Processing of WA-DGNSS Correction Messages:
A Functional Perspective

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요 약 문

Satellite Based Augmentation Systems (SBAS) broadcast standard correction messages for aiding GNSS receivers. The SBAS implementation is envisaged under Development Wide Area Differential GNSS (WA-DGNSS) Systems project. WA-DGNSS correction messages are meant to provide an extensive set of information on corrections along with the confidence bounds. The end-user receiver should decode and interpret these messages every second. An individual message is composed of 250 bits. This levies strict limitation on information carrying capacity of each message. Therefore all correction information is distributed into several interconnected messages and each message is designed to carry certain portion of the corrections. It is responsibility of the end-user receiver not only to decode and interpret a message but also interconnect with other messages in order to obtain complete set of corrections.

A comprehensive discussion on design, content and interconnections of WA-DGNSS broadcast messages can be found in relevant Minimum Operational Performance Standards (MOPS). It requires firm background knowledge about architecture and key sub-systems of WA-DGNSS to understand all the information provided in standards document. Since the document is outcome of extended discussions of diverse members; its narrative is legal and focused on detail. Despite being the standard reference, it is difficult to develop a WA-DGNSS receiver program using the standards document. The basic intent of this paper is to discuss functional aspects of how a WA-DGNSS capable receiver may process the correction messages. Understanding the functional perspective can be easily translated into receiver logic and then program code.

1. Introduction

WA-DGNSS user segment is responsible to recieve, decode, process and apply correction messages broadcast by the GEO satellite. A WA-DGNSS GEO satellite empoys same L1 carrier frequency (i.e. 1575.42 MHz) to modulate correction messages. Same as GPS navigation data, BPSK modulation of carrier encodes the messages on carrier using CDMA. Therefore, a WA-DGNSS message receiver is essentially the same as normal GNSS receiver accept that it has dedicated channels for acquisition, tracking and decoding of correction messages from WA-DGNSS GEO satellites in addition to ranging SVs. Figure 1 shows conceptual system architecture of the constituent components of WA-DGNSS User Segment. As discussed earlier, the WA-DGNSS capable user equipment can process correction messages from GEO SV as well as navigation messages from GNSS SVs. The acquisition & tracking of both GEO and GNSS SVs is similar due to the same underlying communication system. However, the actual messages are processed differently and ultimately combined to achieve a PNT solution.

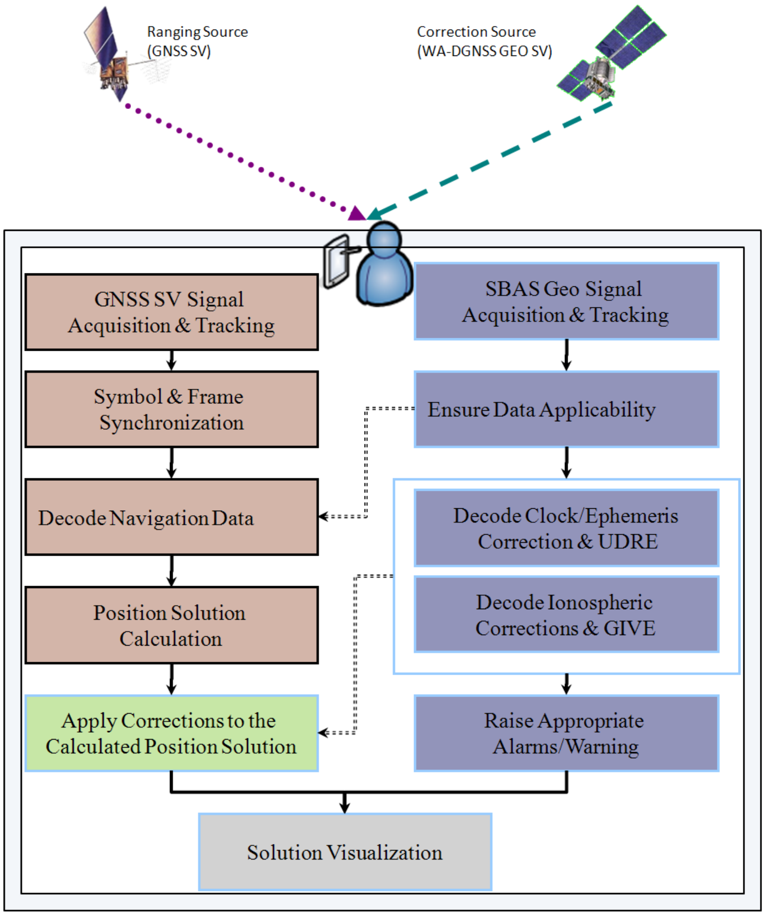

Figure 1. WA-DGNSS User Segment System Architecture

2. WA-DGNSS Correction Messages

A brief overview of the WA-DGNSS correction messages and their contents is given here. The correction messages are broadcast at 250 bps. Due to strictly limited bandwidth the correction information is divided into several inter-related messages. Figure 2 shows a general schematic of the correction messages. A 24 bit preamble is used to mark the start of messages. The preamble is distributed across three consecutive message having 8 starting bits of each message. A 6 bit message type identifier follows which determines the further processing and application of received message. Actual correction information is contained in 212 bits block of data. In order to maintain and ensure error-free reception of the information 24 bit CRC parity is employed at the end of each message.

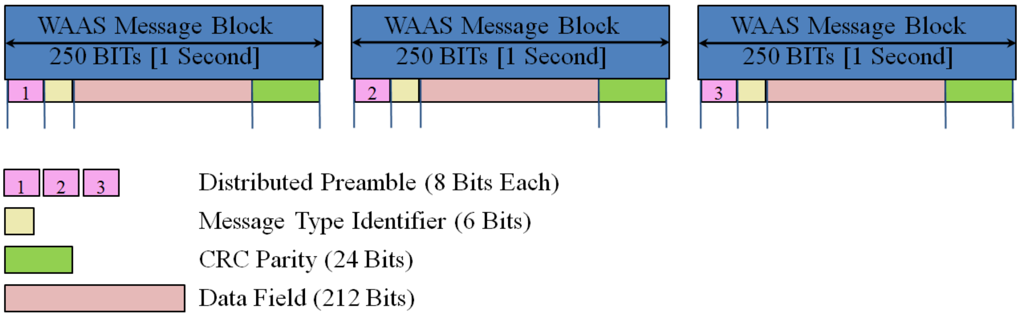

Figure 2. WA-DGNSS (WAAS) Message Schematic

A summary of all messages is shown in Table 1.

Table 1. WA-DGNSS Correction Messages: Types and Relationships

Message Type	Contents	Related Message	Relationship Parameter
0	Don't use for safety applications (Testing)		
01	PRN Mask Assignments	02-05, 07, 24, 25, 28	IODP
02~05	Fast Correction	06	IODF
06	Integrity Information	02-05, 24	IODF
07	Fast Correction Degradation Factor	01	IODP
09*	Geo Navigation Messages (X,Y,Z Time etc)		
10	Degradation Parameters		
12	SBAS Network Time, UTC Offset Parameters		
17	GEO SV Almanac		
18	Ionospheric Grid Point Mask	26	IODI
24	Mixed Fast Corr. / Long time SV Error Corr.		IODF
25	Long time satellite error corrections	01	IODP
26	Ionospheric Delay Corrections	18	IODI
27	SBAS Service Message	27	IODS
28	Clock Ephemeris Covariance Matrix Message	01	IODP
29~61	Reserved for Future Messages		
62	Internal Test Message		
63	Null Message		
08	Reserved for Future Messages		
11	Reserved for Future Messages		
13~16	Reserved for Future Messages		
19~23	Reserved for Future Messages		

* Prevents slow varying GEO Satellite errors

3. WA-DGNSS Correction Message Processing

The operation of user segment receiver constitutes three distinct tasks. Processing flow is illustrated in Figure 3. The first task is to extract correction data extraction. It involves acquisition, tracking and decoding of associated GEO SV signal and storage of received messages in local memory. Section 3.1 provides a detailed treatment of this task. Second task is to process the received correction messages and keep track of the validity and integrity of the messages. The message processing task involves treatment of messages related to; i) Ionospheric estimates, ii) Fast corrections and iii) Long term corrections. Section 3.2 provides conceptual design of the processing algorithms. Third task is to apply the processed messages and compute respective PNT solution.

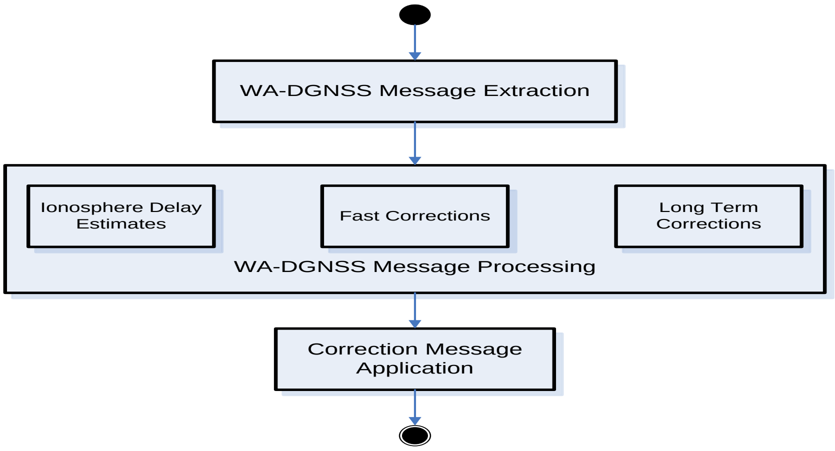

Figure 3. WA-DGNSS Message Processing Block Diagram

3.1 WA-DGNSS Message Extraction

The WA-DGNSS GEO satellite may broadcast any type of message at any given one second interval. Since several messages are inter-related therefore each received message is saved in local memory as an active message until the expiry time. Therefore message extraction is the first task that executes continuously regardless of the message type. Figure 4 shows the data extraction from an SBAS message.

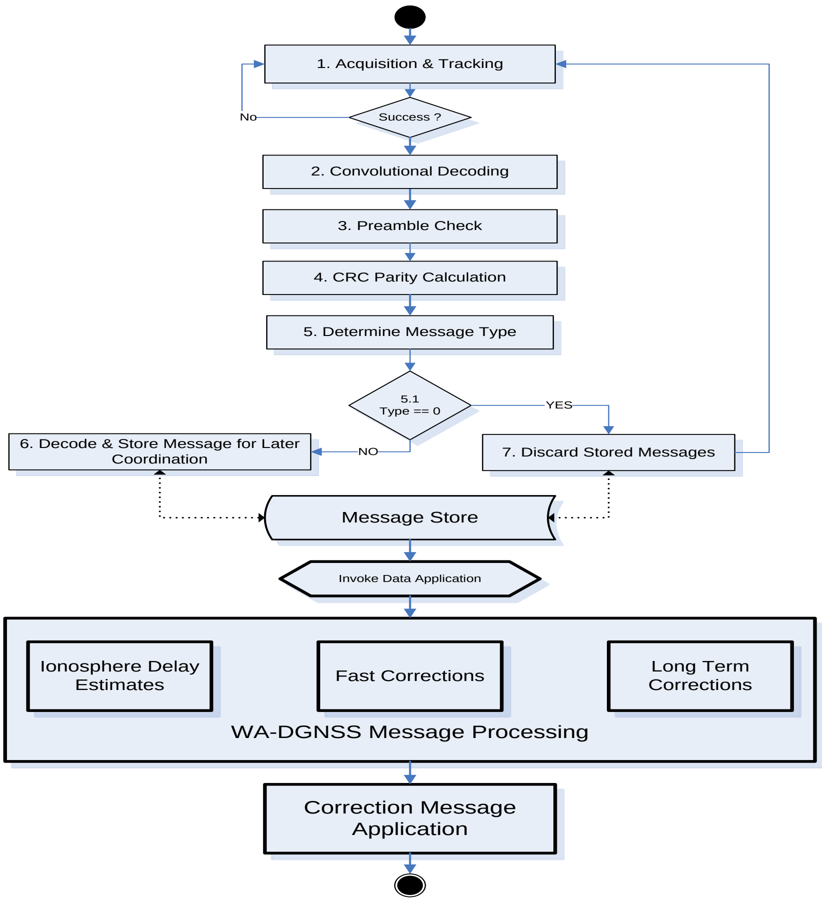

Figure 4. Message Extraction Algorithm Block Diagram

Acquisition of GEO SV signal is similar to the GPS. A correlation peak must be detected between received PRN and Locally known PRN of the GEO. Once the correlation peak is found, the equipment should be able to refine the estimate for Doppler shifted carrier frequency in order to track the signal. Once message data is extracted it is processed with respect to the received message type. There are three main processing algorithms that takes care of the received message.

3.2 Ionospheric Correction Messages

This section describes the algorithm for Ionospheric delay correction messages (Type 18 or 26). First an overview of each of these messages is presented in the following.

Grid Point Masks Message Type 18

The Ionospheric delay corrections are broadcast as vertical delays at Ionospheric Grid Points (IGPs), applicable to a signal modulated on L1. In order to facilitate flexibility in location of these IGPS, a fixed definition of densely spaced IGP locations is used resulting in a large number of possible IGPs. Since it would be impossible to broadcast IGP delays for all possible locations, a mask is broadcast to define the IGP locations providing the most efficient model for the ionosphere at the time.

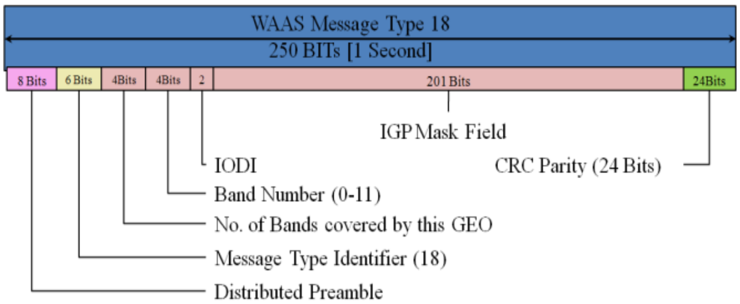

Figure 5. Message Type 18

Vertical Iono-Delay Corrections Message Type 26

The type 26 message provide the users with vertical delays (relative to an L1 signal) and their confidence bounds (GIVE) at IGPs identified by the band number. The schematic of this message is shown below. Band number and block ID that identifies the 15 IGPs for which vertical delay estimate and confidence bound is given in the message.

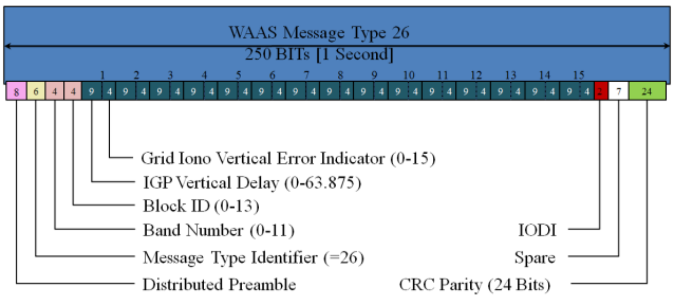

Figure 6. Message Type 26

The following flow chart shows how the user equipment obtains ionosphere delay estimates from message types 18 and 26.

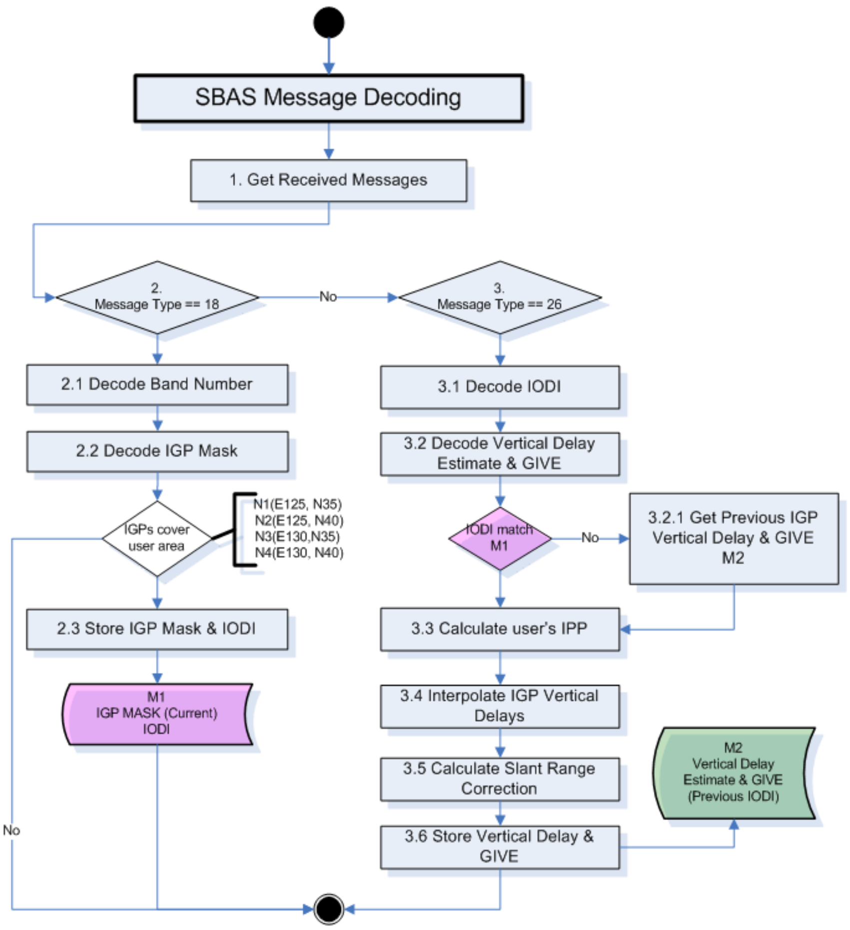

Figure 7. Ionospheric Corrections Message Algorithm Block Diagram

3.3 Fast Corrections

The Message Type 2, 3, 4, 5, 24 are allocated to broadcast fast corrections for errors that may arise in SV's clock and ephemeris. Following figure show and message structure for fast corrections.

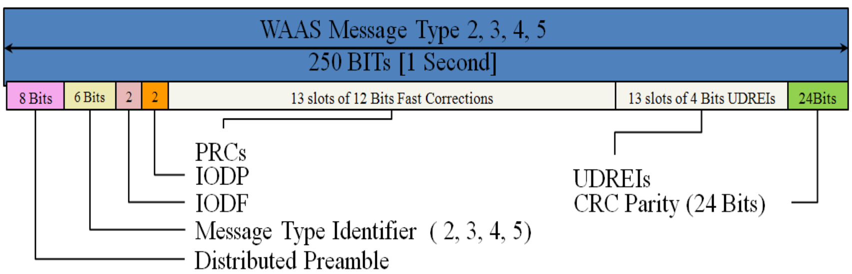

Figure 8. Fast Correction Message Type 2, 3, 4 and 5

The Message Type 6 is also related to Fast Corrections. It contains confidence bounds updates for corrections broadcast by Message 2, 3, 4, 5. The schematic of Message Type 6 is shown as below.

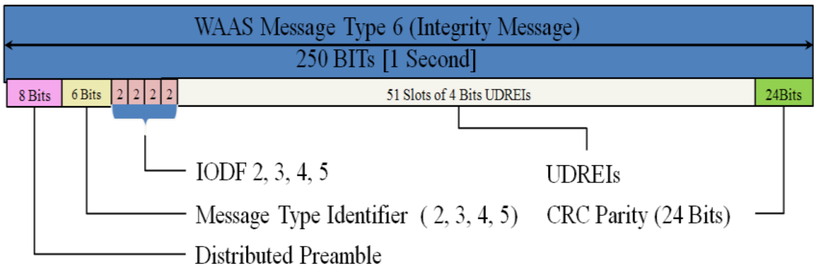

Figure 9. Fast Correction Message Type 6

The confidence bound UDRE in Messages 2, 3, 4, 5 may be updated infrequently by Message 6. All these messaged are linked by 2 bit Issue of Data Fast corrections (IODF). The relationship is shown below.

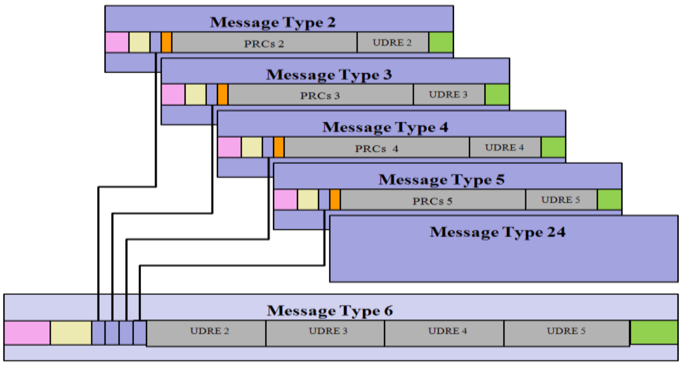

Figure 10. Fast Correction Messages Inter-relationships

The following flowchart shows the processing of fast correction messaged by user equipment.

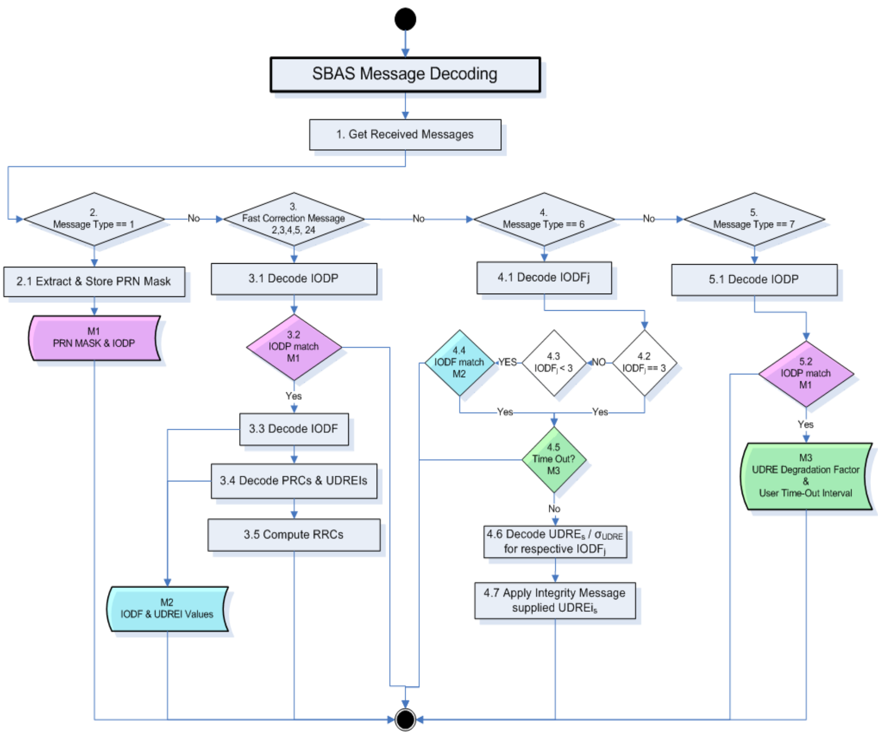

Figure 11. Fast Correction Message Algorithm Block Diagram

3.4 Long Term Corrections

This message shall be broad cast to provide error estimates for slow varying satellite ephemeris and clock errors with respect to WGS-82 ECEF coordinates. Message type 25 may be broadcast in two forms depending upon requirement. Following figures show the schematic of each form. One message may contain corrections for 1-4 ranging sources i.e GPS.

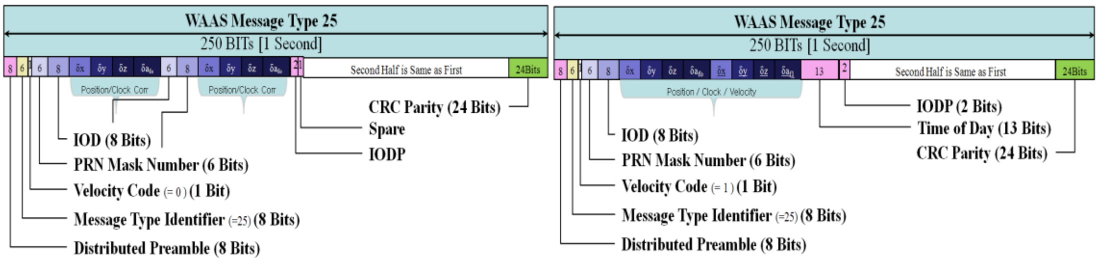

Figure 12. Ionospheric Corrections (Message Type 25)

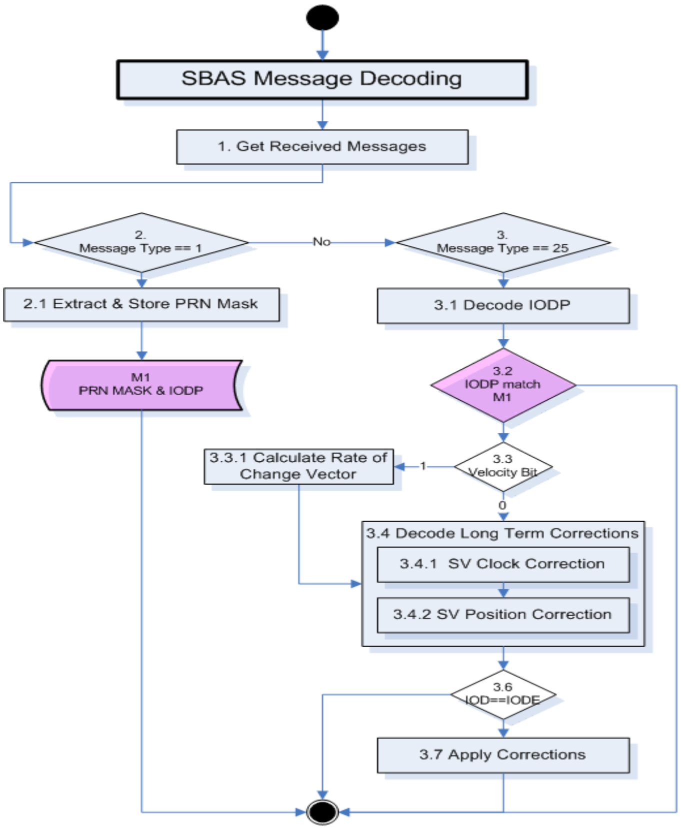

Figure 13. Long Term Corrections (Message Type 1, 25)

Acknowledgement

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References

[1] RTCA Inc, Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment, December 13, 2006.