Quasi-Zenith Satellite System
Interface Specification
Multi-GNSS Advanced Orbit and Clock Augmentation
- Precise Point Positioning
(IS-QZSS-MDC-001)

(February 2022)

Cabinet Office

Revision History

Rev.No.	Date	Page	Revisions
001	February 2022	—	—

"TBD" is an abbreviation for "To be determined." Those items marked "TBD" have not yet been determined but will be determined in the future.

Table of Contents

1. Scope

This interface specification document describes the interface specification between the Quasi-Zenith Satellite System (QZSS) and users of the Multi-GNSS Advanced Orbit and Clock Augmentation-Precise Point Positioning Service (MADOCA-PPP). The interface specification includes the message specification and user algorithm. The signal characteristic shall be referred to Section 3 of the applicable document (4) IS-QZSS-L6, Quasi-Zenith Satellite System Interface Specification Centimeter Level Augmentation Service.

The Service introduction and the system introduction are described in the applicable document (1) PS-QZSS, Quasi-Zenith Satellite System Performance Standard.

2. Relevant Documents and Definition of Terms

2.1 Applicable Documents

The cited parts of the following documents are recognized as being part of this document. This document may be updated when these applicable documents are updated.

(1) PS-QZSS, Quasi-Zenith Satellite System Performance Standard.

(2) RTCM STANDARD 10403.3 DIFFRENTIAL GNSS (GLOBAL NAVIGATION SATELLITE SYSTEMS) SERVICE –VERSION 3, RTCM SPECIAL COMMITTEE NO.104, 7-OCT-2016.

(3) Mitsubishi Electric Corporation, Specification of Compact SSR Messages for Satellite Based Augmentation Service, Version 08, 17-SEP-2019, DOI:10.13140/RG.2.2.10749.49129.

(4) IS-QZSS-L6, Quasi-Zenith Satellite System Interface Specification Centimeter Level Augmentation Service.

2.2 Reference Documents

The following documents are referred on the creation of this document. This document might be updated when these reference documents are updated.

(1) Global Positioning Systems Directorate Systems Engineering & Integration Interface Specification IS-GPS-200, Navstar GPS Space Segment/Navigation User Interfaces, Revision H, 24-SEP-2013.

(2) Wu, J.T., S.C. Wu, G.A. Hajj, W.I. Bertiger, S.M. Lichten., Effects of Antenna Orientation on GPS Carrier Phase, Manuscripta Geodaetica, 18, 91-98, 1993.

(3) G. Petit and B. Luzum (eds.), IERS Technical Note No.36, IERS Conventions (2010), 2010.

(4) J. Kouba, A Guide to using International GNSS Service (IGS) products, May 2009.

(5) IS-QZSS-SAS, Quasi-Zenith Satellite System Interface Specification Navigation Message Signal Authentication Service.

2.3 Terms and Definitions

Terms	Definitions
alert flag	See Section 5.4.1 If the service stops due to an error occurring in the ground or satellite system, an alert flag is notified to the user that the service is not available.
L6 message	See Section 4.2.1 A message transmitted by L6 signal, consisting of a 49-bit header, a 1695-bit data part, and a 256-bit Reed-Solomon code. The message is transmitted in one second.
frame	See Figure 4.2.2-1 Multiple subframe. The number of subframe depends on an update interval of each Compact SSR message.
subframe	See Figure 4.2.2-1 Successive data parts of L6 message from 1 to 0 of multiple Message Indicator
Compact SSR message	See Section 4.2.2 Bandwidth efficient State Space Representation (SSR) format message for Precise Point Positioning -Real Time Kinematic (PPP-RTK) service defined as a proprietary message in the applicable document (2). Compact SSR messages are included in the data part of L6 message.
Technology Demonstration (ionospheric correction)	Wide area ionospheric corrections are provided for the Asia and Oceania region as a Technology Demonstration of MADOCA-PPP. Technology Demonstration (ionospheric correction) messages are transmitted as L6D messages.
Quasi-Zenith Satellite Navigation Message Authentication	Quasi-Zenith Satellite Navigation Message Authentication is the message data for the Navigation Message Authentication generated by the QZSS.

2.4 Abbreviations

-A-

-B-

-C-

CDMA	Code Division Multiple Access
CLAS	Centimeter Level Augmentation Service
CSK	Code Shift Keying
CNAV	Civil Navigation
CNAV-2	L1C Navigation Message
CPC	Carrier Phase Correction

-D-

-E-

ECEF	Earth Centered Earth Fixed

-F-

FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction

-G-

GEO	Geostationary Orbits
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPST	GPS Time

-H-

-I-

ID	Identification
IERS	International Earth Rotation and Reference Systems Service
IOD	Issue Of Data
IODE	Issue Of Data, Ephemeris
ISB	Inter System Bias
ITRF	International Terrestrial Reference Frame
I/NAV	Integrity Navigation Message

-J-

-K-

-L-

LNAV	Legacy Navigation
LSB	Least Significant Bit

-M-

MADOCA-PPP	Multi-GNSS Advanced Orbit Clock Augmentation – Precise Point Positioning
MSB	Most Significant Bit
MT	Message Type

-N-	
-O-	
-P-	
PCO	Phase Center Offset
PCV	Phase Center Variation
PPP	Precise Point Positioning
PRC	Pseudo Range Correction
PRN	Pseudo-Random Noise
-Q-	
QZNMA	Quasi-Zenith Satellite Navigation Message Authentication
QZO	Quasi-Zenith Orbits
QZS	Quasi-Zenith Satellite
QZSS	Quasi-Zenith Satellite System
QZSST	QZSS Time
-R-	
R-S	Reed-Solomon
RSC	Reed-Solomon code
RTCM	Radio Technical Commission for Maritime Services
-S-	
SBAS	Satellite Based Augmentation System
SF	Subframe
SSR	State Space Representation
ST	Sub Type
SV	Space Vehicle
-T-	
TAI	International Atomic Time
TBD	To Be Determined
TTFF	Time To First Fix
-U-	
URA	User Range Accuracy
-V-	
-W-	
-X-	
-Y-	
-Z-	

3. Signal Specifications

MADOCA-PPP data are transmitted as L6D or L6E messages from the QZSS satellites described in Table 3-1. The signal characteristic of L6 shall be referred to as Signal Characteristic in the applicable document (4) .

Table 3-1 Service assignment of L6 messages depending on the satellite

L6D (L6 code 1)		L6E (L6 code 2)		Satellite types	Remarks
PRN	L6D Message	PRN	L6E Message		
193	CLAS	203	–	QZO	Used in Block I (L61) Code1 and Code2 of Block I have the same number (193).
194	CLAS	204	MADOCA-PPP and QZNMA	QZO	–
195	CLAS	205	MADOCA-PPP and QZNMA	QZO	–
196	CLAS	206	MADOCA-PPP and QZNMA	QZO	–
197	Technology Demonstration (ionospheric correction)	207	MADOCA-PPP and QZNMA	QZO	–
198	–	208	–	–	Used as a non-standard code
199	CLAS	209	MADOCA-PPP and QZNMA	(Q)GEO	–
200	Technology Demonstration (ionospheric correction)	210	MADOCA-PPP and QZNMA	(Q)GEO	–
201	Technology Demonstration (ionospheric correction)	211	MADOCA-PPP and QZNMA	(Q)GEO	–
202	–	212	–	–	Used as a non-standard code

Notes

Technology Demonstration (ionospheric correction):

Wide area ionospheric corrections are provided for the Asia and Oceania region as a Technology demonstration of MADOCA-PPP.

CLAS:

See applicable document (4) for the message specification of CLAS.

QZNMA:

See reference document (5) for the message specification of QZNMA.

4. Message Specifications

4.1 Message Structure

4.1.1 General

The L6 message signal structure is shown in Figure 4.1.1-1. Each message has a length of 2000 bits, consisting of a 49-bit header, a 1695-bit data section, and a 256-bit Reed-Solomon code. The transmission of each L6 message takes one second.

The header of the L6 message starts from bit 1 (MSB), followed by the data part (1695-bit), which is transmitted from bit 50. The Reed-Solomon Code is transmitted from bit 1745, after the data part.

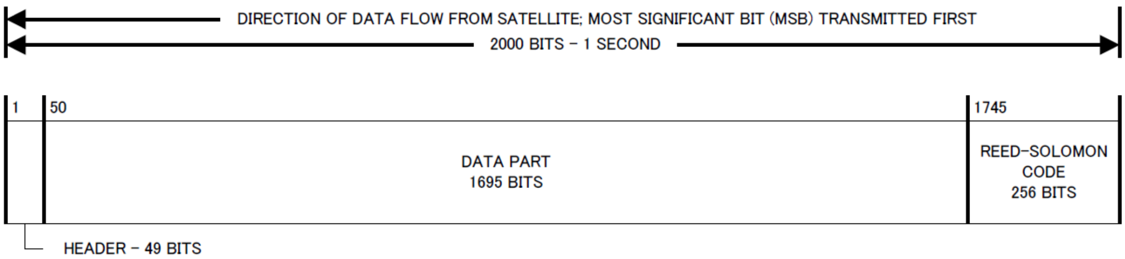

Figure 4.1.1-1 L6 Message Structure

The content of the data part of the L6 message can be identified by the Vender ID, which is the first 3-bit header of the L6 message type ID. (See Table 4.2.1-2)

In the L6D message, each satellite is assigned one of the services of either Technology Demonstration (ionospheric correction) or CLAS. Technology Demonstration (ionospheric correction) and CLAS in L6D messages shall not be intermixed. See Table 3-1 for the assignment of the L6 messages for each satellite.

Messages for MADOCA-PPP and QZNMA are broadcast time-divisionally from the satellites. Of the 30 messages sent in 30 seconds, 6 messages are allocated for QZNMA. See Figure 4.1.1-2 for the assignment for MADOCA-PPP and QZNMA.

5 seconds

1 second

0～4s	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP
5～9s	QZNMA	QZNMA	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP
10～14s	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP
15～19s	QZNMA	QZNMA	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP
20～24s	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP
25～29s	QZNMA	QZNMA	MADOCA-PPP	MADOCA-PPP	MADOCA-PPP

Figure 4.1.1-2 Service assignment for the L6E message

4.1.2 Timing

(1) Transmission Pattern

The nominal transmission pattern for MADOCA-PPP is specified in Section 4.3.

The transmission pattern of the data part in the L6 message may differ between satellites. Therefore, the user algorithm cannot assume any specific transmission pattern.

(2) Transmission Timing

Each satellite might transmit L6 messages with different contents among satellites. See Section 4.2.2 (3) for the treatment of the L6 message for MADOCA-PPP.

4.2 Message contents

4.2.1 Header Part

The header of the L6 message is shown in Figure 4.2.1-1. The header part has a length of 49-bit consisting of a 32-bit preamble, an 8-bit PRN, an 8-bit L6 message type ID and a 1-bit alert flag. Table 4.2.1-1 defines the header parameters.

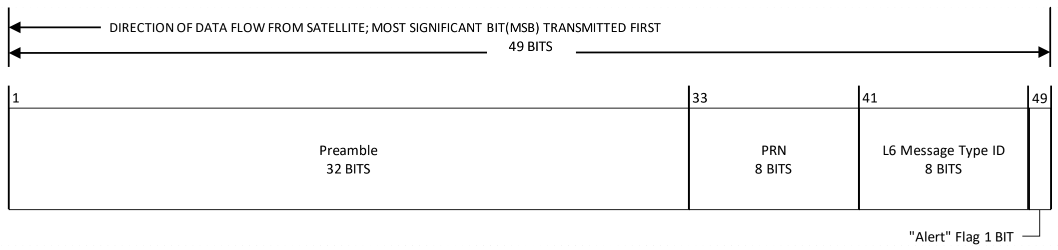

Figure 4.2.1-1 Header of L6 message

Table 4.2.1-1 Definitions of header parameters

DF Name	DF Range	BIT	LSB	DF Unit	Note
Preamble	-	32	-	-	
PRN	-	8	-	-	
L6 Message Type ID	-	8	-	-	See Table 4.2.1-3
"Alert" Flag	-	1	-	-	

(1) Preamble

At the beginning of each message is a 32-bit preamble. The value of the preamble is "00011010110011111111110000011101"$_{(B)}$.

(2) PRN

Each message has an 8-bit PRN number immediately after the preamble. The PRN number is the PRN number of the satellite transmitting that message.

(3) L6 Message Type ID

The initial 3-bit of the L6 message type ID is Vendor ID. Vendor ID is the identifier to identify the service of the L6 message, which is defined in Table 4.2.1-2.

The L6 message type ID of MADOCA-PPP is defined in Table 4.2.1-3. The initial 3-bit of the vendor ID is "010"$_{(B)}$, which indicates MADOCA-PPP. The following 2-bit is the identifier indicating the message generation facilities. The following 1-bit is the identifier that indicates whether the transmitted correction data are Clock/Ephemeris corrections or ionospheric corrections. The following 1-bit is the identifier that indicates the applicable navigation messages of Orbit and Clock Corrections.

The last 1-bit is the indicator for the subframe header. If the value of this indicator is “1”, the message is the start of a subframe. In the user algorithm, the Compact SSR messages with the same Vender ID and Message Generation Facility ID encoded in the header of L6 message every second should be used.

If the above condition is not met, Compact SSR messages with a previous set of the Vender ID and the Message Generation Facility ID should be used.

Table 4.2.1-2 Vendor ID (MSB 3bits) in L6 message type ID

Vendor ID (3bits)	Service Name	Note
"101"$_{(B)}$	CLAS	Broadcast L6D message only See applicable document (4)
"010"$_{(B)}$	MADOCA-PPP	Broadcast L6D and L6E message
"011"$_{(B)}$	QZNMA	Broadcast L6E message only See reference document (5)
others	Reserved	—

Table 4.2.1-3 L6 message type ID（MADOCA-PPP）

Bit Field	Data Name	Note
7-5	Vendor ID	See Table 4.2.1-2
4-3	Message Generation Facility ID	“00”$_{(B)}$, ”01”$_{(B)}$: Hitachi-Ota “10”$_{(B)}$, “11”$_{(B)}$: Kobe
2	Correction Service ID	"0"$_{(B)}$: Clock/Ephemeris Corrections "1"$_{(B)}$: Ionospheric Corrections
1	Applicable navigation message extension	The flag that indicates the applicable messages of Orbit and Clock Correction "0"$_{(B)}$: See Table 4.2.2-12 "1"$_{(B)}$: GPS CNAV/CNAV-2 QZSS CNAV/CNAV-2
0	Subframe indicator	"1"$_{(B)}$: first data part of a subframe "0"$_{(B)}$: others

(4) Alert Flag

Each message has a 1-bit alert flag immediately following the L6 Message Type ID. The Alert Flag indicates the health status of L6 signal and message. When the Alert flag is “1”$_{(B)}$, the service is not available.

4.2.2 Data Part

The nominal sequence of the L6E message consists of 12 subframes. Figure 4.2.2-1 shows the structure of the L6E message, frame, and subframe. Subframe 1,4,5,8,9,12 are assigned to MADOCA-PPP, and subframe 2,3,6,7,10,11 are assigned to QZNMA.

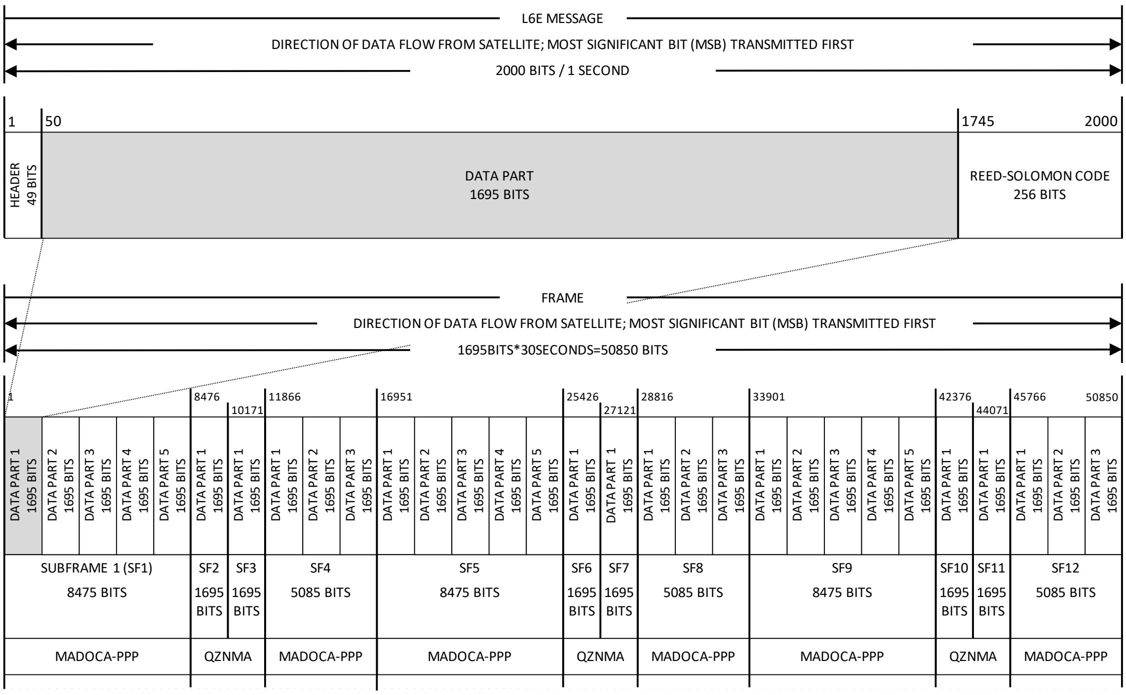

Figure 4.2.2-1 Structure of L6E message, frame, and subframe

The data part of MADOCA-PPP includes any sub type of multiple messages of MT 4073 “Compact SSR” (Table 4.2.2-1), as defined in the applicable document (3). The data in each message is given in state space representation (SSR) form, as standardized in the applicable document (2). The correction in SSR form can be applied to precise point positioning.

The sub type 1-7 structures are transmitted from the beginning of each subframe in a given order which defined in section 4.3 For each last data part of the subframe, there is the reserved field which are filled with zeros.

No sub type message is transmitted through successive subframes.

Table 4.2.2-1 List of MADOCA-PPP Messages

RTCM Message Type	Sub Type	Message Name	No. of Bit (*1), (*2)	Section No.
4073	1	Compact SSR Mask	$49 + (61+N_{cell}) \times N_{sys}$	4.2.2.2
4073	2	Compact SSR GNSS Orbit Correction	$37 + (51 \text{ or } 49) \times N_{sat}$	4.2.2.3
4073	3	Compact SSR GNSS Clock Correction	$37 + 15 \times N_{sat}$	4.2.2.4
4073	4	Compact SSR GNSS Satellite Code Bias	$37 + 11 \times N_{sig(sys)} \times N_{sat(sys)}$	4.2.2.5
4073	5	Compact SSR GNSS Phase Bias	$37 + 17 \times N_{sig(sys)} \times N_{sat(sys)}$	4.2.2.6
4073	7	Compact SSR GNSS URA	$37 + 6 \times N_{sat}$	4.2.2.7

(*1) N_{cell}= No. of Cell Mask of each GNSS, N_{sat} = No. of augmented satellite, N_{sys} = No. of augmented GNSS

N_{sig} = No. of augmented signal, $N_{sat(sys)}$ = No. of augmented satellite of each GNSS,

$N_{sig(sys)}$ = No. of augmented signal of each GNSS

(*2) The sizes of N_{cell} , $N_{sig(sys)}$ and $N_{sat(sys)}$ depend on each GNSS.

(1) Update Interval

Table 4.2.2-2 shows the nominal update interval for each message. Note that the user algorithm cannot rely on any specific transmission cycle because it may be changed in the future for reasons of performance improvement.

Table 4.2.2-2 Nominal Update Interval

Message Name	Message Type ID, Sub Type ID (*1)	Nominal Update Interval [s]
Compact SSR Mask	MT4073,1	30
Compact SSR GNSS Orbit Correction	MT4073,2	30
Compact SSR GNSS Clock Correction	MT4073,3	5
Compact SSR GNSS Satellite Code Bias	MT4073,4	30
Compact SSR GNSS Satellite Phase Bias	MT4073,5	30
Compact SSR GNSS URA	MT4073,7	30
Null Message	(N/A)	(N/A)

(*1) Sub type ID is compliant with Compact SSR (Message Type 4073) which is defined as a proprietary message in the applicable document (3) that is compatible with the applicable document (2) RTCM STANDARD 10403.3. Section 4.2.2 provides more information about the message format for each sub type.

(2) Nominal Validity Period

Each message has a nominal validity period based on each characteristic. Table 4.2.2-3 shows Nominal Validity Period of each message. Origin of the validity interval is exact second of QZSST that is sent in the header part of messages that contains the information (refer to the data field “GPS Epoch Time 1s” and “GNSS Hourly Epoch Time 1s”). The quality of data is not guaranteed if outdated data is used.

Table 4.2.2-3 Nominal Validity Period

Message Name	Message Type ID, Sub Type ID	Nominal Validity Period [s]
Compact SSR Mask	MT4073,1	(*1)
Compact SSR GNSS Orbit Correction	MT4073,2	60
Compact SSR GNSS Clock Correction	MT4073,3	10
Compact SSR GNSS Satellite Code Bias	MT4073,4	60
Compact SSR GNSS Satellite Phase Bias	MT4073,5	60
Compact SSR GNSS URA	MT4073,7	60
Null Message	(N/A)	(N/A)

(*1) Validity interval of Compact SSR Mask is described in 4.2.2.2 .

(3) Relationship Among L6 Messages Transmitted by Each Satellite

The contents of L6 messages transmitted by each QZSS satellite might be different. In this case, the SSR Mask of Sub Type 1 shall be applied for Sub Type 2, 3, 4, 5 and 7 transmitted by the same satellite. Correction data transmitted by different QZSS satellites can be merged and utilized only when Message Generation Facility ID is the same value.

4.2.2.2 Sub Type1 - Compact SSR Mask Message

The sub type 1 message structure is shown in Figure 4.2.2-2. The message header and GNSS specific part are defined in Table 4.2.2-4 and Table 4.2.2-5, respectively.

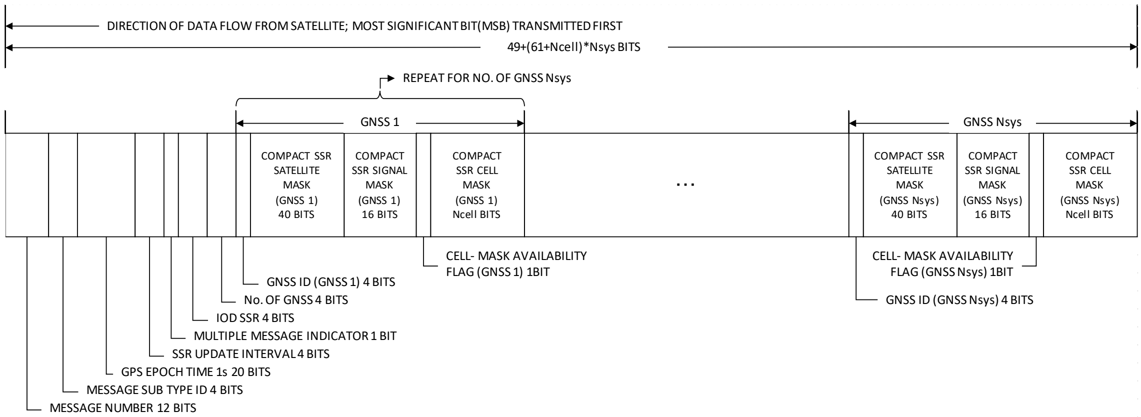

Figure 4.2.2-2 Compact SSR Mask Message structure

Table 4.2.2-4 Contents of message header, Compact SSR Mask Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Message Number	0-4095	12	-	-	4073
Message Sub Type ID	0-15	4	-	-	1
GPS Epoch Time 1s	0-604799	20	1	s	
SSR Update Interval	0-15	4	1	-	
Multiple Message Indicator	0-1	1	-	-	
IOD SSR	0-15	4	1	-	
No. of GNSS	0-15	4	1	-	

Table 4.2.2-5 Contents of GNSS-specific part of Compact SSR Mask Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
GNSS ID 1	0-15	4	-	-	
Compact SSR Satellite mask 1	-	40	-	-	
Compact SSR Signal mask 1	-	16	-	-	
Cell-mask Availability Flag	0-1	1	-	-	
Compact SSR Cell mask 1	-	N_{cell}	-	-	
~					
GNSS ID N_{sys}	0-15	4	-	-	
Compact SSR Satellite mask N_{sys}	-	40	-	-	
Compact SSR Signal mask N_{sys}	-	16	-	-	
Cell-mask Availability Flag	0-1	1	-	-	
Compact SSR Cell mask N_{sys}	-	N_{cell}	-	-	

(1) Message Number

The message number is defined in the applicable document (2). Until the standardization of Compact SSR has been completed, 4073 is used as the proprietary message.

(2) Message Sub Type ID

The message sub type ID is defined in the Compact SSR specification (applicable document (3)).

(3) GPS Epoch Time 1s

Seconds since the beginning of the GPS week. The data is defined in QZSST.

(4) SSR Update Interval

The SSR update intervals for all the SSR parameters start at time 00:00:00 of the QZSST time frame. The supported SSR update intervals are listed in Table 4.2.2-6.

Table 4.2.2-6 SSR update interval

SSR Update Interval	Update Interval
0	1 s
1	2 s
2	5 s
3	10 s
4	15 s
5	30 s
6	60 s
7	120 s
8	240 s
9	300 s
10	600 s
11	900 s
12	1800 s
13	3600 s
14	7200 s
15	10800 s

(5) Multiple Message Indicator

Indicator for transmitting message with the same message number, message sub type ID, and epoch time. ”0”: last message of a sequence, ”1”: multiple message transmitted.

(6) IOD SSR

A change of issue of data SSR is used to indicate a change in the SSR generating configuration. The IOD SSR is counted up from $0_{(10)}$. When the Compact SSR satellite mask, Compact SSR signal mask, or Compact SSR cell mask have been changed, the IOD SSR is counted up.

(7) No. of GNSS

Number of augmented GNSS.

(8) GNSS ID

Indicator for specifying the GNSS. Table 4.2.2-7 lists the reciprocal relationship between the GNSS ID and GNSS.

Table 4.2.2-7 GNSS ID

GNSS ID	GNSS
0	GPS
1	GLONASS
2	Galileo
3	BeiDou
4	QZSS
5	SBAS
6-9	Reserved

(9) Compact SSR Satellite mask

The sequence of bits, which specifies those GNSS satellites for which data is augmented in this message. The most significant bit (MSB), or the first encoded bit corresponds to that GNSS satellite for which ID = 1, the second bit corresponds to a GNSS satellite for which ID = 2, etc. The least significant bit (LSB), or the last-encoded bit corresponds to a GNSS satellite with ID = 40. For QZSS, a satellite with ID = 1-10 is PRN193-202. Table 4.2.2-8 lists the reciprocal relationships between the Compact SSR satellite mask and GNSS.

Table 4.2.2-8 Compact SSR satellite mask

Compact SSR Satellite Mask	0 (MSB)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
GPS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
GLONASS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Galileo	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
BeiDou	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
QZSS	193	194	195	196	197	198	199	200	201	202	Reserved				

Compact SSR Satellite Mask	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
GPS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
GLONASS	16	17	18	19	20	21	22	23	24	Reserved					
Galileo	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
BeiDou	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
QZSS	Reserved														

Compact SSR Satellite Mask	30	31	32	33	34	35	36	37	38	39 (LSB)
GPS	31	32	33	34	35	36	37	38	39	40
GLONASS	Reserved									
Galileo	31	32	33	34	35	36	37	Reserved		
BeiDou	31	32	33	34	35	36	37	38	39	40
QZSS	Reserved									

(10) Compact SSR Signal mask

The sequence of bits which defines the selected signals for correction messages defined for each GNSS, as listed in Table 4.2.2-9.

Table 4.2.2-9 Compact SSR signal mask

Compact SSR Signal mask	GPS	GLONASS	Galileo	BeiDou	QZSS	SBAS
0	L1 C/A	G1 C/A	E1 B I/NAV OS/CS/SoL	B1 I	L1 C/A	L1 C/A
1	L1 P	G1 P	E1 C no data	B1 Q	L1 L1C(D)	L5 I
2	L1 Z-tracking	G2 C/A	E1 B+C	B1 I+Q	L1 L1C(P)	L5 Q
3	L1 L1C(D)	G2 P	E5a I F/NAV OS	B3 I	L1 L1C(D+P)	L5 I+Q
4	L1 L1C(P)	G1a(D)	E5a Q no data	B3 Q	L2 L2C(M)	
5	L1 L1C(D+P)	G1a(P)	E5a I+Q	B3 I+Q	L2 L2C(L)	
6	L2 L2C(M)	G1a(D+P)	E5b I I/NAV OS/CS/SoL	B2 I	L2 L2C(M+L)	
7	L2 L2C(L)	G2a(D)	E5b Q no data	B2 Q	L5 I	
8	L2 L2C(M+L)	G2a(P)	E5b I+Q	B2 I+Q	L5 Q	
9	L2 P	G2a(D+P)	E5 I		L5 I+Q	
10	L2 Z-tracking	G3 I	E5 Q			
11	L5 I	G3 Q	E5 I+Q			
12	L5 Q	G3 I+Q	Service specific 1			
13	L5 I+Q		Service specific 2			
14			Service specific 3			
15						

(11) Cell-mask Availability Flag

If the flag set to “1”(B), the cell-mask is included.

(12) Compact SSR Cell Mask

The sequence of bits, which specifies those signals for which data is available in this message for each satellite. Note that the cell mask is not included if the cell-mask availability flag is set to zero. In this case, all of the signals included in the signal mask are selected for all the selected satellites.

4.2.2.3 Sub Type2 - Compact SSR GNSS Orbit Correction Message

The sub type 2 message structure is shown in Figure 4.2.2-3. The message header and satellite-specific part are defined in Table 4.2.2-10 and Table 4.2.2-11, respectively.

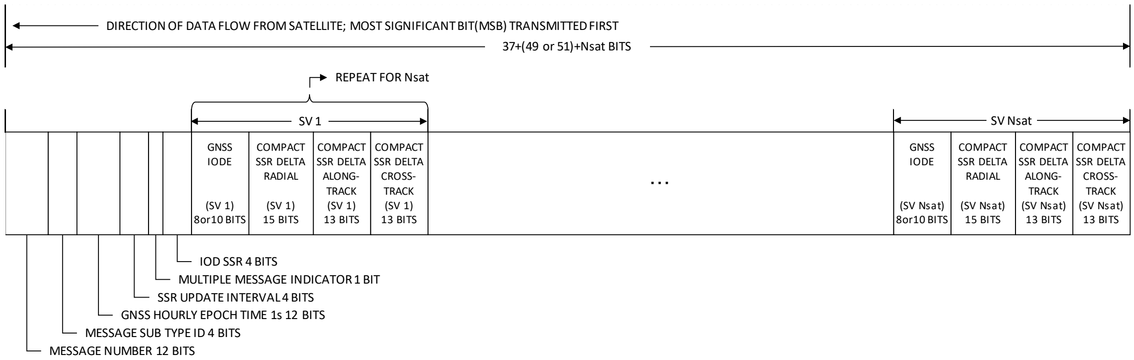

Figure 4.2.2-3 Compact SSR GNSS Orbit Correction Message structure

Table 4.2.2-10 Contents of message header, Compact SSR GNSS Orbit Correction Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Message Number	0-4095	12	-	-	4073
Message Sub Type ID	0-15	4	-	-	2
GNSS Hourly Epoch Time 1s	0-3599	12	1	s	3600-4095 indicates data not available
SSR Update Interval	0-15	4	1	-	
Multiple Message Indicator	0-1	1	-	-	
IOD SSR	0-15	4	1	-	

Table 4.2.2-11 Contents of satellite-specific part of Compact SSR GNSS Orbit Correction Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
GNSS IODE (SV 1)	0-255 or 0-1023	8 or 10	1	-	
Compact SSR Delta Redial (SV 1)	±26.2128	15	0.0016	m	−26.2144 indicates data not available
Compact SSR Delta Along-Track (SV 1)	±26.208	13	0.0064	m	−26.2144 indicates data not available
Compact SSR Delta Cross-Track (SV 1)	±26.208	13	0.0064	m	−26.2144 indicates data not available
~					
GNSS IODE (SV N_{sat})	0-255 or 0-1023	8 or 10	1	-	
Compact SSR Delta Redial (SV N_{sat})	±26.2128	15	0.0016	m	−26.2144 indicates data not available
Compact SSR Delta Along-Track (SV N_{sat})	±26.208	13	0.0064	m	−26.2144 indicates data not available
Compact SSR Delta Cross-Track (SV N_{sat})	±26.208	13	0.0064	m	−26.2144 indicates data not available

(1) GNSS Hourly Epoch Time 1s

Hours, minutes, and seconds part of GPS epoch time.

(2) GNSS IODE

IODE value of broadcast ephemeris used for calculation of range correction. Here, 10-bit are assigned for Galileo, and 8-bit are assigned for other GNSS.

(3) Compact SSR Delta Radial, Along-Track and Cross-Track

Radial, along-track and cross-track orbit correction for broadcast ephemeris. In the user algorithm, the appropriate broadcast ephemeris provided by the navigation message defined in Table 4.2.2-12 should be used.

Correction for LNAV and CNAV/CNAV-2 for GPS and QZSS are exclusively tramsmitted, The augmented navigation message is specifed in by the L6 message type ID.

Table 4.2.2-12 Augmented Navigation Message

GNSS	Navigation Message
GPS	LNAV CNAV / CNAV-2
GLONASS (FDMA)	GLONASS-M
GLONASS (CDMA)	GLONASS-K
Galileo	I/NAV
QZSS	LNAV CNAV / CNAV-2
BeiDou	D1

(4) IOD SSR

A change of issue of data SSR is used to indicate a change in the information included in the Compact SSR mask message.

4.2.2.4 Sub Type3 - Compact SSR GNSS Clock Correction Message

The sub type 3 message structure is shown in Figure 4.2.2-4. The message header and satellite-specific part are defined in Table 4.2.2-13 and Table 4.2.2-14, respectively.

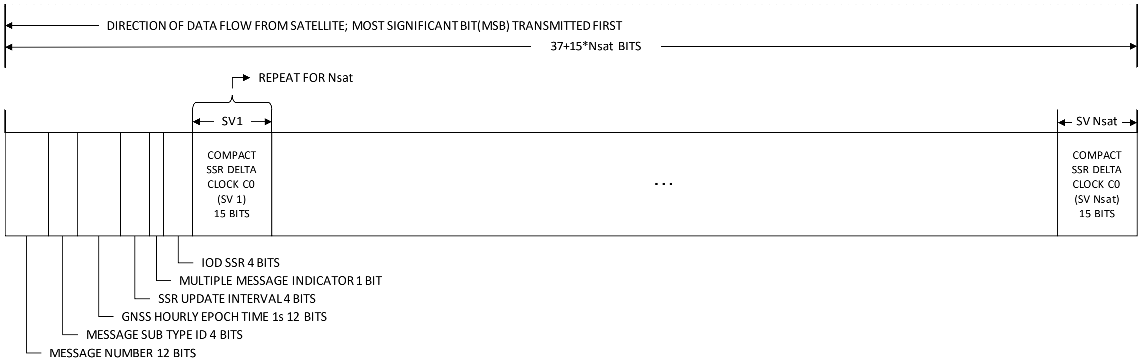

Figure 4.2.2-4 Compact SSR GNSS Clock Correction Message structure

Table 4.2.2-13 Contents of message header, Compact SSR GNSS Clock Correction Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Message Number	0-4095	12	-	-	4073
Message Sub Type ID	0-15	4	-	-	3
GNSS Hourly Epoch Time 1s	0-3599	12	1	s	3600-4095 indicates data not available
SSR Update Interval	0-15	4	1	-	
Multiple Message Indicator	0-1	1	-	-	
IOD SSR	0-15	4	1	-	

Table 4.2.2-14 Contents of satellite-specific part of Compact SSR GNSS Clock Correction Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Compact SSR Delta Clock C0 (SV1)	±26.2128	15	0.0016	m	-26.2144 indicates data not available
~					
Compact SSR Delta Clock C0 (SV N_{sat})	±26.2128	15	0.0016	m	-26.2144 indicates data not available

(1) Compact SSR Delta Clock

The bias term (C0) of clock correction for broadcast ephemeris. In the user algorithm, the appropriate broadcast ephemeris provided by the navigation message defined in Table 4.2.2-12 should be used.

4.2.2.5 Sub Type4 - Compact SSR GNSS Satellite Code Bias Message

The sub type 4 message structure is shown in Figure 4.2.2-5. The message header and satellite-specific part are defined in Table 4.2.2-15 and Table 4.2.2-16, respectively.

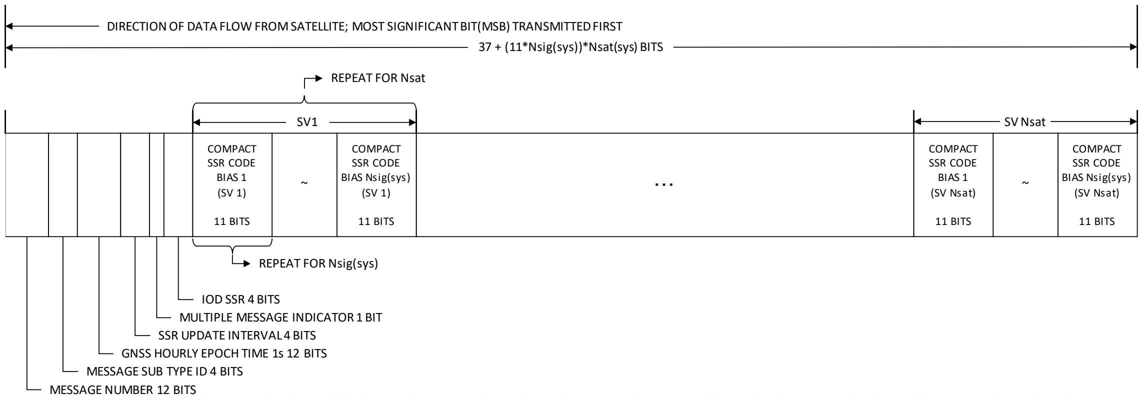

Figure 4.2.2-5 Compact SSR GNSS Satellite Code Bias Message structure

Table 4.2.2-15 Contents of message header, Compact SSR GNSS Satellite Code Bias Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Message Number	0-4095	12	-	-	4073
Message Sub Type ID	0-15	4	-	-	4
GNSS Hourly Epoch Time 1s	0-3599	12	1	s	3600-4095 indicates data not available
SSR Update Interval	0-15	4	1	-	
Multiple Message Indicator	0-1	1	-	-	
IOD SSR	0-15	4	1	-	

Table 4.2.2-16 Contents of satellite-specific part of Compact SSR GNSS Satellite Code Bias Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Compact SSR Code Bias 1 (SV 1)	±20.46	11	0.02	m	-20.48 indicates data not available
~					
Compact SSR Code Bias $N_{sig(sys)}$ (SV 1)	±20.46	11	0.02	m	-20.48 indicates data not available
~					
Compact SSR Code Bias 1 (SV N_{sat})	±20.46	11	0.02	m	-20.48 indicates data not available
~					
Compact SSR Code Bias $N_{sig(sys)}$ (SV N_{sat})	±20.46	11	0.02	m	-20.48 indicates data not available

(1) Compact SSR Code Bias

This code bias is an absolute value. The code biases should be added to the observed pseudorange of the corresponding code signal to get corrected pseudorange.

The Compact SSR code bias for the satellite of each GNSS is transmitted in the order indicated in sub type 1: Compact SSR Mask. Only the signal indicated by the Compact SSR cell mask is transmitted in this message.

4.2.2.6 Sub Type5 - Compact SSR GNSS Satellite Phase Bias Message

The sub type 5 message structure is shown in Figure 4.2.2-6. The message header and satellite-specific part are defined in Table 4.2.2-17 and Table 4.2.2-18, respectively.

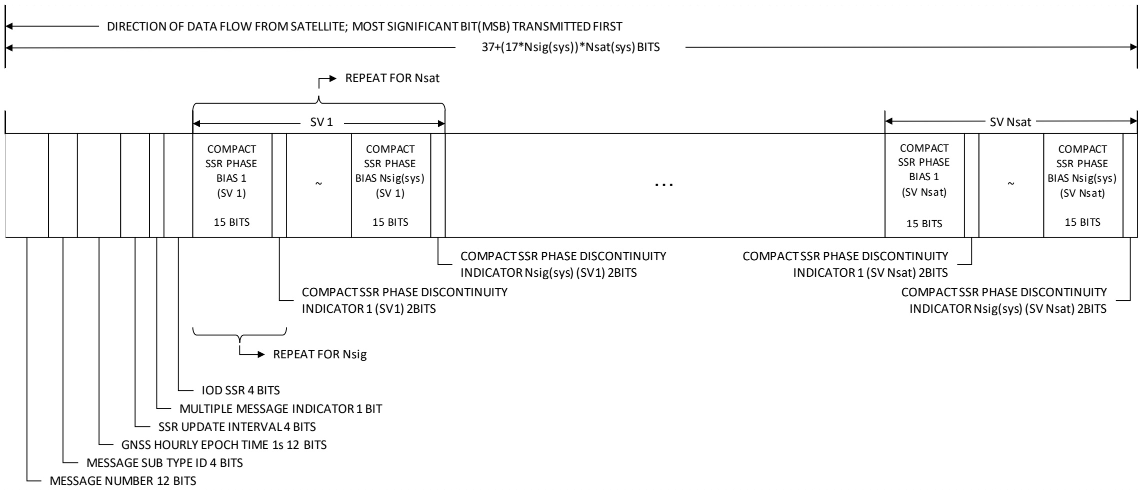

Figure 4.2.2-6 Compact SSR GNSS Satellite Phase Bias Message structure

Table 4.2.2-17 Contents of message header, Compact SSR GNSS Satellite Phase Bias Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Message Number	0-4095	12	-	-	4073
Message Sub Type ID	0-15	4	-	-	5
GNSS Hourly Epoch Time 1s	0-3599	12	1	s	3600-4095 indicates data not available
SSR Update Interval	0-15	4	1	-	
Multiple Message Indicator	0-1	1	-	-	
IOD SSR	0-15	4	1	-	

Table 4.2.2-18 Contents of satellite-specific part of Compact SSR GNSS Satellite Phase Bias Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Compact SSR Phase Bias 1 (SV 1)	±16.383	15	0.001	m	-16.384 indicates data not available
Compact SSR Phase Discontinuity Indicator 1 (SV 1)	0-3	2	1	-	
~					
Compact SSR Phase Bias $N_{sig(sys)}$ (SV 1)	±16.383	15	0.001	m	-16.384 indicates data not available
Compact SSR Phase Discontinuity Indicator $N_{sig(sys)}$ (SV 1)	0-3	2	1	-	
~					
Compact SSR Phase Bias 1 (SV N_{sat})	±16.383	15	0.001	m	-16.384 indicates data not available
Compact SSR Phase Discontinuity Indicator 1 (SV N_{sat})	0-3	2	1	-	
~					
Compact SSR Phase Bias $N_{sig(sys)}$ (SV N_{sat})	±16.383	15	0.001	m	-16.384 indicates data not available
Compact SSR Phase Discontinuity Indicator $N_{sig(sys)}$ (SV N_{sat})	0-3	2	1	-	

(1) Compact SSR Phase Bias

This phase bias is an absolute value. The phase biases should be added to the observed carrier-phase of the corresponding code signal to get corrected carrier-phase.

The Compact SSR phase bias for the satellite of each GNSS is transmitted in the order indicated by sub type 1: Compact SSR mask. Only the signal indicated by Compact SSR cell mask is transmitted in this message.

(2) Phase discontinuity indicator

The phase discontinuity indicator is counted up when the phase bias is discontinuous.

4.2.2.7 Sub Type7 - Compact SSR GNSS URA Message

The sub type 7 message structure is shown in Figure 4.2.2-7. The message header and satellite-specific part are defined in Table 4.2.2-19 and Table 4.2.2-20, respectively.

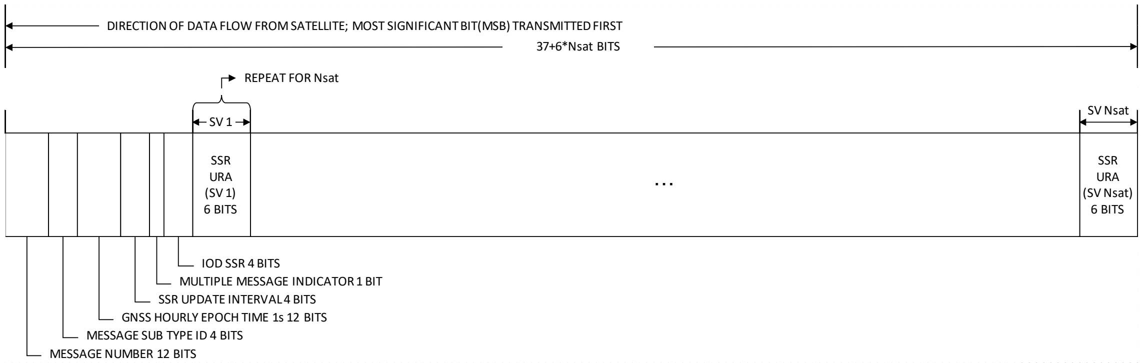

Figure 4.2.2-7 Compact SSR GNSS URA Message structure

Table 4.2.2-19 Contents of message header, Compact SSR GNSS URA Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
Message Number	0-4095	12	-	-	4073
Message Sub Type ID	0-15	4	-	-	7
GNSS Hourly Epoch Time 1s	0-3599	12	1	s	3600-4095 indicates data not available
SSR Update Interval	0-15	4	1	-	
Multiple Message Indicator	0-1	1	-	-	
IOD SSR	0-15	4	1	-	

Table 4.2.2-20 Contents of satellite-specific part of Compact SSR GNSS URA Message

DF Name	DF Range	BIT	LSB	DF Unit	Note
SSR URA (SV 1)	bits5-3: 0-7 bits2-0: 0-7	6	-	-	
~					
SSR URA (SV N_{sat})	bits5-3: 0-7 bits2-0: 0-7	6	-	-	

(1) SSR URA

The SSR users range accuracy (URA) (1 sigma) for range correction computed from a complete signal in space specific SSR set as disseminated by the Compact SSR messages. The URA is represented by a combination of URA_CLASS and URA_VALUE. The 3 MSBs define the URA_CLASS within a range of 0-7 while the 3 LSBs define the URA_VALUE within a range of 0-7. The URA is computed by:

$$\mathrm{SSR\ URA\ [mm]} \leq 3^{\mathrm{URA\_CLASS}}\left(1+\frac{\mathrm{URA\_VALUE}}{4}\right)-1\ \mathrm{[mm]}$$

Special cases are:

000 000 : URA undefined/unknown

111 111 : URA > 5466.5 [mm]

4.2.2.8 Null Message

If there is no information to be transmitted, as determined by the satellite system side, a null message is transmitted.The nominal validity interval of each message after a null message is shown in Table 4.2.2-3. User can use the message within the nominal validity interval.

The following events are envisaged when there is no information to be transmitted.

- When an abnormality occurs in the ground system or the system uplink disconnection occurs
- When the L6 positioning upload data authentication becomes NG in the satellite system

The preamble of the null message is a fixed value. PRN number is numbered (8-bit) with the PRN code to be used. Thus, the L6 message type ID is 0 and the Alert Flag is “1”$_{(B)}$. The first 7-bit of the data part (1695-bit) are “0101010”$_{(B)}$, and the other repeats the “10101010”$_{(B)}$.

4.3 Transmission Pattern

Each sub type is transmitted at a rate of one cycle within 30 seconds, according to the transmission schedule. Table 4.2.2-1 and Figure 4.2.2-1 shows the nominal transmission pattern of the MADOCA-PPP sub type.

Note that the user algorithm should not assume any specific pattern.

Table 4.2.2-1 MADOCA-PPP Sub Type Transmission Pattern (Nominal)

Second	Subframe Number	Sub Type	Notes
0-4	1	1, 2, 3	-
5	2	-	QZNMA
6	3	-	QZNMA
7-9	4	3,7	-
10-14	5	3,4	-
15	6	-	QZNMA
16	7	-	QZNMA
17-19	8	3	-
20-24	9	3,5	-
25	10	-	QZNMA
26	11	-	QZNMA
27-29	12	3	-

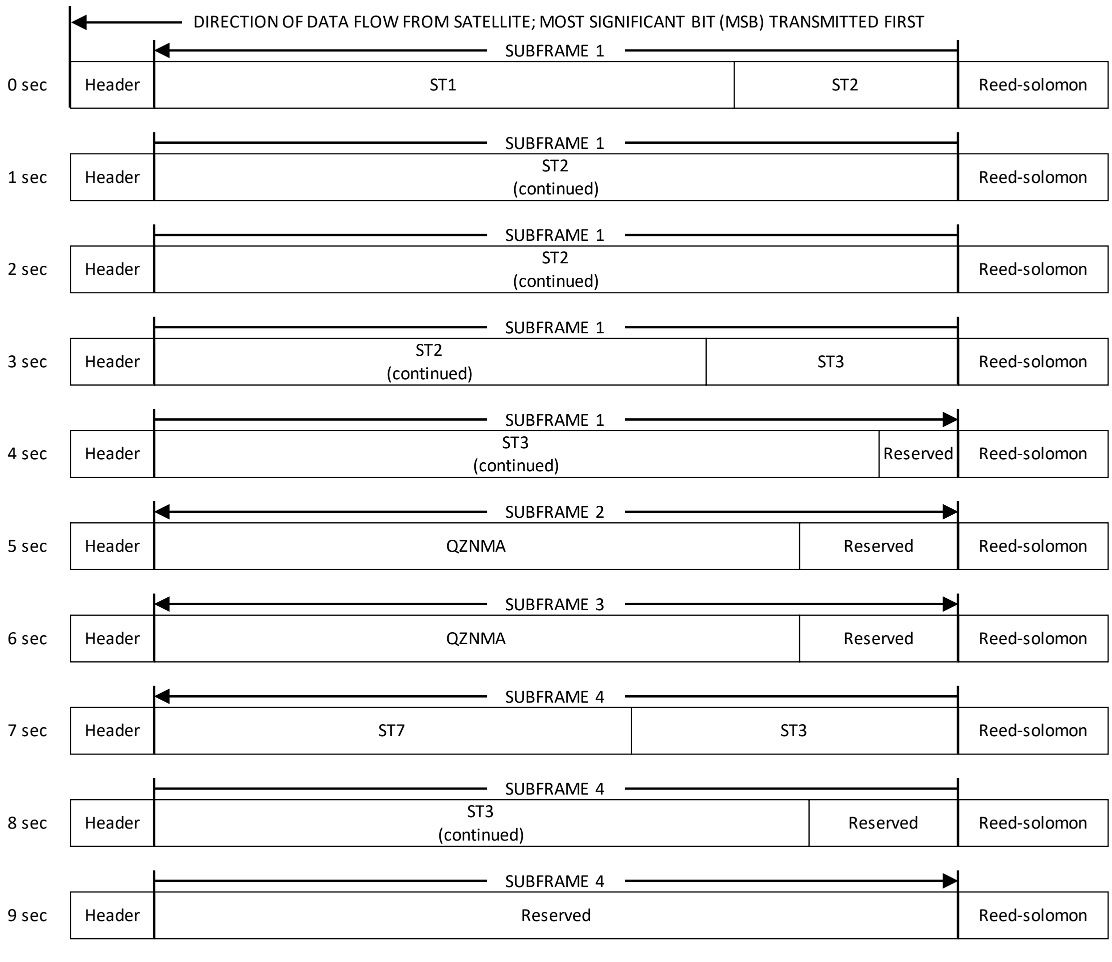

Figure 4.2.2-1 MADOCA-PPP Sub Type Transmission Pattern (Nominal)

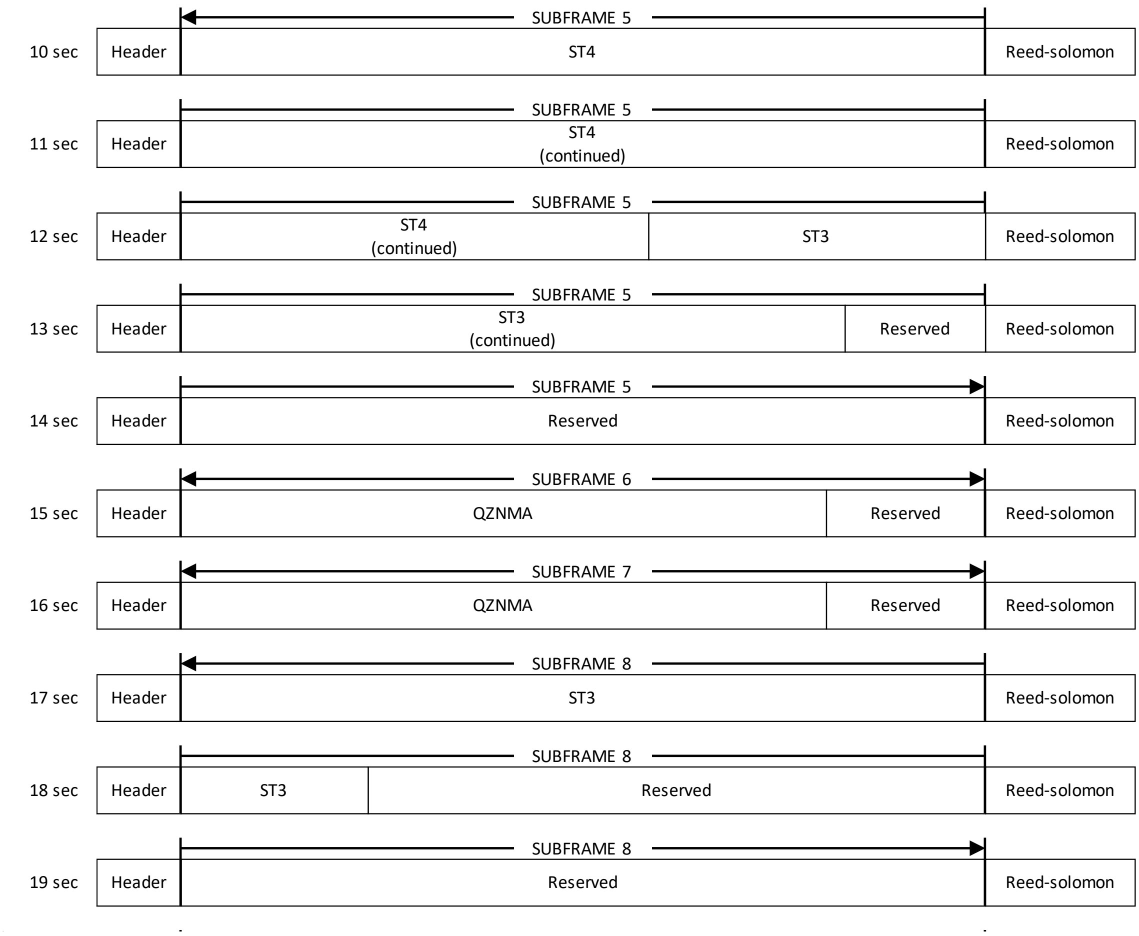

Figure 4.2.2-1 MADOCA-PPP Sub Type Transmission Pattern (Nominal) (continued)

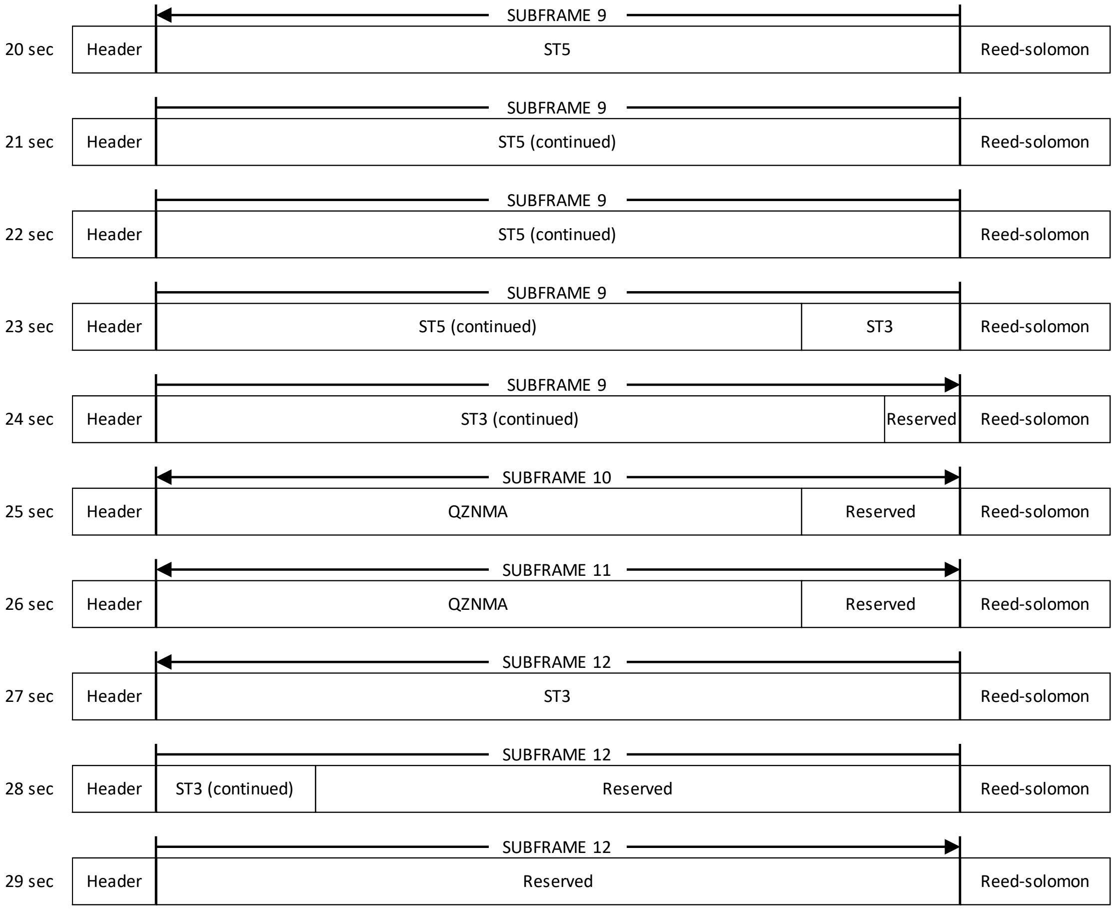

Figure 4.2.2-1 MADOCA-PPP Sub Type Transmission Pattern (Nominal) (continued)

4.4 FEC Encoded Algorithm

Reed-Solomon (255, 223) encoding is applied to the 1744-bit of the navigation message (preamble, PRN, message type ID, alert flag, and data section). Every 8-bit of the resulting bit-stream constitutes one symbol (See Section 4.4.1 for details.)

To add the 32-symbol (256-bit) Reed-Solomon code to the 218-symbol (1744-bit) navigation message, nine "0" symbols (72-bit) are inserted at the beginning of the 214-symbol (1712-bit) data bit string that does not include the 4-symbol (32-bit) preamble at the beginning of the header. The resulting 223-symbol (1784-bit) data bit string (with the 9 zero symbols inserted) is Reed-Solomon encoded (255,223) to generate a 32-symbol (256-bit) parity word. The 250 symbols (2000-bit) that comprise the 32-symbol parity words added to the original 218-symbol (1744-bit) data bit string (including the preamble) are then input to the CSK modulator (see Figure 4.4-1).

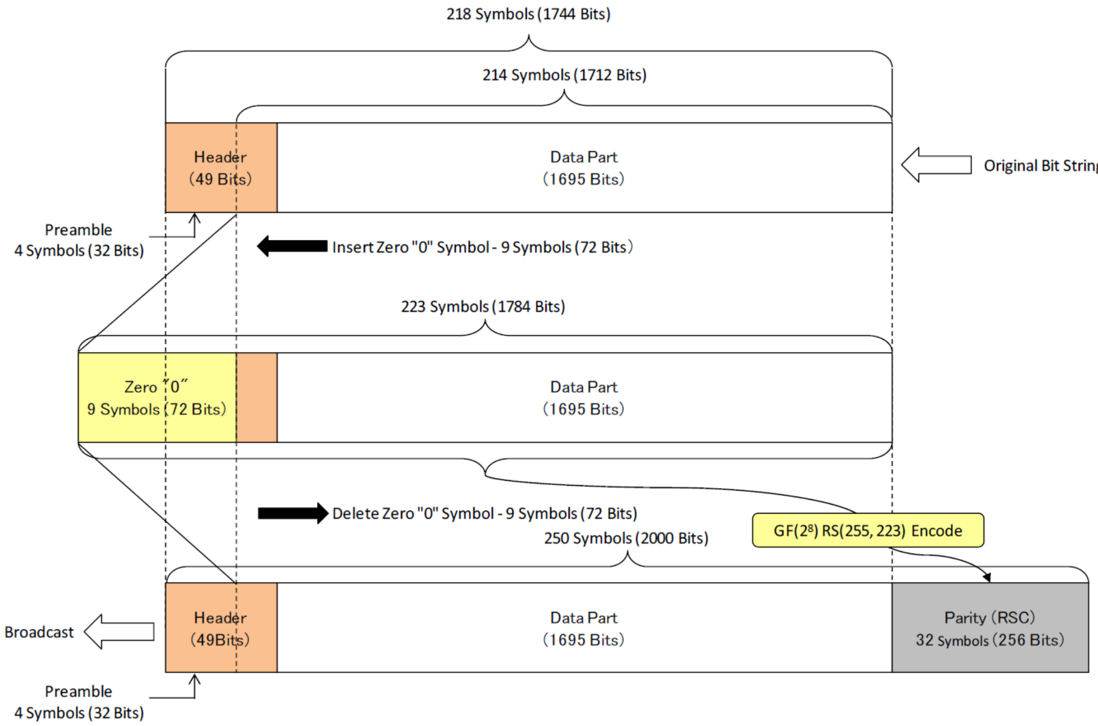

Figure 4.4-1 Encoding of Reed-Solomon code

4.4.1 Reed-Solomon Coding/Decoding Algorithm for L6 Navigation Message

(1) Construct Galois Field $\mathrm{GF}(2^8)$

We choose $F(x) = x^8 + x^7 + x^2 + x + 1$ as a primitive polynomial of degree 8 over $\mathbf{Z}_2$. (Note that, because this is the binary case, addition$(+)$ is equivalent to exclusive-OR (XOR) and multiplication$(\times)$ is equivalent to the logical AND operation.) When α is a root of $F(x) = 0$, we have the following (note that $\alpha^8 = -\alpha^8$ over $\mathbf{Z}_2$):

$$\alpha^8 = -\alpha^8 = \alpha^7 + \alpha^2 + \alpha + 1 \qquad 4.4.1\text{-}1$$

From equation 4.4.1-1 any power of α can be represented by a linear combination of $\alpha^7, \alpha^6, \alpha^5, \alpha^4, \alpha^3, \alpha^2, \alpha^1, \alpha^0 (= 1)$ over $\mathbf{Z}_2$ (note that $\alpha^i + \alpha^i = 0$) as follows:

$$\begin{aligned}
\alpha^8 &= \alpha^7 + \alpha^2 + \alpha + 1 \\
\alpha^9 &= \alpha^8 \times \alpha = \alpha^8 + \alpha^3 + \alpha^2 + \alpha \\
&= (\alpha^7 + \alpha^2 + \alpha + 1) + \alpha^3 + \alpha^2 + \alpha \\
&= \alpha^7 + \alpha^3 + 1 \\
\alpha^{10} &= \alpha^9 \times \alpha = \alpha^8 + \alpha^4 + \alpha \\
&= (\alpha^7 + \alpha^2 + \alpha + 1) + \alpha^4 + \alpha \\
&= \alpha^7 + \alpha^4 + \alpha^2 + 1 \\
&\vdots \\
\alpha^{254} &= \alpha^7 + \alpha^6 + \alpha + 1
\end{aligned} \qquad 4.4.1\text{-}2$$

Then, the order of α is 255, since:

$$\begin{aligned}
\alpha^{255} &= \alpha^{254} \times \alpha = \alpha^8 + \alpha^7 + \alpha^2 + \alpha \\
&= (\alpha^7 + \alpha^2 + \alpha + 1) + \alpha^7 + \alpha^2 + \alpha \\
&= 1 + \alpha^0
\end{aligned} \qquad 4.4.1\text{-}3$$

From equations 4.4.1-3, the addition of two powers of α is as follows: When

$$\alpha^m = \mu_{m7}\alpha^7 + \mu_{m6}\alpha^6 + \cdots + \mu_{m1}\alpha^1 + \mu_{m0} \qquad 4.4.1\text{-}4$$

$$\alpha^n = \mu_{n7}\alpha^7 + \mu_{n6}\alpha^6 + \cdots + \mu_{n1}\alpha^1 + \mu_{n0} \qquad 4.4.1\text{-}5$$

the addition is given by:

$$\begin{aligned}
\alpha^m + \alpha^n &= (\mu_{m7} + \mu_{n7})\alpha^7 + (\mu_{m6} + \mu_{n6})\alpha^6 + \\
&\quad \ldots (\mu_{m1} + \mu_{n1})\alpha^1 + (\mu_{m0} + \mu_{n0})\alpha^0 \\
&= \alpha^1
\end{aligned} \qquad 4.4.1\text{-}6$$

Each μ_{mj}, μ_{nj} coefficient is either a zero or a one, and $\mu_{mj} + \mu_{nj}$ is the logical "exclusive OR" of the two coefficients. As a result of the above operations, $\{0, 1 (= \alpha^0), \alpha^1, \alpha^2, \ldots, \alpha^{254}\}$ makes a Galois Field $\mathrm{GF}(2^8)$.

(2) Change of Basis

From equations 4.4.1-2, one basis for $\{0,1(=\alpha^0),\alpha^1,\alpha^2,\ldots,\alpha^{254}\}$ over $\mathbf{Z}_2$ is the set $\{\alpha^7,\alpha^6,\alpha^5,\alpha^4,\alpha^3,\alpha^2,\alpha^1,\alpha^0\}$.

When $l_0=\alpha^{125}, l_1=\alpha^{88}, l_2=\alpha^{226}, l_3=\alpha^{163}, l_4=\alpha^{46}, l_5=\alpha^{184}, l_6=\alpha^{67}, l_7=\alpha^{242}$, the set $\{l_0,l_1,l_2,l_3,l_4,l_5,l_6,l_7\}$ is another basis for $\{0,1(=\alpha^0),\alpha^1,\alpha^2,\ldots,\alpha^{254}\}$ over $\mathbf{Z}_2$. When the nth power of α is represented by two linear combinations:

$$\begin{aligned}\alpha^n &= u_7\alpha^7+u_6\alpha^6+u_5\alpha^5+u_4\alpha^4+u_3\alpha^3\\&\quad+u_2\alpha^2+u_1\alpha^1+u_0\alpha^0\\&=z_0l_0+z_1l_1+z_2l_2+z_3l_3+z_4l_4+z_5l_5+z_6l_6+z_7l_7\end{aligned} \qquad 4.4.1\text{-}7$$

The relationship between $u_7,u_6,u_5,u_4,u_3,u_2,u_1,u_0$ and $z_0,z_1,z_2,z_3,z_4,z_5,z_6,z_7$ is given by the following two equations:

$$(z_0,z_1,z_2,z_3,z_4,z_5,z_6,z_7) = \begin{pmatrix}u_7\\u_6\\u_5\\u_4\\u_3\\u_2\\u_1\\u_0\end{pmatrix}^t \begin{pmatrix}1&0&0&0&1&1&0&1\\1&1&1&0&1&1&1&1\\1&1&1&0&1&1&0&0\\1&0&0&0&0&1&1&0\\1&1&1&1&1&0&1&0\\1&0&0&1&1&0&0&1\\1&0&1&0&1&1&1&1\\0&1&1&1&1&0&1&1\end{pmatrix} \qquad 4.4.1\text{-}8$$

$$(u_7,u_6,u_5,u_4,u_3,u_2,u_1,u_0) = \begin{pmatrix}z_0\\z_1\\z_2\\z_3\\z_4\\z_5\\z_6\\z_7\end{pmatrix}^t \begin{pmatrix}1&1&0&0&0&1&0&1\\0&1&0&0&0&0&1&0\\0&0&1&0&1&1&1&0\\1&1&1&1&1&1&0&1\\1&1&1&1&0&0&0&0\\0&1&1&1&1&0&0&1\\1&0&1&0&1&1&0&0\\1&1&0&0&1&1&0&0\end{pmatrix} \qquad 4.4.1\text{-}9$$

Each u_i, z_j coefficient is either a zero or a one, and the addition of these matrix operations is simply "exclusive OR".

(3) Encoding

When the header and data parts of the L6 message are given, the Reed-Solomon encoding is performed as follows:

The target encoded length is 214 symbols (5 to 218) followed by the Preamble. Consider the bits in each symbol to be $z_0, z_1, z_2, z_3, z_4, z_5, z_6, z_7$ corresponding to the elements of $\{0,1(=\alpha^0),\alpha^1,\alpha^2,\ldots,\alpha^{254}\}$ (see Section (2)). When the binary string 5th, 6th,・・・, 218th symbol is represented by $A_5, A_6, \ldots, A_{218}$ ($A_i \in \{0,1(=\alpha^0),\alpha^1,\alpha^2,\ldots,\alpha^{254}\}$) polynomial $I(x)$ over $\{0,1(=\alpha^0),\alpha^1,\alpha^2,\ldots,\alpha^{254}\}$ defined as follows:

$$I(x) = A_5x^{213} + A_6x^{212} + \cdots + A_{217}x + A_{218} \qquad 4.4.1\text{-}10$$

If the code generator polynomial over $\{0,1(=\alpha^0),\alpha^1,\alpha^2,\ldots,\alpha^{254}\}$ is defined as follows:

$$g(x) = \prod_{j=112}^{143} \left(x - \alpha^{11j}\right) \qquad 4.4.1\text{-}11$$

Then, $P(x)$ is the remainder after dividing $x^{32}I(x)$ by $g(x)$. Division is used for the operation of the Galois Field $\{0,1(=\alpha^0),\alpha^1,\alpha^2,\ldots,\alpha^{254}\}$ (see Section (1)).

$P(x)$ is written as follows:

$$\begin{aligned} &P(x) = B_1x^{31} + B_2x^{30} + \cdots + B_{31}x + B_{32} \\ &B_i \in \{0,1(=\alpha^0),\alpha^1,\alpha^2,\ldots,\alpha^{254}\} \end{aligned} \qquad 4.4.1\text{-}12$$

When each B_i is represented by a linear combination of set $\{l_0, l_1, l_2, l_3, l_4, l_5, l_6, l_7\}$:

$$B_i = z_0l_0 + z_1l_1 + z_2l_2 + z_3l_3 + z_4l_4 + z_5l_5 + z_6l_6 + z_7l_7 \qquad 4.4.1\text{-}13$$

The 32-symbol Reed-Solomon Code is generated by thinking of $z_0, z_1, z_2, z_3, z_4, z_5, z_6, z_7$ as the bits of the symbol.

(4) Decoding

Similarly, in Section (3), the polynomial $S(x)$ is generated as follows from the 5th to 250th symbols of the received message.

$$S(x) = A'_5x^{245} + A'_6x^{244} + \cdots + A'_{249}x + A'_{250} \qquad 4.4.1\text{-}14$$

Thus, by employing this R-S encoding/decoding, we can detect errors and correct those up until 16 symbol errors occur, by computing 32 polynomials $S\left(\alpha^{11j}\right), j = 112{\sim}143$. Provided there are no errors, $S\left(\alpha^{11j}\right)$ is all zeroes.

5. User Algorithms

5.1 Time System

The time system of QZSS is called QZSST and has the following characteristics.

(1) Definition

(a) One-second length

The length of one second is identical to International Atomic Time (TAI).

(b) Integer second offset for TAI

The integer second offset for TAI is the same as that for GPS and TAI is always 19 seconds ahead of QZSST.

(c) Stating point of week number for QZSST

The starting point of the week number for QZSST is identical to that for GPST (January 6, 1980).

(2) Time system of "Epoch Time" in Compact SSR messages

Data field “GNSS Epoch Time 1s” or “GNSS Hourly Epoch Time 1s” in each Compact SSR message, transmitted from QZS, are represented in QZSST.

5.2 Coordinate System

The reference frame of the MADOCA-PPP corrections is aligned to the ITRF2014.

5.3 Constants

5.3.1 Speed of Light

Expressed using a small letter "c".

The value is c = 299792458 m/s.

5.3.2 Circular Constant

Expressed using the Greek symbol "π".

The value is π = 3.1415926535898.

5.4 Integrity

Integrity for MADOCA-PPP is implemented. Integrity information in MADOCA-PPP consists of the Alert flag and the null message.

5.4.1 Alert Flag

The 1-bit Alert flag that follows the message type ID in each message indicates the comprehensive health status for the satellite system, ground system, and external systems configured in MADOCA-PPP.

When the Alert flag is set to "1"(B), this indicates a situation in which MADOCA-PPP should not be used. In this case, the L6 signal should be used at the user's own risk.

5.4.2 Null Message

The null message indicates those situations in which MADOCA-PPP should not be used.

5.5 Calculation Algorithms for Compact SSR

This section shows the Compact SSR calculation algorithms for MADOCA-PPP, which are also defined in the applicable document (3). Observation equations using the Compact SSR are shown in the section 5.5.5.

5.5.1 Calculation of GNSS Clock Correction

5.5.1.1 Parameter

Table 5.5.1-1 lists the parameters defined in the Compact SSR GNSS Clock Correction message. Table 5.5.1-2 lists the parameter required for the calculations.

Table 5.5.1-1 Compact SSR GNSS Clock Correction message parameters

Parameter	Definition	Unit
C_0	Compact SSR Delta Clock (sub type3)	m

Table 5.5.1-2 Other parameters

Parameter	Definition	Unit
c	Speed of Light (Section 5.3.1.)	m/s

5.5.1.2 Algorithm

Satellite clock correction δC establishes the following relationship between the parameters of the Compact SSR GNSS clock correction.

$$\delta C = C_0$$

The relationship among the SV clock $t_{broadcast}$ derived from the broadcast SV clock parameter, the Satellite clock correction δC derived from the Compact SSR GNSS clock correction message, and the corrected SV clock $t_{satellite}$ are as follows:

$$t_{satellite} = t_{broadcast} - \frac{\delta C}{c}$$

The algorithms are same for GPS, QZSS, Galileo, GLONASS, and BeiDou.

5.5.2 Calculation of GNSS Orbit Correction

5.5.2.1 Parameters

Table 5.5.2-1 lists the parameters defined in the Compact SSR GNSS Orbit Correction message. Table 5.5.2-2 lists the other parameters required for the calculations.

Table 5.5.2-1 Compact SSR GNSS Orbit Correction message parameters

Parameter	Definition	Unit
δO_{radial}	Compact SSR Delta Radial (sub type2)	m
δO_{along}	Compact SSR Delta Along Track (sub type2)	m
δO_{cross}	Compact SSR Delta Cross Track (sub type2)	m

Table 5.5.2-2 Other parameters

Parameter	Definition	Unit
$\delta\boldsymbol{X}$	Satellite Orbit Correction	m
$\boldsymbol{e}_{radial}$	Delta Radial Unit Vector	-
$\boldsymbol{e}_{along}$	Delta Along Track Unit Vector	-
$\boldsymbol{e}_{cross}$	Delta Cross Track Unit Vector	-
$\boldsymbol{r}$	Satellite Position calculated from broadcast ephemeris	m
$\dot{\boldsymbol{r}}$	Satellite Speed calculated from broadcast ephemeris	m/s

5.5.2.2 Algorithm

Satellite orbit correction $\delta\boldsymbol{X}$ at time t is calculated as follows:

$$\delta\boldsymbol{X} = [\boldsymbol{e}_{radial} \quad \boldsymbol{e}_{along} \quad \boldsymbol{e}_{cross}] \begin{bmatrix} \delta O_{radial} \\ \delta O_{along} \\ \delta O_{cross} \end{bmatrix}$$

where

$$\boldsymbol{e}_{along} = \frac{\dot{\boldsymbol{r}}(t)}{|\dot{\boldsymbol{r}}(t)|}$$

$$\boldsymbol{e}_{cross} = \frac{\boldsymbol{r}(t) \times \dot{\boldsymbol{r}}(t)}{|\boldsymbol{r}(t) \times \dot{\boldsymbol{r}}(t)|}$$

$$\boldsymbol{e}_{radial} = \boldsymbol{e}_{along}(t) \times \boldsymbol{e}_{cross}(t)$$

The relationship among the satellite position $\boldsymbol{r}$ derived from the broadcast ephemeris, the satellite orbit correction $\delta\boldsymbol{X}$ derived from the Compact SSR GNSS orbit correction message, and the corrected satellite ECEF position $\boldsymbol{X}_{orbit(ECEF)}$ are as follows:

$$\boldsymbol{X}_{orbit(ECEF)} = \boldsymbol{r} - \delta\boldsymbol{X}$$

The algorithms are same for GPS, QZSS, Galileo, GLONASS and BeiDou.

5.5.3 Calculation of GNSS Code/Phase Bias

5.5.3.1 Applicable Signals of Code/Phase Bias

The Code/Phase Bias which are provided by MADOCA-PPP shall be applied to the pseudo range/carrier phase range based on the lists as shown in Table 5.5.3-1 - Table 5.5.3-5.

Table 5.5.3-1 Applicable Signals of Code/Phase Bias（GPS）

MADOCA-PPP Code/Phase Bias（GPS）		User Applicable Signals
Signal mask bit	Signal name	
0	L1 C/A	L1 C/A
2	L1 Z-tracking	L1 P L1 Z-tracking
5	L1 L1C(D+P)	L1 L1C(D) L1 L1C(P) L1C(D+P)
8	L2 L2C(M+L)	L2 L2C(M) L2 L2C(L) L2 L2C(M+L)
10	L2 Z-tracking	L2 P L2 Z-tracking
13	L5 I+Q	L5 I L5 Q L5 I+Q

Table 5.5.3-2 Applicable Signals of Code/Phase Bias (GLONASS）

MADOCA-PPP Code/Phase Bias（GLONASS）		User Applicable Signals
Signal mask bit	Signal name	
0	G1 C/A	G1 C/A
1	G1 P	G1 P
2	G2 C/A	G2 C/A
3	G2 P	G2 P
6	G1a(D+P)	G1a(D) G1a(P) G1a(D+P)
9	G2a(D+P)	G2a(D) G2a(P) G2a(D+P)
12	G3 I+Q	G3 I G3 Q G3 I+Q

Table 5.5.3-3 Applicable Signals of Code/Phase Bias (Galileo)

MADOCA-PPP Code/Phase Bias（Galileo）		User Applicable Signals
Signal mask bit	Signal name	
2	E1 B+C	E1 B I/NAV OS/CS/SoL E1 C no data E1 B+C
5	E5a I+Q	E5a I F/NAV OS E5a Q no data E5a I+Q
8	E5b I+Q	E5b I I/NAV OS/CS/SoL E5b Q no data E5b I+Q
11	E5 I+Q	E5 I E5 Q E5 I+Q

Table 5.5.3-4 Applicable Signals of Code/Phase Bias (QZSS)

MADOCA-PPP Code/Phase Bias（QZSS）		User Applicable Signals
Signal mask bit	Signal name	
0	L1 C/A	L1 C/A
3	L1 L1C(D+P)	L1 L1C(D) L1 L1C(P) L1 L1C(D+P)
6	L2 L2C(M+L)	L2 L2C(M) L2 L2C(L) L2 L2C(M+L)
9	L5 I+Q	L5 I L5 Q L5 I+Q

Table 5.5.3-5 Applicable Signals of Code/Phase Bias (BeiDou)

MADOCA-PPP Code/Phase Bias（BeiDou）		User Applicable Signals
Signal mask bit	Signal name	
2	B1 I+Q	B1 I B1 Q B1 I+Q
5	B3 I+Q	B3 I B3 Q B3 I+Q
8	B2 I+Q	B2b I B2b Q B2b I+Q

5.5.3.2 Parameters

Table 5.5.3-6 lists the parameters defined in the Compact SSR Satellite Code Bias message and Compact SSR Satellite Phase Bias message. Table 5.5.3-7 lists the other parameters required for the calculations.

Table 5.5.3-6 Compact SSR GNSS Code/Phase Bias Correction message parameters

Parameter	Definition	Unit
$BIAS_{code}^{PRN}$	Compact SSR Code Bias (sub type4)	m
$BIAS_{phase}^{PRN}$	Compact SSR Phase Bias (sub type5)	m

Table 5.5.3-7 Other parameters

Parameter	Definition	Unit
$P_{observed}^{PRN}$	Observed pseudorange	m
$\phi_{observed}^{PRN}$	Observed carrier-phase	cycle
λ^{PRN}	Wavelength of the carrier frequency	m

5.5.3.3 Algorithm

The Compact SSR Code/Phase Bias should be added to the observed pseudorange/carrier-phase of the corresponding code signal to get the corrected pseudorange/carrier-phase.

Corrected pseudorange P^{PRN} and corrected carrier-phase ϕ^{PRN} are calulated by

$$P^{PRN} = P_{observed}^{PRN} + BIAS_{code}^{PRN}$$

$$\phi^{PRN} = \phi_{observed}^{PRN} + \frac{BIAS_{phase}^{PRN}}{\lambda^{PRN}}$$

The algorithms are same for GPS, QZSS, Galileo, GLONASS and BeiDou. The all phase biases for GLONASS(FDMA) are set to zero due to the receiver dependent biases for FDMA signals.

Note that the sign definitions of the Code/Phase biases in MADOC-PPP are opposite to those in CLAS defined in the applicable document (4) Section 5.5.7.

5.5.4 (Reference) User dependent errors

The estimated Compact SSR parameters of MADOCA-PPP are free of reference station site displacements, phase wind up effect, receiver antenna PCV, inter system bias, quarter cycle shifts and other errors. Users should apply corresponding user dependent corrections when using Compact SSR parameters in the positioning calculation process.

The MADOCA-PPP observation model is the ionosphere-free combination of the dual-frequency carrier phase and pseudorange observations. The following correction models should be considered to meet the MADOCA-PPP convergence time described in the applicable document (1) .

- solid earth tides
- ocean loading
- pole tide
- phase wind up
- receiver antenna phase center offset and variation (PCO, PCV)
- receiver inter system bias (ISB)
- receiver quarter cycle carrier phase shifts
  (if provided carrier phase bias for different signals on the same frequency)
- tropospheric delay

References for user site displacements such as solid earth tide, ocean loading and pole tide are the IERS Conventions (3) Section 7. Reference for phase wind-up correction is the reference document (2) . Reference for the estimation of tropospheric delay is the reference document (4) Section 3.

5.5.5 (Reference) Observation Equations

5.5.5.1 Parameter

Table 5.5.5-1 lists the parameters defined in Section 5.5.1, 5.5.2 and 5.5.3. These parameters are used for calculations of the pseudorange correction and the carrier-phase correction.

Table 5.5.5-1 Parameters

Parameter	Definition	Unit
$t_{satellite}^{PRN}$	Satellite clock corrected by Compact SSR GNSS Clock Correction message (see Section 5.5.1)	s
$\boldsymbol{X}_{orbit(ECEF)}^{PRN}$	Satellite ECEF position corrected by Compact SSR GNSS Orbit Correction message (see Section 5.5.2)	m
P^{PRN}	Pseudorange observation corrected by Compact SSR Code Bias message (see Section 5.5.3)	m
ϕ^{PRN}	Carrier-phase observation corrected by Compact SSR Phase Bias message (see Section 5.5.3)	cycle

5.5.5.2 Algorithm

The ionosphere-free combinations of dual-frequency pseudorange and carrier-phase observations are related to the user position, clock, troposphere and ambiguity parameter according to the following simplified observation equations:

$$P_{IF}^{PRN} = \rho^{PRN} + c\left(dT_{GNSS} - t_{satellite}^{PRN}\right) + T_r^{PRN} + \varepsilon_P^{PRN}$$

$$\phi_{IF}^{PRN} = \rho^{PRN} + c\left(dT_{GNSS} - t_{satellite}^{PRN}\right) + T_r^{PRN} + N_{IF}\lambda_{IF} + \varepsilon_\phi^{PRN}$$

where

P_{IF}	: ionosphere-free combination of $F1$ pseudorange and $F2$ pseudorange $(f_1^2 P_1^{PRN} - f_2^2 P_2^{PRN})/(f_1^2 - f_2^2)$
ϕ_{IF}	: ionosphere-free combination of $F1$ carrier-phase and $F2$ carrier-phase $(f_1^2 \lambda_1 \phi_1^{PRN} - f_2^2 \lambda_2 \phi_2^{PRN})/(f_1^2 - f_2^2)$
$F1, F2$	: two signals used for ionosphere-free combination (these signals must be different frequencies)
P_1^{PRN}, P_2^{PRN}	: $F1, F2$ pseudorange observation corrected by Compact SSR Code Bias message
$\phi_1^{PRN}, \phi_2^{PRN}$	: $F1, F2$ carrier-phase observation corrected by Compact SSR Phase Bias message
f_1, f_2	: $F1, F2$ frequencies
λ_1, λ_2	: $F1, F2$ wavelength
λ_{IF}	: combined wavelength corresponding to the frequency f_1 and f_2 $(f_1^2 \lambda_1 - f_2^2 \lambda_2)/(f_1^2 - f_2^2)$
dT_{GNSS}	: receiver clock offet of each GNSS from the QZSST
T_r^{PRN}	: tropospheric delay
N_{IF}	: non-integer ambiguity of the carrier-phase ionosphere-free combination
$\varepsilon_P^{PRN}, \varepsilon_\phi^{PRN}$	: relevant measurement noise components including multipath

ρ^{PRN} is the geometrical range computed by satellite position corrected by orbit correction $\boldsymbol{X}_{orbit(ECEF)}^{PRN} = (x_{orbit}^{PRN}, y_{orbit}^{PRN}, z_{orbit}^{PRN})$ and user position $(x_{user}, y_{user}, z_{user})$ as follow:

$$\rho^{PRN} = \sqrt{(x_{orbit}^{PRN} - x_{user})^2 + (y_{orbit}^{PRN} - y_{user})^2 + (z_{orbit}^{PRN} - z_{user})^2}$$

Note that the user receiver side specific compensations such as user site displacements, phase wind up, user receiver antenna phase center offset (PCO), user receiver phase center variation (PCV), and quarter cycle carrier phase shifts which are described in 5.5.4 are not included in these observation equations. Users should apply the compensations to the GNSS observation data (both carrier phase and pseudo range) in the process of generating single difference observations between satellites required for the positioning calculation process.

6. Correction Information for the Technology Demonstration

6.1 General

Wide-range ionospheric correction for the Asia and Oceania regions is transmitted by the L6D messages to shorten the TTFF (Time To First Fix) of MADOCA-PPP.

6.2 Message Structure

TBD

6.3 Message contents

TBD

6.4 Transmission Pattern

TBD

6.5 User Algorithm

TBD