RTCM RECOMMENDED STANDARDS FOR DIFFERENTIAL GNSS (GLOBAL NAVIGATION SATELLITE SYSTEMS) SERVICE

VERSION 3.0

DEVELOPED BY
RTCM SPECIAL COMMITTEE NO. 104

FEBRUARY 10, 2004

Radio Technical Commission For Maritime Services
1800 N. Kent St., Suite 1060
Arlington, Virginia 22209
E-Mail: info@rtcm.org
Web Site: http://www.rtcm.org

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For information on RTCM Documents or on participation in development of future RTCM documents contact:

Radio Technical Commission For Maritime Services
1800 N. Kent St., Suite 1060
Arlington, Virginia 22209-2109 USA

Telephone: +1-703-527-2000
Telefax: +1-703-351-9932
E-Mail: info@rtcm.org

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PREFACE

This recommended standards document 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.x 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.

This initial release of the new standard, i.e., Version 3.0, consists primarily of messages designed to support real-time kinematic (RTK) operations. The reason for this emphasis is that RTK operation involves broadcasting a lot of information, and thus benefits the most from an efficient data format. Version 3.0 provides messages that support GPS and GLONASS RTK operations, including code and carrier phase observables, antenna parameters, and ancillary system parameters.

Unlike Version 2.x, this standard does 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.

As new message sets are adopted, supplements will be issued to the Version 3 standard, and made available electronically to those who have purchased the standard. Periodically, the standard will be completely updated and released as Version 3.1, 3.2, etc.

RTCM SC-104 believes that the new Version 3 standard for DGNSS services will prove useful in supporting highly accurate differential and kinematic positioning as well as a wide range of navigation applications worldwide throughout the next decade.

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1 INTRODUCTION AND SCOPE

1.1 Introduction

The Global Positioning System (GPS) and the GLObal NAvigation Satellite System (GLONASS) are satellite-based positioning systems that are currently providing global service 24 hours each day. Collectively, these two systems, plus other systems currently being designed and implemented, are called Global Navigation Satellite Systems (GNSS's). GNSS's typically provide navigation and positioning services having accuracies in the 10-40 meter range (2drms). Differential operation provides much higher accuracy.

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.

The initial Version 3.0 document describes messages and techniques for supporting GPS and GLONASS operation. However, the format is specifically designed to make it straightforward to accommodate modifications to these systems (e.g., new L2C and L5 signals), and to new systems that are under development (e.g., Galileo). In addition, augmentation systems that utilize geostationary satellites with transponders operating in the same frequency bands are now in the implementation stages. Generically they 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.

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 RTCM SC-104 Version 3 format will support the most stringent and unique applications of this high-accuracy positioning technique.

1.2 Scope

This document 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 RTCM SC-104 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. Of course, 2-way service can be achieved by augmenting the Differential Service with cell phones or Internet connections, but such a service is still basically 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 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

Version 3 of the RTCM SC-104 Differential GNSS standard 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 data broadcast. 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 SC-104 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, zeros should be used by the reference station designer for undefined bits to fill out the last unfilled byte.

3.1.2 Message Groups

Message types contained in the current Version 3.0 standard 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
Auxiliary Operation Information		1013

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

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

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., GPS and 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 GLONASS and GPS data are not synchronous, 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 ±100 ns. Note that the PhaseRange has the same sign as the Raw Pseudorange.

3.2 Message Type Summary

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

Table 3.2-1. Message Type Table

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

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

3.3 Data Types

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

Table 3.3-1. Data Type Table

Data Type	Description	Range	Data Type Notes
bit(n)	bit field	0 or 1, each bit	Reserved bits set to "0"
char8(n)	8 bit characters, ISO 8859-1 (not limited to ASCII)	character set	Reserved or unused characters: [0x00]
int14	14 bit 2's complement integer	-8192 to +8191	
int20	20 bit 2's complement integer	-524,288 to +524, 287	
int38	38 bit 2's complement integer	-137,438,953,472 to +137,438,953,471	
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	
uint12	12 bit unsigned integer	0 to 4095	
uint16	16 bit unsigned integer	0 to 65,535	
uint17	17 bit unsigned integer	0 to 131,071	
uint20	20 bit unsigned integer	0 to 1,048,575	
uint24	24 bit unsigned integer	0 to 16,777,215	
uint25	25 bit unsigned integer	0 to 33,554,431	
uint27	27 bit unsigned integer	0 to 134,217,727	
uint30	30 bit unsigned integer	0 to 1,073,741,823	

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.
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).

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
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.
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. 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.
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.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
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.
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.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
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.
DF034	GLONASS Epoch Time (t_k)	0-86,400,999 ms	1 ms	uint27	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.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
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.
DF039	GLONASS L1 Code Indicator			bit(1)	"0" = C/A Code; "1" = P Code
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

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
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.
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.

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
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
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.

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	$0 < \text{lock time} < 24$
24-47	$i \cdot 2 - 24$	$24 \leq \text{lock time} < 72$
48-71	$i \cdot 4 - 120$	$72 \leq \text{lock time} < 168$
72-95	$i \cdot 8 - 408$	$168 \leq \text{lock time} < 360$
96-119	$i \cdot 16 - 1176$	$360 \leq \text{lock time} < 744$
120-126	$i \cdot 32 - 3096$	$744 \leq \text{lock time} < 937$
127	---	$\text{lock time} \geq 937$

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

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

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

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

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, 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.

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 Message 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 GPS Service (IGS).

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

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

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

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

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number ("1006"= 0011 1110 1110)	DF002	uint12	12
Reference Station ID	DF003	uint12	12
Reserved for ITRF Realization Year	DF021	uint6	6
GPS Indicator	DF022	bit(1)	1
GLONASS Indicator	DF023	bit(1)	1
Reserved for Galileo Indicator	DF024	bit(1)	1
Reserved	DF001	bit(1)	1
Antenna Reference Point ECEF-X	DF025	int38	38
Reserved	DF001	bit(2)	2
Antenna Reference Point ECEF-Y	DF026	int38	38
Reserved	DF001	bit(2)	2
Antenna Reference Point ECEF-Z	DF027	int38	38
Antenna Height	DF028	uint16	16
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 character 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 ≤ 31
Antenna Setup ID	DF031	uint8	8	
Serial Number Counter M	DF032	uint8	8	
Antenna Serial Number	DF033	char8(M)	8*M	M ≤ 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 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
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

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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 SC-104 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 Version 3.0 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 transmission station identification and/or a sequence count.

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.

The Version 3 standard will use the QualComm CRC algorithm with permission. 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 SC-104 Version 3 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 SC-104 Version 3 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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