequency Channel Number	0-20 (See Table 3.4-5)	1	uint5	<p>The <u>GLONASS Satellite Frequency Channel Number</u> identifies the frequency of the GLONASS satellite. By providing both the Slot ID and the Frequency Code of the satellite, the user instantly knows the frequency of the satellite without requiring an almanac.</p> <p>0 indicates channel number -07 1 indicates channel number -06 20 indicates channel number +13</p>
DF041	GLONASS L1 Pseudorange	0-599,584.92 m	0.02 m	uint25	<p>The <u>GLONASS L1 Pseudorange</u> field provides the raw L1 pseudorange measurement at the reference station in meters, modulo two light-milliseconds (599,584.916 meters). The L1 pseudorange measurement is reconstructed by the user receiver from the L1 pseudorange field by:</p> $(\text{L1 pseudorange measurement}) = (\text{L1 pseudorange field}) \text{ modulo } (599,584.916 \text{ m}) + \text{integer as determined from the user receiver's estimate of the reference station range, or as provided by the extended data set.}$

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF042	GLONASS L1 PhaseRange – L1 Pseudorange	± 262.1435 m (See Data Field Note)	0.0005 m	int20	<p>The <u>GLONASS L1 PhaseRange – L1 Pseudorange</u> field provides the information necessary to determine the L1 phase measurement. Note that the PhaseRange defined here has the same sign as the pseudorange. The PhaseRange has much higher resolution than the pseudorange, so that providing this field is just a numerical technique to reduce the length of the message. At start up and after each cycle slip, the initial ambiguity is reset and chosen so that the L1 PhaseRange should match the L1 Pseudorange as closely as possible (i.e., within 1/2 L1 cycle) while not destroying the integer nature of the original carrier phase observation.</p> <p>The Full GLONASS L1 PhaseRange is constructed as follows (all quantities in units of meters):</p> $(\text{Full L1 PhaseRange}) = (\text{L1 pseudorange as reconstructed from L1 pseudorange field}) + (\text{GLONASS L1 PhaseRange} - \text{GLONASS L1 Pseudorange field})$ <p>Certain ionospheric conditions might cause the <u>GLONASS L1 PhaseRange – L1 Pseudorange</u> to diverge over time across the range limits defined. Under these circumstances the computed value needs to be adjusted (rolled over) by the equivalent of 1500 cycles in order to bring the value back within the range.</p> <p>Note: A bit pattern equivalent to 80000h in this field indicates an invalid carrier phase measurement that should not be processed by the mobile receiver. This indication may be used at low signal levels where carrier tracking is temporarily lost, but code tracking is still possible.</p>
DF043	GLONASS L1 Lock Time Indicator	See Table 3.4-2		uint7	The <u>GLONASS L1 Lock Time Indicator</u> provides a measure of the amount of time that has elapsed during which the Reference Station receiver has maintained continuous lock on that satellite signal. If a cycle slip occurs during the previous measurement cycle, the lock indicator will be reset to zero.
DF044	GLONASS Integer L1 Pseudorange Modulus Ambiguity	0-76,147,284.332 m	599,584.916 m	uint7	The <u>GLONASS Integer L1 Pseudorange Modulus Ambiguity</u> represents the integer number of full pseudorange modulus divisions (599,584.916 m) of the raw L1 pseudorange measurement

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF045	GLONASS L1 CNR	0-63.75 dB-Hz	0.25 dB-Hz	uint8	The <u>GLONASS L1 CNR</u> measurements provide the reference station's estimate of the carrier-to-noise ratio of the satellite's signal in dB-Hz. The value "0" means that the CNR measurement is not computed.
DF046	GLONASS L2 Code Indicator			bit(2)	The <u>GLONASS L2 Code Indicator</u> depicts which L2 code is processed by the reference station. 0= C/A code 1= P code 2, 3 Reserved
DF047	GLONASS L2-L1 Pseudorange Difference	± 163.82 m (See Data Field Note)	0.02m	int14	The <u>GLONASS L2-L1 Pseudorange Difference</u> field is utilized, rather than the full L2 pseudorange, in order to reduce the message length. The receiver must reconstruct the L2 code phase pseudorange by using the following formula: (GLONASS L2 pseudorange measurement) = (L1 pseudorange as reconstructed from L1 pseudorange field) + (L2-L1 pseudorange field) Note: A bit pattern equivalent to 2000h (-163.84) means that there is no valid L2 code available, or that the value exceeds the allowed range

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF048	GLONASS L2 PhaseRange – L1 Pseudorange	± 262.1435 m (See Data Field Note)	0.0005 m	int20	<p>The <u>GLONASS L2 PhaseRange - L1 Pseudorange</u> field provides the information necessary to determine the L2 phase measurement. Note that the PhaseRange defined here has the same sign as the pseudorange. The PhaseRange has much higher resolution than the pseudorange, so that providing this field is just a numerical technique to reduce the length of the message. At start up and after each cycle slip, the initial ambiguity is reset and chosen so that the L2 PhaseRange should match the L1 Pseudorange as closely as possible (i.e., within 1/2 L2 cycle) while not destroying the integer nature of the original carrier phase observation.</p> <p>The Full GLONASS L2 PhaseRange is constructed as follows (all quantities in units of meters):</p> $(\text{Full L2 PhaseRange}) = (\text{L1 pseudorange as reconstructed from L1 pseudorange field}) + (\text{GLONASS L2 PhaseRange - L1 Pseudorange field})$ <p>Certain ionospheric conditions might cause the <u>GLONASS L2 PhaseRange – L1 Pseudorange</u> to diverge over time across the range limits defined. Under these circumstances the computed value needs to be adjusted (rolled over) by the equivalent of 1500 cycles in order to bring the value back within the range.</p> <p>Note: A bit pattern equivalent to 80000h in this field indicates an invalid carrier phase measurement that should not be processed by the mobile receiver. This indication may be used at low signal levels where carrier tracking is temporarily lost, but code tracking is still possible.</p>
DF049	GLONASS L2 Lock Time Indicator	See Table 3.4-2		uint7	The <u>GLONASS L2 Lock Time Indicator</u> provides a measure of the amount of time that has elapsed during which the Reference Station receiver has maintained continuous lock on that satellite signal. If a cycle slip occurs during the previous measurement cycle, the lock indicator will be reset to zero.
DF050	GLONASS L2 CNR	0-63.75 dB-Hz	0.25 dB-Hz	uint8	The <u>GLONASS L2 CNR</u> measurements provide the reference station's estimate of the carrier-to-noise ratio of the satellite's signal in dB-Hz. The value "0" means that the CNR measurement is not computed.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF051	Modified Julian Day (MJD) Number	0-65,535 days	1 day	uint16	<u>Modified Julian Day number (MJD)</u> is the continuous count of day numbers since November 17, 1858 midnight. For example, the first day in GPS week 0 has MJD 44244. The full MJD number shall always be transmitted. At this point in time the rollover of the MJD is quite far away in time, but experience with the Y2K problem showed that the actual life of software and applications can be considerably longer than expected. Therefore, it is foreseen to have a rollover of the MJD in calendar year 2038. At day 65,536 MJD the counter will start at 0 again.
DF052	Seconds of Day (UTC)	0-86,400 s	1 second	uint17	<u>Seconds Of Day (UTC)</u> 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 that a leap second has been issued.
DF053	Number of Message ID Announcements to Follow (N_m)	0-31	1	uint5	The <u>Number of Message ID Announcements</u> to follow informs the receiver of the number of message types and the frequency of their broadcast by the reference station.
DF054	Leap Seconds, GPS-UTC	0-254 s	1 second	uint8	See the GPS/SPS Signal Specification, available from the U.S. Coast Guard Navigation Information Service. 255 indicates that the value is not provided.
DF055	Message ID	0-4095	1	uint12	Each announcement lists the <u>Message ID</u> as transmitted by the reference station.
DF056	Message Sync Flag			bit(1)	0=Asynchronous – not transmitted on a regular basis 1=Synchronous – scheduled for transmission at regular intervals
DF057	Message Transmission Interval	0-6,553.5 s	0.1 seconds	uint16	Each announcement lists the <u>Message Transmission Interval</u> as transmitted by the reference station. If asynchronous, the transmission interval is approximate.
DF058	Number of Auxiliary Stations Transmitted	0 – 31	1	uint5	Number of Auxiliary Reference Stations transmitted in conjunction with designated Master Reference Station. Defines the number of different messages received of one type.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF059	Network ID	0 - 255	1	uint8	Network ID defines the network and the source of the particular set of reference stations and their observation information belongs to. The service provider should ensure that the Network ID is unique in the region serviced. The Network ID indicates an area and its reference stations where the service providers will provide a homogenous solution with leveled integer ambiguities between its reference stations. In general the area indicated by Network ID will comprise one subnetwork with a unique Subnetwork ID. (See description on how to use Network IDs and Subnetwork IDs in Section 3.5.6.).
DF060	Master Reference Station ID	0 – 4095	1	uint12	Station ID of Master Reference Station. The Master Reference Station must have the identical ID as one of the reference stations used within the same data stream for providing observation or correction information. The Master Auxiliary Concept allows in principle for several Master Reference Stations in the same data stream. Every Master Reference Station would require a separate raw observation message transmitted for the identical reference station. However for the current version of the standard it is recommended to have only one Master Reference Station in a data stream (see also Section 3.1.5).
DF061	Auxiliary Reference Station ID	0 – 4095	1	uint12	Station ID to identify Auxiliary Reference Station used to derive attached information.
DF062	Aux-Master Delta Latitude	± 13.1071 degrees	25×10^{-6} degrees	int20	Delta value in latitude of Antenna Reference Point of “Auxiliary Reference Station minus Master Reference Station” in geographical coordinates based on GRS80 ellipsoid parameters for the same ECEF system as used in message 1005 or 1006 within the same data stream. Note: in severe ionospheric conditions it may not be possible to provide complete service over the entire allowed range, because Ionospheric Correction Differences may exceed the allowed range of DF069.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF063	Aux-Master Delta Longitude	± 26.2142 degrees	25×10^{-6} degrees	int21	Delta value in longitude of Antenna Reference Point of “Auxiliary Reference Station minus Master Reference Station” in geographical coordinates based on GRS80 ellipsoid parameters for the same ECEF system as used in message 1005 or 1006 within the same data stream. Note: in severe ionospheric conditions it may not be possible to provide complete service over the entire allowed range, because Ionospheric Correction Differences may exceed the allowed range of DF069.
DF064	Aux-Master Delta Height	± 4194.303 m	1 mm	int23	Delta value in ellipsoidal height of Antenna Reference Point of “Auxiliary Reference Station minus Master Reference Station” in geographical coordinates based on GRS80 ellipsoid parameters for the same ECEF system as used in message 1005 or 1006 within the same data stream.
DF065	GPS Epoch Time (GPS TOW)	0 - 603,799.9 sec	0.1 sec	uint23	Epoch time of observations used to derive correction differences
DF066	GPS Multiple Message Indicator	0-1	1	bit(1)	Set to 1 in case messages with the same Message Number and Epoch Time will be transmitted in sequence. Set to 0 for last message of a sequence.
DF067	# of GPS Satellites	0 - 15	1	uint4	Number of correction differences for GPS satellites contained in message. Only one message per Auxiliary-Master Reference Station pair and Epoch Time is allowed. Each message shall contain respective correction differences for all satellites tracked at the relevant Master-Auxiliary Reference Station combination
DF068	GPS Satellite ID	1 – 32	1	uint6	GPS Satellite ID's only

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF069	GPS Ionospheric Carrier Phase Correction Difference	±32.767 m	0.5 mm	int17	<p>Ionospheric Carrier Phase Correction Difference (ICPCD) is the Correction Difference for ionospheric part calculated based on integer leveled L1 and L2 correction differences (L1CD and L2CD).</p> $ICPCD = \frac{f_2^2}{f_2^2 - f_1^2} L1CD - \frac{f_2^2}{f_2^2 - f_1^2} L2CD$ <p>L1CD, L2CD, and ICPCD are presented in meters. (See discussion of L1 and L2 corrections in Section 3.5.6.)</p> <p>In extreme conditions the value of this field may lie outside the specified range. If this happens, the data block for the specific satellite containing this field (Tables 3.5-18 & 20) should not be transmitted.</p>
DF070	GPS Geometric Carrier Phase Correction Difference	±32.767 m	0.5 mm	int17	<p>Geometric Carrier Phase Correction Difference (GCPD) is the Correction Difference for geometric part calculated based on integer leveled L1 and L2 correction differences (L1CD and L2CD).</p> $GCPD = \frac{f_1^2}{f_1^2 - f_2^2} L1CD - \frac{f_1^2}{f_1^2 - f_2^2} L2CD$ <p>L1CD, L2CD, and ICPCD are presented in meters. (See discussion of L1 and L2 corrections in Section 3.5.6.)</p>
DF071	GPS IODE		1	bit(8)	IODE value of broadcast ephemeris used for calculation of Correction Differences.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF072	Subnetwork ID	0 – 15		uint4	<p>Subnetwork ID identifies the subnetwork of a network identified by Network ID. In general the area indicated by Network ID will consist of one subnetwork. The Subnetwork ID indicates the actual solution number of integer ambiguity level (see the description of Integer Ambiguity Level in Section 3.5.6). If one network has only one subnetwork, this indicates that an ambiguity level throughout the whole network is established. In case of problems it might not be possible to have one homogenous integer ambiguity leveled solution throughout the whole network. The solution might break up into several homogeneous solutions, which can be indicated and distinguished by separate Subnetwork IDs. Every independent homogeneous integer ambiguity leveled solution needs to have an independent Subnetwork ID. Master Reference Stations with different Subnetwork IDs indicate that no hand-over from one to another Master Reference Station is possible since the solutions are not consistent and have no common stations. (See description on how to use Network IDs and Subnetwork IDs in Section 3.5.6. or Appendix A.1.)</p> <p>Note: Subnetwork ID's greater than "0" should be utilized only if the associated messages for Master Reference Station observations (1001 through 1004) are brought to the same Ambiguity Level. It is recommended that this field be set to 0" for now. In the future a Subnetwork ID of "0" will indicate that corresponding raw data streams are not ambiguity-leveled.</p> <p>Note: for Version 10403.1 of the standard, only one Master Reference Station with its associated Auxiliary Stations should be used in a single data stream. The result of this restriction is that Subnetwork ID's may not be needed. Future versions are expected to support Subnetwork ID's.</p>
DF073	RESERVED for Provider ID	0 – 255		uint8	Unique ID identifying a service provider for a region. Service providers have to make that they are using a unique ID that is not used by another service provider in the region.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF074	GPS Ambiguity Status Flag	0 – 3		bit(2)	0 reserved for future use (artificial observations) 1 Correct Integer Ambiguity Level for L1 and L2 2 Correct Integer Ambiguity Level for L1-L2 widelane 3 Uncertain Integer Ambiguity Level. Only a likely guess is used. (See the description of Correct Integer Ambiguity Level and Ambiguity Status Flag in Section 3.5.6.)
DF075	GPS Non Sync Count	0 – 7		uint3	Whenever an unrecoverable cycle slip occurs this count shall be increased. The counter shall not be increased more than once per minute. (See the discussion of cycle slips and ambiguity levels in Section 3.5.6)
DF076	GPS Week number	0 -1023	1 week	uint10	GPS week number. Roll-over every 1024 weeks starting from Midnight on the night of January 5/Morning January 6, 1980
DF077	GPS SV Acc. (URA)		N/A	bit(4)	meters; see GPS SPS Signal Spec, 2.4.3.2
DF078	GPS CODE ON L2	0-3	1	bit(2)	00 = reserved; 01 = P code ON; 10 = C/A code ON; 11 = L2C ON
DF079	GPS IDOT	<i>See Note 1</i>	2^{-43}	int14	semi-circles/sec
DF080	GPS IODE	0-255	1	uint8	unitless; see GPS SPS Signal Spec, 2.4.4.2
DF081	GPS t_{oc}	607,784	2^4	uint16	seconds
DF082	GPS a_{f2}	<i>See Note 1</i>	2^{-55}	int8	sec/sec ²
DF083	GPS a_{fl}	<i>See Note 1</i>	2^{-43}	int16	sec/sec
DF084	GPS a_{f0}	<i>See Note 1</i>	2^{-31}	int22	seconds
DF085	GPS IODC	0-1023	1	uint10	unitless. The 8 LSBs of IODC contains the same bits and sequence as those in IODE; see GPS SPS Signal Spec, 2.4.3.4.
DF086	GPS C_{rs}	<i>See Note 1</i>	2^{-5}	int16	meters

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF087	GPS Δn (DELTA n)	<i>See Note 1</i>	2^{-43}	int16	semi-circles/sec
DF088	GPS M_0	<i>See Note 1</i>	2^{-31}	int32	semi-circles
DF089	GPS C_{uc}	<i>See Note 1</i>	2^{-29}	int16	radians
DF090	GPS Eccentricity (e)	0.03	2^{-33}	uint32	unitless
DF091	GPS C_{us}	<i>See Note 1</i>	2^{-29}	int16	radians
DF092	GPS $(A)^{1/2}$	<i>See Note 1</i>	2^{-19}	uint32	$\text{meters}^{1/2}$
DF093	GPS t_{oe}	604,784	2^4	uint16	seconds
DF094	GPS C_{ic}	<i>See Note 1</i>	2^{-29}	int16	radians
DF095	GPS Ω_0 (OMEGA) ₀	<i>See Note 1</i>	2^{-31}	int32	semi-circles
DF096	GPS C_{is}	<i>See Note 1</i>	2^{-29}	int16	radians
DF097	GPS i_0	<i>See Note 1</i>	2^{-31}	int32	semi-circles
DF098	GPS C_{rc}	<i>See Note 1</i>	2^{-5}	int16	meters
DF099	GPS ω (Argument of Perigee)	<i>See Note 1</i>	2^{-31}	int32	semi-circles
DF100	GPS OMEGADOT (Rate of Right Ascension)	<i>See Note 1</i>	2^{-43}	int24	semi-circles/sec
DF101	GPS t_{GD}	<i>See Note 1</i>	2^{-31}	int8	seconds

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF102	GPS SV HEALTH	See GPS SPS Signal Spec, 2.4.5.3	1	uint6	MSB: 0 = all NAV data are OK; 1 = some or all NAV data are bad. See GPS SPS Signal Spec, 2.4.3.3.
DF103	GPS L2 P data flag	Subframe 1, Word 4, Bit 1	1	bit(1)	0: L2 P-Code NAV data ON 1: L2 P-Code NAV data OFF
DF104	GLONASS almanac health			bit(1)	GLONASS almanac health (C _n word)
DF105	GLONASS almanac health availability indicator			bit(1)	0= GLONASS almanac has not been received: GLONASS almanac health is not available; 1= GLONASS almanac has been received: GLONASS almanac health is available;
DF106	GLONASS P1			bit(2)	GLONASS P1 word
DF107	GLONASS t _k	bits 11-7: 0-23 bits 6-1: 0-59 bit 0: 0-1		bit(12)	Time referenced to the beginning of GLONASS subframe within the current day. The integer number of hours elapsed since the beginning of current day occupies 5 MSB. The integer number of minutes occupies next six bits. The number of thirty-second intervals occupies the LSB.
DF108	GLONASS MSB of B _n word			bit(1)	GLONASS MSB of B _n word. It contains the ephemeris health flag.
DF109	GLONASS P2			bit(1)	GLONASS P2 word
DF110	GLONASS t _b	1-95	15 minutes	uint7	Time to which GLONASS navigation data are referenced.
DF111	GLONASS x _n (t _b), first derivative	±4.3 km/s	±2 ⁻²⁰ km/s	intS24	GLONASS ECEF-X component of satellite velocity vector in PZ-90 datum
DF112	GLONASS x _n (t _b)	±27000 km	±2 ⁻¹¹ km	intS27	GLONASS ECEF-X component of satellite coordinates in PZ-90 datum

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF113	GLONASS $x_n(t_b)$, second derivative	$\pm 6.2 \times 10^{-9}$ km/s	$\pm 2^{-30}$ km/s ²	intS5	GLONASS ECEF-X component of satellite acceleration in PZ-90 datum
DF114	GLONASS $y_n(t_b)$, first derivative	± 4.3 km/s	$\pm 2^{-20}$ km/s	intS24	GLONASS ECEF-Y component of satellite velocity vector in PZ-90 datum
DF115	GLONASS $y_n(t_b)$	± 27000 km	$\pm 2^{-11}$ km	intS27	GLONASS ECEF-Y component of satellite coordinates in PZ-90 datum
DF116	GLONASS $y_n(t_b)$, second derivative	$\pm 6.2 \times 10^{-9}$ km/s	$\pm 2^{-30}$ km/s ²	intS5	GLONASS ECEF-Y component of satellite acceleration in PZ-90 datum
DF117	GLONASS $z_n(t_b)$, first derivative	± 4.3 km/s	$\pm 2^{-20}$ km/s	intS24	GLONASS ECEF-Z component of satellite velocity vector in PZ-90 datum
DF118	GLONASS $z_n(t_b)$	± 27000 km	$\pm 2^{-11}$ km	intS27	GLONASS ECEF-Z component of satellite coordinates in PZ-90 datum
DF119	GLONASS $z_n(t_b)$, second derivative	$\pm 6.2 \times 10^{-9}$ km/s	$\pm 2^{-30}$ km/s ²	intS5	GLONASS ECEF-Z component of satellite acceleration in PZ-90 datum
DF120	GLONASS P3			bit(1)	GLONASS P3 word
DF121	GLONASS $\gamma_n(t_b)$	$\pm 2^{-30}$	2^{-40}	intS11	GLONASS relative deviation of predicted satellite carrier frequency from nominal value
DF122	GLONASS-M P	0-3		bit(2)	GLONASS-M P word
DF123	GLONASS-M l_n (third string)			bit(1)	GLONASS-M l_n word extracted from third string of the subframe
DF124	GLONASS $\tau_n(t_b)$	$\pm 2^{-9}$ seconds	2^{-30}	intS22	GLONASS correction to the satellite time relative to GLONASS system time
DF125	GLONASS-M $\Delta\tau_n$	$\pm 13.97 \times 10^{-9}$ seconds	2^{-30}	intS5	GLONASS time difference between navigation RF signal transmitted in L2 sub-band and navigation RF signal transmitted in L1 sub-band
DF126	GLONASS E_n	0-31 days	1 day	uint5	The age of GLONASS navigation data
DF127	GLONASS-M P4			bit(1)	GLONASS-M P4 word

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF128	GLONASS-M F_T	0-15		uint4	GLONASS-M predicted satellite user range accuracy at time t_b
DF129	GLONASS-M N_T	1-1461	1 day	uint11	GLONASS calendar number of day within four-year interval starting from the 1-st of January in a leap year. Note. For GLONASS satellites this data field (if it is not equal to zero) may contain computed calendar number of day that corresponds to the parameter t_b .
DF130	GLONASS-M M	0-3		bit(2)	Type of GLONASS satellite. If this data field contains “01”, the satellite is GLONASS-M. Correspondingly, all GLONASS-M data fields are valid. If this parameter equals “00”, GLONASS-M parameters are not valid, thus they may contain arbitrary values.
DF131	GLONASS The Availability of Additional Data			bit(1)	The rest parameters of GLONASS ephemeris message contain data (data fields DF132-DF136) extracted from the fifth string of the subframe. These parameters do not belong to predefined ephemeris data. Nevertheless, they can be useful for positioning and timing. Given flag defines whether the parameters are available (=1) in the message. If this flag is set to zero, DF132-DF136 may contain arbitrary values.
DF132	GLONASS N^A	1-1461	1 day	uint11	GLONASS calendar number of day within the four-year period to which τ_c is referenced.
DF133	GLONASS τ_c	± 1 second	2^{-31}	intS32	Difference between GLONASS system time and UTC(SU). This parameter is referenced to the beginning of day N^A .
DF134	GLONASS-M N_4	1-31	4-years interval	uint5	GLONASS four-year interval number starting from 1996
DF135	GLONASS-M τ_{GPS}	$\pm 1.9 \cdot 10^{-3}$ seconds	2^{-31}	intS22	Correction to GPS system time relative to GLONASS system time.
DF136	GLONASS-M l_n (fifth string)			bit(1)	GLONASS-M l_n word extracted from fifth string of the subframe
DF137	GPS Fit Interval	Subframe 2, Word 10, Bit 17	1	bit(1)	0: curve-fit interval is 4 hours 1: curve-fit is greater than 4 hours

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF138	Number of Characters to Follow	0-127	1 character	uint7	Provides the number of fully formed Unicode characters in the message text. It is not necessarily the number of bytes in the string.
DF139	Number of UTF-8 Code Units	0-255	1 byte	uint8	The number of UTF-8 Character Code Units in the message.
DF140	UTF-8 Character Code Units			utf8(n)	Code units of a Unicode 8-bit string.
DF141	Reference-Station Indicator			bit(1)	<p>0: Real, Physical Reference Station 1: Non-Physical or Computed Reference Station</p> <p>Note: A Non-Physical or Computed Reference Station is typically calculated based on information from a network of reference stations. Different approaches have been established over years. The Non-Physical or Computed Reference Stations are sometimes trademarked and may not be compatible. Examples of these names are “Virtual Reference Stations”, “Pseudo-Reference Stations”, and “Individualized Reference Stations”.</p>
DF142	Single Receiver Oscillator Indicator			bit(1)	<p>0: Indicates that all raw data observations in messages 1001-1004 and 1009-1012 may be measured at different instants. This indicator should be set to “0” unless all the conditions for “1” are clearly met.</p> <p>1: Indicates that all raw data observations in messages 1001-1004 and 1009-1012 are measured at the same instant, as described in Section 3.1.4.</p>

Note 1: Effective range is the maximum range attainable with the indicated bit allocation and scale factor.

Table 3.4-2. Lock Time Indicator, Data Fields DF013, DF019, DF043, DF049 (Note 1)

<i>Indicator (i)</i>	<i>Minimum Lock Time (s)</i>	<i>Range of Indicated Lock Times</i>
0-23	i	$0 < lock\ time < 24$
24-47	$i \cdot 2 - 24$	$24 \leq lock\ time < 72$
48-71	$i \cdot 4 - 120$	$72 \leq lock\ time < 168$
72-95	$i \cdot 8 - 408$	$168 \leq lock\ time < 360$
96-119	$i \cdot 16 - 1176$	$360 \leq lock\ time < 744$
120-126	$i \cdot 32 - 3096$	$744 \leq lock\ time < 937$
127	---	$lock\ time \geq 937$

Note 1 - Determining Loss of Lock: In normal operation, a cycle slip will be evident when the Minimum Lock Time (MLT) has decreased in value. For long time gaps between messages, such as from a radio outage, extra steps should be taken on the rover to safeguard against missed cycle slips.

Table 3.4-3. SBAS PRN Codes, Data Fields DF009, DF038

SBAS Code	GPS/GLONASS Satellite ID	SBAS Code	GPS/GLONASS Satellite ID	SBAS Code	GPS/GLONASS Satellite ID
120	40	127	47	134	54
121	41	128	48	135	55
122	42	129	49	136	56
123	43	130	50	137	57
124	44	131	51	138	58
125	45	132	52		
126	46	133	53		

Table 3.4-4. Carrier Smoothing Interval of Code Phase, DF008 and DF037

<i>Indicator</i>	<i>Smoothing Interval</i>
000 (0)	<i>No smoothing</i>
001 (1)	< 30 s
010 (2)	30-60 s
011 (3)	1-2 min
100 (4)	2-4 min
101 (5)	4-8 min
110 (6)	>8 min
111 (7)	<i>Unlimited smoothing interval</i>

Table 3.4-5. GLONASS Carrier Frequencies in L1 and L2 Bands

Satellite Frequency Channel Indicator	No. of channel	Nominal value of frequency in L1 Band, MHz	Nominal value of frequency in L2 Band, MHz
0	-07	1598.0625	1242.9375
1	-06	1598.6250	1243.3750
2	-05	1599.1875	1243.8125
3	-04	1599.7500	1244.2500
4	-03	1600.3125	1244.6875
5	-02	1600.8750	1245.1250
6	-01	1601.4375	1245.5625
7	00	1602.0	1246.0
8	01	1602.5625	1246.4375
9	02	1603.125	1246.875
10	03	1603.6875	1247.3125
11	04	1604.25	1247.75
12	05	1604.8125	1248.1875
13	06	1605.375	1248.625
14	07	1605.9375	1249.0625
15	08	1606.5	1249.5
16	09	1607.0625	1249.9375
17	10	1607.625	1250.375
18	11	1608.1875	1250.8125
19	12	1608.75	1251.25
20	13	1609.3125	1251.6875

3.5 Messages

This section describes the messages. Each message contains a specific set of data fields, sometimes repeated, as in the case where information on several satellites is provided. The data fields are broadcast in the order listed. Multi-byte values are expressed with the most significant byte transmitted first and the least significant byte transmitted last. Unlike version 2 of the SC-104 standard (RTCM 10402.x), there is no reversal of bits within a byte.

3.5.1 GPS RTK Messages

Tables 3.5-1 through 3.5-5 provide the contents of the GPS real-time kinematic (RTK) messages, which are based on raw data. From these data, valid RINEX files can be obtained, although when the Pseudorange Modulus Ambiguity (DF014, DF044) is not provided, ephemeris and clock information will be required to make the conversion. As a consequence, this set of messages offers a high level of interoperability and compatibility with standard surveying practices. If GPS RTK Messages (1001-1004) are used in a Network RTK application, their content representing L1 and L2 PhaseRanges might be altered by correcting for antenna phase center variations (see also 3.1.6). However the properties of the PhaseRanges have to be indicated properly with an Antenna Description message. Note: observations corrected for antenna phase center variations are no longer compatible with RINEX standard definition.

Table 3.5-1. Contents of the Message Header, Types 1001, 1002, 1003, 1004: GPS RTK Messages

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number (e.g., “1001”= 0011 1110 1001)	DF002	uint12	12
Reference Station ID	DF003	uint12	12
GPS Epoch Time (TOW)	DF004	uint30	30
Synchronous GNSS Flag	DF005	bit(1)	1
No. of GPS Satellite Signals Processed	DF006	uint5	5
GPS Divergence-free Smoothing Indicator	DF007	bit(1)	1
GPS Smoothing Interval	DF008	bit(3)	3
TOTAL			64

The Type 1001 Message supports single-frequency RTK operation. It does not include an indication of the satellite carrier-to-noise ratio as measured by the reference station.

Table 3.5-2. Contents of the Satellite-Specific Portion of a Type 1001 Message, Each Satellite – GPS Basic RTK, L1 Only

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GPS Satellite ID	DF009	uint6	6
GPS L1 Code Indicator	DF010	bit(1)	1
GPS L1 Pseudorange	DF011	uint24	24
GPS L1 PhaseRange – L1 Pseudorange	DF012	int20	20
GPS L1 Lock time Indicator	DF013	uint7	7
<i>TOTAL</i>			<i>58</i>

The Type 1002 Message supports single-frequency RTK operation, and includes an indication of the satellite carrier-to-noise (CNR) as measured by the reference station. Since the CNR does not usually change from measurement to measurement, this message type can be mixed with the Type 1001, and used primarily when a satellite CNR changes, thus saving broadcast link throughput.

Table 3.5-3. Contents of the Satellite-Specific Portion of a Type 1002 Message, Each Satellite – GPS Extended RTK, L1 Only

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GPS Satellite ID	DF009	uint6	6
GPS L1 Code Indicator	DF010	bit(1)	1
GPS L1 Pseudorange	DF011	uint24	24
GPS L1 PhaseRange – L1 Pseudorange	DF012	int20	20
GPS L1 Lock time Indicator	DF013	uint7	7
GPS Integer L1 Pseudorange Modulus Ambiguity	DF014	uint8	8
GPS L1 CNR	DF015	uint8	8
<i>TOTAL</i>			74

The Type 1003 Message supports dual-frequency RTK operation, but does not include an indication of the satellite carrier-to-noise (CNR) as measured by the reference station.

Table 3.5-4. Contents of the Satellite-Specific Portion of a Type 1003 Message, Each Satellite – GPS Basic RTK, L1 & L2

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GPS Satellite ID	DF009	uint6	6
GPS L1 Code Indicator	DF010	bit(1)	1
GPS L1 Pseudorange	DF011	uint24	24
GPS L1 PhaseRange – L1 Pseudorange	DF012	int20	20
GPS L1 Lock time Indicator	DF013	uint7	7
GPS L2 Code Indicator	DF016	bit(2)	2
GPS L2-L1 Pseudorange Difference	DF017	int14	14
GPS L2 PhaseRange – L1 Pseudorange	DF018	int20	20
GPS L2 Lock time Indicator	DF019	uint7	7
<i>TOTAL</i>			<i>101</i>

The Type 1004 Message supports dual-frequency RTK operation, and includes an indication of the satellite carrier-to-noise (CNR) as measured by the reference station. Since the CNR does not usually change from measurement to measurement, this message type can be mixed with the Type 1003, and used only when a satellite CNR changes, thus saving broadcast link throughput.

Table 3.5-5. Contents of the Satellite-Specific Portion of a Type 1004 Message, Each Satellite – GPS Extended RTK, L1 & L2

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GPS Satellite ID	DF009	uint6	6
GPS L1 Code Indicator	DF010	bit(1)	1
GPS L1 Pseudorange	DF011	uint24	24
GPS L1 PhaseRange – L1 Pseudorange	DF012	int20	20
GPS L1 Lock time Indicator	DF013	uint7	7
GPS Integer L1 Pseudorange Modulus Ambiguity	DF014	uint8	8
GPS L1 CNR	DF015	uint8	8
GPS L2 Code Indicator	DF016	bit(2)	2
GPS L2-L1 Pseudorange Difference	DF017	int14	14
GPS L2 PhaseRange – L1 Pseudorange	DF018	int20	20
GPS L2 Lock time Indicator	DF019	uint7	7
GPS L2 CNR	DF020	uint8	8
<i>TOTAL</i>			<i>125</i>

3.5.2 *Stationary Antenna Reference Point Messages*

Message Type 1005 (see Table 3.5-6) provides the earth-centered, earth-fixed (ECEF) coordinates of the antenna reference point (ARP) for a stationary reference station. No height above a monument is provided.

Message Type 1006 (see Table 3.5-7) provides all the same information as Message Type 1005, but additionally provides the height of the ARP above a survey monument.

These messages are designed for GPS operation, but are equally applicable to GLONASS and the future Galileo, and system identification bits are reserved for them.

The phase center is not a point in space that can be used as a standard reference. For one thing, it varies with frequency. In addition, the location of L1 phase center is strongly dependent on the antenna calibration method used during the calibration process. Therefore, the location of the L1 phase center may vary between different calibration tables for the same antenna model. Message Types 1005 and 1006 avoid the phase center problem by utilizing the Antenna Reference Point, which is used throughout the International GPS Service (IGS).

Message Types 1005 and 1006 contain the coordinates of the installed antenna's ARP in Earth-Center-Earth-Fixed (ECEF) coordinates -- datum definitions are not yet supported. The coordinates always refer to a physical point on the antenna, typically the bottom of the antenna mounting surface.

Table 3.5-6. Contents of the Type 1005 Message – Stationary Antenna Reference Point, No Height Information

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number (“1005”= 0011 1110 1101)	DF002	uint12	12
Reference Station ID	DF003	uint12	12
Reserved for ITRF Realization Year	DF021	uint6	6
GPS Indicator	DF022	bit(1)	1
GLONASS Indicator	DF023	bit(1)	1
Reserved for Galileo Indicator	DF024	bit(1)	1
Reference-Station Indicator	DF141	bit(1)	1
Antenna Reference Point ECEF-X	DF025	int38	38
Single Receiver Oscillator Indicator	DF142	bit(1)	1
Reserved	DF001	bit(1)	1
Antenna Reference Point ECEF-Y	DF026	int38	38
Reserved	DF001	bit(2)	2
Antenna Reference Point ECEF-Z	DF027	int38	38
TOTAL			152

Table 3.5-7. Contents of the Type 1006 Message – Stationary Antenna Reference Point, with Height Information

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number (“1006”= 0011 1110 1110)	DF002	uint12	12
Reference Station ID	DF003	uint12	12
Reserved for ITRF Realization Year	DF021	uint6	6
GPS Indicator	DF022	bit(1)	1
GLONASS Indicator	DF023	bit(1)	1
Reserved for Galileo Indicator	DF024	bit(1)	1
Reference-Station Indicator	DF141	bit(1)	1
Antenna Reference Point ECEF-X	DF025	int38	38
Single Receiver Oscillator Indicator	DF142	bit(1)	1
Reserved	DF001	bit(1)	1
Antenna Reference Point ECEF-Y	DF026	int38	38
Reserved	DF001	bit(2)	2
Antenna Reference Point ECEF-Z	DF027	int38	38
Antenna Height	DF028	uint16	16
<i>TOTAL</i>			<i>168</i>

3.5.3 Antenna Description Messages

Table 3.5-8 provides an ASCII descriptor of the reference station antenna. As noted for DF031 in Table 3.4-1, the International GPS Service (IGS) Central Bureau convention will be used most of the time, since it is universally accessible.

Table 3.5-9 provides the same information, plus the antenna serial number, which removes any ambiguity about the model number or production run.

The Committee adopted the naming convention from the IGS equipment-naming table as supplied by the International GPS Service Central Bureau (IGS CB). This table provides a unique antenna descriptor for antennas used for high-precision surveying type applications, which is utilized in the *Antenna Descriptor* (DF030). IGS limits the number of characters to 20 at this time, but the standard allows more characters for future extension.

The *Antenna Setup ID* (DF031) is a parameter for use by the service provider to indicate the particular reference station-antenna combination. "0" for this value means that the values of a standard model type calibration should be used. The *Antenna Serial Number* (DF033) is the individual antenna serial number as issued by the manufacturer of the antenna

Table 3.5-8. Contents of the Type 1007 Message – Antenna Descriptor

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number ("1007"=0011 1110 1111)	DF002	uint12	12	
Reference Station ID	DF003	uint12	12	
Descriptor Counter N	DF029	uint8	8	$N \leq 31$
Antenna Descriptor	DF030	char8(N)	$8*N$	
Antenna Setup ID	DF031	uint8	8	
TOTAL			$40+8*N$	

Table 3.5-9. Contents of the Type 1008 Message – Antenna Descriptor & Serial Number

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number (“1008”=0011 1111 0000)	DF002	uint12	12	
Reference Station ID	DF003	uint12	12	
Descriptor Counter N	DF029	uint8	8	
Antenna Descriptor	DF030	char8(N)	8*N	$N \leq 31$
Antenna Setup ID	DF031	uint8	8	
Serial Number Counter M	DF032	uint8	8	
Antenna Serial Number	DF033	char8(M)	8*M	$M \leq 31$
TOTAL			48+ 8*(M+N)	

3.5.4 GLONASS RTK Observables

Tables 3.5-9 through 3.5-14 provide the contents of the GLONASS real-time kinematic (RTK) messages, which are based on raw data. From these data, complete RINEX files can be obtained. As a consequence, this set of messages offers a high level of interoperability and compatibility with standard surveying practices. The service provider using these messages should also transmit an Antenna Reference Point message (Type 1005 or 1006) and an Antenna Descriptor message (Type 1007 or 1008). A provider of combined GPS-GLONASS service should provide completely independent sets of Observables. In addition, if the time tags of the GPS and GLONASS RTK data are synchronized, the Synchronous GNSS Flag should be used to connect the entire RTK data block.

Table 3.5-10 Contents of the Message Header, Types 1009 through 1012: GLONASS RTK Messages

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number (“1009”=0011 1111 0001)	DF002	uint12	12
Reference Station ID	DF003	uint12	12
GLONASS Epoch Time (t_k)	DF034	uint27	27
Synchronous GNSS Flag	DF005	bit(1)	1
No. of GLONASS Satellite Signals Processed	DF035	uint5	5
GLONASS Divergence-free Smoothing Indicator	DF036	bit(1)	1
GLONASS Smoothing Interval	DF037	bit(3)	3
TOTAL			61

The Type 1009 Message supports single-frequency RTK operation, but does not include an indication of the satellite carrier-to-noise (CNR) as measured by the reference station.

Table 3.5-11.
Contents of the Satellite-Specific Portion of a Type 1009 Message, Each Satellite – GLONASS Basic RTK, L1 Only

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GLONASS Satellite ID (Satellite Slot Number)	DF038	uint6	6
GLONASS Code Indicator	DF039	bit(1)	1
GLONASS Satellite Frequency Channel Number	DF040	uint5	5
GLONASS L1 Pseudorange	DF041	uint25	25
GLONASS L1 PhaseRange – L1 Pseudorange	DF042	int20	20
GLONASS L1 Lock time Indicator	DF043	uint7	7
<i>TOTAL</i>			<i>64</i>

The Type 1010 Message supports single-frequency RTK operation, and includes an indication of the satellite carrier-to-noise (CNR) as measured by the reference station. Since the CNR does not usually change from measurement to measurement, this message type can be mixed with the Type 1009, and used only when a satellite CNR changes, thus saving broadcast link throughput.

Table 3.5-12.
Contents of the Satellite-Specific Portion of a Type 1010 Message, Each Satellite – GLONASS Extended RTK, L1 Only

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GLONASS Satellite ID (Satellite Slot Number)	DF038	uint6	6
GLONASS L1 Code Indicator	DF039	bit(1)	1
GLONASS Satellite Frequency Channel Number	DF040	uint5	5
GLONASS L1 Pseudorange	DF041	uint25	25
GLONASS L1 PhaseRange – L1 Pseudorange	DF042	int20	20
GLONASS L1 Lock time Indicator	DF043	uint7	7
GLONASS Integer L1 Pseudorange Modulus Ambiguity	DF044	uint7	7
GLONASS L1 CNR	DF045	uint8	8
TOTAL			79

The Type 1011 Message supports dual-frequency RTK operation, but does not include an indication of the satellite carrier-to-noise (CNR) as measured by the reference station.

Table 3.5-13.
Contents of the Satellite-Specific Portion of a Type 1011 Message, Each Satellite – GLONASS Basic RTK, L1 & L2

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GLONASS Satellite ID (Satellite Slot Number)	DF038	uint6	6
GLONASS L1 Code Indicator	DF039	bit(1)	1
GLONASS Satellite Frequency Channel Number	DF040	uint5	5
GLONASS L1 Pseudorange	DF041	uint25	25
GLONASS L1 PhaseRange – L1 Pseudorange	DF042	int20	20
GLONASS L1 Lock time Indicator	DF043	uint7	7
GLONASS L2 Code Indicator	DF046	bit(2)	2
GLONASS L2-L1 Pseudorange Difference	DF047	uint14	14
GLONASS L2 PhaseRange – L1 Pseudorange	DF048	int20	20
GLONASS L2 Lock time Indicator	DF049	uint7	7
TOTAL			107

The Type 1012 Message supports dual-frequency RTK operation, and includes an indication of the satellite carrier-to-noise (CNR) as measured by the reference station. Since the CNR does not usually change from measurement to measurement, this message type can be mixed with the Type 1011, and used only when a satellite CNR changes, thus saving broadcast link throughput.

Table 3.5-14.
Contents of the Satellite-Specific Portion of a Type 1012 Message, Each Satellite – GLONASS Extended RTK, L1 & L2

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GLONASS Satellite ID (Satellite Slot Number)	DF038	uint6	6
GLONASS L1 Code Indicator	DF039	bit(1)	1
GLONASS Satellite Frequency Channel Number	DF040	uint5	5
GLONASS L1 Pseudorange	DF041	uint25	25
GLONASS L1 PhaseRange – L1 Pseudorange	DF042	int20	20
GLONASS L1 Lock time Indicator	DF043	uint7	7
GLONASS Integer L1 Pseudorange Modulus Ambiguity	DF044	uint7	7
GLONASS L1 CNR	DF045	uint8	8
GLONASS L2 Code Indicator	DF046	bit(2)	2
GLONASS L2-L1 Pseudorange Difference	DF047	uint14	14
GLONASS L2 PhaseRange – L1 Pseudorange	DF048	int20	20
GLONASS L2 Lock time Indicator	DF049	uint7	7
GLONASS L2 CNR	DF050	uint8	8
TOTAL			130

3.5.5 System Parameters

The complete list of record announcements summarizes all messages transmitted by the particular reference station.

3.5.15 Contents of the Type 1013 Message, System Parameters

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number	DF002	uint12	12
Reference Station ID	DF003	uint12	12
Modified Julian Day (MJD) Number	DF051	uint16	16
Seconds of Day (UTC)	DF052	uint17	17
No. of Message ID Announcements to Follow (N_m)	DF053	uint5	5
Leap Seconds, GPS-UTC	DF054	uint8	8
Message ID #1	DF055	uint12	12
Message #1 Sync Flag	DF056	bit(1)	1
Message #1 Transmission Interval	DF057	uint16	16
Message ID #2	DF055	uint12	12
Message #2 Sync Flag	DF056	bit(1)	1
Message #2 Transmission Interval	DF057	uint16	16
(Repeat until N_m sets)			
TOTAL			70+29* N_m

3.5.6 GPS Network RTK Correction Messages

The use of single reference stations to transmit RTK data is limited by the fact that the accuracy and reliability of integer ambiguity resolution deteriorates with increasing distance from the reference station. A powerful solution to this problem is offered by a synchronized network of RTK stations. Networks of reference stations mitigate the distance-dependency of RTK solutions. With such networks, a provider can generate measurement corrections for receivers operating within a large defined region, and this information can be supplied to the user in a standard format. As the current kinematic and high-accuracy message types 1001-1012 do not support an efficient use of data from multiple reference stations, new approaches must be developed to facilitate the valuable information afforded by networks of reference stations.

The standardization of network information and processing models is also necessary to reduce the size of the network RTK corrections, as well as the satellite-independent error information. A simplified approach of transmitting data from reference station networks to roving users is utilized below in the form of a new message set capable of supporting reference network operations.

Individual reference stations often support more than one network in a large region. A detailed description of how the message set below supports these networks is given below. The approach used here provides considerable flexibility for the service provider to support a wide variety of services within range of a large network of reference stations.

The principle of determining L1 and L2 corrections is defined in Version 2.3 (RTCM Paper 136-2001/SC104-STD – now designated as RTCM 10402.3) as 4.3.18 section B. However version 2.3 is defined for any type of geodetic carrier phase observation, while version 3 assumes clock adjusted carrier phase observations (see RTCM Paper 30-2004/SC104-STD or RTCM 10402.3 section 3.1.4).

The Correction Difference components have been split into a dispersive and a non-dispersive part. The dispersive Correction Difference is also called ionospheric Correction Difference, after its contributor. The opposite, the non-dispersive, is also called ionosphere-free Correction Difference or geometric Correction Difference, recognizing that it is not purely due to geometry because of the tropospheric contribution.

The L1 Correction (L1C) and the L2 Correction (L2C) can be determined in general by:

$$L1C_S = s_S - \Phi_{S,1}(t) - \frac{c}{f_1} N_{S,1} + t_{S,1} + A_{S,1} \text{, and}$$

$$L2C_s = s_s - \Phi_{s,2}(t) - \frac{c}{f_2} N_{s,2} + t_{s,2} + A_{s,2}, \text{ with}$$

s_s = Computed Geometric Range in meters between the ARP of station S and satellite

$\Phi_{S,1}(t)$	=	Phase Range Measurement in meters for station S, L1 (similarly for L2)
$\frac{c}{f_1} N_{S,1}$	=	Integer Ambiguity part scaled to meters, L1 (similarly for L2). The integer can be arbitrarily chosen for an initial measurement in order to bring the resulting Phase Correction within range of the field definition. For Network RTK the all-integer ambiguities have to be brought onto a common integer level. Therefore all values per-satellite and per-frequency have to be synchronized between reference stations.
$t_{S,1}, t_{S,2}$	=	Receiver clock term for the respective frequency of Phase Range Measurement
$A_{S,1}, A_{S,2}$	=	Antenna Offset and Phase Center Variation Correction for the respective frequency; the service provider has to ensure that the antenna phase center corrections does not introduce biases. (See also Section 3.1.6, "Proper Handling of Antenna Phase Center Variation Corrections")
f_1	=	L1 carrier frequency
f_2	=	L2 carrier frequency

Satellite and relativistic clock term have been neglected in the given formula. These terms cancel sufficiently in the inter-station single difference. A difference of the clock between both station receivers remains in the Correction Differences. However, the value common to all Correction Differences for every Master-Auxiliary Reference Station pair can be estimated and removed from the Correction Differences. These inter-station clock biases are also minimized for typical Network RTK applications. The clock difference term between reference stations in the L1 and L2 Correction Difference may be treated independently. Therefore clock effects may influence Ionospheric and Geometric Correction Differences. Nevertheless, this approach chosen is sufficient for general positioning approaches, since residual clock effects are removed in double differences. Proper treatment of antenna phase center corrections are crucial to avoid unrecoverable biases in Correction Differences (See also section 3.1.6, "Proper handling of antenna phase center variation corrections").

The L1 Correction Difference (L1CD) is calculated as the single-difference of the "Auxiliary Reference Station Carrier Phase Correction" minus "Master Reference Station Carrier Phase Correction".

$$L1CD = L1C_A - L1C_M$$

An alternate way of calculation is to carry out:

$$L1CD = \Delta s_{AM}(t) - \Delta \Phi_{AM,1}(t) - \frac{c}{f_1} \cdot \Delta N_{AM,1} + \Delta t_{AM,1} + \Delta A_{AM,1}$$

$\Delta\Phi_{AM,1}(t)$ = Single-differenced Phase Ranges of Auxiliary Reference Station A minus Master Reference Station M
 $\Delta s_{AM}(t)$ = Single-differenced slope distances between Satellite and reference station antenna of Auxiliary Reference Station A minus Master Reference Station M
 $\frac{c}{f_1} \cdot \Delta N_{AM,1}$ = Single-differenced Integer Ambiguity values of Auxiliary Reference Station A minus Master Reference Station M scaled to meters. In practice only double-differenced Integer Ambiguities can be fixed due to insufficient modeling of various error sources. The single-differenced Integer Ambiguities for a particular Auxiliary Reference Station minus Master Reference Station might incorporate an arbitrary Integer number. The number is arbitrary but common for all satellites and therefore is observed as a common clock error.
 $\Delta t_{AM,1}$ = Estimated single differenced receiver clock term on L1.
 $\Delta A_{AM,1}$ = Single-differenced antenna offset and PCV on L1

Similarly, the L2 Correction Difference (L2CD) is computed as follows:

$$L2CD = \Delta s_{AM}(t) - \Delta\Phi_{AM,2}(t) - \frac{c}{f_2} \cdot \Delta N_{AM,2} + \Delta t_{AM,2} + \Delta A_{AM,2}$$

Correct integer ambiguity resolution between reference stations is only possible on a double-difference basis. The correct set of double-differenced integer ambiguities is unique for a given data set. A common Integer Ambiguity Level indicates that Correction Differences are derived from a homogenous solution satisfying the double-difference requirement between all involved reference stations.

Correction Differences are typically based on integer-adjusted raw observation data. Certain rules must be observed to preserve the correctness of the double-difference requirement. In particular, introducing a cycle for one specific satellite-station combination must be compensated for by adjusting other satellite-station combinations in order to maintain a homogenous solution.

However, the Correction Differences are defined as single-differenced values between two reference stations. Therefore the introduction of a fixed number of cycles for the observations of one satellite for all reference stations throughout the whole network will not show up in the Correction Differences. Changing all observations for a specific reference station by a fixed number of cycles will change all Correction Differences. The number of introduced cycles will be absorbed by the clock bias estimation in the rover.

Two subsets of a network might satisfy the requirement of correct double-differenced Integer Ambiguities, without necessarily being on the same Integer Ambiguity Level since the choices of integers are arbitrary. As soon as a reference station has common Integer Ambiguity Levels with two subsets of a network these two subsets can be joined and brought to the same Integer Ambiguity Level. These two subsets will then form one subnetwork with the same Integer Ambiguity Level. If circumstances are such that not enough satellites with correct fixed Integer Ambiguities are available for one reference station or a number of reference stations connecting two subsets of a network, it is advisable to treat the subsets separately. Both subsets will be considered to form different subnetworks with different Integer Ambiguity Levels indicated by assigning different subnetwork ID's.

The Correct Integer Ambiguity Level L1-L2 widelane indicates that only the L1-L2 widelane is correctly fixed. The individual L1 and L2 integer ambiguities may contain integer offsets. The L1 and the L2 offsets will be the same.

Changing the Ambiguity Status Flag from 3 to 2, 3 to 1, or 2 to 1 without increasing the Non Sync Count indicates that the previous good guess of the integer ambiguity turned out to be the correct integer and the correctness of the integer has been approved by the networking software.

Unrecoverable cycle slips might occur for permanent reference station applications as well. If the Integer Ambiguity for the satellite with the cycle slip is on the Integer Ambiguity Level (see also the discussion above on Integer Ambiguity Level), the unrecoverable cycle will cause the loss of the Integer Ambiguity Level for the specific satellite, reference station, and frequency. Correction Difference information for this specific combination needs proper flagging in the Ambiguity Status Flag and increasing the Non Sync Count. The Non Sync Count must be increased if there is an unrecoverable cycle slip in a Correction Difference that is not on the Integer Ambiguity Level. Frequent cycle slips may cause problems with the counter's range. The Non Sync Count should not be increased more than once per minute in order to reduce counter roll-overs. Satellites with cycle slips more frequent than once per minute should not be transmitted.

Arbitrarily fixed, and therefore possibly non-correct integers, provide only sufficient information when the identical integers are used for a certain amount of time. An increase of the Non Sync Count will be associated with Ambiguity Status Flag of 3. In the continuation of the operation the networking software might prove that the arbitrarily chosen integers are actually on the correct integer ambiguity level. Under these circumstances the Ambiguity Status Flag might be changed to the appropriate status of 1 or 2. This is discussed further in Appendix A.1

Table 3.5-16 Contents of the Network Auxiliary Station Data Message 1014

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	1014
Network ID	DF059	uint8	8	
Subnetwork ID	DF072	uint4	4	
Number of Auxiliary Stations Transmitted	DF058	uint5	5	0 - 31
Master Reference Station ID	DF060	unit12	12	
Auxiliary Reference Station ID	DF061	uint12	12	
Aux-Master Delta Latitude	DF062	int20	20	
Aux-Master Delta Longitude	DF063	int21	21	
Aux-Master Delta Height	DF064	int23	23	
TOTAL			117	

Table 3.5-17 Contents of Header Network RTK -- Messages 1015, 1016 or 1017

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	1015, 1016 or 1017
Network ID	DF059	uint8	8	
Subnetwork ID	DF072	uint4	4	
GPS Epoch Time (GPS TOW)	DF065	uint23	23	
GPS Multiple Message Indicator	DF066	bit(1)	1	
Master Reference Station ID	DF060	uint12	12	
Auxiliary Reference Station ID	DF061	uint12	12	
# of GPS Sats	DF067	uint4	4	
TOTAL			76	

Table 3.5-18 Contents of Data Block for GPS Ionospheric Correction Differences 1015

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
GPS Ambiguity Status Flag	DF074	bit(2)	2	
GPS Non Sync Count	DF075	uint3	3	
GPS Ionospheric Carrier Phase Correction Difference	DF069	int17	17	
TOTAL			28	

Table 3.5-19 Contents of Data Block for GPS Geometric Correction Differences 1016

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
GPS Ambiguity Status Flag	DF074	bit(2)	2	
GPS Non Sync Count	DF075	uint3	3	
GPS Geometric Carrier Phase Correction Difference	DF070	int17	17	
GPS IODE	DF071	uint8	8	
TOTAL			36	

Table 3.5-20 Contents of Data Block for GPS Combined Geometric and Ionospheric Correction Differences 1017

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
GPS Ambiguity Status Flag	DF074	bit(2)	2	
GPS Non Sync Count	DF075	uint3	3	
GPS Geometric Carrier Phase Correction Difference	DF070	int17	17	
GPS IODE	DF071	uint8	8	
GPS Ionospheric Carrier Phase Correction Difference	DF069	int17	17	
TOTAL			53	

3.5.7 GPS Ephemerides

The GPS ephemeris message contains GPS satellite ephemeris information. This message could be broadcast in the event that the IODC does not match the IODE, which would require the differential reference station to base corrections on the previous good satellite ephemeris. This would allow the user equipment just entering the differential system to utilize the corrections being broadcast for that ephemeris, and would support the use of the satellite for differential navigation despite the fact that the satellite ephemeris was in error. It is anticipated that this message type would be broadcast every 2 minutes or so while this condition persisted. The schedule would be maintained until the satellite broadcast was corrected, or until the satellite dropped below the coverage area of the reference station.

Another use of the message is to assist user receivers to quickly acquire satellites. For example, if the user receiver has access to a wireless service with this message, rather than waiting until one satellite has been acquired and its almanac data processed, it can utilize the ephemeris information immediately.

All data fields have the same number of bits, the same scale factor and units defined in GPS SPS Signal Specification, Sections 2.4.3 and 2.4.4. The name of the data fields are also kept as close as possible to those defined in GPS SPS Signal Specification document for cross-reference.

Table 3.5-21. Contents of GPS Satellite Ephemeris Data, Message Type 1019

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	1019
GPS Satellite ID	DF009	uint6	6	
GPS Week Number	DF076	uint10	10	0 - 1023
GPS SV ACCURACY	DF077	uint4	4	See GPS SPS Signal Specification, 2.4.3
GPS CODE ON L2	DF078	bit(2)	2	00 = Reserved 01 = P code on 10 = C/A code on 11 = L2C on
GPS IDOT	DF079	int14	14	See GPS SPS Signal Specification, 2.4.3
GPS IODE	DF071	uint8	8	See GPS SPS Signal Specification, 2.4.3

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS t_{oc}	DF081	uint16	16	See GPS SPS Signal Specification, 2.4.3
GPS a_{f2}	DF082	int8	8	See GPS SPS Signal Specification, 2.4.3
GPS a_{f1}	DF083	int16	16	See GPS SPS Signal Specification, 2.4.3
GPS a_{f0}	DF084	int22	22	See GPS SPS Signal Specification, 2.4.3
GPS IODC	DF085	uint10	10	See GPS SPS Signal Specification, 2.4.3
GPS C_{rs}	DF086	int16	16	See GPS SPS Signal Specification, 2.4.3
GPS Δn (DELTA n)	DF087	int16	16	See GPS SPS Signal Specification, 2.4.3
GPS M_0	DF088	int32	32	See GPS SPS Signal Specification, 2.4.3
GPS C_{uc}	DF089	int16	16	See GPS SPS Signal Specification, 2.4.3
GPS Eccentricity (e)	DF090	uint32	32	See GPS SPS Signal Specification, 2.4.3
GPS C_{us}	DF091	int16	16	See GPS SPS Signal Specification, 2.4.3
GPS $(A)^{1/2}$	DF092	uint32	32	See GPS SPS Signal Specification, 2.4.3
GPS t_{oe}	DF093	uint16	16	See GPS SPS Signal Specification, 2.4.3
GPS C_{ic}	DF094	int16	16	See GPS SPS Signal Specification, 2.4.3
GPS Ω_0 (OMEGA) ₀	DF095	int32	32	See GPS SPS Signal Specification, 2.4.3
GPS C_{is}	DF096	int16	16	See GPS SPS Signal Specification, 2.4.3
GPS i_0	DF097	int32	32	See GPS SPS Signal Specification, 2.4.3
GPS C_{rc}	DF098	int16	16	See GPS SPS Signal Specification, 2.4.3
GPS ω (Argument of Perigee)	DF099	int32	32	See GPS SPS Signal Specification, 2.4.3
GPS OMEGADOT (Rate of Right Ascension)	DF100	int24	24	See GPS SPS Signal Specification, 2.4.3
GPS t_{GD}	DF101	int8	8	See GPS SPS Signal Specification, 2.4.3

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS SV HEALTH	DF102	uint6	6	See GPS SPS Signal Specification, 2.4.3
GPS L2 P data flag	DF103	bit(1)	1	0: L2 P-Code NAV data ON 1: L2 P-Code NAV data OFF
GPS Fit Interval	DF137	bit(1)	1	See GPS SPS Signal Specification, 2.4.3
<i>TOTAL</i>			<i>488</i>	

3.5.8 GLONASS Ephemerides

The GLONASS ephemeris message contains GLONASS satellite ephemeris information. One use of the message is to assist user receivers to quickly acquire satellites. For example, if the user receiver has access to a wireless service that distributes this message, it can utilize the ephemeris information immediately, rather than waiting until one satellite has been acquired and its almanac data processed. The GLONASS ephemeris message contains GLONASS satellite ephemeris information. This message could be broadcast in the event that an anomaly in new ephemeris data set is detected, which would require the differential reference station to base corrections on the previous good satellite ephemeris. This would allow the user equipment just entering the differential system to utilize the corrections being broadcast for that ephemeris, and would support the use of the satellite for differential navigation despite the fact that the satellite ephemeris was in error. It is anticipated that this message type would be broadcast every 2 minutes or so while this condition persisted. The schedule would be maintained until the satellite broadcast was corrected, or until the satellite dropped below the coverage area of the reference station.

The GLONASS ephemeris message contains GLONASS satellite ephemeris information. This message could be broadcast in the event that an anomaly in new ephemeris data set is detected, which would require the differential reference station to base corrections on the previous good satellite ephemeris. This would allow the user equipment just entering the differential system to utilize the corrections being broadcast for that ephemeris, and would support the use of the satellite for differential navigation despite the fact that the satellite ephemeris was in error. It is anticipated that this message type would be broadcast every 2 minutes or so while this condition persisted. The schedule would be maintained until the satellite broadcast was corrected, or until the satellite dropped below the coverage area of the reference station.

All data fields have the same number of bits, the same scale factor and units defined in the 5th edition of GLONASS ICD, which contains the most recent information about GLONASS-M navigation data. This document can be downloaded from the official source of information about GLONASS at the website <http://www.glonass-center.ru>, under the heading “ICD 2002”. The names of the data fields are also kept as close as possible to those defined in the GLONASS ICD for cross-referencing.

Table 3.5-22. Contents of GLONASS Satellite Ephemeris Data, Message Type 1020

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	1020
GLONASS Satellite ID (Satellite Slot Number)	DF038	uint6	6	
GLONASS Satellite Frequency Channel Number	DF040	uint5	5	
GLONASS almanac health (C _n word)	DF104	bit(1)	1	See GLONASS ICD Version 5.0

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS almanac health availability indicator	DF105	bit(1)	1	See GLONASS ICD Version 5.0
GLONASS P1	DF106	bit(2)	2	See GLONASS ICD Version 5.0
GLONASS t_k	DF107	bit(12)	12	See GLONASS ICD Version 5.0
GLONASS MSB of B_n word	DF108	bit(1)	1	See GLONASS ICD Version 5.0
GLONASS P2	DF109	bit(1)	1	See GLONASS ICD Version 5.0
GLONASS t_b	DF110	uint7	7	See GLONASS ICD Version 5.0
GLONASS $x_n(t_b)$, first derivative	DF111	intS24	24	See GLONASS ICD Version 5.0
GLONASS $x_n(t_b)$	DF112	intS27	27	See GLONASS ICD Version 5.0
GLONASS $x_n(t_b)$, second derivative	DF113	intS5	5	See GLONASS ICD Version 5.0
GLONASS $y_n(t_b)$, first derivative	DF114	intS24	24	See GLONASS ICD Version 5.0
GLONASS $y_n(t_b)$	DF115	intS27	27	See GLONASS ICD Version 5.0
GLONASS $y_n(t_b)$, second derivative	DF116	intS5	5	See GLONASS ICD Version 5.0
GLONASS $z_n(t_b)$, first derivative	DF117	intS24	24	See GLONASS ICD Version 5.0
GLONASS $z_n(t_b)$	DF118	intS27	27	See GLONASS ICD Version 5.0
GLONASS $z_n(t_b)$, second derivative	DF119	intS5	5	See GLONASS ICD Version 5.0
GLONASS P3	DF120	bit(1)	1	See GLONASS ICD Version 5.0
GLONASS $\gamma_n(t_b)$	DF121	intS11	11	See GLONASS ICD Version 5.0
GLONASS-M P	DF122	bit(2)	2	See GLONASS ICD Version 5.0
GLONASS-M l_n (third string)	DF123	bit(1)	1	See GLONASS ICD Version 5.0
GLONASS $\tau_n(t_b)$	DF124	intS22	22	See GLONASS ICD Version 5.0
GLONASS-M $\Delta\tau_n$	DF125	intS5	5	See GLONASS ICD Version 5.0
GLONASS E_n	DF126	uint5	5	See GLONASS ICD Version 5.0

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS-M P4	DF127	bit(1)	1	See GLONASS ICD Version 5.0
GLONASS-M F _T	DF128	uint4	4	See GLONASS ICD Version 5.0
GLONASS-M N _T	DF129	uint11	11	See GLONASS ICD Version 5.0
GLONASS-M M	DF130	bit(2)	2	See GLONASS ICD Version 5.0
GLONASS The Availability of Additional Data	DF131	bit(1)	1	See GLONASS ICD Version 5.0
GLONASS N ^A	DF132	uint11	11	See GLONASS ICD Version 5.0
GLONASS τ _c	DF133	intS32	32	See GLONASS ICD Version 5.0
GLONASS-M N ₄	DF134	uint5	5	See GLONASS ICD Version 5.0
GLONASS-M τ _{GPS}	DF135	intS22	22	See GLONASS ICD Version 5.0
GLONASS-M l _n (fifth string)	DF136	bit(1)	1	See GLONASS ICD Version 5.0
Reserved		bit(7)	7	
TOTAL			360	

Note: GLONASS-M data are valid for GLONASS-M satellites only: refer to the description of data field DF130.

3.5.9 *Unicode Text String*

Message type 1029 contains a variable length text string for any displayable information the service provider may want to transmit to the user. For maximum flexibility, the characters in this message are in the Unicode encoding scheme. Unicode is a system for providing a unique numeric code for each character in every language, while allowing for support of any subset of the complete code space. See <http://www.unicode.org> for the Unicode specification and conformance information.

The characters in this message are in the UTF-8 encoding form to provide transparency for ASCII code points (00h-7Fh). That is, the 128 ASCII characters are encoded in the identical 8-bit form in UTF-8. All other characters are multi-byte and each byte in that sequence will be in the range 80h-FFh. Therefore, each byte does not necessarily constitute a full character, but is instead referred to as a “code unit” of a character. The Unicode specification defines how to identify the number of 8-bit code units constituting a received character and how to handle unknown or ill-formed characters.

Because the length of the string is known, a terminating NULL must not be included.

Table 3.5-23. Contents of the Unicode Text String, Message Type 1029

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	1029
Reference Station ID	DF003	uint12	12	
Modified Julian Day (MJD) Number	DF051	uint16	16	(Note 1)
Seconds of Day (UTC)	DF052	uint17	17	(Note 1)
Number of Characters to Follow	DF138	uint7	7	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. Note that for some messages it may not be possible to utilize the full range of this field, e.g. where many characters require 3 or 4 byte representations and together will exceed 255 code units.
Number of UTF-8 Code Units (N)	DF139	uint8	8	The length of the message is limited by this field, or possibly by DF+1 (see previous note).
UTF-8 Character Code Units	DF140	utf8(N)	$8*N$	
TOTAL			$72+8*N$	

Note 1 – The time tag used in this message refers to the approximate time of message transmission (the actual time of transmission may be delayed by buffering). If a different time of applicability is required, the service provider may include that time within the Unicode message text.

Example Unicode Text String Message

The following is an example of the Unicode Text String Message represented in hexadecimal with the UTF-8 code units in bold:

```
D3 00 27 40 50 17 00 84 73 6E 15 1E 55 54 46 2D
38 20 D0 BF D1 80 D0 BE D0 B2 D0 B5 D1 80 D0 BA
D0 B0 20 77 C3 B6 72 74 65 72 ED A3 3B
```

The parameters of the message are

- Message Number = 1029
- Reference Station ID = 23
- Modified Julian Day (MJD) Number = 132
- Seconds of Day (UTC) = 59100
- Number of Characters to Follow = 21
- Number of UTF-8 Code Units = 30

The message text used in the example is “UTF-8 проверка wörter” (UTF-8 check words) without quotes. The Unicode code points and character names for this message are:

0055	LATIN CAPITAL LETTER U	0440	CYRILLIC SMALL LETTER ER
0054	LATIN CAPITAL LETTER T	043A	CYRILLIC SMALL LETTER KA
0046	LATIN CAPITAL LETTER F	0430	CYRILLIC SMALL LETTER A
002D	HYPHEN-MINUS	0020	SPACE
0038	DIGIT EIGHT	0077	LATIN SMALL LETTER W
0020	SPACE	00F6	LATIN SMALL LETTER O WITH DIAERESIS
043F	CYRILLIC SMALL LETTER PE	0072	LATIN SMALL LETTER R
0440	CYRILLIC SMALL LETTER ER	0074	LATIN SMALL LETTER T
043E	CYRILLIC SMALL LETTER O	0065	LATIN SMALL LETTER E
0432	CYRILLIC SMALL LETTER VE	0072	LATIN SMALL LETTER R
0435	CYRILLIC SMALL LETTER IE		

3.6 Proprietary Messages

The 95 message types from 4001 through 4095 are reserved for proprietary use. Each company or organization may be assigned by RTCM one message type for proprietary use. The format is similar to the other messages, in that the transport layer is defined in the same way, and the first data field is a 12-bit message number. Each company is free to define several sub-types of messages, but they must all utilize the assigned message type.

At the time of printing, the following Proprietary Message types have been assigned. Contact RTCM to acquire a new message type.

Table 3.6-1. Assigned Proprietary Message Types

Message Type	Organization	Contact
4095	Magellan Navigation Inc.	http://www.magellangps.com
4094	Trimble Navigation Ltd.	http://www.trimble.com
4093	NovAtel Inc.	http://www.novatel.ca
4092	Leica Geosystems	http://www.leica-geosystems.com
4091	Topcon Positioning Systems	http://www.topconpositioning.com
4090	Geo++	http://www.geopp.de
4089	Septentrio Satellite Navigation	http://www.septentrio.com
4088	IfEN GmbH	http://www.ifen.com
4087-4001	RESERVED	

4 TRANSPORT LAYER

4.1 Description

The transport layer defines the frame architecture for sending or receiving RTCM SC-104 Version 3 messages. The purpose of defining this layer is to ensure that RTCM 10403.1 data can be properly decoded by applications. The frame is mandatory from this respect but it is not required throughout the transmission of the data. Providers may package the messages into a separate frame structure that best suits the transmission medium. The data set would need to have this frame structure re-established before transfer to the application. For high-integrity applications, it would be up to the provider to demonstrate that adequate integrity is maintained in the process of disassembling and reassembling the transport layer frame structure. The basic frame structure consists of a fixed preamble, a message length definition, a message, and a 24-bit Cyclic Redundancy Check (CRC) for high data transfer integrity.

The structure of the frame format is shown in Table 4-1.

Table 4-1. Version 3 Frame Structure

Preamble	Reserved	Message Length	Variable Length Data Message	CRC
8 bits	6 bits	10 bits	Variable length, integer number of bytes	24 bits
11010011	Not defined – set to 000000	Message length in bytes	0-1023 bytes	QualComm definition CRC-24Q

The Preamble is a fixed 8-bit sequence.

The next six bits are reserved in RTCM10403.1 and should be set to zero by the Transport Layer Control for all messages. The mobile user receiver should ignore these bits and not assume they will always be set to zero. In future versions these bits may contain the version number of the standard.

The Variable Length Messages are those defined in Chapter 3. If the data link requires short messages in order to maintain a continuous stream of data, the message length may be set to "0", providing a "filler" message of 48 bits in length, because the data message length will be zero.

This standard uses the QualComm CRC algorithm. Twenty-four bits of CRC parity will provide protection against burst as well as random errors with a probability of undetected error $\leq 2^{-24} = 5.96 \times 10^{-8}$ for all channel bit error probabilities ≤ 0.5 . The CRC operates on the sequence of bits beginning with the preamble, through to the end of the Variable Length Message Field, using a seed of 0. The sequence of 24 bits $(p_1, p_2, \dots, p_{24})$ is generated from the sequence of information bits $(m_1, m_2, \dots, m_{8N})$, where N is the total number of bytes in the sequence consisting of the message plus preamble and Message Length Definition Parameter. This is accomplished by means of a code that is generated by the polynomial

$$g(X) = \sum_{i=0}^{24} g_i X^i$$

where

$$\begin{aligned} g_i &= 1 \text{ for } i = 0, 1, 3, 4, 5, 6, 7, 10, 11, 14, 17, 18, 23, 24 \\ &= 0 \text{ otherwise} \end{aligned}$$

This code is called CRC-24Q (Q for Qualcomm Corporation). The generator polynomial of this code is in the following form (using binary polynomial algebra):

$$g(X) = (1 + X)p(X)$$

where $p(X)$ is the primitive and irreducible polynomial

$$\begin{aligned} p(X) &= X^{23} + X^{17} + X^{13} + X^{12} \\ &\quad + X^{11} + X^9 + X^8 + X^7 + X^5 + X^3 + 1 \end{aligned}$$

When, by the application of binary polynomial algebra, the above $g(X)$ is divided into $m(X)X^{24}$, where the information sequence $m(X)$ is expressed as

$$m(X) = m_k + m_{k-1}X + m_{k-2}X^2 + \dots + m_1X^{k-1}$$

the result is a quotient and a remainder $R(X)$ of degree < 24 . The bit sequence formed by this remainder represents the parity check sequence. Parity bit p_i , for any i from 1 to 24, is the coefficient of X^{24-i} in $R(X)$.

This code has the following characteristics:

- 1) It detects all single bit errors per code word.
- 2) It detects all double bit error combinations in a codeword because the generator polynomial $g(X)$ has a factor of at least three terms.
- 3) It detects any odd number of errors because $g(X)$ contains a factor $1 + X$.
- 4) It detects any burst error for which the length of the burst is ≤ 24 bits.
- 5) It detects most large error bursts with length greater than the parity length $r = 24$ bits.

The fraction of error bursts of length $b > 24$ that are undetected is:

- a) $2^{-24} = 5.96 \times 10^{-8}$, if $b > 25$ bits.
- b) $2^{-23} = 1.19 \times 10^{-7}$, if $b = 25$ bits.

As noted earlier, the reference station should insert zero's in all reserved fields, and for messages whose lengths that don't line up with byte boundaries, zero's should be used for undefined bits to fill out the last unfilled byte.

4.2 Example

The following is a Hex-ASCII example of a message type 1005 (Stationary Antenna Reference Point, No Height Information).

```
D3 00 13 3E D7 D3 02 02 98 0E DE EF 34 B4 BD 62
AC 09 41 98 6F 33 36 0B 98
```

The parameters for this message are:

- Reference Station Id = 2003
- GPS Service supported, but not GLONASS or Galileo
- ARP ECEF-X = 1114104.5999 meters
- ARP ECEF-Y = -4850729.7108 meters
- ARP ECEF-Z = 3975521.4643 meters

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5 DATA LINK LAYER

The Data Link Layer defines how the RTCM 10403.1 message data stream is encoded on the Physical Layer. This may also include flow control, packetization, encryption, or additional error checking.

It is up to the service provider to determine how to define this layer as appropriate to the application.

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6 PHYSICAL LAYER

The Physical Layer defines how the RTCM 10403.1 message data is conveyed at the electrical and mechanical level – e.g.: beacons, MSK; UHF, VHF Modems; DARC FM Subcarrier, Satellite links, fixed cable.

It is up to the service provider to determine how to define this layer as appropriate to the application.

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APPENDIX A. SUGGESTIONS AND EXAMPLES FOR NETWORK OPERATION

The following two sections provide additional guidance and information for Vendors, Service Providers and Mobile Users. Appendix A.1 provides guidance to Service Providers on the selection of master and auxiliary stations, and to Users on how to best use the information in the messages. Appendix A.2 provides a scheduling example that demonstrates one method of utilizing the Synchronous Message Flags and Multiple Message Indicators to support operation with multiple GNSS's.

A.1 How to Use Network ID's and Subnetwork ID's

Figure A.1-1 gives an example of a network containing 23 reference stations identified by Network ID. In general the network will consist of only one subnetwork identified by Subnetwork ID. Every one of these 23 reference stations can be used as a Master Reference Station and all reference stations within a certain range around the Master Reference Station might be used as Auxiliary Reference Stations. The figure shows 3 different Master Reference Stations (11 <red>, 14 <blue>, and 17 <purple>) and associated radii. The radii are defining in the example the range holding all associated Auxiliary Reference Stations for the designated Master Reference Station. However other ways of selecting Auxiliary Reference Stations for a designated Master Reference Station are possible and the selection process might have to be adapted to the specific environment of the permanent networking application.

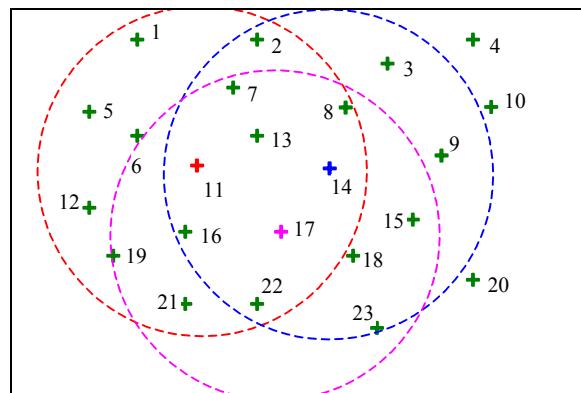


Figure A.1-1. Network Example

Master Reference Station M11 has the Auxiliary Reference Stations A1, A2, A5, A6, A7, A8, A12, A13, A14, A16, A17, A19, A21, and A22. Master Reference Station M14 has the Auxiliary Reference Stations A2, A3, A7, A8, A9, A11, A13, A15, A16, A17, A18, A22, and A23. Master Reference Station M17 has the Auxiliary Reference Stations A7, A8, A11, A13, A14, A15, A16, A18, A19, A21, A22, and A23. All three Master Reference Stations (M11, M14, and M17) are also Auxiliary Reference Stations (A11, A14, and A17) for each other. Under the assumption that all Master Reference Stations are on a common Integer Ambiguity Level, a handover to the next Master Reference Station data stream would be possible without reinitialization of the integer ambiguities as used in the rover application. However, Integer Ambiguity Leveling is not mandatory for Master Reference Stations. Normally, all stations would be available to a network processing facility and a networking provider could combine all stations in one network (e.g. 122). When all Reference Stations could be brought to a joint Ambiguity Level, a common Subnetwork ID 0 would be assigned.

An example of individual data streams may be for Master Reference Stations M11, M14, and M17 respectively as a sequence of information of Network ID (122), Subnetwork ID (0), Master Reference Station ID, Auxiliary Reference Station ID, ...:

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122, 0, M11, A1, ...	122, 0, M14, A2, ...	122, 0, M17, A7, ...
122, 0, M11, A2, ...	122, 0, M14, A3, ...	122, 0, M17, A8, ...
122, 0, M11, A5, ...	122, 0, M14, A7, ...	122, 0, M17, A11, ...
122, 0, M11, A6, ...	122, 0, M14, A8, ...	122, 0, M17, A13, ...
122, 0, M11, A7, ...	122, 0, M14, A9, ...	122, 0, M17, A14, ...
122, 0, M11, A8, ...	122, 0, M14, A11, ...	122, 0, M17, A15, ...
122, 0, M11, A12, ...	122, 0, M14, A13, ...	122, 0, M17, A16, ...
122, 0, M11, A13, ...	122, 0, M14, A15, ...	122, 0, M17, A18, ...
122, 0, M11, A14, ...	122, 0, M14, A16, ...	122, 0, M17, A19, ...
122, 0, M11, A16, ...	122, 0, M14, A17, ...	122, 0, M17, A21, ...
122, 0, M11, A17, ...	122, 0, M14, A18, ...	122, 0, M17, A22, ...
122, 0, M11, A19, ...	122, 0, M14, A22, ...	122, 0, M17, A23, ...
122, 0, M11, A21, ...	122, 0, M14, A23, ...	
122, 0, M11, A22, ...		

Message streams such as those in the example above might be transmitted on separate data links or jointly in one data link. Note that the current standard document recommends disseminating only one Master Reference Station per data link (See section 3.1.5).

As long as all reference stations are on the same integer ambiguity level, a hand-over to another Master Reference Station is possible as long as the new Master Reference Station was already an Auxiliary Reference Station for the previous Master Reference Station. In the example user equipment could operate using the red Master Reference Station with fixed integer ambiguities on the rover. When roving it might be desirable to switch to the pink or blue Master Reference Station and its associated Auxiliary Reference Stations. Note that with the current recommendation of only one Master Reference Station per data link, switching Master Reference Stations requires that different data links be used.

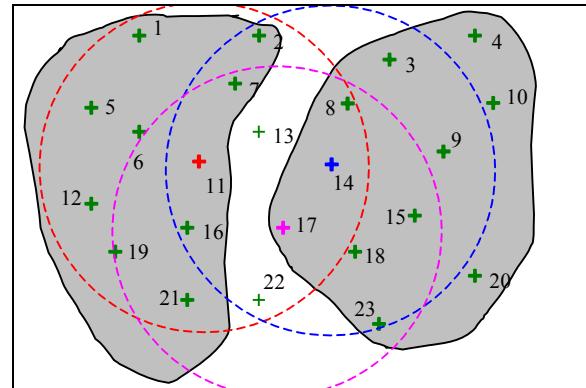


Figure A.1-2. Example of Multiple Solutions

There are situations where a homogeneous integer ambiguity solution might fall apart. For instance, some stations in the center could have communication problems with the central computation facility, or their observations might become unavailable for some other reason. The example given in Figure A.1-2 shows 2 independent homogenous solutions with separated integer ambiguity levels (gray shaded areas). The circles marking the initial area with all the associated Auxiliary Reference Stations for particular Master Reference Stations span both shaded areas.

Since the correction differences (with Ambiguity Status Flag = 1, i.e., correct Integer Ambiguity Level for L1 and L2) may be generated only between Master Reference Station and its Auxiliary Reference Stations on the same integer ambiguity level, the example data streams will be different:

122, 1, M11, A1, ...	122, 2, M14, A3, ...	122, 2, M17, A8, ...
122, 1, M11, A2, ...	122, 2, M14, A8, ...	122, 2, M17, A14, ...
122, 1, M11, A5, ...	122, 2, M14, A9, ...	122, 2, M17, A15, ...
122, 1, M11, A6, ...	122, 2, M14, A15, ...	122, 2, M17, A18, ...
122, 1, M11, A7, ...	122, 2, M14, A17, ...	122, 2, M17, A23, ...
122, 1, M11, A12, ...	122, 2, M14, A18, ...	
122, 1, M11, A16, ...	122, 2, M14, A23, ...	
122, 1, M11, A19, ...		
122, 1, M11, A21, ...		

Note: It is possible to form other Correction Differences as well, but their Ambiguity Status Flag will be different from “1”.

The reaction of the user system may be manifold and is strongly dependent on the processing strategy implemented in the system itself. The simplest strategy is to use only homogenous information of Master Reference Station-Auxiliary Reference Stations combinations referring to the identical epoch. In this case the implementation and handling within the user system is quite straightforward. The user system will first receive the homogenous ones of any of the Master Reference Station-Auxiliary Reference Station combinations and may correct its observations. When a second data stream, with a different Master Reference Station, becomes more suitable the user system may switch to the new data stream, and probably needs only to ensure that no jump occurs in its results due to the switch of the Master Reference Station. However this again is dependent on designated strategy of the user system’s processing strategy.

When a homogenous solution with a common integer ambiguity level as given in Figure A.1-1 breaks apart, resulting in a setup as given in Figure A.1-2, the reaction of the user system might depend on the area of actual operation. Within the white area, the zone where the reference stations are no longer part of any solution, the user system’s only chance is to use the remaining information and try an extrapolation. The resulting positioning will probably be degraded under this circumstance.

If the user system is operating in one of the gray areas and is using a Master Reference Station-Auxiliary Reference Station combination outside his gray area, the user system may continue without major interruption, but eventually with less flexibility in modeling the information for proper mitigation of biases.

If the user system is operating in one of the gray areas, but is utilizing a Master Reference Station-Auxiliary Reference Station combination of the opposite gray area, the user system probably will have to change to a Master Reference Station-Auxiliary Reference Station combination in its area of operation. Ultimately this will probably result in a reset of the user system’s integer ambiguities and the user has to reinitialize again.

As stated above, a processing strategy using only information of the latest available epoch is probably the simplest strategy possible. More sophisticated processing strategies may involve the usage of the information of Master Reference Station-Auxiliary Reference Station combinations of different Master Reference Stations and/or different observation epochs. The information of the Network RTK messages have the potential to be used within another centralized networking solution. In the future a further application might be a complete network solution on a user

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receiver. The status information of the network calculation transmitted in form of the data fields Network ID and Subnetwork ID provide sufficient proof to indicate to the user system that it is secure or non-secure to continue operation with the new set of information. At the time the complete description of all these potential applications is not possible, due to the number of variations. The experienced developer in the field of network RTK will understand the meaning of the Network ID and Subnetwork ID for his envisioned applications. Therefore further details are left open and will need further description in case the given description is considered ambiguous.

A.2 A Scheduling Example for RTK Networks Demonstrating the Proper Use of Synchronous Message Flags and Multiple Message Indicators

It is anticipated that RTK services in the future will transmit data for more than one satellite system concurrently. Such facilities already exist for non-network RTK service, using GPS and GLONASS data, all referenced to the same time epoch. Such operation supports the mixing of measurements from different GNSS's. As Galileo comes on line, it will initially be used in conjunction with GPS and GLONASS, so RTK services utilizing multiple GNSS's will be common. The Synchronous Message Flags and Multiple Message Indicator in the RTK messages are designed to support multiple GNSS operation.

However, not all rover receivers will be designed to receive and process information from more than one GNSS, and the RTCM standard should enable rovers to know when relevant information has been completely transmitted for a particular epoch. Otherwise such user receivers would have to wait until data for the next epoch has been received before they could begin processing. Such delays are neither desirable nor necessary.

The Synchronous Message Flag supports the use of two or more GNSS's. It is set to "1" if data from another GNSS will follow, and it is set to "0" if there are no other services, or if this data set is for the last GNSS for that epoch.

With networks, it might be necessary to transmit data for different Auxiliary Reference Stations at different times, but referenced to a single epoch. For example, if there are 5 Auxiliary Reference Stations and one particular message is sent for one auxiliary station every epoch, it will take 5 epochs to provide a complete set of information. The Multiple Message Indicator is set to "0" for the last Auxiliary Reference Station in the specific message set (e.g. 1015 or 1016), and the others are set to "1".

With more than one GNSS, the data stream will contain the Auxiliary Reference Station data first for one satellite system, then the other.

How these rules are applied is demonstrated in Table A.2-1 below for a combined GPS and GLONASS service. The Epoch is the reference time in seconds. GPS 1004 refers to the GPS Master Reference Station reference epoch, and 1004 SMF refers to the value of the Synchronous Message Flag in the 1004 message. GLONASS 1012 refers to the GLONASS Master Reference Station reference epoch, and 1012 SMF refers to the corresponding GLONASS flag. For ease of explanation at each epoch Network RTK data for one Auxiliary Reference Station and one GNSS is transmitted. Actual service implementations may send several messages per epoch, but the explained principle is readily apparent. GPS 1015 refers to the reference epoch for the GPS Auxiliary Reference Station Iono message, and the corresponding MMI refers to the value of the Multiple Message Indicator in the 1015 message; similarly for the 1016 Geometric message. The

corresponding GLONASS values are then given, where 1015* refers to the not-yet-defined GLONASS Iono message, and similarly for 1016*.

Table A.2-1. Example Showing the Use of SMF's and MMI's

Epoch	GPS		GLONASS		GPS Network RTK				GLONASS Network RTK			
	1004	SMF	1012	SMF	1015	MMI	1016	MMI	1015*	MMI	1016*	MMI
1	1	1	1	0	1	1	1	1				
2	2	1	2	0	1	1	1	1				
3	3	1	3	0	1	1	1	1				
4	4	1	4	0	1	1	1	1				
5	5	1	5	0	1	1	1	1				
6	6	1	6	0	1	1	1	1				
7	7	1	7	0	1	1	1	1				
8	8	1	8	0	1	1	1	1				
9	9	1	9	0	1	0	1	0				
10	10	1	10	0					1	1	1	1
11	11	1	11	0					1	1	1	1
12	12	1	12	0					1	1	1	1
13	13	1	13	0					1	1	1	1
14	14	1	14	0					1	0	1	0
15	15	1	15	0	15	1	15	1				
16	16	1	16	0	15	1	15	1				
17	17	1	17	0	15	1	15	1				
18	18	1	18	0	15	1	15	1				
19	19	1	19	0	15	1	15	1				
20	20	1	20	0	15	1	15	1				
21	21	1	21	0	15	1	15	1				
22	22	1	22	0	15	1	15	1				
23	23	1	23	0	15	0	15	0				
24	24	1	24	0					15	1	15	1
25	25	1	25	0					15	1	15	1
26	26	1	26	0					15	1	15	1
27	27	1	27	0					15	1	15	1
28	28	1	28	0					15	0	15	0

It can be seen that all the GPS and GLONASS Auxiliary Reference Station messages are referenced to Epoch 1, until the entire set of data has been broadcast, after which the data is referenced to Epoch 15. Note that the GPS SMF's are all "1", indicating that the GLONASS message is to follow, while the GLONASS SMF's are all "0", indicating that there is not a third GNSS represented in the data stream. The final MMI for each GNSS and message type is set to "0", indicating that the complete set of network corrections have been transmitted, and the rover can proceed immediately to apply them.

The extension of this technique to three or more GNSS's is readily apparent.

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