RTCM 10403.1
RTCM Paper 177-2006-SC104-STD
with Amendment 1
RTCM Paper 100-2007-SC104-STD
with Amendment 2
RTCM Paper 150-2007-SC104-STD
with Amendment 3
RTCM Paper 137-2009-SC104-STD
with Amendment 4
RTCM Paper 024-2011-SC104-STD
with Amendment 5
RTCM Paper 142-2011-SC104-STD

RTCM STANDARD 10403.1

DIFFERENTIAL GNSS (GLOBAL NAVIGATION SATELLITE SYSTEMS) SERVICES – VERSION 3

DEVELOPED BY
RTCM SPECIAL COMMITTEE NO. 104

JULY 1, 2011

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This document includes Amendment 1.
The following page deletions and insertions have been made:

AMENDMENT 1
to
RTCM STANDARD 10403.1

DIFFERENTIAL GNSS
(GLOBAL NAVIGATION SATELLITE SYSTEMS)
SERVICES – VERSION 3

RTCM Standard 10403.1 - Differential GNSS (Global Navigation Satellite Systems) Services Version 3, dated October 27, 2006 (RTCM Paper 177-2006-SC104-STD)[1] is revised as follows:

1. p. iii: insert new Table of Contents
2. pp. 3-10 and 3-11: replace Section 3.2 and Table 3.2-1 with enclosed Section 3.2 and Table 3.2-1 (pp. 3-10, 3-11, and 3-11-A)
3. pp. 3-12 and 3.13: replace Section 3.3 and Table 3.3-1 with enclosed Section 3.3 and Table 3.3-1 (pp. 3-12, 3-13, and 3-13-A)
4. p. 3-36: add new Data Field entries DF143 through DF217 to Table 3.4-1 (insert pp. 3-36-A through 3-36-M)
5. p. 3-71: add new section 3.5.10 (insert pp. 3-71-A through 3-71-X)

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[1] Early editions of this standard were identified only as RTCM Paper 177-2006-SC104-STD, RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Services, Version 3.1, dated October 27, 2006.

RTCM 10403.1 – Amendment 2

This document includes Amendment 2.
The following page deletions and insertions have been made:

AMENDMENT 2
to
RTCM STANDARD 10403.1

DIFFERENTIAL GNSS
(GLOBAL NAVIGATION SATELLITE SYSTEMS)
SERVICES – VERSION 3

RTCM Standard 10403.1 - Differential GNSS (Global Navigation Satellite Systems) Services Version 3, dated October 27, 2006 (RTCM Paper 177-2006-SC104-STD)[1] as revised by Amendment 1, dated May 21, 2007 (RTCM Paper 100-2007-SC104-STD), is further revised as follows:

1. p. iii: insert new Table of Contents
2. Replace Section 3.2 and Table 3.2-1 (pp. 3-10, 3-11, and 3-11-A) with enclosed Section 3.2 and Table 3.2-1 (pp. 3-10, 3-11, and 3-11-A).
3. Replace Section 3.3 and Table 3.3-1 (pp. 3-12, 3-13, and 3-13-A) with enclosed Section 3.3 and Table 3.3-1 (pp. 3-12, 3-13, and 3-13-A).
4. Insert additions to Table 3.4.1 including Data Field entries DF218 through DF232 after p. 3-36-M (pp. 3-36-N to 3-36-P).
5. Insert new section 3.5.11 after p. 3-71-X (pp. 3-71-Y to 3-71-EE).

[1] Early editions of this standard were identified only as RTCM Paper 177-2006-SC104-STD, RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Services, Version 3.1, dated October 27, 2006.

This document includes Amendment 3.
The following page deletions and insertions have been made:

AMENDMENT 3
to
RTCM STANDARD 10403.1

DIFFERENTIAL GNSS
(GLOBAL NAVIGATION SATELLITE SYSTEMS)
SERVICES – VERSION 3

RTCM Standard 10403.1 - Differential GNSS (Global Navigation Satellite Systems) Services Version 3, dated October 27, 2006 (RTCM Paper 177-2006-SC104-STD)[1] as revised by Amendment 1, dated May 21, 2007 (RTCM Paper 100-2007-SC104-STD), as revised by Amendment 2, dated August 31, 2007 (RTCM Paper 150-2007-SC104-STD), is further revised as follows:

1. p. iii: insert new Table of Contents
2. Insert a new Section 3.1.8 and Table 3.1-5 by replacing pp. 3-9 and 3-10 with enclosed pages 3-9, 3-9A, 3-9B, and 10 (p. 10 is unchanged from Amendment 2).
3. Add a new Data Field DF364 to Table 3.4-1 by inserting page 3-36-Q.
4. Replace Section 3.5.2 and Tables 3.5-6 and 3.5-**7** by replacing pp. 3-45 to 3-48 with enclosed pp. 3-45 to 3-48.
5. Replace Table 3.6-1 by replacing p. 3-72 with enclosed p. 3-72.

[1] Early editions of this standard were identified only as RTCM Paper 177-2006-SC104-STD, RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Services, Version 3.1, dated October 27, 2006.

AMENDMENT 4
to
RTCM STANDARD 10403.1

DIFFERENTIAL GNSS
(GLOBAL NAVIGATION SATELLITE SYSTEMS)
SERVICES – VERSION 3

RTCM Standard 10403.1 - Differential GNSS (Global Navigation Satellite Systems) Services Version 3, dated October 27, 2006 (RTCM Paper 177-2006-SC104-STD)[1]
as revised by Amendment 1, dated May 21, 2007 (RTCM Paper 100-2007-SC104-STD),
as revised by Amendment 2, dated August 31, 2007 (RTCM Paper 150-2007-SC104-STD),
as revised by Amendment 3, dated June 5, 2009 (RTCM Paper 137-2009-SC104-STD),
is further revised as follows:

1. Replace p. iii: inserting a new Table of Contents
2. Replace pages 3-1 to 3-8 with pages 3-1 to 3-8-D –
    - Adding "Receiver and Antenna Description" group to Table 3.1-1
    - Adding the GLONASS Network RTK messages and FKP Network RTK Messages to the "Network RTK Corrections" group in Table 3.1-1
    - Adding the Network RTK services "Precision GLONASS Network RTK" and "Precision GPS and GLONASS Network RTK" to the Table 3.1-2
    - Amending title and text of section ***3.1.5 GPS Network RTK Corrections***
    - Amending title and text of section ***3.1.7 Scheduling of Network RTK messages***
3. Replace pages 3-11 and 3-11-A with new pages 3-11 and 3-11-A, adding Messages Types 1034 to 1039 to Table 3.2-1
4. Replace page 3-29 and 3-30 with new pages 3-29 and 3-30, amending the data type notes of DF072
5. Replace page 3-36-Q with new pages 3-36-Q through 3-36-V, adding Data Fields DF233 to DF245 and DF 392 to Table 3.4-1
6. Replace page 3-72 with new pages 3-72 to 3-83 -
    - Adding section ***3.5.13 GLONASS Network RTK Correction Messages***
    - Adding section ***3.5.14 FKP Network RTK Correction Messages***
    - Replacing Table 3.6-1 with a revised table

[1] Early editions of this standard were identified only as RTCM Paper 177-2006-SC104-STD, RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Services, Version 3.1, dated October 27, 2006.

AMENDMENT 5
to
RTCM STANDARD 10403.1

DIFFERENTIAL GNSS
(GLOBAL NAVIGATION SATELLITE SYSTEMS)
SERVICES – VERSION 3

RTCM Standard 10403.1 - Differential GNSS (Global Navigation Satellite Systems) Services Version 3, dated October 27, 2006 (RTCM Paper 177-2006-SC104-STD)[1]
as revised by Amendment 1, dated May 21, 2007 (RTCM Paper 100-2007-SC104-STD),
as revised by Amendment 2, dated August 31, 2007 (RTCM Paper 150-2007-SC104-STD),
as revised by Amendment 3, dated June 5, 2009 (RTCM Paper 137-2009-SC104-STD),
as revised by Amendment 4, dated February 16, 2011 (RTCM Paper 024-2011-SC104-STD),
is further revised as follows:

1. Replace pages 3-11 to 3-13A with new pages 3-11 to 3-13-A –
    - Correcting Message Types 1015, 1016, 1017, 1019, and 1031
    - Adding Message Types 1057 to 1068
    - Adding Data Types int25, int26, and int27
    - Correcting Data Type uint14
2. Replace pages 3-35 and 3-36 with new pages 3-35 and 3-36, revising the DF Resolution for DF135.
3. Replace pages 3-36-U and 3-36-V with new pages 3-36-U to 3-36BB adding DF365 to DF 391, and DF 413 to DF 415.
4. After page 3-71EE, insert pages 3-71FF to 3-71CCC containing new section 3.5.12, “State Space.”

[1] Early editions of this standard were identified only as RTCM Paper 177-2006-SC104-STD, RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Services, Version 3.1, dated 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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TABLE OF CONTENTS

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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.

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

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.

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
Receiver and Antenna Description		1033
Network RTK Corrections	Network Auxiliary Station Data Message	1014
	GPS Ionospheric Correction Differences	1015
	GPS Geometric Correction Differences	1016
	Combined GPS Geometric and Ionospheric Correction Differences	1017
	GPS Network RTK Residual Message	1030
	GLONASS Network RTK Residual Message	1031
	GPS Network FKP Gradient Message	1034
	GLONASS Network FKP Gradient Message	1035
	GLONASS Ionospheric Correction Differences	1037
	GLONASS Geometric Correction Differences	1038
	Combined GLONASS Geometric and Ionospheric Correction Differences	1039

Group Name	Sub-Group Name	Message Type
Auxiliary Operation Information	System Parameters	1013
	Satellite Ephemeris Data	1019
		1020
	Unicode Text String	1029
Proprietary Information		Assigned in the range 4001 – 4095 *See Table 3.6-1*

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	1007 or	1007 or

Service	Group	Mobile Receiver (minimum decoding requirement)	Reference Station Message Type(s)	
			Minimum Service Operation	Full Service Operation
		1008	1008	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
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 (MAC)		1014	1014
			1017	1015 and 1016

Service	Group	Mobile Receiver (minimum decoding requirement)	Reference Station Message Type(s)	
			Minimum Service Operation	Full Service Operation
				or 1017
				1030
	Network RTK Corrections (FKP)		1034	1034
				1030
Precision GLONASS Network RTK	Observations (GLONASS)	1011-1012	1011	1012
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Receiver and Antenna Description	1033	1033	1033
	Auxiliary Operation Information			1013
	Network RTK Corrections (MAC)		1014	1014
			1039	1037 and 1038 or 1039 1031
	Network RTK Corrections (FKP)		1035	1035
				1031
Precision GPS and GLONASS Network RTK	Observations (GPS)	1003-1004	1003	1004
	Observations (GLONASS)	1011-1012	1011	1012
	Station Description	1005 and 1006	1005 or 1006	1005 or 1006
	Receiver and Antenna Description	1033	1033	1033
	Auxiliary Operation Information			1013
	Network RTK Corrections (MAC)		1014	1014
	Network RTK Corrections (MAC) - GPS-		1017	1015 and 1016 or 1017
	Network RTK Corrections – (MAC) - GLONASS			1030

Service	Group	Mobile Receiver (minimum decoding requirement)	Reference Station Message Type(s)	
			Minimum Service Operation	Full Service Operation
			1039	1037 and 1038 or 1039
				1031
	Network RTK Corrections (FKP)			
	Network RTK Corrections (FKP) - GPS		1034	1034
				1030
	Network RTK Corrections (FKP) - GLONASS		1035	1035
				1031

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 ±1 µs. 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 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 Network RTK corrections

Different concepts to provide corrections from Network RTK are supported. There are

- FKP: range correction gradients
- Non-Physical Reference Station
- MAC: Master Auxiliary Concept

FKP, range correction gradients

With the concept of FKP (from the German word: "Flächenkorrekturparameter" = Area Correction Parameters) horizontal gradients of distance-dependent errors like ionosphere, troposphere and orbits are derived from a network of GNSS reference stations and transmitted to a rover together with raw or correction data of a corresponding reference station.

Non-Physical Reference Station

The 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".

Master Auxiliary Concept (MAC)

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). Master-Auxiliary Network RTK Corrections (MAC) are designed as additional information for improved performance and precision. A service provider utilizing the network capability will broadcast previously defined Precision GPS and GLONASS 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 for GPS and 1011 or 1012 for GLONASS) 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 for GPS and (1037 and 1038) or 1039 for GLONASS) at identical epoch times. The chosen epoch time should be identical to an epoch time as for the respective 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 and1016) or (1037 and 1038), the epoch time should be identical for both messages. 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 ionospheric and the geometric carrier phase components may be filtered to reduce the effect of noise.

- Next, Network Auxiliary Station Data (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 required for single baseline operation.

- For combined GPS/GLONASS operation, GPS data should be transmitted first.

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

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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

3.1.8 Handling of Quarter Cycle Carrier Phase Shifts

Some GNSS receiver manufacturers have implemented carrier phase encoding of RTCM 3 messages 1001, 1002, 1003, 1004, 1009, 1010, 1011, 1012 in a way that carrier phase observations are in phase for all carrier phases of a specific frequency, i.e. they correct for quarter cycle phase shifts. Others retain the quarter cycle offset between the carrier phase observations in the data.

The following table gives the status of implementation as provided by the individual manufacturers:

Table 3.1-5 GNSS Receiver Manufacturers – Handling of Quarter-Cycle Phase Shifts

	Geo++	Javad	Leica	Magellan	NavCom	NovAtel	Septen-trio	Trimble	Topcon
GPS L1CA	No correction	No correction	No correction	No correction	No correction	No correction	No correction	No correction	No correction
GPS L1P	No correction			0.25 cycles x λ_{L1}) ** added					
GPS L2P	No correction	No correction	No correction	No correction	No correction	No correction		No correction	No correction
GPS L2Y	No correction	No correction	No correction	No correction	No correction	No correction	No correction	No correction	No correction
GPS L2C	No correction	No correction	No correction	(0.25 cycles x λ_{L2}) ** added	No correction	No correction	No correction	(0.25 cycles x λ_{L2}) ** added	No correction
GLN L1CA	No correction	No correction	No correction	No correction	No correction	No correction	No correction	No correction	No correction
GLN L1P	No correction	No correction			No correction	No correction	No correction	0.25 cycles x λ_{L1}) ** subtracted	No correction
GLN L2P	No correction	No correction	No correction	No correction	No correction	No correction	No correction	No correction	No correction
GLN L2CA	No correction	No correction	No correction	(0.25 cycles x λ_{L2}) ** added	No correction	No correction	No correction	(0.25 cycles x λ_{L2}) ** added	No correction

** λ_{L1} = L1 wavelength and λ_{L2} = L2 wavelength

To avoid inconsistencies between different manufacturers a two bit indicator was introduced in the messages 1005 and 1006 indicating whether the carrier phases are corrected for satellite induced quarter-cycle phase shifts (provided carrier phase for different signals on the same frequency are available), or whether the carrier phases are not corrected. This indicator provides information only for Message Types1001, 1002, 1003, 1004, 1009, 1010, 1011, 1012. If the Quarter cycle carrier phase indicator is zero, there is no information on the correction of quarter cycle shifts.

For message types 1001, 1002, 1003, 1004, 1009, 1010, 1011, 1012, each manufacturer shall maintain the phase relationship conventions specified in Table 3.1-5. This ensures backwards compatibility with legacy receivers that do not make use of the Quarter Cycle Indicator. Manufacturers not listed in this table shall not apply 1/4 cycle shifts. To augment the information in the Type 1033 message, the phase relationships shall be indicated using the Quarter Cycle

Indicator in the Type 1005 and 1006 messages (see Tables 3.5-6 and 3.5-7). However, the use of the Quarter Cycle Indicator shall not contradict the information provided in Table 3.1-5.

For the network message types 1015-1017 it is necessary that in the case of mixed phase observations derived from a common frequency (e.g. L2C and L2P for GPS), the network software must ensure that the observations are processed with a consistent phase relationship.

Firmware updates for any manufacturer should include implementation of Message Type 1033 (to indicate the receiver type) and should also implement the definition of 2 bits in 1005 and 1006.

Future messages will require that no corrections be applied to any of the signals in Table 3.1-5.

3.2 Message Type Summary

The message types shown in Table 3.2-1 support Real-Time Kinematic (RTK) individual and network broadcasts for GPS, GLONASS.

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	

Message Type	Message Name	No. of Bytes **	Notes
1015	GPS Ionospheric Correction Differences	9.5 + 3.5*Ns	Ns = Number of Satellites
1016	GPS Geometric Correction Differences	9.5 + 4.5*Ns	Ns = Number of Satellites
1017	GPS Combined Geometric and Ionospheric Correction Differences	9.5 + 6.625*Ns	Ns = Number of Satellites
1018	RESERVED for Alternative Ionospheric Correction Difference Message		
1019	GPS Ephemerides	61	One message per satellite
1020	GLONASS Ephemerides	45	One message per satellite
1021	Helmert / Abridged Molodenski Transformation Parameters	51.5+N+M	N = Number of characters in Source Name M = Number of characters in Target Name
1022	Molodenski-Badekas Transformation Parameters	64.625+N+M	N = Number of characters in Source Name M = Number of characters in Target Name
1023	Residuals, Ellipsoidal Grid Representation	72.25	
1024	Residuals, Plane Grid Representation	73.75	
1025	Projection Parameters, Projection Types other than Lambert Conic Conformal (2 SP) and Oblique Mercator	24.5	
1026	Projection Parameters, Projection Type LCC2SP (Lambert Conic Conformal (2 SP))	29.25	
1027	Projection Parameters, Projection Type OM (Oblique Mercator)	32.25	
1028	(Reserved for Global to Plate-Fixed Transformation)		

Message Type	Message Name	No. of Bytes **	Notes
1029	Unicode Text String	9+N	N = Number of UTF-8 Code Units
1030	GPS Network RTK Residual Message	$7+6.125*N_S$	N_s = Number of GPS Satellites
1031	GLONASS Network RTK Residual Message	6.625+6.125*Ns	N_s = Number of GLONASS Satellites
1032	Physical Reference Station Position Message	19.5	
1033	Receiver and Antenna Descriptors	9+M+N+I+J+K	N = Number of characters in antenna descriptor M = Number of characters in antenna serial number I = Number of characters in receiver descriptor J = Number of characters in firmware descriptor K = Number of characters in receiver serial number
1034	GPS Network FKP Gradient	$6.125+8.25*N_S$	N_s = No. of Satellites
1035	GLONASS Network FKP Gradient	$5.75+8.25*N_S$	N_s = No. of Satellites
1037	GLONASS Ionospheric Correction Differences	$9.125+3.5*N_S$	N_s = No. of Satellites
1038	GLONASS Geometric Correction Differences	$9.125+4.5*N_S$	N_s = No. of Satellites
1039	GLONASS Combined Geometric and Ionospheric Correction Differences	$9.125+6.625*N_S$	N_s = No. of Satellites
1057	SSR GPS Orbit Correction	$8.5+16.875*N_S$	N_s = No. of Satellites
1058	SSR GPS Clock Correction	$8.375+9.5*N_S$	N_s = No. of Satellites
1059	SSR GPS Code Bias	$8.375+1.375*N_S$ $+2.375\ \Sigma\ N_{CB}$	N_s = No. of Satellites N_{CB} = No. of Code Biases per individual Satellite

1060	SSR GPS Combined Orbit and Clock Corrections	$8.5+25.625*N_S$	N_s = No. of Satellites
1061	SSR GPS URA	$8.375+1.5*N_S$	N_s = No. of Satellites
1062	SSR GPS High Rate Clock Correction	$8.375+3.5*N_S$	N_s = No. of Satellites
1063	SSR GLONASS Orbit Correction	$8.125+16.75*N_S$	N_s = No. of Satellites
1064	SSR GLONASS Clock Correction	$8+9.375*N_S$	N_s = No. of Satellites
1065	SSR GLONASS Code Bias	$8+1.250*N_S$ $+2.375\ \Sigma\ N_{CB}$	N_s = No. of Satellites, N_{CB} = No. of Code Biases per individual Satellite
1066	SSR GLONASS Combined Orbit and Clock Correction	$8.125+25.5*N_S$	N_s = No. of Satellites
1067	SSR GLONASS URA	$8+1.375*N_S$	N_s = No. of Satellites
1068	SSR GLONASS High Rate Clock Correction	$8+3.375*N_S$	N_s = No. of Satellites
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]
int8	8 bit 2’s complement integer	± 127	-128 indicates data not available
int9	9 bit 2’s complement integer	± 255	-256indicates data not available
int10	10 bit 2’s complement integer	± 511	-512 indicates data not available
int14	14 bit 2’s complement integer	± 8191	-8192 indicates data not available
int15	15 bit 2’s complement integer	± 16,383	-16,384 indicates data not available
int16	16 bit 2’s complement integer	± 32,767	-32,768 indicates data not available
int17	17 bit 2’s complement integer	± 65,535	-65,536 indicates data not available
int19	19 bit bit 2’s complement integer	± 262,143	-262,144 indicates data not available
int20	20 bit 2’s complement integer	± 524, 287	-524,288 indicates data not available
int21	21 bit 2’s complement integer	± 1,048,575	-1,048,576 indicates data not available
int22	22 bit 2’s complement integer	± 2,097,151	-2,097,152 indicates data not available
int23	23 bit 2’s complement integer	± 4,194,303	-4,194,304 indicates data not available
int24	24 bit 2’s complement integer	± 8,388,607	-8,388,608 indicates data not available
int25	25 bit 2’s complement integer	± 16,777,215	-16,777,216 indicates data not available
int26	26 bit 2’s complement integer	± 33,554,431	-33,554,432 indicates data not available

Data Type	Description	Range	Data Type Notes
int27	27 bit 2's complement integer	± 67,108,814	-67,108,815 indicates data not available
int30	30 bit 2’s complement integer	± 536,870,911	-536,870,912 indicates data not available
int32	32 bit 2’s complement integer	± 2,147,483,647	-2,147,483,648 indicates data not available
int34	34 bit 2’s complement integer	± 8,589,934,591	-8,589,934,592 indicates data not available
int35	35 bit 2’s complement integer	± 17,179,869,183	-17,179,869,184 indicates data not available
int38	38 bit 2’s complement integer	± 137,438,953,471	-137,438,953,472 indicates data not available
uint2	2 bit unsigned integer	0 to 3	
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	
uint8	8 bit unsigned integer	0 to 255	
uint9	9 bit unsigned integer	0 to 511	
uint10	10 bit unsigned integer	0 to 1023	
uint11	11 bit unsigned integer	0 to 2047	
uint12	12 bit unsigned integer	0 to 4095	
uint14	14 bit unsigned integer	0 to 16,383	
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	

Data Type	Description	Range	Data Type Notes
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	
uint26	26 bit unsigned integer	0 to 67,108,863	
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	
uint35	35 bit unsigned integer	0 to 34,359,738,367	
uint36	36 bit unsigned integer	0 to 68,719,476,735	
intS5	5 bit sign-magnitude integer	± 15	*See Note 1*
intS11	11 bit sign-magnitude integer	± 1023	*See Note 1*
intS22	22 bit sign-magnitude integer	± 2,097,151	*See Note 1*
intS24	24 bit sign-magnitude integer	± 8,388,607	*See Note 1*
intS27	27 bit sign-magnitude integer	± 67,108,863	*See Note 1*
intS32	32 bit sign-magnitude integer	± 2,147,483,647	*See Note 1*
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.

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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	The Reference Station ID 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. In reference network applications the Reference Station ID 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 Reference Station ID is unique within the whole network, and that ID’s should be reassigned only when absolutely necessary. Service Providers may need to coordinate their Reference Station ID 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.

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	GPS Epoch Time 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 Synchronous GNSS Message Flag 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 Number of GPS Satellite Signals Processed 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 GPS Smoothing Interval 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 GPS Satellite ID 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 GPS L1 Code Indicator 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	The GPS L1 Pseudorange 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: (GPS L1 pseudorange measurement) = (GPS L1 pseudorange field) modulo (299,792.458 m) + integer as determined from the user receiver's estimate of the reference station range, or as provided by the extended data set. 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.
DF012	GPS L1 PhaseRange – L1 Pseudorange	± 262.1435 m (See Data Field Note)	0.0005 m	int20	The GPS L1 PhaseRange – L1 Pseudorange 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. The Full GPS L1 PhaseRange is constructed as follows (all quantities in units of meters): (Full L1 PhaseRange) = (L1 pseudorange as reconstructed from L1 pseudorange field) + (GPS L1 PhaseRange – L1 Pseudorange field) Certain ionospheric conditions might cause the GPS L1 PhaseRange – L1 Pseudorange 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. See also comments in sections 3.1.6 and 3.5.1 for correction of antenna phase center variations in Network RTK applications. 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.

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 GPS L1 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.
DF014	GPS Integer L1 Pseudorange Modulus Ambiguity	0-76,447,076.790 m	299,792.458 m	uint8	The GPS Integer L1 Pseudorange Modulus Ambiguity 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 GPS L1 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.
DF016	GPS L2 Code Indicator			bit(2)	The GPS L2 Code Indicator depicts which L2 code is processed by the reference station, and how it is processed. 0= C/A or L2C code 1= P(Y) code direct 2= P(Y) code cross-correlated 3= Correlated P/Y 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.

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	The GPS L2-L1 Pseudorange Difference 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: (GPS L2 pseudorange measurement) = (GPS L1 pseudorange as reconstructed from L1 pseudorange field) + (GPS L2-L1 pseudorange field) 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.
DF018	GPS L2 PhaseRange – L1 Pseudorange	± 262.1435 m (See Data Field Note)	0.0005 m	int20	The GPS L2 PhaseRange - L1 Pseudorange 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. The Full GPS L2 PhaseRange is constructed as follows (all quantities in units of meters): (Full L2 PhaseRange) = (L1 pseudorange as reconstructed from L1 pseudorange field) + (GPS L2 PhaseRange – L1 Pseudorange field) Certain ionospheric conditions might cause the GPS L2 PhaseRange – L1 Pseudorange 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. See also comments in sections 3.1.6 and 3.5.1 for correction of antenna phase center variations in Network RTK applications.

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 Antenna Height field provides the height of the Antenna Reference Point above the marker used in the survey campaign.
DF029	Descriptor Counter	0-31		uint8	The Descriptor Counter 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	0=Use standard IGS Model 1-255=Specific Antenna Setup ID# The Antenna Setup ID 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 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.
DF032	Serial Number Counter	0-31		uint8	The Serial Number Counter defines the number of characters (bytes) to follow in Antenna Serial Number
DF033	Antenna Serial Number			char8 (n)	Alphanumeric characters. The Antenna Serial Number 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	GLONASS Epoch Time 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 Number of GLONASS Satellite Signals Processed 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 GLONASS Smoothing Interval 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 GLONASS Satellite ID 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. *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.*
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	The GLONASS Satellite Frequency Channel Number 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. 0 indicates channel number –07 1 indicates channel number –06 ….. 20 indicates channel number +13
DF041	GLONASS L1 Pseudorange	0-599,584.92 m	0.02 m	uint25	The GLONASS L1 Pseudorange 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: (L1 pseudorange measurement) = (L1 pseudorange field) modulo (599,584.916 m) + 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	The GLONASS L1 PhaseRange – L1 Pseudorange 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. The Full GLONASS L1 PhaseRange is constructed as follows (all quantities in units of meters): (Full L1 PhaseRange) = (L1 pseudorange as reconstructed from L1 pseudorange field) + (GLONASS L1 PhaseRange – GLONASS L1 Pseudorange field) Certain ionospheric conditions might cause the GLONASS L1 PhaseRange – L1 Pseudorange 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.
DF043	GLONASS L1 Lock Time Indicator	See Table 3.4-2		uint7	The GLONASS L1 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.
DF044	GLONASS Integer L1 Pseudorange Modulus Ambiguity	0-76,147,284.332 m	599,584.916 m	uint7	The GLONASS Integer L1 Pseudorange Modulus Ambiguity 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 GLONASS L1 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.
DF046	GLONASS L2 Code Indicator			bit(2)	The GLONASS L2 Code Indicator 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 GLONASS L2-L1 Pseudorange Difference 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	The GLONASS L2 PhaseRange - L1 Pseudorange 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. The Full GLONASS L2 PhaseRange is constructed as follows (all quantities in units of meters): (Full L2 PhaseRange) = (L1 pseudorange as reconstructed from L1 pseudorange field) + (GLONASS L2 PhaseRange – L1 Pseudorange field) Certain ionospheric conditions might cause the GLONASS L2 PhaseRange – L1 Pseudorange 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.
DF049	GLONASS L2 Lock Time Indicator	See Table 3.4-2		uint7	The GLONASS 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.
DF050	GLONASS L2 CNR	0-63.75 dB-Hz	0.25 dB-Hz	uint8	The GLONASS 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.

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	Modified Julian Day number (MJD) 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	Seconds Of Day (UTC) are the seconds of the day counted from midnight Greenwich time. GPS seconds of week have to be adjusted for the appropriate number of leap seconds. The value of 86,400 is reserved for the case that a leap second has been issued.
DF053	Number of Message ID Announcements to Follow (N_m)	0-31	1	uint5	The Number of Message ID Announcements 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 Message ID 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 Message Transmission Interval 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 Type Notes
DF069	GPS Ionospheric Carrier Phase Correction Difference	±32.767 m	0.5 mm	int17	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). $ICPCD = \frac{f_2^2}{f_2^2 - f_1^2} L1CD - \frac{f_2^2}{f_2^2 - f_1^2} L2CD$ L1CD, L2CD, and ICPCD are presented in meters. (See discussion of L1 and L2 corrections in Section 3.5.6.) 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.
DF070	GPS Geometric Carrier Phase Correction Difference	±32.767 m	0.5 mm	int17	Geometric Carrier Phase Correction Difference (GCPCD) is the Correction Difference for geometric part calculated based on integer leveled L1 and L2 correction differences (L1CD and L2CD). $GCPCD = \frac{f_1^2}{f_1^2 - f_2^2} L1CD - \frac{f_2^2}{f_1^2 - f_2^2} L2CD$ *L1CD, L2CD, and ICPCD are presented in meters.* (See discussion of L1 and L2 corrections in Section 3.5.6.)
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 Type Notes
DF072	Subnetwork ID	0 – 15		uint4	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.) Note: Subnetwork ID's greater than "0" should be utilized only if the associated messages for Master Reference Station observations (1001 through 1004 for GPS or 1009 through 1012 for GLONASS) 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. 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.
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	*See Note 1*	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}	*See Note 1*	2^{-55}	int8	sec/sec^2
DF083	GPS a_{f1}	*See Note 1*	2^{-43}	int16	sec/sec
DF084	GPS a_{f0}	*See Note 1*	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}	*See Note 1*	2^{-5}	int16	meters

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF087	GPS Δn (DELTA n)	*See Note 1*	2^{-43}	int16	semi-circles/sec
DF088	GPS M_0	*See Note 1*	2^{-31}	int32	semi-circles
DF089	GPS C_{uc}	*See Note 1*	2^{-29}	int16	radians
DF090	GPS Eccentricity (e)	0.03	2^{-33}	uint32	unitless
DF091	GPS C_{us}	*See Note 1*	2^{-29}	int16	radians
DF092	GPS $(A)^{1/2}$	*See Note 1*	2^{-19}	uint32	$meters^{1/2}$
DF093	GPS t_{oe}	604,784	2^{4}	uint16	seconds
DF094	GPS C_{ic}	*See Note 1*	2^{-29}	int16	radians
DF095	GPS Ω_0 $(OMEGA)_0$	*See Note 1*	2^{-31}	int32	semi-circles
DF096	GPS C_{is}	*See Note 1*	2^{-29}	int16	radians
DF097	GPS i_0	*See Note 1*	2^{-31}	int32	semi-circles
DF098	GPS C_{rc}	*See Note 1*	2^{-5}	int16	meters
DF099	GPS ω (Argument of Perigee)	*See Note 1*	2^{-31}	int32	semi-circles
DF100	GPS OMEGADOT (Rate of Right Ascension)	*See Note 1*	2^{-43}	int24	semi-circles/sec
DF101	GPS t_{GD}	*See Note 1*	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	$\pm 2^{-20}$ km/s	intS24	GLONASS ECEF-X component of satellite velocity vector in PZ-90 datum
DF112	GLONASS $x_n(t_b)$	±27000 km	$\pm 2^{-11}$ 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	$\pm 6.2 * 10^{-9}$ 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	$\pm 6.2 * 10^{-9}$ 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	$\pm 6.2 * 10^{-9}$ 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 $\Delta\tau_n$	$\pm 13.97 * 10^{-9}$ 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}	$\pm 1.9*10^{-3}$ seconds	2^{-30}	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
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)	0: Real, Physical Reference Station 1: Non-Physical or Computed Reference Station 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".
DF142	Single Receiver Oscillator Indicator			bit(1)	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. 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.

3.4 Data Fields (Additions)

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 (Additions)

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF143	Source-Name Counter	0 – 31		uint5	The Source-Name Counter defines the number of characters (bytes) to follow in Source-Name
DF144	Source-Name			char8(N)	Alphanumeric characters. Name of Source Coordinate-System. If available, the EPSG identification code for the CRS has to be used. Otherwise, service providers should try to introduce unknown CRS's into the EPSG database or could use other reasonable names.
DF145	Target-Name Counter	0 – 31		uint5	The Target-Name Counter defines the number of characters (bytes) to follow in Target-Name
DF146	Target-Name			char8(N)	Alphanumeric characters. Name of Target Coordinate-System. If available, the EPSG identification code for the CRS has to be used. Otherwise, service providers should try to introduce unknown CRS's into the EPSG database or could use other reasonable names.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF147	System Identification Number	0 – 255		uint8	A unique system identification number has to be used for all messages related to the same sets of CRS's. This is necessary if transformation information for more than one set of CRS's should be transferred within one data stream.
DF148	Utilized Transformation Message Indicator			bit(10)	This data fields says which are assigned to Transformation messages for the system identification number mentioned under DF147. Bit(n) = 0 : Message not utilized Bit(n) = 1 : Message utilized Bit(1) : 1023 Bit(2) : 1024 Bit(3) : 1025 Bit(4) : 1026 Bit(5) : 1027 Bit(6) : 0 (reserved) Bit(7) : 0 (reserved) Bit(8) : 0 (reserved) Bit(9) : 0 (reserved) Bit(10) : 0 (reserved)

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF149	Plate Number	0 – 31		uint5	0: unknown plate 1: AFRC - Africa 2: ANTA - Antarctica 3: ARAB - Arabia 4: AUST - Australia 5: CARB - Caribbea 6: COCO - Cocos 7: EURA - Eurasia 8: INDI - India 9: NOAM - N. America 10: NAZC - Nazca 11: PCFC - Pacific 12: SOAM - S. America 13: JUFU - Juan de Fuca 14: PHIL - Philippine 15: RIVR - Rivera 16: SCOT - Scotia 17 to 31: Reserved
DF150	Computation Indicator	0 – 15		uint4	Transformation method to be used: 0 = standard seven parameter, approximation 1 = standard seven parameter, strict formula 2 = Molodenski, abridged 3 = Molodenski-Badekas 4 to 15: Reserved
DF151	Height Indicator	0 – 3		uint2	0 = Geometric heights result 1 = Physical heights result If physical heights are derived via Helmert/Molodenski transformation: $H = h_{Target} - (\text{Mean } \Delta H + \Delta H \text{ (Grid interpolation)})$ 2 = Physical heights result Height definition is in Source System for instance if a geoid model is involved: $H = h_{Source} - (\text{Mean } \Delta H + \Delta H \text{ (Grid interpolation)})$ 3= Reserved

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF152	Φ_V	± 324000 [″]	2 [″]	int19	Area of validity (Ref.: Figure 3.5-3) of the Helmert/Molodenski transformation: Latitude of Origin in Degrees Coordinates defined in Source-System
DF153	Λ_V	± 648000 [″]	2 [″]	int20	Area of validity (Ref.: Figure 3.5-3) of the Helmert/Molodenski transformation: Longitude of Origin in Degrees Coordinates defined in Source-System
DF154	$\Delta\Phi_V$	0 – 32766 [″]	2 [″]	uint14	Area of validity (Ref.: Figure 3.5-3) of the Helmert/Molodenski transformation: Area Extension to North and to South in Degrees Delta Coordinates defined in Source-System 0: undefined
DF155	$\Delta\Lambda_V$	0 – 32766 [″]	2 [″]	uint14	Area of validity (Ref.: Figure 3.5-3) of the Helmert/Molodenski transformation: Area Extension to East and to West in Degrees Delta Coordinates defined in Source-System 0: undefined
DF156	dX	± 4194.303 m	0.001 m	int23	Translation in X (dX, dY, dZ) : Translation vector, to be added to the point's position vector in the source coordinate reference system in order to transform from source coordinate reference system to target coordinate reference system; also: the coordinates of the origin of source coordinate reference system in the target frame.
DF157	dY	± 4194.303 m	0.001 m	int23	Translation in Y
DF158	dZ	± 4194.303 m	0.001 m	int23	Translation in Z

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF159	*R_1*	± 42,949.67294 [″]	0.00002 [″]	int32	Rotation around the X-axis in arc seconds (*RX*, *RY*, *RZ*): Rotations to be applied to the coordinate reference frame. The sign convention is such that a positive rotation of the frame about an axis is defined as a clockwise rotation of the coordinate reference frame when viewed from the origin of the Cartesian coordinate reference system in the positive direction of that axis, that is a positive rotation about the Z-axis only from source coordinate reference system to target coordinate reference system will result in a smaller longitude value for the point in the target coordinate reference system.
DF160	*R_2*	± 42,949.67294 [″]	0.00002 [″]	int32	Rotation around the Y-axis in arc seconds
DF161	*R_3*	± 42,949.67294 [″]	0.00002 [″]	int32	Rotation around the Z-axis in arc seconds
DF162	*dS*	± 167.77215 PPM	0.00001 PPM	int25	dS is the scale correction expressed in parts per million (PPM).
DF163	X_P	± 17,179,869.184 m	0.001 m	int35	X Coordinate for Molodenski-Badekas rotation point (X_P, Y_P, Z_P): Coordinates of the point about which the coordinate reference frame is rotated, given in the source Cartesian coordinate reference system. Must always be the same within the area of a service provider
DF164	Y_P	± 17,179,869.184 m	0.001 m	int35	Y Coordinate for Molodenski-Badekas rotation point Must always be the same within the area of a service provider
DF165	Z_P	± 17,179,869.184 m	0.001 m	int35	Z Coordinate for Molodenski-Badekas rotation point Must always be the same within the area of a service provider
DF166	add a_S	0 – 16,777.215	0.001 m	uint24	Semi-major axis of source system ellipsoid a_S = 6370000 + add a_S 0: undefined If add a_S , add b_S , add a_T or add b_T is 0 (undefined) then only the 7 parameter transformation could be performed. The conversion to ellipsoidal coordinates, the projection and the local transformation (Helmert) have to be omitted.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF167	add b_S	0 – 33,554.431	0.001 m	uint25	Semi-minor axis of source system ellipsoid b_S = 6350000 + add b_S 0: undefined (see add a_S)
DF168	add a_T	0 – 16,777.215	0.001 m	uint24	Semi-major axis of target system ellipsoid a_T = 6370000 + add a_T 0: undefined (see add a_S)
DF169	add b_T	0 – 33,554.431	0.001 m	uint25	Semi-minor axis of target system ellipsoid b_T = 6350000 + add b_T 0: undefined (see add a_S)

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF170	Projection Type	0 – 63		uint6	**Projection type** **0: unknown projection type** **1: TM - Transverse Mercator** (OGP 1.4.5.1, EPSG dataset coordinate operation method code 9807) **2: TMS - Transverse Mercator (South Orientated)** (OGP 1.4.5.3, EPSG dataset coordinate operation method code 9808) **3: LCC1SP - Lambert Conic Conformal (1SP)** (OGP 1.4.1.2, EPSG dataset coordinate operation method code 9801) **4: LCC2SP - Lambert Conic Conformal (2SP)** (OGP 1.4.1.1, EPSG dataset coordinate operation method code 9802) **5: LCCW - Lambert Conic Conformal (West Orientated)** (OGP 1.4.1.3, EPSG dataset coordinate operation method code 9826) **6: CS - Cassini-Soldner** (OGP 1.4.4, EPSG dataset coordinate operation method code 9806) **7: OM - Oblique Mercator** (OGP 1.4.6, EPSG dataset coordinate operation method code 9815) **8: OS - Oblique Stereographic** (OGP 1.4.7.1, EPSG dataset coordinate operation method code 9809) **9: MC - Mercator** (OGP 1.4.3, EPSG dataset coordinate operation method code 9804 or 9805) **10:PS - Polar Stereographic** (OGP 1.4.7.2, EPSG dataset coordinate operation method code 9810) **11:DS - Double Stereographic** **12 to 63: Reserved** If the Projection type is 0 (unknown) then only the 7 parameter transformation and the interpolations for $\delta\varphi_i$, $\delta\lambda_i$ δh_i (1023) could be performed. The Projection and interpolations for δN_i, δE_i δh_i (1024) have to be omitted.
DF171	LaNO	± 90.0000 [°]	0.000000011 [°]	int34	Latitude of natural origin (TM, TMS, LCC1SP, LCCW, CS, OS, PS, DS)
DF172	LoNO	± 180.0000 [°]	0.000000011 [°]	int35	Longitude of natural origin (TM, TMS, LCC1SP, LCCW, CS, OS, MC, PS, DS)

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF173	add SNO	0 – 10737.41823 PPM	0.00001 PPM	uint30	Scale factor at natural origin (TM, TMS, LCC1SP, LCCW, OS, PS, DS) SNO = 993000 + add SNO [PPM]
DF174	FE	0 – 68,719,476.735 m	0.001 m	uint36	False Easting (TM, TMS, LCC1SP, LCCW, CS, OS, MC, PS, DS) (Contains zone term if exists)
DF175	FN	± 17,179,869.183 m	0.001 m	int35	False Northing (TM, TMS, LCC1SP, LCCW, CS, OS, MC, PS, DS)
DF176	LaFO	± 90.0000 [°]	0.000000011 [°]	int34	Latitude of false origin (LCC2SP)
DF177	LoFO	± 180.0000 [°]	0.000000011 [°]	int35	Longitude of false origin (LCC2SP)
DF178	LaSP1	± 90.0000 [°]	0.000000011 [°]	int34	Latitude of 1st standard parallel (LCC2SP)
DF179	LaSP2	± 90.0000 [°]	0.000000011 [°]	int34	Latitude of 2nd standard parallel (LCC2SP)
DF180	EFO	0 – 68,719,476.735 m	0.001 m	uint36	Easting of false origin (LCC2SP)
DF181	NFO	± 17,179,869.183 m	0.001 m	int35	Northing of false origin (LCC2SP) (Contains zone term if exists)
DF182	Rectification Flag	0-1		bit(1)	0 = not rectified (OM) 1 = rectified Oblique Mercator projection
DF183	LaPC	± 90.0000 [°]	0.000000011 [°]	int34	Latitude of projection centre (OM)
DF184	LoPC	± 180.0000 [°]	0.000000011 [°]	int35	Longitude of projection centre (OM)

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF185	AzIL	0 – 360 [°]	0.000000011 [°]	uint35	Azimuth of initial line (OM)
DF186	Diff ARSG	± 0.369098741 [°]	0.000000011 [°]	int26	Difference from Azimuth of initial line to Angle from Rectified to Skew Grid ARSG = AzIL + Diff ARSG (OM)
DF187	Add SIL	0 – 10,737.41823 PPM	0.00001 PPM	uint30	Scale factor on initial line (OM) SIL = 993000 + add SIL [PPM]
DF188	EPC	0 – 68,719,476.735 m	0.001 m	uint36	Easting at projection centre (OM) (Contains zone term if exists)
DF189	NPC	± 17,179,869.183 m	0.001 m	int35	Northing at projection centre (OM)
DF190	Horizontal Shift Indicator	0-1		bit(1)	0 = no horizontal shift 1 = apply horizontal shift
DF191	Vertical Shift Indicator	0-1		bit(1)	0 = no vertical shift 1 = apply vertical shift
DF192	Φ_0	± 324000 [″]	0.5 [″]	int21	Latitude of Origin of the grids in Degrees (See Figure 3.5-4) Coordinates defined in Target-System. In this context “Target system” means directly after utilizing Helmert or Molodenski transformation (1021 or 1022).
DF193	Λ_0	± 648000 [″]	0.5 [″]	int22	Longitude of Origin of the grids in Degrees (See Figure 3.5-4) Coordinates defined in Target-System. In this context [“]Target system” means directly after utilizing Helmert or Molodenski transformation (1021 or 1022).
DF194	$\Delta\varphi$	0 – 2047.5 [″]	0.5 [″]	uint12	Grid area extension North to South in Degrees (See Figure 3.5-4) Delta Coordinates defined in Target-System. In this context “Target system” means directly after utilizing Helmert or Molodenski transformation (1021 or 1022). 0: undefined

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF195	$\Delta\lambda$	0 – 2047.5 [″]	0.5 [″]	uint12	Grid area extension East to West in Degrees (See Figure 3.5-4) Delta Coordinates defined in Target-System. In this context [“]Target system” means directly after utilizing Helmert or Molodenski transformation (1021 or 1022). 0: undefined
DF196	Mean $\Delta\varphi$	± 0.127 [″]	0.001 [″]	int8	Mean offset for all 16 grid points.
DF197	Mean $\Delta\lambda$	± 0.127 [″]	0.001 [″]	int8	Mean offset for all 16 grid points.
DF198	Mean ΔH	± 163.84 m	0.01 m	int15	Mean height offset for all 16 grid points to cover all possible geoid heights. If “Height Indicator” = 2 - defined in Source CRS else - defined in Target CRS
DF199	$\delta\varphi_i$	± 0.00765 [″]	0.00003 [″]	int9	Residual in latitude for point i (See Figure 3.5-4) - only for small areas - defined in Target CRS
DF200	$\delta\lambda_i$	± 0.00765 [″]	0.00003 [″]	int9	Residual in longitude for point i (See Figure 3.5-4) - only for small areas - defined in Target CRS
DF201	δh_i	± 0.255 m	0.001 m	int9	Residual in height for point i (See Figure 3.5-4) - only for small areas If “Height Indicator” = 2 - defined in Source CRS else - defined in Target CRS
DF202	N_0	± 167,772,150 m	10 m	int25	Northing of Origin of the grids in meters (See Figure 3.5-4) Coordinates defined in local system after projection

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF203	E_0	0 – 671,088,630 m	10 m	uint26	Easting of Origin of the grids in meters (See Figure 3.5-4) Coordinates defined in local system after projection
DF204	ΔN	0 – 40,950 m	10 m	uint12	Grid area extension North to South in meters (See Figure 3.5-4) Delta Coordinates defined in local system after projection 0: undefined
DF205	ΔE	0 – 40,950 m	10 m	uint12	Grid area extension East to West in meters (See Figure 3.5-4) Delta Coordinates defined in local system after projection 0: undefined
DF206	Mean ΔN	± 5.11 m	0.01 m	int10	Mean local Northing offset for all 16 grid points.
DF207	Mean ΔE	± 5.11 m	0.01 m	int10	Mean local Easting offset for all 16 grid points.
DF208	Mean Δh	± 163.84 m	0.01 m	int15	Mean local height offset for all 16 grid points to cover all possible geoid heights. If "Height Indicator" = 2 - defined in Source CRS else defined in local system after projection
DF209	δN_i	± 0.255 m	0.001 m	int9	Residual in local Northing for point i (See Figure 3.5-4) - only for small areas
DF210	δE_i	± 0.255 m	0.001 m	int9	Residual in local Easting for point i (See Figure 3.5-4) - only for small areas
DF211	δh_i	± 0.255 m	0.001 m	int9	Residual in height for point i (See Figure 3.5-4) - only for small areas
DF212	Horizontal Interpolation Method Indicator	0-3		uint2	Defining horizontal interpolation method to be used (Figures 3.5-5 through 3.5-7) 0 = bi-linear 1 = bi-quadratic 2 = bi-spline 3 = reserved

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF213	Vertical Interpolation Method Indicator	0-3		uint2	Defining vertical interpolation method to be used (Figures 3.5-5 through 3.5-7) 0 = bi-linear 1 = bi-quadratic 2 = bi-spline 3 = reserved
DF214	Horizontal Helmert/Molodenski Quality Indicator	0 – 7		uint3	Maximum approximation error after application of Helmert/Molodenski transformation within the 'area of validity'. The quality could be further improved by application of information in the residual message (grid residuals). 0 = unknown quality 1 = Quality better 21 Millimeters 2 = Quality 21 to 50 Millimeters 3 = Quality 51 to 200 Millimeters 4 = Quality 201 to 500 Millimeters 5 = Quality 501 to 2000 Millimeters 6 = Quality 2001 to 5000 Millimeters 7 = Quality worse than 5001 Millimeters
DF215	Vertical Helmert/Molodenski Quality Indicator	0 – 7		uint3	Maximum approximation error after application of Helmert/Molodenski transformation within the 'area of validity'. The quality could be further improved by application of information in the residual message (grid residuals). 0 = unknown quality 1 = Quality better 21 Millimeters 2 = Quality 21 to 50 Millimeters 3 = Quality 51 to 200 Millimeters 4 = Quality 201 to 500 Millimeters 5 = Quality 501 to 2000 Millimeters 6 = Quality 2001 to 5000 Millimeters 7 = Quality worse than 5001 Millimeters

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF216	Horizontal Grid Quality Indicator	0 – 7		uint3	Maximum horizontal case within the given area after applying the grid residuals. Replaces the Helmert/Molodenski Quality 0 = unknown quality 1 = Quality 0 to 10 Millimeters 2 = Quality 11 to 20 Millimeters 3 = Quality 21 to 50 Millimeters 4 = Quality 51 to 100 Millimeters 5 = Quality 101 to 200 Millimeters 6 = Quality 201 to 500 Millimeters 7 = Quality worse than 501 Millimeters
DF217	Vertical Grid Quality Indicator	0 – 7		uint3	Maximum vertical case within the given area after applying the grid residuals. Replaces the Helmert/Molodenski Quality 0 = unknown quality 1 = Quality 0 to 10 Millimeters 2 = Quality 11 to 20 Millimeters 3 = Quality 21 to 50 Millimeters 4 = Quality 51 to 100 Millimeters 5 = Quality 101 to 200 Millimeters 6 = Quality 201 to 500 Millimeters 7 = Quality worse than 501 Millimeters

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF218	s_{oc}	0 - 127 mm	0.5 mm	uint8	Constant term of standard deviation (1 sigma) for non-dispersive interpolation residuals
DF219	s_{od}	0 - 5.11 ppm	0.01 ppm	uint9	Distance dependent term of standard deviation(1 sigma) for non-dispersive interpolation residuals
DF220	s_{oh}	0 - 5.11 ppm	0.1 ppm	uint6	Height dependent term of standard deviation (1 sigma) for non-dispersive interpolation residuals. The complete standard deviation for the expected non-dispersive interpolation residual is computed from DF218,DF219 and DF220 using the formula: $s_0 = \sqrt{s_{0c}^2 + s_{0d}^2 \cdot d_{\mathrm{Re}\,f}^2 + s_{0h}^2 \cdot dh_{\mathrm{Re}\,f}^2}$ [mm] where $d_{\mathrm{Re}\,f}$ is the distance of the rover from the nearest physical reference station in [km] and $\lvert dh_{\mathrm{Re}\,f} \rvert$ is the absolute value of the height difference between nearest physical reference station and rover in [km].
DF221	s_{Ic}	0 - 511 mm	0.5 mm	uint10	Constant term of standard deviation (1 sigma) for dispersive interpolation residuals (as affecting GPS L1 frequency)

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF222	s_{Id}	0 - 10.23 ppm	0.01 ppm	uint10	Distance dependent term of standard deviation (1 sigma) for dispersive interpolation residuals. (as affecting GPS L1 frequency) The complete standard deviation for the expected dispersive interpolation residual is computed from DF221 and DF222 using the formula: $s_I(\mathrm{L1}) = \sqrt{s_{Ic}^2 + s_{Id}^2 \cdot d_{\mathrm{Re}\,f}^2}$ [mm] where $d_{\mathrm{Re}\,f}$ is the distance of the rover from the nearest physical reference station in [km]. The standard deviation for the GPS L2 frequency is calculated using the formula: $s_I(L2) = s_I(L1) \cdot \frac{\lambda_2^2}{\lambda_1^2}$ [mm]
DF223	N-Refs	0 - 127	-	uint7	Number of reference stations used to derive residual statistics (1 to 127, use 127 for 127 or more stations). The number of reference stations should never be zero. If zero is encountered the rover should ignore the message.
DF224	GPS Residuals Epoch Time (TOW)	0 – 604800 s	1 s	uint20	
DF225	GLONASS Residuals Epoch Time (tk)	0 – 86400 s	1 s	uint17	
DF226	Physical Reference Station ID	0 – 4095	-	uint12	The Physical Reference Station ID specifies the station ID of a real reference station, when the data stream itself is based on a non-physical reference station. Consequently, for the Physical Reference Station ID the same notes apply as for DF003.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF227	Receiver Type Descriptor Counter	0-31	-	uint8	Number of characters in the name of the receiver type
DF228	Receiver Type Descriptor		-	char8 (n)	Standard ASCII characters
DF229	Receiver Firmware Version Counter	0-31	-	uint8	Number of characters in the name of the receiver firmware
DF230	Receiver Firmware Version		-	char8 (n)	Standard ASCII characters
DF231	Receiver Serial Number Counter	0-31	-	uint8	Number of characters in the name of the receiver serial number
DF232	Receiver Serial Number		-	char8 (n)	Standard ASCII characters

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF233	GLONASS NW Epoch Time	0 – 86,400.9 sec	0.1 sec	uint20	Epoch time of observations used to derive correction differences
DF234	# of GLONASS Data Entries	0-15		uint4	The number of data entries (total number of satellites for which given data blocks are available).
DF235	GLONASS 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 Sections 3.5.6 and 3.5.13)
DF236	GLONASS Non Sync Count	0-7		uint3	Whenever an unrecoverable cycle slip occurs this count must 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 and 3.5.13)

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF237	GLONASS Ionospheric Carrier Phase Correction Difference	±32.767 m	0.5 mm	int17	The GLONASS Ionospheric Carrier Phase Correction Difference (ICPCDR) is the correction difference for ionospheric part calculated from integer leveled L1 and L2 correction differences (L1CDR and L2CDR). $ICPCDR = \frac{f_2^2}{f_2^2 - f_1^2} L1CDR - \frac{f_2^2}{f_2^2 - f_1^2} L2CDR$ L1CDR, L2CDR, and ICPCDR are presented in meters. The terms f_1 and f_2 represent the GLONASS L1 and L2 carrier frequencies respectively. Note that the coefficient $\frac{f_2^2}{f_2^2 - f_1^2}$ is constant for all GLONASS frequency channel numbers. 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 3.5-64 & 3.5-66) shall not be transmitted. (See discussion of L1 and L2 corrections in Section 3.5.13).

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF238	GLONASS Geometric Carrier Phase Correction Difference	±32.767 m	0.5 mm	int17	The GLONASS Geometric Carrier Phase Correction Difference (GCPCDR) is the correction difference for geometric part calculated from integer leveled L1 and L2 correction differences (L1CDR and L2CDR). $GCPCDR = \frac{f_1^2}{f_1^2 - f_2^2} L1CDR - \frac{f_2^2}{f_1^2 - f_2^2} L2CDR$ L1CDR, L2CDR, and GCPCDR are presented in meters. The terms f_1 and f_2 represent the GLONASS L1 and L2 carrier frequencies respectively. Note that the coefficients $\frac{f_1^2}{f_1^2 - f_2^2}$ and $\frac{f_2^2}{f_1^2 - f_2^2}$ are constant for all GLONASS frequency channel numbers. (See discussion of L1 and L2 corrections in Section 3.5.13).
DF239	GLONASS IOD	0-255		bit(8)	Issue Of Data (IOD) of GLONASS broadcast ephemeris. Bits 0-5 are the 6 LSB's of the t_b field in the current ephemeris (see DF110). Bits 6-7 are set to zero in this version. If these bits are not equal to zero, the given satellite should be excluded from positioning.
DF240	GPS FKP Epoch Time	0 – 604799 s	1 s	uint20	Seconds since the beginning of the GPS week.
DF241	GLONASS FKP Epoch Time	0 – 86400 s	1 s	uint17	Seconds since beginning of GLONASS day.
DF242	N0: Geometric gradient in north (ppm)	±20.47 ppm	0.01 ppm	int12	Gradient (FKP) of the geometric (non-dispersive) error components in South-North direction in parts per million of the south-north distance to the reference station. Note: A bit pattern equivalent to 800h in this field indicates the Geometric Gradient in North is invalid.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF243	E0: Geometric gradient in east (ppm)	±20.47 ppm	0.01 ppm	int12	Gradient (FKP) of the geometric (non-dispersive) error components in West-East direction in parts per million of the west-east distance to the reference station. Note: A bit pattern equivalent to 800h in this field indicates the Geometric Gradient in East is invalid.
DF244	NI: Ionospheric gradient in north (ppm)	±81.91 ppm	0.01 ppm	int14	Gradient (FKP) of the ionospheric (dispersive) error component in South-North direction. Note: A bit pattern equivalent to 2000h in this field indicates the Ionospheric Gradient in North is invalid.
DF245	EI: Ionospheric gradient in east (ppm)	±81.91 ppm	0.01 ppm	int14	Gradient (FKP) of the ionospheric (dispersive) error component in West-East direction. Note: A bit pattern equivalent to 2000h in this field indicates the Ionospheric Gradient in East is invalid.
DF246-DF363					RESERVED

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF364	Quarter Cycle Indicator			bit(2)	The Quarter Cycle Indicator denotes whether different carrier phase signals tracked on the same frequency have a common phase, i.e. whether or not the fractional PhaseRanges of two signals on the same frequency show a quarter cycle difference (see also section 3.1.7 for further explanation).The definition of the indicator relates exclusively to the correction status of the quarter cycle, and applies to Messages Types 1001, 1002, 1003, 1004, 1009, 1010, 1011, 1012. Other possible corrections cannot be indicated by this indicator. 00= Correction status unspecified 01= PhaseRanges in Message Types 1001, 1002, 1003, 1004, 1009, 1010, 1011, 1012 are corrected in such a way that whenever PhaseRanges for different signals on the same frequency are present in these messages, they are guaranteed to be in phase and thus shall show no Quarter-Cycle bias between them (see Table 3.1-5 for details on the adjustments made). Double differences of PhaseRanges tracked with different signals shall show no Quarter- Cycle differences. 10= Phase observations are not corrected. Double differences may show Quarter-Cycle differences for PhaseRanges based on different signals on the same frequency. Processing will require appropriate corrections. 11= Reserved
DF365	Delta Radial	±209.7151 m	0.1 mm	int22	Radial orbit correction for broadcast ephemeris. The reference time t0 is Epoch Time (DF385, DF386) plus ½ SSR Update Interval. The reference time t0 for SSR Update Interval "0" is Epoch Time.
DF366	Delta Along-Track	±209.7148 m	0.4 mm	int20	Along-Track orbit correction for broadcast ephemeris. See note on reference time t0 of DF365.
DF367	Delta Cross-Track	±209.7148 m	0.4 mm	int20	Cross-Track orbit correction for broadcast ephemeris. See note on reference time t0 of DF365.
DF368	Dot Delta Radial	±1.048575 m/s	0.001 mm/s	int21	Velocity of Radial orbit correction for broadcast ephemeris. See note on reference time t0 of DF365.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF369	Dot Delta Along-Track	±1.048572 m/s	0.004 mm/s	int19	Velocity of Along-Track orbit correction for broadcast ephemeris. See note on reference time t0 of DF365.
DF370	Dot Delta Cross-Track	±1.048572 m/s	0.004 mm/s	int19	Velocity of Cross-Track orbit correction for broadcast ephemeris. See note on reference time t0 of DF365.
DF371	RESERVED for Dot Dot Delta Radial	±1.34217726 m/s2	0.00002 mm/s2	int27	Acceleration of Radial orbit correction for broadcast ephemeris. See note on reference time t0 of DF365.
DF372	RESERVED for Dot Dot Delta Along-Track	±1.3421772 m/s2	0.00008 mm/s2	int25	Acceleration of Along-Track orbit correction for broadcast ephemeris. See note on reference time t0 of DF365.
DF373	RESERVED for Dot Dot Delta Cross-Track	±1.3421772 m/s2	0.00008 mm/s2	int25	Acceleration of Cross-Track orbit correction for broadcast ephemeris. See note on reference time t0 of DF365.
DF374	Satellite Reference Point	0-1	N/A	bit(1)	Orbit corrections refer to Satellite Reference Point: "0"=Satellite Reference Point (SRP) currently L1/L2 phase center of the ionospheric free signal "1"=Reserved for future extension to Center Of Mass (COM) representation
DF375	Satellite Reference Datum	0-1	N/A	bit(1)	Orbit corrections refer to Satellite Reference Datum: "0"=ITRF "1"=regional
DF376	Delta Clock C0	±209.7151 m	0.1 mm	int22	C0 polynomial coefficient for correction of broadcast satellite clock. The reference time t0 is Epoch Time (DF385, DF386) plus ½ SSR Update Interval. The reference time t0 for SSR Update Interval "0" is Epoch Time.
DF377	Delta Clock C1	±1.048575 m/s	0.001 mm/s	int21	C1 polynomial coefficient for correction of broadcast satellite clock. See note on reference time t0 of DF376.
DF378	Delta Clock C2	±1.34217726 m/s2	0.00002 mm/s2	int27	C2 polynomial coefficient for correction of broadcast satellite clock. See note on reference time t0 of DF376.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF379	No. of Code Biases Processed	0-31	1	uint5	Number of Code Biases for one individual satellite
DF380	GPS Signal and Tracking Mode Identifier	0-31	1	uint5	Indicator to specify the GPS signal and tracking mode: 0= L1 C/A 1= L1 P 2= L1 Z-tracking and similar (AS on) 3= Reserved 4= Reserved 5= L2 C/A 6= L2 L1(C/A)+(P2-P1) (semi-codeless) 7= L2 L2C (M) 8= L2 L2C (L) 9= L2 L2C (M+L) 10= L2 P 11= L2 Z-tracking and similar (AS on) 12= Reserved 13= Reserved 14= L5 I 15= L5 Q Descriptors >15 are reserved.
DF381	GLONASS Signal and Tracking Mode Identifier	0-31	1	uint5	Indicator to specify the GLONASS signal and tracking mode: 0= G1 C/A 1= G1 P 2= G2 C/A (GLONASS M) 3= G2 P Descriptors >3 are reserved

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF382	RESERVED for Galileo Signal and Tracking Mode Identifier	0-31	1	uint5	Indicator to specify the Galileo signal and tracking mode: 0= E1 A PRS 1= E1 B I/NAV OS/CS/SoL 2= E1 C no data 3= Reserved 4= Reserved 5= E5a I F/NAV OS 6= E5a Q no data 7= Reserved 8= E5b I I/NAV OS/CS/SoL 9= E5b Q no data 10= Reserved 11= E5 I 12= E5 Q 13= Reserved 14= E6 A PRS 15= E6 B C/NAV CS 16= E6 C no data Descriptors >16 are reserved.
DF383	Code Bias	±81.91 m	0.01 m	int14	Code Bias for specified Signal
DF384	GLONASS Satellite ID	1 – 24	1	uint5	GLONASS Satellite ID's only
DF385	GPS Epoch Time 1s	0 – 604799 s	1 s	uint20	Full seconds since the beginning of the GPS week
DF386	GLONASS Epoch Time 1s	0 – 86400 s	1 s	uint17	Full seconds since the beginning of GLONASS day
DF387	No. of Satellites	0-63	1	uint6	Number of satellites
DF388	Multiple Message Indicator	0-1	1	bit(1)	Indicator for transmitting messages with the same Message Number and Epoch Time: "0"= last message of a sequence "1"= multiple message transmitted

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF389	SSR URA	bits 5-3: 0-7 bits 2-0: 0-7		bit(6)	SSR User Range Accuracy (URA) (1 sigma) for a range correction computed from complete SSR set as disseminated by RTCM SSR messages. The URA is represented by a combination of URA_CLASS and URA_VALUE. The 3 MSB define the URA_CLASS with a range of 0-7 and the 3 LSB define the URA_VALUE with a range of 0-7. The URA is computed by: $\mathrm{URA}\ [\mathrm{mm}] \leq 3^{\mathrm{URA\_CLASS}}\left(1+\frac{\mathrm{URA\_VALUE}}{4}\right)-1\ [\mathrm{mm}]$ Special cases are: all bits zero “000 000” =URA undefined/unknown, SSR corrections for the corresponding satellite may not be reliable all bits set “111 111” =URA > 5466.5 mm
DF390	High Rate Clock Correction	±209.7151 m	0.1 mm	int22	High Rate Clock correction to be added to the polynomial clock correction (see DF376, DF377, DF378)

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF391	SSR Update Interval	0-15	1	bit(4)	SSR Update Interval. The SSR Update Intervals for all SSR parameters start at time 00:00:00 of the GPS time scale. A change of the SSR Update Interval during the transmission of a SSR data stream should ensure consistent data for a rover. The supported SSR Update Intervals are: 0=1 s 1=2 s 2=5 s 3=10 s 4=15 s 5=30 s 6=60 s 7=120 s 8=240 s 10=300 s 10=600 s 11=900 s 12=1800 s 13=3600 s 14=7200 s 15=10800 s Note that the update intervals are aligned to the GPS time scale for all GNSS in order to allow synchronous operation for multiple GNSS services. This means that the update intervals may not be aligned to the beginning of the day for another GNSS. Due to the leap seconds this is generally the case for GLONASS.
DF392	GLONASS Issue Of Data (IOD)	0-255		bit(8)	Issue Of Data of GLONASS broadcast ephemeris If bit 7 is 0 (bit 7 is MSB): Bits 0-6 represent the 7 bits of the GLONASS tb field in the current ephemeris (see DF110) If bit 7 is 1: Reserved for future use. Data should not be used. This can be the case for pre-GLONASS-M satellite if ephemeris changed within tb interval.
DF393-DF412					RESERVED

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF413	IOD SSR	0-15	1	uint4	A change of Issue Of Data SSR is used to indicate a change in the SSR generating configuration, which may be relevant for rover operation.
DF414	SSR Provider ID	0-65535	1	uint16	SSR Provider ID is provided by RTCM on request to identify a SSR service. The Provider ID shall be globally unique. Providers should contact "rtcm.org". 0 – 255 = reserved for experimental services 256 – 65535 = unique SSR Provider ID
DF415	SSR Solution ID	0-15	1	uint4	SSR Solution ID indicates different SSR services of one SSR provider

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

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

Indicator	***Smoothing Interval***
000 (0)	*No smoothing*
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)	*Unlimited smoothing interval*

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
TOTAL			***58***

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
TOTAL			***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
TOTAL			***101***

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
TOTAL			***125***

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 GNSS 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.

The Quarter Cycle Indicator was introduced to avoid inconsistencies between different approaches by different receiver hardware manufacturers to handle quarter cycle shifts between carrier phase observations on the same frequency (see Section 3.1.8).

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
Quarter Cycle Indicator	DF364	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
Quarter Cycle Indicator	DF364	bit(2)	2
Antenna Reference Point ECEF-Z	DF027	int38	38
Antenna Height	DF028	uint16	16
TOTAL			***168***

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
TOTAL			***64***

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:

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

$$L2C_S = s_S - \Phi_{S,2}(t) - \frac{c}{f_2} N_{S,2} + t_{S,2} + A_{S,2}$$, 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
TOTAL			***488***	

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

3.5.10 Coordinate Transformation Messages

Further information about coordinate transformations can be found at "OGP Surveying and Positioning Guidance Note Number 7, part 2 - Coordinate Conversions and Transformations including Formulas" (Further on referred to as OGP) and EPSG database Version 6.11_2 (Further on referred to as EPSG) at http://www.epsg.org/ or at the European Coordinate Reference System (CRS) website at http://www.crs.bkg.bund.de/.

3.5.10.1 Transformation Information

For RTCM data supporting a RTK service, coordinates are measured within the ITRF or a regional realization. Surveyors and other users of RTK services must normally present their results in the coordinates of local datums. Therefore, coordinate transformations are necessary.

Currently, transformation parameters are calculated and manually transferred to GPS receivers, a process which can be a source of confusion. Another method is to store models on the GPS receivers and to use these for the transformation. However, it often happens that revised models are not available in the GPS receiver, so that users end up utilizing obsolete information.

Users have often expressed their desire to be able to utilize a simpler and more convenient method. By having RTCM messages that contain transformation data and information about the Coordinate Reference Systems, the users of the RTK service can obtain their results in the desired datum without any manual operations. The RTK service providers can then ensure that current information for the computation of the transformations is always used. The convenience of this method will promote the acceptance of RTK services.

3.5.10.2 Concatenated Coordinate Operation (ISO 19111)

The change of coordinates from one coordinate reference system to another coordinate reference system follows from a series of coordinate operations consisting of one or more coordinate transformations and/or one or more coordinate conversions. This is called a concatenated coordinate operation.

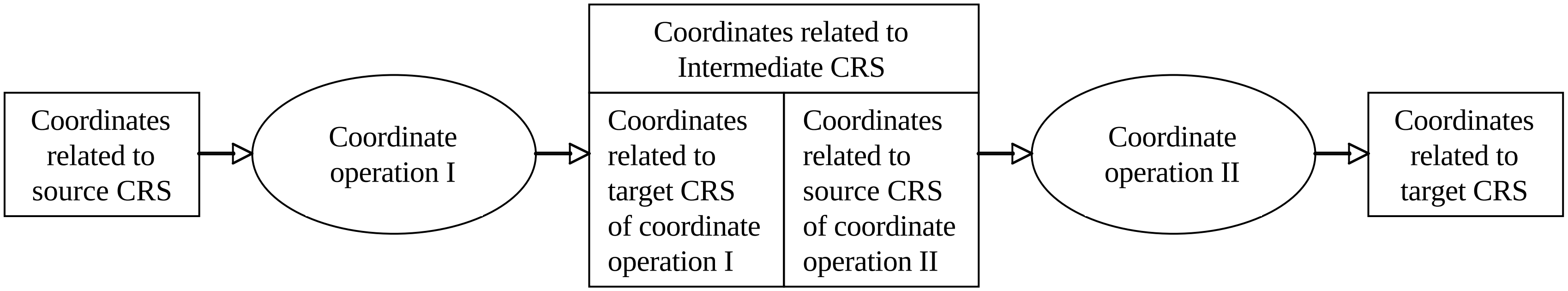

Figure 3.5-1. Steps in the Coordinate Transformation Process

The transformation of coordinates from an ECEF coordinate system to a local coordinate system generally requires several steps, as described in the next few paragraphs.

Datum transformation

The transformation from the global ECEF (ITRF, ETRF, ...) to the local geodetic datum is generally accomplished by means of a 7-*parameter transformation. The ISO19111 specifies the linearized, or approximate, transformation formula. The parameters found in many publications as well as databases like the EPSG or European initiatives, and all the IGS and IERS parameters correspond to this formula. The use of the linearized formula and a respective 7-parameter set is specified by the computation-indicator "0". The strict formula of a 7-parameter transformation is also often used in practice and is related to finite rotations' parameterization. The application of the strict formula and a respective set of 7 parameters is specified by the computation-indicator "1" in data field DF150. The 7 parameters belonging to the indicator "0" and "1"*, respectively are self-consistent also with respect to the given and different inversion formulas, while the different transformation parameterizations and related parameters themselves can not to be interchanged without a loss of transformation correctness and accuracy.

Coordinate conversion from geocentric Cartesian representation to ellipsoidal latitude, longitude and height

This conversion requires the knowledge of the ellipsoidal parameters (a,b).

Coordinate conversion to plane coordinates

This coordinate conversion uses projection formulas like the Transverse Mercator projection (Gauss-Krüger, UTM,..) or other (mostly) conformal projections to obtain 2-D Cartesian plane coordinates (Northing, Easting) and 3.5-D height. The projection step requires the knowledge of the ellipsoidal parameters as well as the parameters for the projection (prime meridian, scale, false northing and easting etc.).

Height transformation

From ellipsoidal heights to the local, leveling-related height system requires the knowledge of the difference between the ellipsoid and the reference surface for the local height system. This reference surface may be the geoid, quasi-geoid or a similar surface. The representation of such a reference surface includes the vertical datum as well as systematic and stochastic effects in the realization of the local height systems. The height surface can be related either to the global datum and ellipsoid, or to the local datum and ellipsoid.

The height transition from ellipsoidal to physical heights can also be accomplished within the 7-parameter transformation, if the area is very small (see DF152, DF153).

Transformation from global ECEF to plate-fixed ECEF coordinates

The dynamic earth causes movements of the tectonic plates on the order of centimeters per year. This means that the transformation parameters are not constant. To account for this, different organizations have established quasi-global coordinate reference systems, which are tied to the tectonic plates (ETRS in Europe). If the starting point for step no. 1 is such a plate-fixed coordinate system, then the transformation parameters may be considered constant for a longer period of time, since only local movements within the plates would be responsible for changes. Since global GNSS (satellite coordinates) are described in a global ECEF coordinate system, an additional transformation step is necessary:

An additional message will be defined for this function in the future. It will be omitted in this document.

3.5.10.3 3-D Coordinate Transformation Formulas

There are four sets of transformations that will be supported in this Standard: (1) the linear form of the Helmert Transformation, (2) the strict form of the Helmert Transformation, (3) the abridged Molodenski Transformation, and (4) the Molodenski-Badekas Transformation. They are described in EPSG Guidance Note 7, which is on the website of the "Surveying and Positioning Committee of the International Association of Oil and Gas Producers (OGP)", the former "European Petroleum Survey Group" (EPSG, http://www.epsg.org). Figure 3.5-2 shows the geometry of the transformation and the senses of rotation used herein.

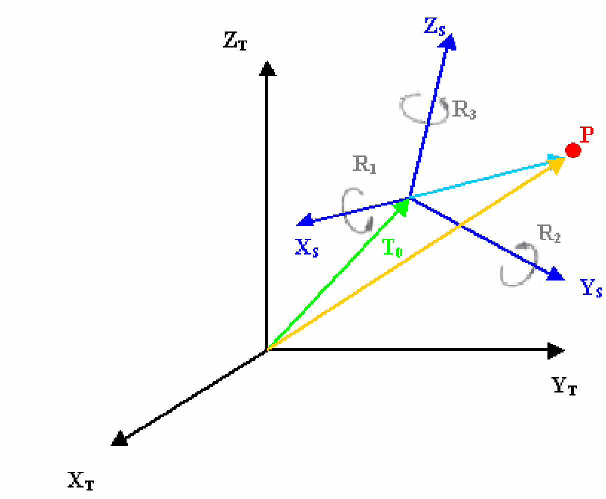

Figure 3.5-2. Definition of Translation and Rotations

3.5.10.3.1 Helmert Transformation, linear expression

(OGP 2.4.3.2.2 Coordinate Frame Rotation, EPSG dataset coordinate operation method code 9607)

Transformation of coordinates from one geographic coordinate reference system into another (also known as a "datum transformation") is usually carried out as an implicit concatenation of three transformations:

[geographical to geocentric >> geocentric to geocentric >> geocentric to geographic]

The middle part of the concatenated transformation, from geocentric to geocentric, is usually described as a simplified 7-parameter Helmert transformation.

The formula is:

$$\begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} = M * \begin{bmatrix} 1 & +R_Z & -R_Y \\ -R_Z & 1 & +R_X \\ +R_Y & -R_X & 1 \end{bmatrix} * \begin{bmatrix} X_S \\ Y_S \\ Z_S \end{bmatrix} + \begin{bmatrix} dX \\ dY \\ dZ \end{bmatrix} \quad (3.5\text{-}1)$$

and the parameters are defined as:

(R_1, R_2, R_3): Rotations to be applied to the coordinate reference frame. The sign convention is such that a positive rotation of the frame about an axis is defined as a clockwise rotation of the coordinate reference frame when viewed from the origin of the Cartesian coordinate system in the positive direction of that axis, that is a positive rotation about the Z-axis only from source coordinate reference system to target coordinate reference system will result in a smaller longitude value for the point in the target coordinate reference system. Although rotation angles may be quoted in any angular unit of measure, the formula as given here requires the angles to be provided in radians.

The formula as given here requires the angles to be provided in radians - conversion from arc seconds (R_1, R_2, R_3) to radians (R_X, R_Y, R_Z):

$$R_X = R_1 * \left(\frac{\pi}{3600 \; * \; 180} \right) \quad (3.5\text{-}2)$$

$$R_Y = R_2 * \left(\frac{\pi}{3600 \; * \; 180} \right) \quad (3.5\text{-}3)$$

$$R_Z = R_3 * \left(\frac{\pi}{3600 \; * \; 180} \right) \quad (3.5\text{-}4)$$

M : The scale factor to be applied to the position vector in the source coordinate reference system in order to obtain the correct scale of the target coordinate reference system.

$$M = (1+dS*10^{-6}) \quad (3.5\text{-}5)$$

3.5.10.3.2 Helmert Transformation, Strict formula

$$\begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} = \begin{bmatrix} dX \\ dY \\ dZ \end{bmatrix} + M * \mathbf{R} * \begin{bmatrix} X_S \\ Y_S \\ Z_S \end{bmatrix} \qquad (3.5\text{-}6)$$

where **R** is the rotation matrix defined by

$$\mathbf{R} = \mathbf{R}_z \mathbf{R}_y \mathbf{R}_x = \begin{bmatrix} \cos R_3 & \sin R_3 & 0 \\ -\sin R_3 & \cos R_3 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos R_2 & 0 & -\sin R_2 \\ 0 & 1 & 0 \\ \sin R_2 & 0 & \cos R_2 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos R_1 & \sin R_1 \\ 0 & -\sin R_1 & \cos R_1 \end{bmatrix} \qquad (3.5\text{-}7)$$

M : The scale factor to be applied to the position vector in the source coordinate reference system in order to obtain the correct scale of the target coordinate reference system.

$$M = (1 + dS * 10^{-6}) \qquad (3.5\text{-}8)$$

<u>Inverse formula</u>

To transform in the opposite direction using the same numerical values as for the forward formula use the following strict inverse formula:

$$\begin{bmatrix} X_S \\ Y_S \\ Z_S \end{bmatrix} = \frac{\mathbf{R}^{-1}}{M} \left[\begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} - \begin{bmatrix} dX \\ dY \\ dZ \end{bmatrix} \right] \qquad (3.5\text{-}9)$$

where $\mathbf{R}^{-1}$ is the mathematical inverse of the rotation matrix = the transposed matrix $\mathbf{R}^{\mathbf{T}}$.

3.5.10.3.3 Molodenski Transformation, abridged

$$\begin{aligned} \varphi_T &= \varphi_S + d\varphi \\ \lambda_T &= \lambda_S + d\lambda \\ h_T &= h_S + dh \end{aligned} \qquad (3.5\text{-}10)$$

$$d\varphi[rad] = \frac{\left(-dX \cdot \sin\varphi_S \cos\lambda_S - dY \cdot \sin\varphi_S \sin\lambda_S + dZ \cdot \cos\varphi_S + \left[(M \cdot a_s / b_s + N \cdot b_s / a_s) \cdot df + (N \cdot e_s^{\,2}) / a_s \cdot da\right] \cdot \sin 2\varphi_S / 2\right)}{(M + h_S)}$$

$$d\lambda[rad] = \frac{(-dX \cdot \sin\lambda_S + dY \cdot \cos\lambda_S)}{((N + h_S) \cdot \cos\varphi_S)} \tag{3.5-11}$$

$$dh = dX \cdot \cos\varphi_S \cdot \cos\lambda_S + dY \cdot \cos\varphi_S \cdot \sin\lambda_S + dZ \cdot \sin\varphi_S + \left(df \cdot N \cdot b_s / a_s\right) \cdot \sin^2\varphi_S - da \cdot a_s / N$$

where M and N are the meridian and prime vertical radii of curvature at the given latitude φ_s,

$$M = \frac{a_S \cdot (1 - e_s^{\,2})}{\left(1 - e_s^{\,2} \cdot \sin(\varphi_S)^2\right)^{3/2}} \tag{3.5-12}$$

$$N = \frac{a_S}{\sqrt{\left(1 - e_s^{\,2} \cdot \sin(\varphi_S)^2\right)}} \tag{3.5-13}$$

$$e_S^{\,2} = (a_s^{\,2} - b_s^{\,2}) / a_s^{\,2} \tag{3.5-14}$$

da is the difference in the semi-major axes of the target and source ellipsoids [da = $a_T - a_S$] and df is the difference in the flattening of the two ellipsoids [df = $f_t - f_s = 1/(1/f_t) - 1/(1/f_s)$] where 1/f = a/(a - b).

The formulas for dφ and dλ indicate changes in φ_S and λ_S in radians. Finally it holds for the translations of the origins: $dX = X_T - X_S$, $dY = Y_T - Y_S$ and $dZ = Z_T - Z_S$

3.5.10.3.4 Molodenski-Badekas Transformation

(OGP 2.4.3.3 Molodensky-Badekas 10-parameter transformation, EPSG dataset coordinate operation method code 9636)

To eliminate high correlation between the translations and rotations in the derivation of parameter values for these Helmert transformation methods, instead of the rotations being derived about the geocentric coordinate reference system origin they may be derived at a location within the points used in the determination. Three additional parameters, the coordinates of the rotation point, are then required. The formula is:

$$\begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} = M * \begin{bmatrix} 1 & +R_Z & -R_Y \\ -R_Z & 1 & +R_X \\ +R_Y & -R_X & 1 \end{bmatrix} * \begin{bmatrix} X_S & -X_P \\ Y_S & -Y_P \\ Z_S & -Z_P \end{bmatrix} + \begin{bmatrix} X_P \\ Y_P \\ Z_P \end{bmatrix} + \begin{bmatrix} dX \\ dY \\ dZ \end{bmatrix} \qquad (3.5\text{-}15)$$

and the parameters are defined as:

(R_1, R_2, R_3): Rotations to be applied to the coordinate reference frame. The sign convention is such that a positive rotation of the frame about an axis is defined as a clockwise rotation of the coordinate reference frame when viewed from the origin of the Cartesian coordinate system in the positive direction of that axis, that is a positive rotation about the Z-axis only from source coordinate reference system to target coordinate reference system will result in a smaller longitude value for the point in the target coordinate reference system. Although rotation angles may be quoted in any angular unit of measure, the formula as given here requires the angles to be provided in radians.

(X_P, Y_P, Z_P): Coordinates of the point about which the coordinate reference frame is rotated, given in the source Cartesian coordinate reference system.

The formula as given here requires the angles to be provided in radians - conversion from arc seconds (R_1, R_2, R_3) to radians (R_X, R_Y, R_Z):

$$R_X = R_1 * \left(\frac{\pi}{3600 \quad * \quad 180} \right) \qquad (3.5\text{-}16)$$

$$R_Y = R_2 * \left(\frac{\pi}{3600 \quad * \quad 180} \right) \qquad (3.5\text{-}17)$$

$$R_Z = R_3 * \left(\frac{\pi}{3600 \quad * \quad 180} \right) \qquad (3.5\text{-}18)$$

M : The scale factor to be applied to the position vector in the source coordinate reference system in order to obtain the correct scale of the target coordinate reference system.

$$M = (1+dS*10^{-6}) \qquad (3.5\text{-}19)$$

Reversibility

The Molodensky-Badekas transformation in a strict mathematical sense is not reversible, i.e. in principle the same parameter values cannot be used to execute the reverse transformation. This is because the evaluation point coordinates are in the forward direction source coordinate reference system and the rotations have been derived about this point. They should not be applied about the point having the same coordinate values in the target coordinate reference system, as is required for the reverse transformation. However, in practical application there are exceptions when applied to the approximation of small differences between the geometry of a set of points in two different coordinate reference systems. The typical vector difference in coordinate values is in the order of $6*10^1$ to $6*10^2$ meters, whereas the evaluation point on or near the surface of the earth is $6.3*10^6$ meters from the origin of the coordinate systems at the Earth's centre. This difference of four or five orders of magnitude allows the transformation in practice to be considered reversible. Note that in the reverse transformation, only the signs of the translations and rotation parameter values are reversed; the coordinates of the evaluation point remain unchanged.

3.5.10.4 Procedures for Utilizing the Messages

Seven message types are defined here in support of the application of coordinate transformations, namely Message Types 1021 through 1027. Message Type 1021 provides the basic transformation parameters for the first three sets, while Message Type 1022 provides the information for the fourth set, the Molodenski-Badekas transformation. Message Types 1023 and 1024 define the residuals for ellipsoidal and plane grid representations, respectively. Message Types 1025, 1026 and 1027 define the parameters that support the Lambert Conic Conformal (LCC2SP) projection, the Oblique Mercator (OM) projection, and others.

At a minimum, the Service Provider should send out either Message Type 1021 or 1022, each of which contains transformation parameters. The other messages provide useful information for many applications. Either Message Type 1023 or 1024 should be utilized, but not both; similarly for Message Types, 1025-1027, only one type should be utilized.

The interval between successive Coordinate Transformation messages is arbitrary, but the following guidelines are provided here. If the communications link is bi-directional,

- 1021 or 1022: Initially send out after 3, 8 and 13 GNSS epochs, each 60 epochs thereafter
- 1023 or 1024: Initially send out after 4, 9 and 14 GNSS epochs, each 60 epochs thereafter
- 1025 *or* 1026 *or* 1027: Initially send out after 5, 10 and 15 GNSS epochs, each 60 epochs thereafter.

For a one-way broadcast link,

- 1021 or 1022: Each 60 epochs
- 1023 or 1024: 10 epochs after 1021 or 1022
- 1025 *or* 1026 *or* 1027: 20 epochs after 1021 or 1022.

If it is necessary to cover larger areas with a one-way broadcast link, neighbouring grids - for the 'Area of validity of the Helmert/Molodenski transformation' - can be transmitted with Message Type 1023 or 1024.

The Mobile Receiver must perform the following procedures:

- First, the Mobile Receiver should check which Transformation messages are utilized by inspecting the data field DF148, "Utilized Transformation Message Indicator", which is included in Message Types 1021 and 1022.
- All identified messages should be processed before performing the transformation.
- The Mobile Receiver should process the residual messages using the interpolation technique identified by the Service Provider.
- An estimate of the complete positioning error should be determined using proper error propagation. The contributions of the coordinate transformation are determined by the terms of Helmert/Molodenski error and grid error, respectively.

The Service Provider should observe the following guidelines:

- The Service Provider should utilize a fixed set of Areas of Validity rather than attempt to define the Area of Validity in terms of the location of a particular User.
- If service is provided to a User in the outer 10% of the Area of Validity, as described in Figure 3.5-2, the corresponding messages for the adjacent Area should be sent out (see Figure 3.5-3).
- If the communications link is bi-directional and a User moves into the outer 10% of the Area of Validity, a residual message (1023 or 1024) should be sent out immediately.
    - A new residual message (1023 or 1024) for the neighbouring meshes should be sent out immediately, and repeated 5 and 10 epochs later.
    - Type 1021 (or 1022) and 1025 (or 1026 or 1027) messages should be postponed, if they would normally be sent at the same time.
- The grid extensions should be the same within the area of a Service Provider
- The raster points of the grid should not change and should be independent of the rover position. The Service Provider should determine the origin of the raster according to the rover position and then send the appropriate raster.

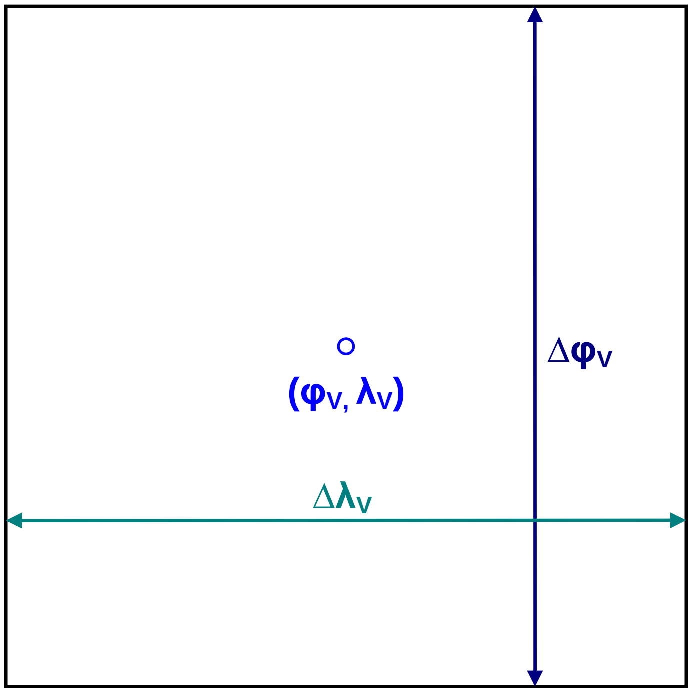

Figure 3.5-3. Area of Validity

Figure 3.5-3 shows the Area of Validity for the Helmert/Molodenski transformation, with the latitude and longitude coordinates of the origin, and the extent of the area in latitude and longitude.

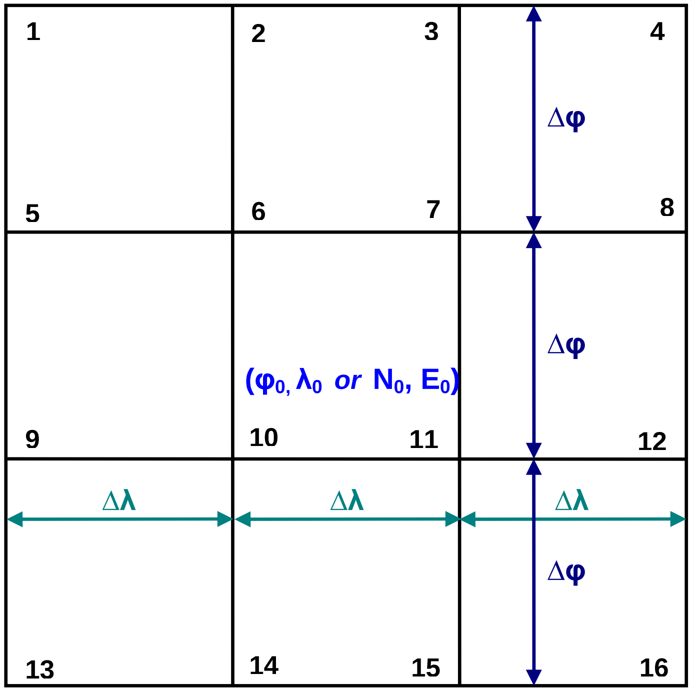

Figure 3.5-4. Grid Definition for Residual Messages

Figure 3.5-4 shows the grid definition for the residual messages, i.e., Message Types 1023 and 1024. The Area of Validity is shown in the center, with the eight adjacent Areas surrounding it. The parameters of Message Type 1023 are defined with respect to longitude and latitude, while the parameters of Message Type 1024 are defined with respect to East and North, respectively. The residual messages define the 3-dimensional shifts for each point number.

The squares are identified in Roman numerals as follows:

I	II	III
IV	V	VI
VII	VIII	IX

Figures 3.5-5 through 3.5-7 show the raster points used for each interpolation method identified in Message Types 1023 and 1024, namely bi-linear, bi-quadratic, and bi-spline, respectively. The mesh points as provided by messages 1023 and 1024 do not have to overlap with neighboring meshes transmitted. For example 4 messages might cover overall 8 by 8 mesh points.

In the bi-linear method, the rover can be located anywhere in the shaded area – not just the location shown in Figure 3.5-5; however, it uses only the four surrounding grid points in the interpolation.

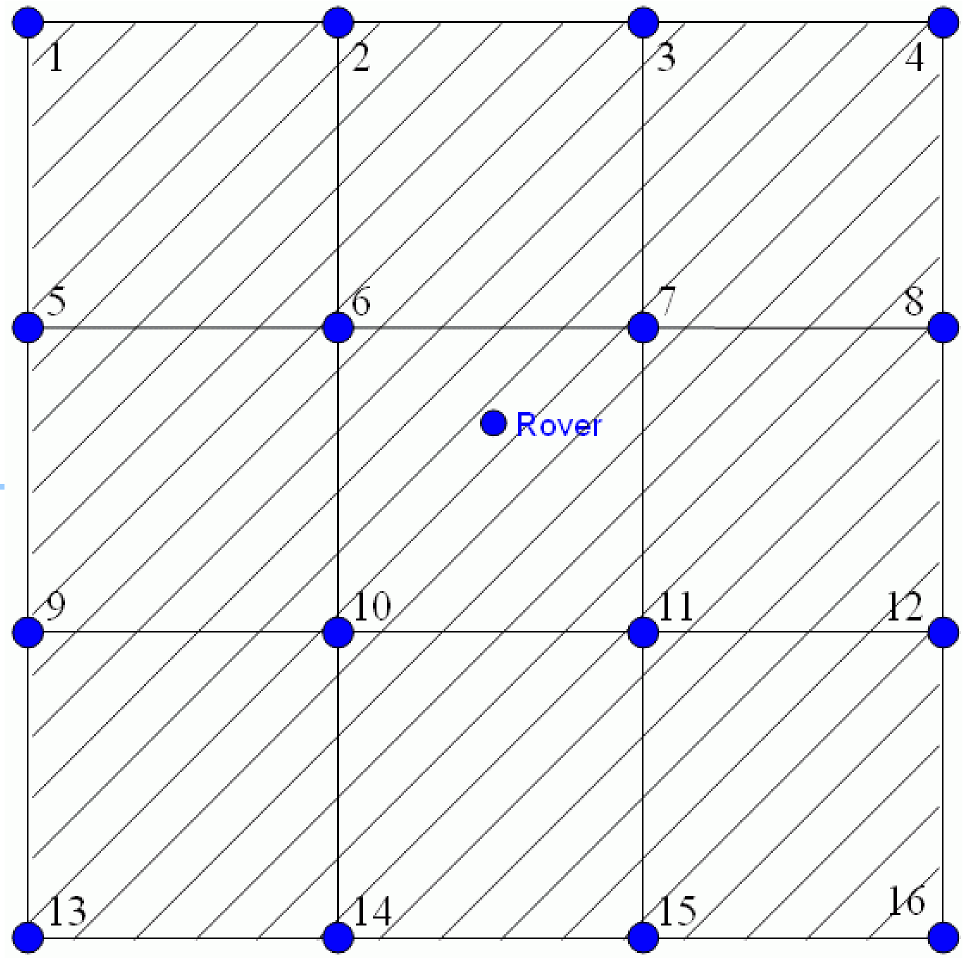

Figure 3.5-5. Raster Points Used for Bi-Linear Interpolation

While it is similar to the bi-linear interpolation, only a section of grid points will be used for the bi-quadratic interpolation. The squares West, North-West and North of the interpolation square are always used for quadratic interpolations. For instance, the grid points in the upper left (1, 2, 3, 5, 6, 7, 9, 10, and 11, squares I, II, IV, and V) are used for interpolation when the rover is within one square, namely the shaded square shown in Figure 3.5-6. For one particular message 1023 or 1024 interpolations can be performed for squares V, VI, VIII, and IX. Note that the squares shown in this example do not necessarily correlate with the content of messages 1023 and 1024.

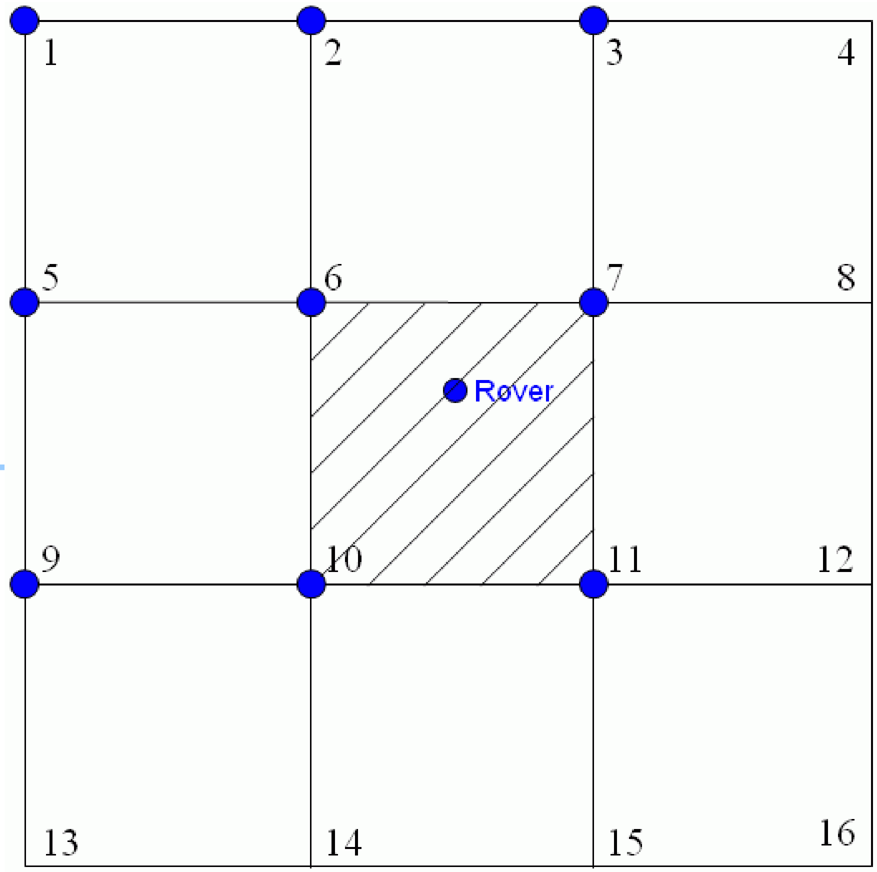

Figure 3.5-6. Raster Points Used for the Bi-quadratic Interpolation.

In the bi-spline method, the rover can be located only in the shaded central square, as indicated in Figure 3.5-7. It uses all 16 grid points in the interpolation.

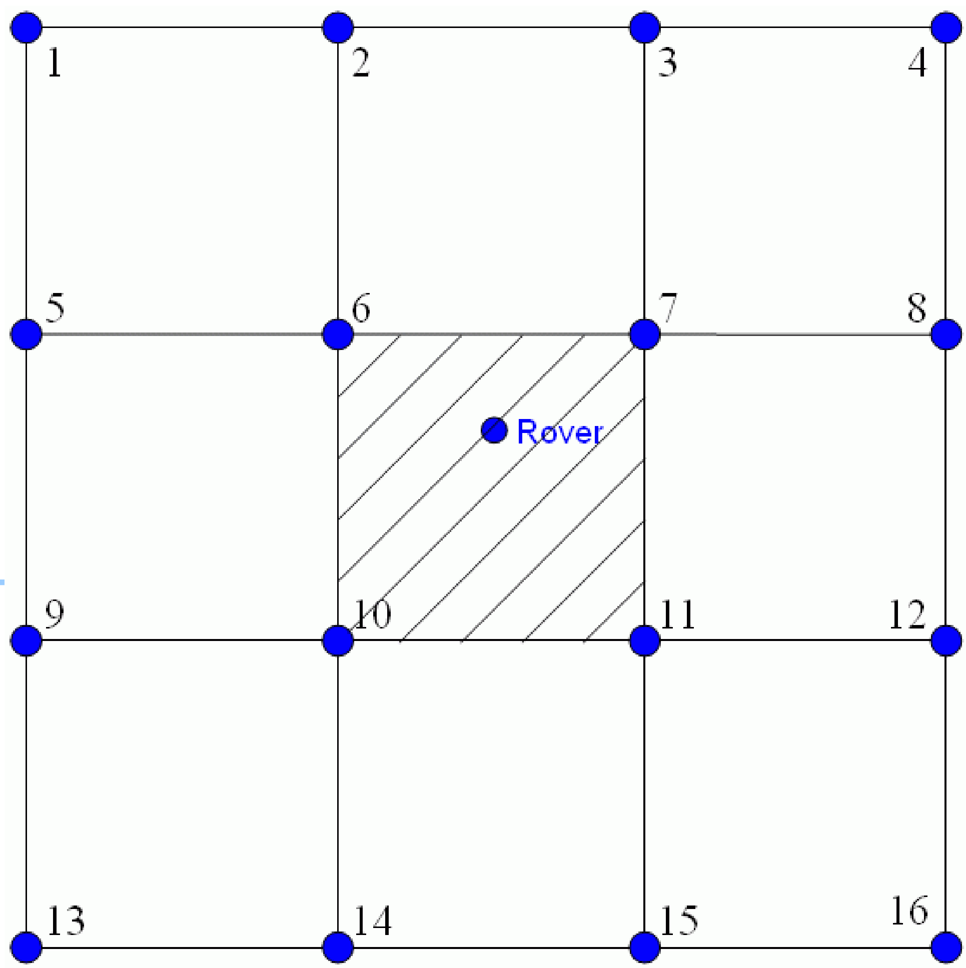

Figure 3.5-7. Raster Points Used for the Bi-Spline Interpolation.

3.5.10.5 *Contents of the Coordinate Transformation Messages*

Table 3.5-24. Contents of the Helmert / Abridged Molodenski Message Type 1021

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
Source-Name Counter	DF143	uint5	5	
Source-Name	DF144	char8(N)	8*N	
Target-Name Counter	DF145	uint5	5	
Target-Name	DF146	char8(M)	8*M	
System Identification Number	DF147	uint8	8	
Utilized Transformation Message Indicator	DF148	bit(10)	10	
Plate Number	DF149	uint5	5	
Computation Indicator	DF150	uint4	4	
Height Indicator	DF151	uint2	2	
Φ_V - Latitude of Origin, Area of Validity	DF152	int19	19	See Figure 3.5-3
Λ_V – Longitude of Origin, Area of Validity	DF153	int20	20	See Figure 3.5-3
$\Delta\varphi_V$ – N/S Extension, Area of Validity	DF154	uint14	14	See Figure 3.5-3
$\Delta\lambda_V$ – E/W Extension, Area of Validity	DF155	uint14	14	See Figure 3.5-3
dX – Translation in X-direction	DF156	int23	23	See Equations 3.5-1, 3.5-6, 3.5-9 & 3.5-15
dY – Translation in Y-direction	DF157	int23	23	See notes for *dX*
dZ – Translation in Z-direction	DF158	int23	23	See notes for *dX*

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
R_1 – Rotation Around the X-axis	DF159	int32	32	See Section 3.5.10.3.1, para. 3 and Section 3.5.10.3.4, para. 2, and equations 3.5-2, 3.5-3, 3.5-4, 3.5-7, 3.5-15, 3.5-16, 3.5-17, & 3.5-18
R_2 – Rotation Around the Y-axis	DF160	int32	32	See notes for R_1
R_3 – Rotation Around the Z-axis	DF161	int32	32	See notes for R_1
dS – Scale Correction	DF162	int25	25	See equations 3.5-5, 3.5-8 & 3.5-19
add a_S – Semi-major Axis of Source System Ellipsoid	DF166	uint24	24	See Section 3.5.10.2 and final two para's in Section 3.5.10.3.3, and equations 3.5-11 through 3.5-14.
add b_S – Semi-minor Axis of Source System Ellipsoid	DF167	uint25	25	See notes for add a_S
add a_T – Semi-major Axis of Target System Ellipsoid	DF168	uint24	24	See notes for add a_S
add b_T – Semi-minor Axis of Target System Ellipsoid	DF169	uint25	25	See notes for add a_S
Horizontal Helmert/Molodenski Quality Indicator	DF214	uint3	3	
Vertical Helmert/Molodenski Quality Indicator	DF215	uint3	3	
TOTAL			***412 + 8*N + 8*M***	

Table 3.5-25: Contents of the Molodenski-Badekas Transformation Message Type 1022

DATA FIELD	DF NO.	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
Source-Name Counter	DF143	uint5	5	
Source-Name	DF144	char8(N)	8*N	
Target-Name Counter	DF145	uint5	5	
Target-Name	DF146	char8(M)	8*M	
System Identification Number	DF147	uint8	8	
Utilized Transformation Message Indicator	DF148	bit(10)	10	
Plate Number	DF149	uint5	5	
Computation Indicator	DF150	uint4	4	
Height Indicator	DF151	uint2	2	
Φ_V - Latitude of Origin, Area of Validity	DF152	int19	19	See Figure 3.5-3
Λ_V - Longitude of Origin, Area of Validity	DF153	int20	20	See Figure 3.5-3
$\Delta\varphi_V$ – N/S Extension, Area of Validity	DF154	uint14	14	See Figure 3.5-3
$\Delta\lambda_V$ – E/W Extension, Area of Validity	DF155	uint14	14	See Figure 3.5-3
dX – Translation in X-direction	DF156	int23	23	See Equations 3.5-1, 3.5-6, 3.5-9 & 3.5-15
dY – Translation in Y-direction	DF157	int23	23	See notes for *dX*
dZ – Translation in Z-direction	DF158	int23	23	See notes for *dX*
R_1 – Rotation Around the X-axis	DF159	int32	32	See Section 3.5.10.3.1, para. 3 and Section 3.5.10.3.4, para. 2, and equations 3.5-2, 3.5-3, 3.5-4, 3.5-7, 3.5-15, 3.5-16, 3.5-17, & 3.5-18

DATA FIELD	DF NO.	DATA TYPE	NO. OF BITS	NOTES
R_2 – Rotation Around the Y-axis	DF160	int32	32	See notes for R_1
R_3 – Rotation Around the Z-axis	DF161	int32	32	See notes for R_1
dS – Scale Correction	DF162	int25	25	See equations 3.5-5, 3.5-8 & 3.5-19
X_P – X Coordinate for M-B Rotation Point	DF163	int35	35	See equation 3.5-15
Y_P – Y Coordinate for M-B Rotation Point	DF164	int35	35	See notes for X_P
Z_P – Z Coordinate for M-B Rotation Point	DF165	int35	35	See notes for X_P
add a_S – Semi-major Axis of Source System Ellipsoid	DF166	uint24	24	See Section 3.5.10.2 and final two para's in Section 3.5.10.3.3, and equations 3.5-11 through 3.5-14.
add b_S – Semi-minor Axis of Source System Ellipsoid	DF167	uint25	25	See notes for add a_S
add a_T – Semi-major Axis of Target System Ellipsoid	DF168	uint24	24	See notes for add a_S
add b_T – Semi-minor Axis of Target System Ellipsoid	DF169	uint25	25	See notes for add a_S
Horizontal Helmert/Molodenski Quality Indicator	DF214	uint3	3	
Vertical Helmert/Molodenski Quality Indicator	DF215	uint3	3	
TOTAL			***517 + 8*N + 8*M***	

Table 3.5-26. Contents of the Residual Message, Ellipsoidal Grid Representation, Message Type 1023

DATA FIELD	DF NO.	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
System Identification Number	DF147	uint8	8	
Horizontal Shift Indicator	DF190	bit(1)	1	
Vertical Shift Indicator	DF191	bit(1)	1	
φ_0 – Latitude of Origin of Grids	DF192	int21	21	See Figure 3.5-4
λ_0 – Longitude of Origin of Grids	DF193	int22	22	See Figure 3.5-4
$\Delta\varphi$ – N/S Grid Area Extension	DF194	uint12	12	See Figure 3.5-4
$\Delta\lambda$ – E/W Grid Area Extension	DF195	uint12	12	See Figure 3.5-4
Mean $\Delta\varphi$ – Mean Latitude Offset	DF196	int8	8	
Mean $\Delta\lambda$ – Mean Longitude Offset	DF197	int8	8	
Mean ΔH – Mean Height Offset	DF198	int15	15	
Three shifts for 16 grid points (i=1,16)			**16*(9+9+9)**	
$\delta\varphi_i$ – Latitude Residual	DF199	int9		See Figure 3.5-4
$\delta\lambda_i$ – Longitude Residual	DF200	int9		See Figure 3.5-4
δh_i – Height Residual	DF201	int9		See Figure 3.5-4
Horizontal Interpolation Method Indicator	DF212	uint2	2	See Figures 3.5-5 through 3.5-7
Vertical Interpolation Method Indicator	DF213	uint2	2	See Figures 3.5-5 through 3.5-7
Horizontal Grid Quality Indicator	DF216	uint3	3	
Vertical Grid Quality Indicator	DF217	uint3	3	
Modified Julian Day (MJD) Number	DF051	uint16	16	
TOTAL			***578***	

Table 3.5-27. Contents of the Residual Message, Plane Grid Representation, Message Type 1024

DATA FIELD	DF NO.	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
System Identification Number	DF147	uint8	8	
Horizontal Shift Indicator	DF190	bit(1)	1	
Vertical Shift Indicator	DF191	bit(1)	1	
N_0 – Northing of Origin	DF202	int25	25	See Figure 3.5-4
E_0 – Easting of Origin	DF203	uint26	26	See Figure 3.5-4
ΔN – N/S Grid Area Extension	DF204	uint12	12	See Figure 3.5-4
ΔE – E/W Grid Area Extension	DF205	uint12	12	See Figure 3.5-4
Mean ΔN – Mean Local Northing Offset	DF206	int10	10	
Mean ΔE – Mean Local Easting Offset	DF207	int10	10	
Mean Δh – Mean Local Height Offset	DF208	int15	15	
Three shifts for 16 grid points (i=1,16)			**16*(9+9+9)**	
δN_i – Residual in Local Northing	DF209	int9		See Figure 3.5-4
δE_i – Residual in Local Easting	DF210	int9		See Figure 3.5-4
δh_i – Residual in Local Height	DF211	int9		See Figure 3.5-4
Horizontal Interpolation Method Indicator	DF212	uint2	2	See Figures 3.5-5 through 3.5-7
Vertical Interpolation Method Indicator	DF213	uint2	2	See Figures 3.5-5 through 3.5-7
Horizontal Grid Quality Indicator	DF216	uint3	3	
Vertical Grid Quality Indicator	DF217	uint3	3	
Modified Julian Day (MJD) Number	DF051	uint16	16	
TOTAL			***590***	

Table 3.5-28: Contents of the Projection Message Type 1025 (Projection Types except LCC2SP, OM)

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
System Identification Number	DF147	uint8	8	
Projection Type	DF170	uint6	6	
LaNO – Latitude of Natural Origin	DF171	int34	34	See EPSG dataset coordinate operation
LoNO – Longitude of Natural Origin	DF172	int35	35	See EPSG dataset coordinate operation
add SNO – Scale Factor at Natural Origin	DF173	uint30	30	See EPSG dataset coordinate operation Ignore if projection = CS
FE – False Easting	DF174	uint36	36	See EPSG dataset coordinate operation
FN – False Northing	DF175	int35	35	See EPSG dataset coordinate operation
TOTAL			***196***	

Table 3.5-29. Contents of the Projection Message 1026 (Projection Type LCC2SP - Lambert Conic Conformal (2 SP))

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
System Identification Number	DF147	uint8	8	
Projection Type	DF170	uint6	6	
LaFO – Latitude of False Origin	DF176	int34	34	See EPSG dataset coordinate operation
LoFO – Longitude of False Origin	DF177	int35	35	See EPSG dataset coordinate operation
LaSP1 – Latitude of Standard Parallel No. 1	DF178	int34	34	See EPSG dataset coordinate operation
LaSP2 – Latitude of Standard Parallel No. 2	DF179	int34	34	See EPSG dataset coordinate operation
EFO – Easting of False Origin	DF180	uint36	36	See EPSG dataset coordinate operation
NFO – Northing of False Origin	DF181	int35	35	See EPSG dataset coordinate operation
TOTAL			***234***	

Table 3.5-30. Contents of the Projection Message 1027 (Projection Type OM - Oblique Mercator)

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
System Identification Number	DF147	uint8	8	
Projection Type	DF170	uint6	6	
Rectification Flag	DF182	bit(1)	1	
LaPC – Latitude of Projection Center	DF183	int34	34	See EPSG dataset coordinate operation
LoPC – Longitude of Projection Center	DF184	int35	35	See EPSG dataset coordinate operation
AzIL – Azimuth of Initial Line	DF185	uint35	35	See EPSG dataset coordinate operation
Diff ARSG – Difference, Angle from Rectified to Skew Grid	DF186	int26	26	See EPSG dataset coordinate operation
Add SIL – Scale factor on Initial Line	DF187	uint30	30	See EPSG dataset coordinate operation
EPC – Easting at Projection Center	DF188	uint36	36	See EPSG dataset coordinate operation
NPC – Northing at Projection Center	DF189	int35	35	See EPSG dataset coordinate operation
TOTAL			***258***	

3.5.11 Network RTK Residual Error Messages

3.5.11.1 Background

The Network RTK concept is based on having a plurality of GNSS reference stations continuously connected via data links to a control center. One or more computers at the control center continuously gather the information from all receivers and create network error models such as ionospheric, geometric (including troposphere and orbit) models and site-specific multipath error models in real time. One approach providing Network RTK services is described in Section 3.5.6, and utilizes Message Types 1014 through 1017. Another approach is to have the rover working in the network area send its approximate position to the control center via a bi-direction data link. The control center can then generate an "optimal" data stream derived from the physical reference station data and the network error models at the approximate rover position, and then sends the data stream to the rover via the same data link. This technique creates reference station data for a new invisible, unoccupied station. Hereafter this will be referred to as a "non-physical reference station".

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 the 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".

3.5.11.2 Network RTK Residual Error Information

The Network RTK correction information provided to the rover can be considered as interpolated corrections between the reference stations in the RTK network. Depending on the actual conditions of the atmosphere, this interpolation is not perfect. A residual interpolation error has to be expected. With sufficient redundancy in the RTK network, the network server process can provide an estimate for residual interpolation errors. Such quality estimates may be used by the rover to optimize the performance of RTK solutions. The values may be considered by the rover as a priori estimates only, with sufficient tracking data available the rover might be able to judge residual geometric and ionospheric errors itself.

The method of interpolating corrections and quality information for the rover position is proprietary and different solutions may be expected from different network service providers. It is the responsibility of the network server software provider to ensure that the residual information is representative of the actual situation.

Network RTK residual error information should be transmitted every 10-60 seconds.

The standard deviation for the residuals in the messages below may refer to the physical or the non-physical reference station position (indicated by the physical reference station flag in the messages 1005 or 1006) allowing maximum flexibility for the network system.

Different scenarios are:

- The interpolation of the corrections for the rover location are performed by the network processing software resulting in a non-physical reference station. This approach requires the rover to transmit via NMEA GGA its position to the network processing control center and, hence, bidirectional communication is required. In this scenario the information in the Network RTK Residual Error Messages can be estimated together with the corrections transmitted to the rover. The Network RTK Residual Error Messages will be referenced to the non-physical reference station.
- The interpolation of the correction is performed by the rover using data from RTCM 3.1 Network RTK Messages. The rover then has the option to use the Network RTK Residual Error Messages instead of self-computed values. In this the Network RTK Residual Error Messages are referenced to the closest master or auxiliary station to the rover. This approach requires bidirectional communication as the rover’s position is needed to determine the closest reference station.

3.5.11.3 New Physical Reference Station Position Messages

Message Type 1032 (see Table 3.5-35) is similar to the Message Type 1005, but provides the earth-centered, earth-fixed (ECEF) coordinates of the antenna reference point (ARP) for the real (or “physical”) reference station used. No height above a monument is provided.

Message Type 1032 contains the coordinates of the ARP in the GNSS coordinate system Earth-Center-Earth-Fixed (ECEF) coordinates -- local datums are not supported. The coordinates always refer to a physical point at the bottom of the antenna.

Message Type 1032 is used in case of the non-physical reference station approach to allow the rover to refer baseline vectors to a physical reference rather than to a non-physical reference without any connection to a physical point. This feature is mainly desired for post-processing in office software applications.

3.5.11.4 *Contents of the Network RTK Residual Error Messages*

Table 3.5-31. Header Part of the GPS Network RTK Residual Message Type 1030

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GPS Residuals Epoch Time (TOW)	DF224	uint20	20	
Reference Station ID	DF003	uint12	12	May be the ID of a physical or non-physical station
N-Refs	DF223	uint7	7	
GPS Number of Satellite Signals Processed	DF006	uint5	5	
TOTAL			***56***	

Table 3.5-32. Satellite Specific Part of the GPS Network RTK Residual Message Type 1030

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF009	uint6	6	
s_{oc}	DF218	uint8	8	
s_{od}	DF219	uint9	9	
s_{oh}	DF220	uint6	6	
s_{Ic}	DF221	uint10	10	
s_{Id}	DF222	uint10	10	
TOTAL			***49***	

Table 3.5-33. Header Part of the GLONASS Network RTK Residual Message Type 1031

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GLONASS Residuals Epoch Time (tk)	DF225	uint17	17	
Reference Station ID	DF003	uint12	12	May be the ID of a physical or non-physical station
N-Refs	DF223	uint7	7	
GLONASS Number of Satellite Signals Processed	DF035	uint5	5	
TOTAL			***53***	

Table 3.5-34. Satellite Specific Part of the GLONASS Network RTK Residual Message Type 1031

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Satellite ID	DF038	uint6	6	
s_{oc}	DF218	uint8	8	
s_{od}	DF219	uint9	9	
s_{oh}	DF220	uint6	6	
s_{Ic}	DF221	uint10	10	
s_{Id}	DF222	uint10	10	
TOTAL			***49***	

Table 3.5-35. Physical Reference Station Position Information Message Type 1032

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number	DF002	uint12	12
Non-Physical Reference Station ID	DF003	uint12	12
Physical Reference Station ID	DF226	uint12	12
ITRF Epoch Year	DF021	uint6	6
Physical reference station ARP ECEF-X	DF025	int38	38
Physical reference station ARP ECEF-Y	DF026	int38	38
Physical reference station ARP ECEF-Z	DF027	int38	38
TOTAL			***156***

3.5.11.5 Receiver and Antenna Descriptors Message

This message is an elaboration of Message Type 1008, and can be transmitted instead of 1008. It contains not only the antenna information on the reference station but information about receiver type and the firmware version of the receiver type. This message serves several purposes:

1. It allows recipients of RTCM data messages to directly generate RINEX files from the data stream. By utilizing the proper IGS syntax for receiver and names, this data as well as serial numbers and firmware versions can be place in the header of the RINEX observation files.
2. It enables proper identification of the reference station receiver type via the RTCM data stream.

The serial number and firmware version strings are not standardized. They will correspond to the manufacturer's naming convention.

The receiver type descriptor should conform to the IGS 20 character definition used by the IGS as defined in the IGS file "rcvr_ant.tab". If the receiver type, antenna, type, serial numbers, etc., are unknown, the length of the counters should be set to zero, in which case the succeeding descriptor field is not utilized.

Table 3.5-36. Contents of the Type 1033 Message – Receiver and Antenna Descriptors

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
Reference Station ID	DF003	uint12	12	
Antenna Descriptor Counter N	DF029	uint8	8	
Antenna Descriptor	DF030	char(N)	8*N	N ≤ 31
Antenna Setup ID	DF031	uint8	8	
Antenna Serial Number Counter M	DF032	uint8	8	
Antenna Serial Number	DF033	char(M)	8*M	M ≤ 31
Receiver Type Descriptor Counter I	DF227	uint8	8	
Receiver Type Descriptor	DF228	char(I)	8*I	I ≤ 31
Receiver Firmware Version Counter J	DF229	uint8	8	
Receiver Firmware Version	DF230	char(J)	8*J	J ≤ 31
Receiver Serial Number Counter K	DF231	uint8	8	
Receiver Serial Number	DF232	char(K)	8*K	K ≤ 31
TOTAL			***72+ 8*(M+N+ I+J+K)***	

3.5.12 State Space

3.5.12.1 Background

The principle of the state space concept is to provide information on the status of individual GNSS error sources. Therefore the term "State Space Representation" (SSR) is used. Differential GNSS and RTK operation using corrections and/or raw measurements from single or multiple reference stations must be distinguished from SSR. Differential positioning using "observation space" to transport information is called "Observation Space Representation" (OSR).

The GNSS state vector of SSR consists of the following basic parameters:

- satellite orbit errors
- satellite clock errors
- satellite signal biases (delays of codes and carrier phases within satellite hard- and software)
- ionospheric delay parameters
- tropospheric delay parameters
  and
- quality indicators for state parameters

RTCM SSR messages are used to disseminate the state space information, which is combined with individual tracked GNSS data of a user (rover) to improve its positioning. Already a sub-set of state space parameters can be sufficient for meaningful applications. Different levels of accuracy are supported depending on the provided SSR messages and the corresponding properties.

The actual application scenario for a GNSS rover is flexible and varies. The state space information can be converted into observation space for a rover position and can thus be used to correct the rover observables for more accurate positioning. Then, the application is a conventional OSR process for the rover. Alternatively the state information can directly be used in the rover's processing or adjustment model.

The state space approach is a commonly applied concept. The PPP (Precise Point Positioning) concept uses mainly precise satellite orbit and clock parameters derived consistently from global networks of reference stations as well as global atmospheric models to perform single station positioning. Accuracies in the sub-meter or even sub-decimeter level can be achieved with dual frequency receivers on a global scale.

For RTK applications, the SSR concept has been demonstrated in an indirect mode. Some network RTK software is based on state space models and the network RTK services are derived from the state vector(s). Without RTCM SSR messages, the state space information is transformed to observation space and represented by observation based RTCM messages.

3.5.12.2 State Space – SSR Messages

The SSR Messages are developed in three major steps:

1. The development of messages for precise orbits, satellite clocks and satellite code biases.
   This is compatible to the basic PPP mode using IGS products. Such messages will enable real-time PPP for dual frequency receivers: DF-RT-PPP.
2. The development of vertical TEC (VTEC) messages.
   This will enable RT-PPP for single frequency receivers: SF-RT-PPP.
3. The development of slant TEC (STEC) messages, tropospheric messages and satellite phase biases messages.
   This will enable RTK-PPP.

The current SSR Message Types cover the first stage of DF-RT-PPP.

3.5.12.3 GPS SSR Orbit Correction, Clock Correction and Code Bias Messages

Tables 3.5.37 to 3.5.49 describe the GPS SSR messages including a SSR URA quality message.

Table 3.5.37. Header Part of the SSR GPS Orbit Correction Message 1057

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GPS Epoch Time 1s	DF385	uint20	20	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
Satellite Reference Datum	DF375	bit(1)	1	
IOD SSR	DF413	uint4	4	

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***68***	

Table 3.5.38. Satellite Specific Part of the SSR GPS Orbit Correction Message 1057

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
GPS IODE	DF071	uint8	8	
Delta Radial	DF365	int22	22	
Delta Along-Track	DF366	int20	20	
Delta Cross-Track	DF367	int20	20	
Dot Delta Radial	DF368	int21	21	
Dot Delta Along-Track	DF369	int19	19	
Dot Delta Cross-Track	DF370	int19	19	
TOTAL			***135***	

Table 3.5.39. Header Part of the SSR GPS Clock Correction Message 1058

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GPS Epoch Time 1s	DF385	uint20	20	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***67***	

Table 3.5.40. Satellite Specific Part of the of the SSR GPS Clock Correction Message 1058

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
Delta Clock C0	DF376	int22	22	
Delta Clock C1	DF377	int21	21	
Delta Clock C2	DF378	int27	27	
TOTAL			***76***	

Table 3.5.41. Header Part of the SSR GPS Satellite Code Bias Message 1059

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GPS Epoch Time 1s	DF385	uint20	20	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	(No. of Satellites) * (SV Block) will immediately follow this DF.
TOTAL			***67***	

SV Block consists of Satellite Specific Part immediately followed by Code specific part for the corresponding satellite.

Table 3.5.42. Satellite Specific Part of the of the SSR GPS Satellite Code Bias Message 1059

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
No. of Code Biases Processed	DF379	uint5	5	The Code Specific Parts for all processed Code Biases are directly following the Satellite Specific Part of the corresponding satellite. (No. of Code Biases Processed) * (Code Specific Part) will immediately follow this DF.
TOTAL			***11***	

Table 3.5.43. Code Specific Part of the of the SSR GPS Satellite Code Bias Message 1059

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Signal and Tracking Mode Indicator	DF380	uint5	5	
Code Bias	DF383	int14	14	
TOTAL			***19***	

Table 3.5.44. Header Part of the SSR GPS Combined Orbit and Clock Correction Message 1060

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GPS Epoch Time 1s	DF385	uint20	20	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
Satellite Reference Datum	DF375	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***68***	

Table 3.5.45. Satellite Specific Part of the SSR GPS Combined Orbit and Clock Correction Message 1060

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
GPS IODE	DF071	uint8	8	
Delta Radial	DF365	int22	22	

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Delta Along-Track	DF366	int20	20	
Delta Cross-Track	DF367	int20	20	
Dot Delta Radial	DF368	int21	21	
Dot Delta Along-Track	DF369	int19	19	
Dot Delta Cross-Track	DF370	int19	19	
Delta Clock C0	DF376	int22	22	
Delta Clock C1	DF377	int21	21	
Delta Clock C2	DF378	int27	27	
TOTAL			***205***	

Table 3.5.46. Header Part of the SSR GPS URA Message 1061

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GPS Epoch Time 1s	DF385	uint20	20	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***67***	

Table 3.5.47. Satellite Specific Part of the SSR GPS URA Message 1061

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
SSR URA	DF389	bit(6)	6	
TOTAL			***12***	

Table 3.5.48. Header Part of the SSR GPS High Rate Clock Correction Message 1062

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GPS Epoch Time 1s	DF385	uint20	20	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***67***	

Table 3.5.49. Satellite Specific Part of the SSR GPS High Rate Clock Message 1062

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF068	uint6	6	
High Rate Clock Correction	DF390	int22	22	
TOTAL			***28***	

3.5.12.4 GLONASS SSR Orbit Correction, Clock Correction and Code Bias Messages

Tables 3.5.50 to 3.5.62 describe the GLONASS SSR messages including a SSR URA quality message.

Table 3.5.50. Header Part of the SSR GLONASS Orbit Correction Message 1063

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GLONASS Epoch Time 1s	DF386	uint17	17	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
Satellite Reference Datum	DF375	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***65***	

Table 3.5.51. Satellite Specific Part of the SSR GLONASS Orbit Correction Message 1063

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Satellite ID	DF384	uint5	5	
GLONASS IOD	DF392	bit(8)	8	
Delta Radial	DF365	int22	22	
Delta Along-Track	DF366	int20	20	
Delta Cross-Track	DF367	int20	20	
Dot Delta Radial	DF368	int21	21	
Dot Delta Along-Track	DF369	int19	19	
Dot Delta Cross-Track	DF370	int19	19	
TOTAL			***134***	

Table 3.5.52. Header Part of the SSR GLONASS Clock Correction Message 1064

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GLONASS Epoch Time 1s	DF386	uint17	17	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***64***	

Table 3.5.53. Satellite Specific Part of the of the SSR GLONASS Clock Correction Message 1064

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Satellite ID	DF384	uint5	5	
Delta Clock C0	DF376	int22	22	
Delta Clock C1	DF377	int21	21	
Delta Clock C2	DF378	int27	27	
TOTAL			***75***	

Table 3.5.54. Header Part of the SSR GLONASS Satellite Code Bias Message 1065

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GLONASS Epoch Time 1s	DF386	uint17	17	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	(No. of Satellites) * (SV Block) will immediately follow this DF.
TOTAL			***64***	

SV Block consists of Satellite Specific Part immediately followed by Code specific part for the corresponding satellite.

Table 3.5.55. Satellite Specific Part of the of the SSR GLONASS Satellite Code Bias Message 1065

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Satellite ID	DF384	uint5	5	
No. of Code Biases Processed	DF379	uint5	5	The Code Specific Parts for all processed Code Biases are directly following the Satellite Specific Part of the corresponding satellite. (No. of Code Biases Processed) * (Code Specific Part) will immediately follow this DF.
TOTAL			***10***	

Table 3.5.56. Code Specific Part of the of the SSR GLONASS Satellite Code Bias Message 1065

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Signal and Tracking Mode Indicator	DF381	uint5	5	
Code Bias	DF383	int14	14	
TOTAL			***19***	

Table 3.5.57. Header Part of the SSR GLONASS Combined Orbit and Clock Correction Message 1066

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GLONASS Epoch Time 1s	DF386	uint17	17	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Satellite Reference Datum	DF375	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***65***	

Table 3.5.58. Satellite Specific Part of the SSR GLONASS Combined Orbit and Clock Correction Message 1066

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Satellite ID	DF384	uint5	5	
GLONASS IOD	DF392	bit(8)	8	
Delta Radial	DF365	int22	22	
Delta Along-Track	DF366	int20	20	
Delta Cross-Track	DF367	int20	20	
Dot Delta Radial	DF368	int21	21	
Dot Delta Along-Track	DF369	int19	19	
Dot Delta Cross-Track	DF370	int19	19	
Delta Clock C0	DF376	int22	22	
Delta Clock C1	DF377	int21	21	
Delta Clock C2	DF378	int27	27	
TOTAL			***204***	

Table 3.5.59. Header Part of the SSR GLONASS URA Message 1067

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GLONASS Epoch Time 1s	DF386	uint17	17	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***64***	

Table 3.5.60. Satellite Specific Part of the SSR GLONASS URA Message 1067

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Satellite ID	DF384	uint5	5	
SSR URA	DF389	bit(6)	6	
TOTAL			***11***	

Table 3.5.61. Header Part of the SSR GLONASS High Rate Clock Correction Message 1068

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
GLONASS Epoch Time 1s	DF386	uint17	17	
SSR Update Interval	DF391	bit(4)	4	
Multiple Message Indicator	DF388	bit(1)	1	

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
IOD SSR	DF413	uint4	4	
SSR Provider ID	DF414	uint16	16	
SSR Solution ID	DF415	uint4	4	
No. of Satellites	DF387	uint6	6	
TOTAL			***64***	

Table 3.5.62. Satellite Specific Part of the SSR GLONASS High Rate Clock Correction Message 1068

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Satellite ID	DF384	uint5	5	
High Rate Clock Correction	DF390	int22	22	
TOTAL			***27***	

Tables 3.5.37 through 3.5.45 and 3.5.50 through 3.5.57 provide the contents of the basic GPS and GLONASS SSR orbit, clock and code bias messages, which support GNSS Precise Point Positioning (PPP) for dual frequency receiver applications. The orbit and clock messages contain data to be combined with the corresponding values obtained from the satellites broadcast message. The supported broadcast messages are currently the GPS navigation message (NAV data, D(t), IS-GPS-200D) and GLONASS-M navigation message (GLONASS ICD Version 5.1).

All messages may be split over several messages using the Multiple Message Indicator. It increases the number of e.g. satellites to be transmitted, but it also enables the receiver to begin immediately processing of data after decoding the first message of a multiple message type.

3.5.12.5 SSR Orbit Correction Message

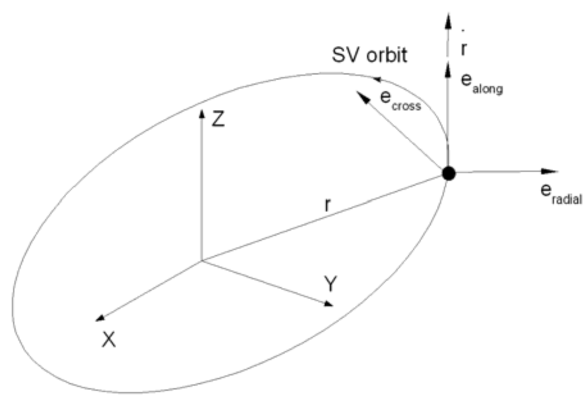

Figure 3.12.1. Radial, along-track and cross-track orbit components

The Orbit Correction Message contains the parameters for orbit corrections $\delta\boldsymbol{O}\delta\boldsymbol{O}$ in radial, along-track and cross-track component. These orbit corrections are used to compute a satellite position correction $\delta\boldsymbol{X}\delta\boldsymbol{X}$, to be combined with satellite position $\boldsymbol{X}_{broadcast}\boldsymbol{X}_{broadcast}$ calculated from broadcast ephemeris. The sign definition of the correction is

$$\boldsymbol{X}_{orbit} = \boldsymbol{X}_{broadcast} - \delta\boldsymbol{X} \qquad (3.12\text{-}1)$$

with

$\boldsymbol{X}_{orbit}\boldsymbol{X}_{orbit}$	satellite position corrected by SSR Orbit Correction message
$\boldsymbol{X}_{broadcast}$	satellite position computed according to corresponding GNSS ICD from broadcast ephemeris parameter set identified by IOD/IODE in SSR Orbit Correction message
$\delta\boldsymbol{X}$	satellite position correction

The satellite position correction $\delta\boldsymbol{X}$ is computed according to

$$\boldsymbol{e}_{along} = \frac{\dot{\boldsymbol{r}}}{|\dot{\boldsymbol{r}}|} \qquad (3.12\text{-}2)$$

$$\boldsymbol{e}_{cross} = \frac{\boldsymbol{r} \times \dot{\boldsymbol{r}}}{|\boldsymbol{r} \times \dot{\boldsymbol{r}}|} \qquad (3.12\text{-}3)$$

$$\boldsymbol{e}_{radial} = \boldsymbol{e}_{along} \times \boldsymbol{e}_{cross} \qquad (3.12\text{-}4)$$

$$\delta\boldsymbol{X} = [\boldsymbol{e}_{radial} \quad \boldsymbol{e}_{along} \quad \boldsymbol{e}_{cross}]\ \delta\boldsymbol{O} \qquad (3.12\text{-}5)$$

with

$\boldsymbol{r} = \boldsymbol{X}_{\boldsymbol{broadcast}}\boldsymbol{r} = \boldsymbol{X}$	satellite broadcast position vector
$\dot{\boldsymbol{r}} = \dot{\boldsymbol{X}}_{\boldsymbol{broadcast}}\dot{\boldsymbol{r}} = \dot{\boldsymbol{X}}$	satellite broadcast velocity vector
$\boldsymbol{e}_i\boldsymbol{e}_i$	direction unit vector, i = {radial, along, cross}
$\delta\boldsymbol{O}\delta\boldsymbol{O}$	orbit correction vector

Note: The radial vector according to formula (3.12-4) has to be used for the computation and should not be confused with a radial vector of a circular orbit.

The complete orbit correction vector $\delta\boldsymbol{O}\delta\boldsymbol{O}$ is computed from the individual correction terms and their velocities:

$$\delta\boldsymbol{O} = \begin{bmatrix} \delta O_{radial} \\ \delta O_{along} \\ \delta O_{cross} \end{bmatrix} + \begin{bmatrix} \delta\dot{O}_{radial} \\ \delta\dot{O}_{along} \\ \delta\dot{O}_{cross} \end{bmatrix} (t - t_0) \qquad (3.12\text{-}6)$$

w*ith*

tt	time
t_0t_0	reference time obtained from SSR Orbit Correction message
$\delta O_i, \delta\dot{O}_i$	$\delta O_i, \delta\dot{O}_i, \delta\ddot{O}_i$orbit correction terms from SSR Orbit message, i = {radial, along, cross}

The reference time for the velocity term is computed from the GNSS epoch time (GPS: DF385, GLONASS: DF386) plus half the SSR Update Interval (DF391). Exception is SSR Update Interval "0", which uses the GNSS Epoch time as reference time.

Orbit representation requires the definition of a coordinate reference system. For global services the coordinate system should be related to the ITRS. For regional services a reference system related to the tectonic plate of the region is often used. The messages (1057, 1060, 1063, 1066) allow orbits transformed from ITRF to a global coordinate system close to ITRF (e.g. ETRF, NAD, JGD2000). Then, it is not necessary for the rover to perform the corresponding transformation. A regional datum is indicated by the Satellite Reference Datum flag, while the actual coordinate reference system will be identified by the configured stream of the service provider.

3.5.12.6 SSR Clock Correction Message

The Clock Message contains the parameters to compute the clock correction δC applied to the broadcast satellite clock. The polynomial representation describes the clock differences for a certain time period. The sign definition of the corrections is

$$t_{satellite} = t_{broadcast} - \frac{\delta C}{Speed\ of\ light} \qquad (3.12\text{-}7)$$

with

$t_{broadcast}$ $t_{broadcast}$ satellite time computed according to corresponding GNSS ICD from broadcast clock parameters, identified by IOD/IODE of corresponding SSR Orbit Correction message

$t_{satellite}$$t_{satellite}$ satellite time corrected by SSR Clock Correction message

δC δC clock correction obtained from SSR Clock Correction message

The polynomial is computed according to

$$\delta C = C_0 + C_1(t - t_0) + C_2(t - t_0)^2 \qquad (3.12\text{-}8)$$

with

tt time

t_0 t_0 reference time obtained from SSR Clock Correction message

C_i C_iC_i polynomial coefficients from SSR Clock Correction message, i = {0, 1, 2}

The reference time for the polynomial terms is computed from the GNSS epoch time (GPS: DF385, GLONASS: DF386) plus half the SSR Update Interval (DF391). Exception is SSR Update Interval "0", which uses the Epoch time as reference time.

Note: The relativity correction has to be applied for GPS according to IS-GPS-200D to compute $t_{broadcast}$. Referring to paragraph 20.3.3.3.3.1 the relativistic correction term $\Delta \boldsymbol{t}_T$ is

$$\Delta \boldsymbol{t}_T = -\frac{\mathbf{2}\,\boldsymbol{r} \cdot \dot{\boldsymbol{r}}}{c^2}$$

with vectors $\boldsymbol{r}$ and $\dot{\boldsymbol{r}}$ computed from broadcast ephemeris.

The relativistic effects are already taken into account in the broadcast clock parameters for GLONASS.

Satellite clocks are determined from ionospheric free signals derived from observations used by the service provider. Such observations are affected by delays introduced in the satellite hardware (code biases). For example, GPS broadcast clocks are referenced to the ionospheric free linear combination of the P codes on L1 and L2, ignoring any code biases of these signals. For SSR, the selection of signals used to generate the satellite clock corrections and the treatment of code biases are left to the service provider. The service provider shall ensure a consistent transmission of clock and code bias parameters. A rover must then consistently apply the code biases and clock corrections.

3.5.12.7 SSR Code Bias Message

The Code Bias Message uses a Signal and Tracking Mode Indicator to describe the actual signal properties. The Signal and Tracking Mode Indicator maps the RINEX 3.0 observation types into a more compact storage scheme of integer indices. The RINEX 3.0 observation types based on type (code, carrier, etc.), band (L1, L2, etc.) and attribute (tracking mode) are required to account for the future variety of signal tracking.

The Code Biases reported in the SSR Code Bias Message must be added to the pseudo range measurements of the corresponding code signal to get corrected pseudo ranges. Any code biases transmitted in the broadcast messages (e.g. the GPS group delay differential, T_{GD}, IS-GPS 200D) are not applied at all.

The Code Bias message contains absolute values, but also enables the alternative use of differential code biases by setting one of the biases to zero.

The provider shall support as much signals as possible and must report code biases which are zero. A rover can consistently use signals for which a code bias is transmitted. It is not reliable for a rover to use a signal without retrieving a corresponding code bias from the data stream.

Satellite code biases, especially for GLONASS, may depend on the receiver type used to track the signals. The SSR stream provider shall correct the bias level to be consistent with a certain receiver type and shall indicate this receiver type by sending a corresponding Message Type 1033 Receiver and Antenna Descriptors.

3.5.12.8 SSR High Rate Clock Message

To support higher resolution of the clock state and also higher update rates, a High Rate Clock SSR message is used. Both constituents, Clock Message and High Rate Clock Message, define the complete state of the satellite clock. The High Rate Clock correction is added to the corresponding clock correction.

3.5.12.9 SSR Combined Orbit and Clock Correction Message

A Combined Orbit and Clock Correction Message is provided, which reduces the bandwidth and can easily maintain the consistency of orbit and clock data. The Combined Orbit and Clock Message requires that orbit and clock have the same SSR Update Interval.

3.5.12.10 SSR URA Message

Clock and radial orbit state parameters are correlated. A SSR User Range Accuracy (URA) is used as one single statistical indicator to describe the quality of both parameters. The SSR User Range Accuracy is transmitted in a SSR URA message. A special formula is used to enable high resolution for small numbers and low resolution for large numbers.

3.5.12.11 Consistency of Data and Processing

A state space parameter may consist of different constituents disseminated in different SSR messages. The use of different SSR messages is intentional to support different applications, update rates and accuracy requirements. Additional SSR messages will consequently add additional resolution and positioning accuracy. This creates the need to know the consistency of the SSR parameters for an application. Only a consistent set of SSR parameters can build up a complete and accurate correction. The consistency of SSR data becomes more important with increasing resolution provided by additional messages.

Generally the continuous chronology of messages can be used to check the consistency, but in real-time applications messages may be lost or delayed. A consistency parameter is also the IOD (IODE for GPS) for orbit in the correction messages, which is used to obtain consistency in the computation and applications of RTCM messages. A similar requirement exists for state space parameters distributed over several SSR messages.

The combination of SSR data depends on the consistent update of the state parameters as correlations of the parameters exist. It is of advantage, if a SSR message contains all relevant information on the state parameter update without any dependency on other messages. The consistency of data is enabled through the SSR Update Interval. The meaning of SSR Update Interval is different from the transmission rate of SSR messages. The validity interval of SSR parameters can be longer than the SSR Update Interval.

There are several SSR Update Intervals defined, which all start at the start of a day in the GPS time scale (time: 00:00:00). The SSR message contains the GNSS epoch time (DF385, DF386). From both information the consistency of the SSR parameters can be verified. A change of an SSR Update Interval is only allowed, if the consistency of SSR data is maintained, i.e. at the end of a SSR Update Interval. The rover is then capable to combine all relevant SSR parameters consistently and it secures the combination of state parameters from different messages.

Note: To align GPS and GLONASS SSR Update Intervals, the leap second time difference must be considered for GLONASS.

Figure 3.12-2 shows a sketch of the state parameter influence on the Range for a certain location. The updates of five different SSR Range errors are displayed over time. Code biases are state parameters with a static character or a very low update rate. Typically orbit and clock parameters do have different update rates. In the example, the same SSR Update Interval is used for the two different SSR parameters orbit and troposphere. The High Rate Clock will have the highest update rate.

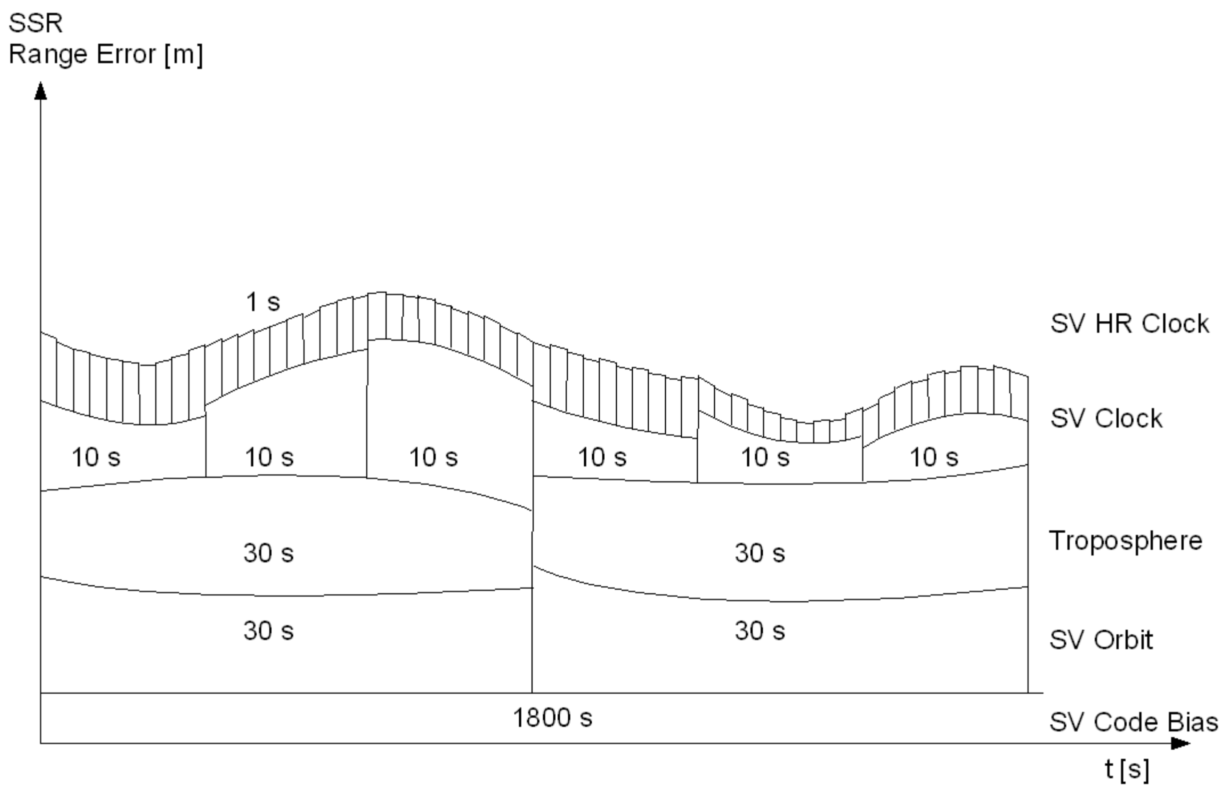

Figure 3.12-2. Sketch of Concept of SSR Update Interval to ensure the consistency of data for five different SSR parameters. Please note, that the sketch is only meant to demonstrate the concept. The quantities shown do not represent real physical behavior. All influences are e.g. positive values, however, negative values will also occur in real application.

IOD information of broadcast clocks are redundant information and are not required in addition to the orbit IOD. I.e., the SSR Orbit and Clock corrections refer to the same IOD. The service provider should refer to the latest set of broadcast messages, which are generally also received in real-time by a GNSS rover. However, it is recommended to delay the use of the latest broadcast message for a period of 60 seconds, measured from the time of complete reception of ephemeris and clock parameters, in order to accommodate rover applications to obtain the same set of broadcast orbital and clock parameters. It is left to the service provider to send the RTCM Satellite Ephemeris Data (e.g. Message Types 1019 for GPS and 1020 for GLONASS) before switching to a new IOD. It is not allowed to send corrections for more than one IOD for the same orbit Update Interval. The consistency of SSR Orbit and Clock messages is maintained through the SSR Update Interval.

The computation of satellite positions and satellite clock offsets from broadcast data must be consistent. The GLONASS ICD refers to two different algorithms. For SSR, the GLONASS broadcast ephemeris computation "Simplify of algorithm for re-calculation of ephemeris to current time" must be used (see GLONASS ICD Version 5.1, A.3.1.2).

Note: Please consider two corrections in the GLONASS ICD Version 5.1. In appendix A.3.1.2 the sign of the 4th term in dV_y/dt correctly reads $-2\omega V_x$ instead of $+2\omega V_x$ and for dV_z/dt the term in parentheses correctly reads $\left(3 - \frac{5z^2}{r^2}\right)$ instead of $\left(1 - \frac{5z^2}{r^2}\right)$.

Note: The numerical integration of satellite coordinates from broadcast ephemeris should be performed with sufficient accuracy. For instance, the Runge-Kutta method of 4th order with the step of numerical integration that does not exceed 30 seconds can be used to obtain a precision of 0.1 mm.

The SSR Update Interval serves to uniquely identify all consistent parameters from different messages, which can be used to compute consistent corrections at one epoch.

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3.5.13 GLONASS Network RTK Correction Messages

The principle of GPS Network RTK as described in Section 3.5.6 can also be adopted for GLONASS Network RTK. A simplified approach of transmitting GLONASS data from reference station networks to roving users is utilized below in the form of a new message set capable of supporting GLONASS reference network operations. The GLONASS carrier phase correction difference messages follow the same format defined for the GPS Network RTK messages and are intended to be utilized by the rover software using the same general processing algorithms.

The GLONASS L1 carrier phase correction (L1CR) and L2 carrier phase correction (L2CR) can be determined by:

$$L1CR_S = S_S - \Phi_{S,1}(t) - \frac{c}{f_1} N_{S,1} + t_{S,1} + A_{S,1}\text{, and}$$

$$L2CR_S = S_S - \Phi_{S,2}(t) - \frac{c}{f_2} N_{S,2} + t_{S,2} + A_{S,2}\text{, with}$$

S_S	=	Computed geometric range in meters between the ARP of station S and satellite
$\Phi_{S,1}(t)$	=	GLONASS L1 phase range measurement in meters for station S, (similarly for L2)
$\frac{c}{f_1} N_{S,1}$	=	GLONASS L1 integer ambiguity part scaled to meters, (similarly for L2).
$t_{S,1}$	=	L1 receiver clock term for the GLONASS phase range measurement, (similarly for L2)
$A_{S,1}$	=	GLONASS L1 antenna offset and phase center variation correction (similarly for L2). The service provider shall ensure that the antenna phase center corrections do not introduce biases. (See also Section 3.1.6 "Proper Handling of Antenna Phase Center Variation Corrections")
f_1	=	L1 carrier frequency of the GLONASS satellite signal

f_2 = L2 carrier frequency of the GLONASS satellite signal

The GLONASS L1 Carrier Phase Correction Difference (L1CDR) is calculated as the single-difference of the "Auxiliary Reference Station Carrier Phase Correction" minus "Master Reference Station Carrier Phase Correction".

$$L1CDR = L1CR_A - L1CR_M$$

An alternate way of calculation is to carry out:

$$L1CDR = \Delta S_{AM}(t) - \Delta\Phi_{AM,1}(t) - \frac{c}{f_1}\Delta N_{AM,1} + \Delta t_{AM,1} + \Delta A_{AM,1}$$

$\Delta\Phi_{AM,1}(t)$ = Single-differenced GLONASS 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

$\frac{c}{f_1}\Delta N_{AM,1}$ = GLONASS single-differenced integer ambiguity values of Auxiliary Reference Station A minus

Master Reference Station M scaled to meters. For network RTK, all GLONASS integer ambiguities shall be brought onto a common integer level. Therefore, the single-differenced integer ambiguities for a particular Auxiliary Reference Station minus Master Reference Station might incorporate an arbitrary integer number. Although this number is common for all satellites, it will not be observed as a common clock error or cancel in a double difference due to the GLONASS FDMA signal structure. The service provider shall adjust the absolute magnitude of the GLONASS ambiguity level to minimize inter-frequency biases in the GLONASS double-difference correction differences (see also the description of the GLONASS ambiguity level in this section).

$\Delta t_{AM,1}$ = Estimated single-differenced receiver clock term on L1

$\Delta A_{AM,1}$ = Single-differenced antenna offset and PCV on L1

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

$$L2CDR = \Delta S_{AM}(t) - \Delta\Phi_{AM,2}(t) - \frac{c}{f_2}\Delta N_{AM,2} + \Delta t_{AM,2} + \Delta A_{AM,2}$$

Like GPS correction differences, the L1 and L2 GLONASS correction differences are factored into ionospheric and geometric components (see also Section 3.5.6 "GPS Network RTK Correction Messages"). Satellite and relativistic clock term have been neglected in the given formula. These terms cancel sufficiently in the inter-station single difference. Proper treatment of antenna phase center corrections is crucial to avoid unrecoverable biases in correction differences (see also section 3.1.6 “Proper handling of antenna phase center variation corrections”).

A difference of the clock between both station receivers remains in the L1 and L2 correction differences. However, the value is common to all correction differences for a given master-auxiliary reference station pair can be estimated and removed. The clock difference term between reference stations in the GLONASS L1 and L2 correction difference may be treated independently. Therefore residual clock effects may influence GLONASS ionospheric and geometric correction differences. Nevertheless, this approach is sufficient for general positioning schemes, since residual clock effects cancel in double differences.

The GPS correction differences for a given master-auxiliary pair may contain an arbitrary integer bias that cancels in double differences (see also Section 3.5.6 "GPS Network RTK Correction Messages"). However, an arbitrary integer bias influencing GLONASS correction differences may manifest as so-called inter-frequency biases in double differences as a consequence of the GLONASS frequency division multiple access (FDMA) signal structure. For example, approximately 4.3 mm of error will be introduced for every 5 cycles of bias in the L1 ambiguity level if the difference between the frequency channel numbers of the two GLONASS satellite signals involved in the double-difference is a maximum (13 for the current GLONASS frequency plan). However, the error is only 0.3 mm for the same integer bias if the frequency channel number difference is a minimum. These apparent inter-frequency biases will not be absorbed by the clock estimation in the rover software or cancel in the double difference and may degrade ambiguity resolution and RTK positioning performance. The Network RTK service provider, through appropriate data processing strategies, shall adjust the absolute magnitude of the L1 and L2 integer ambiguity levels to minimize inter-frequency biases in the GLONASS double-differenced correction differences. In practice, the GLONASS ambiguity level is typically adjusted using algorithms that utilize unambiguous single differenced pseudorange measurements. The Network RTK service provider should be especially prudent if the network consists of heterogeneous GLONASS receiver makes and models. Interoperability testing has shown that between-station single difference pseudorange and carrier phase measurements involving mixed receiver types may be influenced by receiver-dependent biases that may introduce significant inter-frequency biases of several centimeters if not treated correctly by the network software.

Tables 3.5.63 through 3.5.66 provide the contents of the GLONASS Network RTK correction messages.

Table 3.5-63. Contents of Header for GLONASS Network RTK Messages 1037, 1038, or 1039

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number	DF002	uint12	12
Network ID	DF059	uint8	8
Subnetwork ID	DF072	uint4	4
GLONASS Network Epoch Time	DF233	uint20	20
Multiple Message Indicator	DF066	bit(1)	1
Master Reference Station ID	DF060	uint12	12
Auxiliary Reference Station ID	DF061	uint12	12
# of GLONASS Data Entries	DF234	uint4	4
TOTAL			***73***

Table 3.5-64. Contents of Data Block for Ionospheric Correction Difference Message 1037

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GLONASS Satellite ID (Satellite Slot Number)	DF038	uint6	6
GLONASS Ambiguity Status Flag	DF235	bit(2)	2
GLONASS Non Sync Count	DF236	uint3	3
GLONASS Ionospheric Carrier Phase Correction Difference	DF237	int17	17
TOTAL			***28***

Table 3.5-65. Contents of Data Block for Geometric Correction Difference Message 1038

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GLONASS Satellite ID (Satellite Slot Number)	DF038	uint6	6
GLONASS Ambiguity Status Flag	DF235	bit(2)	2
GLONASS Non Sync Count	DF236	uint3	3
GLONASS Geometric Carrier Phase Correction Difference	DF238	int17	17
GLONASS IOD	DF239	bit(8)	8
TOTAL			***36***

Table 3.5-66. Contents of Data Block for Combined Geometric and Ionospheric Correction Differences Message 1039

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
GLONASS Satellite ID (Satellite Slot Number)	DF038	uint6	6
GLONASS Ambiguity Status Flag	DF235	bit(2)	2
GLONASS Non Sync Count	DF236	uint3	3
GLONASS Geometric Carrier Phase Correction Difference	DF238	int17	17
GLONASS IOD	DF239	bit(8)	8
GLONASS Ionospheric Carrier Phase Correction Difference	DF237	int17	17
TOTAL			***53***

3.5.14 FKP Network RTK Correction Messages

With the concept of FKP (from the German word: “Flächenkorrekturparameter” = Area Correction Parameters) horizontal gradients of distance-dependent errors like ionosphere, troposphere and orbits are derived from a network of GNSS reference stations and transmitted to a rover together with raw or correction data of a corresponding reference station. The rover may use the gradients to compute the influence of the distance dependent errors for its own position.

It can be used as a stand-alone technique or in combination with a non-physical reference station. The gradient message thus can be used as follows:

- In connection with a physical reference station the gradients are applicable in the neighborhood of the physical station.
- In connection with a non-physical reference station the gradient messages are defined with respect to the non-physical reference station, so that the gradients are applicable in the neighborhood of the non-physical station.

The horizontal gradients serve as a first order approximation of the geometric and ionospheric errors for rovers that are located apart or moving away from the non-physical or physical reference station position. Tables 3.5-67 and 3.5-69 define the headers for the GPS and GLONASS FKP Gradient messages, respectively, and Tables 3.5-68 and 3.5-70 define the satellite specific data.

Network FKP gradient information should be typically transmitted every 10-60 seconds.

The horizontal gradients (FKP) are a linear approximation of the geometric and ionospheric errors in the neighborhood of the physical or virtual reference station. The geometric gradient contains non-dispersive (orbit and troposphere residual) errors while the ionospheric gradient contains the dispersive errors. The horizontal gradients are defined on a surface parallel to the ellipsoid at the height of the physical or non-physical reference station. Hence, troposphere effects caused by differences in station heights and station location must be corrected before computation of the geometric gradient by using a standard troposphere model. The following relations shall be used to apply the gradient corrections. The geographical coordinates φ_R and λ_R are the ellipsoidal coordinates of the corresponding reference station and the rover has the coordinates φ, λ. The corrections are then:

$$\delta\rho_0 = 6.37 \cdot (N_0(\varphi - \varphi_R) + E_0(\lambda - \lambda_R)\cos(\varphi_R))$$
$$\delta\rho_I = 6.37 \cdot H \cdot (N_I(\varphi - \varphi_R) + E_I(\lambda - \lambda_R)\cos(\varphi_R))$$

with:

N_0	the gradient in north-south direction for the geometric (ionosphere free) signal in [ppm]
E_0	the gradient in east-west direction for the geometric (ionosphere free) signal in [ppm]
N_I	the gradient in north-south direction for the ionospheric signal in [ppm] (influence on GPS L1 frequency)
E_I	the gradient in east-west direction for the ionospheric signal in [ppm] (influence on GPS L1 frequency)
φ, λ	the ellipsoidal coordinates of the rover in radians
φ_R, λ_R	the ellipsoidal coordinates of the reference station in radians
H	$H = 1 + 16\,(0.53 - E/\pi)^3$
E	the elevation angle of the satellite at the rover position in radians
$\delta\rho_0$	the distance dependent error for the geometric (ionosphere free) signal [m]
$\delta\rho_I$	the distance dependent error for the ionospheric signal [m]

The distance dependent error $\delta\rho_{\phi,f}$ for a carrier phase measurement Φ on a signal with frequency f can be computed in [m] by:

$$\delta\rho_{\phi,f} = \delta\rho_0 + \left(\frac{f_1}{f}\right)^2 \delta\rho_I$$

where f_1 is the GPS L1 frequency (1575.42 MHz).

The PhaseRange measurement P_f of the rover is corrected by

$$P_{corr,f} = P_f - \delta\rho_{\phi,f}$$

The distance dependent error $\delta\rho_{r,f}$ for a Pseudorange measurement r on a signal with frequency f can be computed in [m] by

$$\delta\rho_{r,f} = \delta\rho_0 - \left(\frac{f_1}{f}\right)^2 \delta\rho_I$$

and the Pseudorange measurement PR_f of the rover is corrected by

$$PR_{corr,f} = PR_f - \delta\rho_{r,f}$$

The gradient corrections are applied to the reference station data. Standard single base rover algorithm can then be utilized. No further modifications are necessary.

The gradients can, for instance, be computed from three Non-Physical Reference Stations located at the reference station itself as well as at a position 1000 m north and 1000 m east on the same height. Assuming that the clocks of all three stations are identical and the carrier phase ambiguities have been resolved, the north-south respectively east-west gradients can be derived from the observation differences of the geometric and ionospheric observables between the physical or non-physical reference station and the non-physical station north respectively east. For the geometric gradient a standard troposphere model has to be applied before computing the difference. It is recommended to use the Niell mapping function and the Saastamoinen troposphere zenith delay model. However, it is noted, that the geometric gradients are not significantly affected by changes of the troposphere model, therefore it is not required to use the same model in the rover algorithm. The obtained geometric and ionospheric signal differences in millimeters can be treated as gradients in ppm. Refer to 3.5.6 GPS Network RTK Messages and 3.5.3 Antenna Description Messages for details on a Non-Physical or Computed Reference Station.

Tables 3.5-67 through Table 3.5-70 describe the GPS and GLONASS FKP Network RTK message types.

Table 3.5-67. Header Part of the GPS Network FKP Gradient Message 1034

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
Reference Station ID	DF003	uint12	12	May be the ID of a physical or non-physical station
GPS FKP Epoch Time (TOW)	DF240	uint20	20	
No. of GPS Satellite Signals Processed	DF006	uint5	5	
TOTAL			***49***	

Table 3.5-68. Satellite Specific Part of the GPS Network FKP Gradient Message 1034

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GPS Satellite ID	DF009	uint6	6	
GPS Issue of data ephemeris (IODE)	DF071	bit(8)	8	Issue Of Data (GPS broadcast) Ephemeris to reference the geometric gradients
N0: Geometric gradient (North)	DF242	int12	12	
E0: Geometric gradient (East)	DF243	int12	12	
NI: Ionospheric gradient (North)	DF244	int14	14	
EI: Ionospheric gradient (East)	DF245	int14	14	
TOTAL			***66***	

Table 3.5-69. Header Part of the GLONASS Network FKP Gradient Message 1035

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
Message Number	DF002	uint12	12	
Reference Station ID	DF003	uint12	12	May be the ID of a physical or non-physical station
GLONASS FKP Epoch Time	DF241	uint17	17	
No. of GLONASS Satellite Signals Processed	DF035	uint5	5	
TOTAL			***46***	

Table 3.5-70. Satellite Specific Part of the Network FKP GLONASS Gradient Message 1035

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS	NOTES
GLONASS Satellite ID	DF038	uint6	6	
GLONASS Issue Of Data (IOD)	DF392	bit(8)	8	Issue Of Data of GLONASS ephemeris to reference the geometric gradients
N0: Geometric gradient (North)	DF242	int12	12	
E0: Geometric gradient (East)	DF243	int12	12	
NI: Ionospheric gradient (North)	DF244	int14	14	
EI: Ionospheric gradient (East)	DF245	int14	14	
TOTAL			***66***	

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	Ashtech	http://www.ashtech.com
4094	Trimble Navigation Ltd.	http://www.trimble.com
4093	NovAtel Inc.	http://www.novatel.ca
4092	Leica Geosystems	http://www.leica-geosystems.com

Message Type	Organization	Contact
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	Fugro	http://www.fugro.com
4086	inPosition GmbH	http://www.inposition.ch
4085	European GNSS Supervisory Authority	http://www.gsa.europa.eu
4084	Geodetics, Inc.	http://www.geodetics.com
4083	German Aerospace Center, Institute of Communications and Navigation (DLR)	http://www.dlr.de/kn/en/desktopdefault.aspx/tabid-2204/3257_read-19445/
4082	Cooperative Research Centre for Spatial Information	http://www.crcsi.com.au
4081	Seoul National University GNSS Lab	http://gnss.snu.ac.kr/nav/
4080	NavCom Technology, Inc.	http://navcomtech.com
4079-4001	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 $\leq 2^{-24} = 5.96\times10^{-8}$ 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 $(p_1,p_2,\ldots,p_{24})$ is generated from the sequence of information bits $(m_1,m_2,\ldots,m_{8N})$, 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

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

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

$$p(X) = X^{23} + X^{17} + X^{13} + X^{12} + X^{11} + X^9 + X^8 + X^7 + X^5 + X^3 + 1$$

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

$$m(X) = m_k + m_{k-1}X + m_{k-2}X^2 + \cdots + m_1 X^{k-1}$$

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.

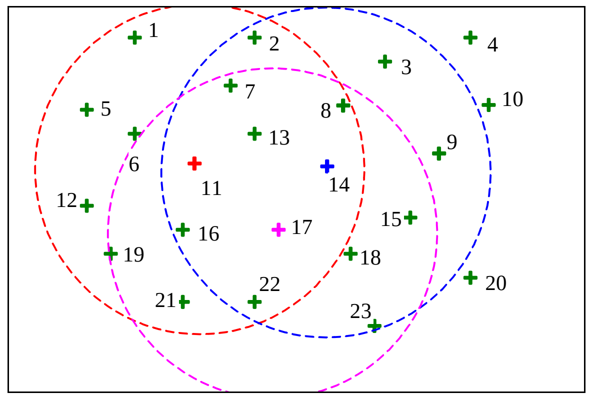

Figure A.1-1. Network Example

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,…:

122, 0, M11, A1, …
122, 0, M11, A2, …
122, 0, M11, A5, …
122, 0, M11, A6, …
122, 0, M11, A7, …
122, 0, M11, A8, …
122, 0, M11, A12, …
122, 0, M11, A13, …
122, 0, M11, A14, …
122, 0, M11, A16, …
122, 0, M11, A17, …
122, 0, M11, A19, …
122, 0, M11, A21, …
122, 0, M11, A22, …

122, 0, M14, A2, …
122, 0, M14, A3, …
122, 0, M14, A7, …
122, 0, M14, A8, …
122, 0, M14, A9, …
122, 0, M14, A11, …
122, 0, M14, A13, …
122, 0, M14, A15, …
122, 0, M14, A16, …
122, 0, M14, A17, …
122, 0, M14, A18, …
122, 0, M14, A22, …
122, 0, M14, A23, …

122, 0, M17, A7, …
122, 0, M17, A8, …
122, 0, M17, A11, …
122, 0, M17, A13, …
122, 0, M17, A14, …
122, 0, M17, A15, …
122, 0, M17, A16, …
122, 0, M17, A18, …
122, 0, M17, A19, …
122, 0, M17, A21, …
122, 0, M17, A22, …
122, 0, M17, A23, …

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.

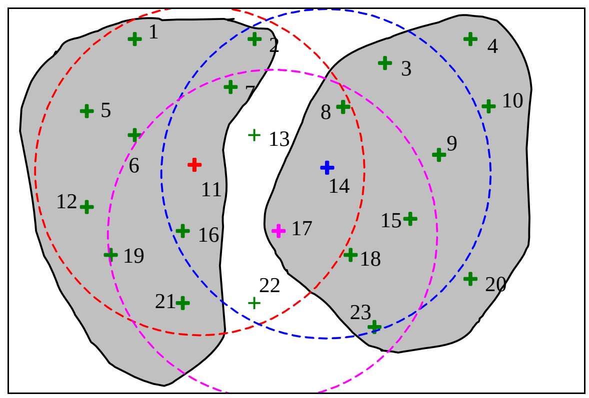

Figure A.1-2. Example of Multiple Solutions

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 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.

TheSynchronous 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, and1012 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

	GPS		GLONASS		GPS Network RTK				GLONASS Network RTK			
Epoch	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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