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

VERSION 2.3

DEVELOPED BY
RTCM SPECIAL COMMITTEE NO. 104

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4.3.1 Message Type 1 - Differential GPS Corrections (Fixed)

Figure 4-2 and Table 4-4 present the content of Message Type 1, the differential corrections. This is the primary message type which provides the pseudorange correction (PRC(t)) for any user receiver GPS measurement time "t":

$$PRC(t) = PRC(t_0) + RRC \bullet [t - t_0] \qquad \text{(Eq. 4-1)}$$

where $PRC(t_0)$ is the 16 bit pseudorange correction, RRC is the 8-bit rate of change of the pseudorange correction (range rate correction), and t_0 is the 13-bit modified Z-count of the second word. These parameters are all associated with the satellite indicated by the 5-bit Satellite ID, which indicates its PRN number. The pseudorange measured by the user, PRM(t), is then corrected as follows:

$$PR(t) = PRM(t) + PRC(t) \qquad \text{(Eq. 4-2)}$$

Note that the correction is added to the measurement. PR(t) is the differentially corrected pseudorange measurement that should be processed by the User Equipment navigation filter. Also provided is a l-bit Scale Factor (see Table 4-5) and 2-bit User Differential Range Error ("UDRE" - see Table 4-6). The UDRE is a one-sigma estimate of the uncertainty in the pseudorange correction as estimated by the reference station, and combines the estimated effects of multipath, signal-to-noise ratio, and other effects. It should be noted that the real-time kinematic messages use signal quality indicators which separate out multipath effects from other effects, as described in Appendix B. User receivers applying the UDRE values should utilize the upper values of the range in Table 4-6 to be conservative. Note that the UDRE values should be multiplied by the UDRE scale factor in the Station Health field of the header message, if the user receiver decodes that field.

The Type 1 Message contains data for all satellites in view of the reference station (N_S). Since 40 bits are required for the corrections from each satellite, there won't always be an exact integer number of words required. There will be messages that require 8 or 16 bits of fill to finish the frame. The fill will be alternating l's and 0's so as not to be confused with the "preamble" synchronization code. The format of the Type 1 Message is illustrated in Figure 4-2. Each word has one of five formats unless it is the last word in the message. If N_s is not a multiple of 3, the last word has one of two formats, containing either 8 or 16 fill bits.

The pseudorange correction $PRC(t_0)$ will diverge from the proper value as it "grows old." Because of this characteristic, it will be updated and transmitted as often as possible. The User Equipment should update the corrections accordingly.

The pseudorange correction $PRC(t_0)$ is the difference between the computed geometric range (see Appendix C) and the adjusted pseudorange. The adjusted pseudorange is the raw pseudorange measurement adjusted for:

a. Receiver clock offset, scaled to meters.
b. T_{gd}, the L1-L2 group delay correction (see GPS/SPS Signal Specification)
c. Satellite clock offset, scaled to meters (see GPS/SPS Signal Specification)
d. Satellite relativistic correction, scaled to meters (see GPS/SPS Signal Specification)

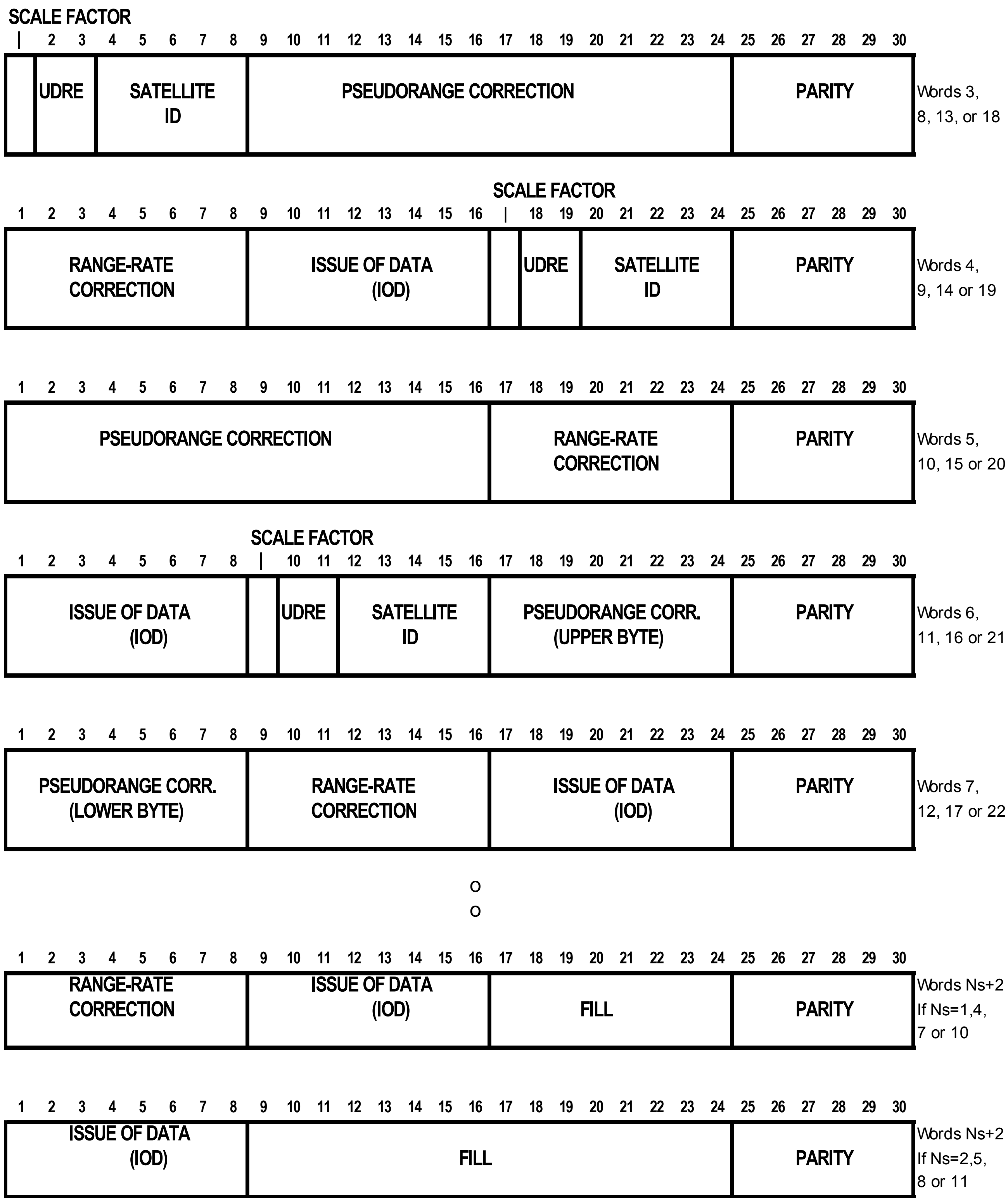

Figure 4-2. MESSAGE TYPE 1 - DIFFERENTIAL GPS CORRECTIONS

Table 4-4. CONTENTS OF A TYPE 1 MESSAGE

PARAMETER	NO. OF BITS	SCALE FACTOR AND UNITS	RANGE
SCALE FACTOR	1	*See Table 4-5*	2 states
UDRE	2	*See Table 4-6*	4 states
SATELLITE ID	5	1	1-32 *(Note 1)*
PRC(t_0) *(Note 2)*	16	0.02 or 0.32 m	±655.34 or ±10485.44 m *(Note 3)*
RRC* *(Note 2)*	8	0.002 or 0.032 m/s	±0.254 or ±4.064 m/s *(Note 4)*
ISSUE OF DATA	8	*(Note 5)*	
Total	40 x N_S		
FILL	8 x [N_S mod 3]	bits	
PARITY	N x 6	*(Note 5)*	

N_s = Number of satellite corrections contained in message.
N = Number of words in message containing data. Frame length = N+2 words.

Note 1: Satellite number 32 is indicated with all zeros (00000).
Note 2: 2's complement
Note 3: Binary 1000 0000 0000 0000 indicates a problem and the User Equipment should immediately stop using this satellite.
Note 4: Binary 1000 0000 indicates a problem and the User Equipment should immediately stop using this satellite.
Note 5: See GPS/SPS Signal Specification, available from U.S. Coast Guard Navigation Information Service, see Appendix F.

The reference station shall apply neither ionospheric nor tropospheric delay models in deriving the differential corrections. The reference station clock offset will be a common offset in all pseudorange corrections, which does not affect position calculations. The reference station may also adjust the PRC(t_0) for multipath effects.

11	3	> 8 meters

Note that the 1-sigma differential errors should be multiplied by the UDRE scale factor provided in the message header.

The range rate correction (RRC) is designed to compensate for the predicted rate of change of the pseudorange correction. This is an attempt to "extend the life" of the pseudorange correction as it "grows old." The RRC can also be used to correct the user receiver's velocity. The User Equipment should not use the RRC as a carrier phase correction -- it may degrade that type of measurement. Carrier phase measurements should be corrected only using Message Types 18 or 20.

The Issue of Data (IOD) is included in the message so that the User Equipment may compare it with the IOD of the GPS navigation data being used. The IOD is the key that ensures that the user equipment calculations and reference station corrections are based on the same set of broadcast orbital and clock parameters. If they don't agree, it is the responsibility of the differential user equipment to take the appropriate actions to acquire parameters that match the ones in use at the reference station. This can be done two ways: test the present IOD for a match to the IOD in a Type l or Type 2 message, or acquire another navigation data message from the appropriate satellite. In general, the reference station attempts to use the present navigation data being broadcast by a satellite. The user receiver should be designed to accommodate the possibility that the reference receiver may delay the broadcast of corrections based on a new satellite ephemeris for a period of up to 90 seconds, in order to avoid the necessity of broadcasting Type 2 messages. Note that the Type 5 Message also contains useful information concerning navigation data.

Under no circumstances should a "partial" differential solution be attempted, i.e., processing both differentially corrected and non-differentially-corrected pseudoranges in the same position calculation. The resulting position will usually be no better than a non-differential solution.

Table 4-5. SCALE FACTOR

CODE	NUMBER	INDICATION
0	0	Scale factor for pseudorange correction is 0.02 meter and for range rate correction is 0.002 meter/second
1	1	Scale factor for pseudorange correction is 0.32 meter and for range rate correction is 0.032 meter/second (also refer to Table 4-4)

The rationale for the two-level scale factor is to maintain a high degree of precision most of the time, and allow the ability to increase the range of the corrections on those rare occasions when it is needed.

Table 4-6. USER DIFFERENTIAL RANGE ERROR (UDRE)

CODE	NUMBER	ONE-SIGMA DIFFERENTIAL ERROR
00	0	$\leq$ 1 meter
01	1	> 1 meter and $\leq$ 4 meters
10	2	> 4 meters and $\leq$ 8 meters

4.3.2 Message Type 2 - Delta Differential GPS Corrections (Fixed)

Message Type 2 is provided for situations where the user equipment may not immediately decode new satellite ephemerides in the satellite data. Since the reference station should be designed to immediately decode the new ephemerides, there could be periods of time where the user and reference station are using different ephemerides, which could result in position errors, particularly after a satellite upload. Type 2's can be omitted if both reference stations and mobile receivers of a differential service are properly designed; that is, if the reference stations are designed to postpone the application of new ephemerides and mobile receivers are designed to continue to apply old ephemerides until reference station messages are received which utilize the new ephemerides.

If Type 2's are employed, the reference station shall transmit both Type 1 and Type 2 messages any time it starts using new GPS navigation message data to calculate satellite position and compensate for satellite clock offsets. This is indicated by a change in the Issue of Data parameter in the Type l Message. Each new set of satellite navigation data is identified with an Issue of Data (IOD) parameter. Differential user equipment should not use new satellite navigation data until the reference station indicates the appropriate IOD in the Type l Message.

Upon a change in ephemeris, the reference station shall broadcast a Type 2 message paired with a Type 1 message, and continue to broadcast Type 2 messages over a period of several minutes following a change in satellite navigation data in order to accommodate users coming on line. During this period, the differential user equipment will acquire the new navigational data and begin using the "new" Type l Message data. The Type 2 Message acts as a bridge to continue high accuracy navigation during this transition period. Accuracy is maintained if Type 2's are utilized correctly. It is preferred, but not required, to transmit the Type 2 message first; this may become a requirement in the future. If Type 2's are used with Type 9 transmissions, a Type 2 shall precede the Type 9's using the new ephemerides.

This message contains the difference in the pseudorange and range rate corrections caused by the change in satellite navigation data. At the reference station, two calculations will be performed for the pseudorange correction (PRC) and range rate correction (RRC). The first calculation will use the latest navigation data available from the satellite. The second calculation will use the navigation data that is being replaced by the most recent navigation data. The reference station will difference the corrections to determine the DELTA PRC and DELTA RRC needed for the Type 2 Message.

The DELTA PRC is equal to the PRC (calculated using the older navigation data) minus the PRCs (calculated using the latest navigation data), or:

$$\text{DELTA PRC} = \text{PRC (old IOD)} - \text{PRC (new IOD)} \qquad \text{(Eq. 4-3)}$$

In a similar manner, the DELTA RRC is equal to the RRC (calculated using the older navigation data) minus the PRC (calculated using the latest navigation data), or:

$$\text{DELTA RRC} = \text{RRC (old IOD)} - \text{RRC (new IOD)} \qquad \text{(Eq. 4-4)}$$

In order to use a Type 2 correction the user equipment must:

1. Presently be using the satellite navigation data with an IOD that matches the Type 2 Message IOD for that satellite;
2. Acquire a Type 1 Message with a new IOD that does not match the present IOD being used;

3. Calculate the correct pseudorange correction with the following equation using information from both the Type 1 and Type 2 Messages:

PRC(t) =	[PRC(new IOD)	(from Type 1 Message)	
	+		
	DELTA PRC (old IOD)]	(from Type 2 Message)	
	+		
	[RRC(new IOD)]• $[t - t_1]$	(from Type 1 Message)	
	+		
	[DELTA RRC(old IOD)]• $[t - t_2]$	(from Type 2 Message)	(Eq. 4-5)

where
t = the time of application of the correction,
t_1 = modified Z-count from Type 1 Message, and
t_2 = modified Z-count from Type 2 Message.

Note that this equation is a simple extension of Eq. 4-1.

The general format is the same as that of a Type 1 Message. In fact, the description of the 1-bit Scale Factor is found in Table 4-5 and the description of the 2-bit User Differential Range Error is found in Table 4-6. The content of the Type 2 Message is given in Table 4-7; it is illustrated in Figure 4-3.

4.3.9 Message Type 9 -- GPS Partial Correction Set (Fixed)

The Type 9 Message serves the same purpose as the Type 1 Message, in that it contains the primary differential GPS corrections. However, unlike Type 1's, Type 9 Messages do not require a complete satellite set. As a result, they require the use of a more stable clock than a station transmitting only Type 1's, because the satellite corrections have different time references. To prevent degradation of navigation accuracy due to unmodelable clock drift that can occur between Type 9 messages, a highly stable clock source is required. Type 9's are useful in the presence of SA for providing additional updates for satellites whose rate correction variations are high. They are also useful for slow data links in the presence of impulse noise, such as that encountered in radiobeacon operation. During high noise periods, the higher rate of preambles supports a faster re-synchronization.

The Type 9 Message can also be used to improve the performance of data links that are susceptible to interference from impulse noise, such as radiobeacon data links. Grouping satellites in blocks of three significantly improves the data link performance in two ways. First, when Type 9 Messages contain the corrections for three satellites, their initially lower age of corrections more than compensates for their longer propagation time associated with the increased overhead. This is illustrated in Table 4-13. Second, the short length of the Type 9 Message provides increased noise immunity and allows a more rapid re-synchronization, due to the fact that the preamble is transmitted at a much higher rate. Note that unlike the case for Type 1 Messages, corrections from partial Type 9 Messages can be applied as soon as they are received (see Section 5.3.5) thus further reducing the average PRC latency and lowering the susceptibility of the messages to channel noise.

Table 4-13. PRC AGE OF CORRECTIONS AT 100 bps

	MAXIMUM PRC LATENCY	
NO. OF SATELLITES	TYPE 1	TYPE 9 (3 SATS/MSG)
4	5.4 s	5.4 s
6	7.2 s	6.3 s
8	9.6 s	8.1 s
9	10.2 s	8.4 s

The content and the format of the Type 9 Message is identical to that of the Type 1 Message, except that N_s, the number of satellites, and N, the number of 30 bit words, will be much smaller.

4.3.10 Message Type 10 - P-Code Differential Corrections (Reserved)

Message Type 10 has been assigned to the P-code users, who will want differential corrections for both L1 and L2 frequencies. Its form and content are TBD. It should be noted that Message Types 19 and 21 can be used with P-code signals.